UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Text to Accompany:

COAL RESOURCE OCCURRENCE MAP AND COAL DEVELOPMENT POTENTIAL MAP OF THE DUNN CENTER NE QUADRANGLE, DUNN COUNTY, NORTH DAKOTA

[Report includes 29 plates]

By

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This report has not been edited for conformity with U.S. Geological Survey editorial standards or stratigraphic nomenclature.

TABLE OF CONTENTS

INTRODUCTION

The occurrence, extent, and preliminary geologic evaluation of coal beds in the Dunn Center NE quadrangle in west-central North Dakota are described in this report. Subsurface data consisting of oil and gas well and exploration drill hole logs and surface data comprised of measured sections are presented on the Coal Data Map and Coal Data Sheet, Plates 1 and 3, respectively. Federal ownership of coal and total Reserve Base and Hypothetical Resources of coal by section are presented on the Boundary and Coal Data Map, Plate 2. Derivative maps, which consist of coal isopachs, structure contours, overburden/interburden isopachs, mining ratios, reserve categories, and Reserves and Reserve Base, have been compiled for each coal seam of reserve base thickness underlying the quadrangle, and are presented on Plates 4 through 28, respectively. A Coal Development Potential Map for surface mining is presented on Plate 29.

This work has been performed under contract with the Conservation Division of the U.S. Geological Survey (Contract No. 14-08-0001-17118).

The resource information gathered in this program is in response to the Federal Coal Leasing Amendments Act of 1975 and is a part of the U.S. Geological Survey's (USGS) coal program.

This information is intended to provide basic data on coal resources for land-use planning purposes by the Bureau of Land Management, state and local governments, and the public.

LOCATION

The Dunn Center NE 7 1/2 minute quadrangle is located in Dunn County, North Dakota about 38 miles (61.1 km) north of Dickinson and 6 miles (9.7 km) east of Killdeer.

ACCESSIBILITY

The area is accessible by county road to State Highway 22 eight miles (12.9 km) to the west which connects with Interstate 94 at Dickinson, 32 miles (51.5 km) to the south.

The Burlington Northern Railroad operates and maintains an east-west route which extends through Halliday, Dunn Center, and Killdeer about 2.5 miles (4.0 km) south of the quadrangle. No railroad routes currently pass through or closer to the quadrangle than the existing Burlington Northern route to the south.

PHYSIOGRAPHY

The quadrangle lies in the central portion of a large topographic high known as the Missouri Plateau which is being dissected by the Knife, Heart, Cannonball, and Cedar Creek Rivers. In the eastern portion of the plateau the topography is qenerally hilly and along the Missouri River there are

bluffs 500-600 feet (152-183 m) high. The western part of the Missouri Plateau is characterized by more irregular topography than that which prevales throughout the remainder of the plateau. This area, known collectively as "the Badlands", comprises an intricate maze of narrow ravines, sharp crested ridges, and pinnacles.

The Dunn Center NE quadrangle may be characterized as gently rolling to hilly in all but the northern part of the quadrangle, but it is heavily dissected by stream drainage. Chimney Butte Creek, the major drainage of the area, is an intermittent stream flowing east to west in the northwestern portion of the quadrangle. Numerous shallow drainages feed into the Lake Sakakawea in the northern section of the quadrangle. The maximum relief across the quadrangle of Dunn Center NE is 400 feet (121.9 m).

The vegetation is mixed prairie grasses, and some of the land is cultivated.

CLIMATE

North Dakota's climate may be characterized as semi-arid; the average annual precipitation is 17 inches (43.2 cm) at Dunn Center which is located about 2 miles (3.2 km) south of the quadrangle.

Maximum precipitation occurs during late spring and early summer with slightly over half the total annual precipitation

occurring during May, June, and July. Although the mean annual temperature is about 40°F (4.4°C), temperatures as recorded at the Dunn Center weather station by the U.S. Department of Commerce, can range from 102°F (38.9°C) in summer months to -25°F (-31.7°C) in winter months. The prevailing northerly winds increase in velocity during the colder months of November through March.

LAND STATUS

The quadrangle lies in the western one-half of the Knife River Known Recoverable Coal Resource Area (KRCRA). The Federal Government owns the coal rights to approximately 40 percent of the quadrangle. In addition, the Federal Government has restricted coal rights on less than one percent of the area incorporated in the quadrangle.

PREVIOUS WORK

This report has drawn on a number of basic data reports on coal occurrences in the Knife River KRCRA, including: Law (1977), Benson (1953), and United States Geological Survey (USGS) and North Dakota Geological Survey (NDGS) (1976, 1977). Ground water data reports in the Knife River area were also used, including: Croft (1970) and Klausing (1971, 1974, 1976).

METHOD OF STUDY

Lithologic and geophysical logs from 32 drill holes

provided the basic data for this study. The most important sources of data were Electric Log Services (1977), Klausing (1976), Law (1977), and USGS and NDGS (1976). The quality of available coal information is variable. Lithologic and geophysical logs from exploration holes drilled by the North Dakota Geological Survey, North Dakota State Water Commission, and private coal companies generally provide the most detailed and reliable subsurface data. Lithologic logs of private water wells are less detailed and less reliable, but they provide usable information in some cases. Where the data for a specific coal bed appear to be inaccurate or inconsistent with surrounding drill hole data, they were not included in the data base that was used for construction of derivative maps for that coal bed. For instance, in some drill holes coal intervals were not noted and the data appeared anomalous in relation to data from adjacent drill holes, rather than plotting a zero coal thickness, the coal bed was assumed to be laterally extensive. Many coal splits were not mapped because of inconsistent data that did not allow projection of split thicknesses with reasonable reliability or accuracy. Where the data was sufficient to justify the projection of coal parting thicknesses, and both of the coal seams are greater than reserve base thickness, interburden isopach maps were constructed.

Drill hole data and projected coal outcrop traces from previous investigations (Law, 1977) were plotted on the Coal Data Map, Plate 1. These outcrop data were then modified in accordance with structural trends noted in the present mapping. It was assumed that all beds extended to the surface although it is known that thick alluvial, colluvial, and glacial materials are sometimes locally present. Subsurface information (collected to depths of 1,000 feet (305 m) was used to construct correlation diagrams of coal beds (Coal Data Sheet, Plate 3). Correlation diagrams for the Dunn Center NE quadrangle and the adjoining Halliday NW, Dunn Center NW, Mandaree SE, and Dunn Center quadrangles were then integrated and coal structure contours, isopachs, overburden isopachs, and mining ratio maps were constructed for coal beds of reserve base thickness (5 feet minimum) (Plates 4 through 28).

GEOLOGY

STRATIGRAPHY

The oldest rocks present in the uppermost 1000 feet (305 m) of the stratigraphic section in the Dunn Center NE quadrangle are the Ludlow-Cannonball, the coal-bearing Tongue River, and the Sentinel Butte members of the Paleocene Fort Union Formation (Rehbein, 1977). Sandstones, siltstones and shales of this formation are locally mantled by erosional

remnants of the Upper Paleocene-Lower Eocene Golden Valley Formation and by Quaternary glacial, eolian, and alluvial deposits.

Fort Union Formation - Paleocene.

Ludlow-Cannonball member - these sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the northern Great Plains region. Where it has been measured in the vicinity, it is about 350 feet (107 m) thick and consists of shale and thin-bedded sandstone which thins and interfingers to the west with the time-equivalent Ludlow rocks deposited in a continental environment.

Tongue River member - this member ranges in thickness from 350 to 900 feet (107 to 274 m) and consists of an alternating sequence of fluvially deposited sandstone, siltstone, shale, and lignite. It conformably overlies the marine Cannonball rocks and the time-equivalent nonmarine Ludlow member. The Tongue River member is similar to the overlying Sentinel Butte member and in places cannot be distinguished from it. The contact between the Tongue River and Sentinel Butte members, which has been arbitrarily set at the top of the HT Butte lignite, is conformable.

Sentinel Butte member - this member averages 500 feet (152 m) in thickness and consists of alternating sequences of fluvially deposited sandstone, siltstone, shale, carbonaceous

shale, and lignite. In general, the sandstones are fine grained and poorly cemented. Shales range from soft, plastic, clay to moderately indurated claystone. Locally, the member contains thin calcareous or silicious concretions. Shales and siltstones readily break down and form gentle slopes beneath the sandstone ledges.

Golden Valley Formation - Eocene.

This formation consists of about 200 feet (61 m) of alternating shales, siltstones, and crossbedded sandstones. These sediments, which comformably overlie the Sentinel Butte member, have been eroded away in much of the study area.

Channel Deposits - Pleistocene.

Sand and gravel channel deposits of indeterminate thickness lie beneath alluvial deposits. These deposits underlie early Wisconsinan glacial till and Quaternary alluvium in the area.

Glacial Till - Pleistocene.

The glacial till is a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders which was deposited during Wisconsinan episodes of continental glaciation.

Eolian Deposits - Pleistocene and Recent.

Unconsolidated dune and loess-like deposits, from several inches to more than five feet thick, mantle most of the study area. The loess-like deposits consist of silty clays, clayey

silt, and silty to clayey sands and are probably of late Pleistocene to Recent age. Recent dunes, consisting of silts and very fine-grained uniform sand, have been deposited on the lee side of knobs and ridges.

Alluvium - Recent.

Alluvium consisting of clay, silt, sand, and gravel mantles valley floors in the study area.

DEPOSITIONAL ENVIRONMENTS OF THE LIGNITES

Many of the Ludlow member lignites are of small areal extent, display lenticularity and are interbedded with distributary channels indicative of deposition in a delta plain.

The thinner Ludlow lignites are laterally more extensive than the lenticular beds; there is evidence of them having been deposited on the plains of abandoned delta lobes (Rehbein, 1977).

The Tongue River lignites differ from the Ludlow lignites of deltaic origin in that they are thicker and laterally more extensive. The HT Butte bed at the top of the Tongue River Formation can be traced over thousands of square miles. The lignite beds of the Tongue River member, in contrast to the Ludlow lignites, were formed in large swamps adjacent to fluvial channels (Rehbein, 1977).

The Sentinel Butte lignites, though fewer in number, are almost as continuous as the Tongue River lignites and had a similar depositional environment.

STRUCTURE

Regionally, the Knife River KRCRA is located on the southeastern flank of the Williston Basin, approximately 60 miles (97 km) from the basin center. Generally, the sedimentary units are flat lying or gently undulating, with a northward to northeastward regional dip ranging from less than 10 feet per mile (1.9 m per km) to 180 feet per mile (34 m per km). Upper strata have been warped into a gentle syncline with a northeast to southwest trending axis located approximately 10 miles (16 km) east of the town of Dodge. The dips on the flanks of the syncline are approximately 18 feet per mile (3.4 m per km). The coal beds, as mapped within this quadrangle, show minor structural variations from the regional stuuctural framework. More definitive descriptions of the structural aspects of the coal seams may be found in the "Coal Geology" section which follows. Major faulting has not been observed in the area (Menge, 1977). Surficial materials generally mask most of the older stratigraphic units, making it difficult to assess the importance and occurrence of both major and minor faulting.

COAL GEOLOGY

Seven major coal beds and several local coal beds are either mapped at the surface or identified in the subsurface in this quadrangle. The H Lignite coal bed is stratigraphically the lowest recognized coal bed. It is successively overlain by non-coal bearing rocks approximately 255 feet (77.7 m) thick; the Garner Creek coal bed; a sequence of rocks approximately 200 feet (61.0 m) thick which one local coal bed (Local 5, a local bed correlatable between several quadrangles); the Meyer coal bed; a sequence of non-coal bearing rocks approximately 50 feet (15.2 m) thick; the HT Butte coal bed; a sequence of rocks approximately 140 feet (42.7 m) thick which contain one local coal bed (Local 4, a local coal bed correlatable between several quadrangles); the Hazen coal bed; a sequence of rocks which average 120 feet (36.6 m) thick which include one local coal bed (Local 3, a local bed correlatable between several quadrangles); the Beulah-Zap coal bed; a sequence of non-coal bearing rocks which averages 75 feet (22.9 m) thick; and the Schoolhouse coal bed, which is overlain by non-coal bearing rocks and Local 1 coal bed (which is correlatable between adjacent quadrangles). Table 1 shows the coal bed names and their stratigraphic position.

The coal beds of the Fort Union Formation in the Knife River area are lignite in rank and contain 0.4 to 1.2 percent sulfur, less than 10 percent ash, and between 5910 and 7330 BTU/lb (Table A-1). Coal analyses indicate that these coals have less than or about the same amount of trace elements as coal beds in other areas of the northern Great Plains coal province (Tables A-2 through A-5).

H LIGNITE COAL BED

The lowest mapped coal bed, the H Lignite, does not crop out in the Dunn Center NE quadrangle and is not found in any drill holes in this quadrangle. Based upon projections from adjacent quadrangles, the H Lignite probably dips north at 20 feet per mile (3.8 m per km) as shown on Plate 4.

The thickness of the bed ranges from 8.5 feet (2.6 m) to 14 feet (4.3 m) with the bed increasing in thickness from north to south as shown on Plate 4. The overburden ranges in thickness from 800 feet (244 m) to 1000 feet (305 m) as shown on Plate 4.

Chemical Analyses of the H Lignite Coal Bed - No proximate or elemental analyses of the H Lignite coal bed have been found in the literature. It is assumed, however, that the quality of the coal is comparable to that of the other coal beds of the Fort Union Formation and is lignite in rank.

GARNER CREEK COAL BED

The Garner Creek coal bed overlies the H Lignite coal bed

Table 1 -- Coal Bed Names and Stratigraphic Position

Bed Name	Stratigraphic Equivalent
Schoolhouse	Otter Creek
↑ 80 ft ↓	
Beulah-Zap	Dunn Center, Herman
↑ 35 ft ↓	
Local 3	
↑ 60 ft ↓	
Hazen	Spear, Hazen "B", Kruckenberg, Red Butte
↑ 70 ft ↓	
Local 4	
↑ 65 ft ↓	
HT Butte	Hazen "A", Garrison Creek, Yeager, Hagel, Berg Keuther, Stanton
↑ 50 ft ↓	
Meyer	
↑ 200 ft ↓	
Garner Creek	
↑ 225 ft ↓	
H Lignite	

and is separated from it by approximately 255 feet (77.7 m) of rock. No records of drill holes penetrating the Garner Creek coal bed in this quadrangle were found. Based upon projections from adjacent quadrangles, the Garner Creek coal bed dips northeast at approximately 25 feet per mile (4.7 m per km) as shown on Plate 6.

The bed ranges in thickness from 4 feet (1.2 m) to 14 feet (4.3 m) with the thickening increasing from north to south as shown on Plate 6. The overburden ranges from 400 feet (121.9 m) to 900 feet (274.3 m) thick, as shown on Plate 6.

Chemical Analyses of the Garner Creek Coal - No proximate and elemental analyses of the Garner Creek coal have been found in the literature, however, the coal is comparable to that of other coal beds in the Fort Union Formation and is lignite in rank.

MEYER COAL BED

The Meyer coal bed overlies the Garner Creek coal bed. It is separated from the Garner Creek coal bed by approximtely 200 feet (61.0 m) of rock and one local coal bed. Records of two drill holes penetrating the Meyer coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Meyer coal bed dips from the northeast and west to the center of the quadrangle at approximately 8 feet per mile (1.5 m per km) as shown on Plate 8.

The bed ranges from 2 feet (0.6 m) to 10 feet (3.1 m) thick with the thickness increasing from south to north as shown on Plate 9 and has one parting totaling 9 feet (2.7 m) thick. The overburden ranges from 100 feet (30.5 m) to 600 feet (182.9 m) thick, a shown on Plate 8.

Chemical Analyses of the Meyer Coal - No proximate or elemental analyses of the Meyer coal have been made or found in the literature; it is assumed, however, that the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

HT BUTTE COAL BED

The HT Butte coal bed overlies the Meyer coal bed. It is separated from the Meyer coal bed by approximtely 50 feet (15.2 m) of rock. Records of four drill holes penetrating the HT Butte coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the HT Butte coal bed dips east at approximately 20 feet per mile (3.8 m per km), as shown on Plate 11.

The bed ranges from 5 feet (1.5 m) to 12 feet (3.7 m) in thickness with the thickness increasing from 5 to 12 feet to northeast and southeast as shown on Plate 12. The overburden ranges from 100 feet (30.5 m) to 600 feet (182.9 m) thick, as shown on Plate 11.

Chemical Analyses of the HT Butte Coal - A number of proximate and elemental analyses of the HT Butte coal bed are presented in Tables A-1 and A-2, respectively, and indicate that the HT Butte coal is lignite in rank.

No coal analyses are available for this quadrangle, but analysis of coal samples from the Center Quadrangle indicate the following: ash content varies between 4.9 and 5.9 percent, the sulfur content varies between 0.5 and 0.7 percent, and the BTU/lb varies between 6970 and 7150.

LOCAL 4 COAL BED

The Local 4 coal bed overlies the HT Butte coal bed. It is separated from the HT Butte coal bed by approximately 65 feet (19.8 m) of rock. Records of three drill holes penetrating the Local 4 coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Local 4 coal bed dips northeast at approximately 30 feet per mile (5.7 m per km) in the southern portion of the quadrangle and to the south at approximately 30 feet per mile (5.7 m per km) in the northern half (Plate 14).

The bed ranges from 0 feet (0 m) to 9 feet (2.7 m) thick with the thickness increasing from northeast to southwest in the southern half of the quadrangle as shown on Plate 15. The overburden ranges from 100 feet (30.4 m) to 400 feet (121.9 m) thick, as shown on Plate 14.

Chemical Analyses of the Local 4 Coal - No proximate and elemental analyses of the Local 4 coal have been made; it is assumed, however, that the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

HAZEN COAL BED

The Hazen coal bed overlies the Local 4 coal bed. It is separated from the Local 4 coal bed by approximately 70 feet (21.3 m) of rock. Records of five drill holes penetrating the Hazen coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the coal bed dips east and west at approximately 30 feet per mile (5.7 m per km), as shown on Plate 17.

The bed ranges from 5 feet (1.5 m) to 11 feet (3.4 m) in thickness with thickness increasing from north to south as shown on Plate 18, and has one parting 2 feet (0.6 m) thick. The overburden ranges from 50 feet (15 m) to 450 feet (121.9 m) thick, as shown on Plate 17.

Chemical Analyses of the Hazen Coal - Only one chemical analysis of the Hazen coal bed from within the KRCRA is available (Table A-1). Analysis of the coal sample indicates the following: ash content is approximately 4.2 percent, sulfur content is approximately 0.5 percent, and the BTU/lb is approximately 6290. Two elemental analyses are given in Table A-3. All are from the same locality near Center in Oliver County. The Hazen coal bed is lignite in rank.

LOCAL 3 COAL BED

The Local 3 coal bed overlies the Hazen coal bed. It is separated from the Hazen coal bed by approximately 60 feet (18.3 m) of rock and underlies approximately 98 percent of the quadrangle. In the remainder of the quadrangle the Local 3 coal bed has been removed by erosion. Records of six drill holes penetrating the Local 3 coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Local 3 coal bed regionally dips northeast although there are many local changes in dip from southwest to southeast ranging from about 60 feet per mile (18 m per km) to less than 10 feet per mile (3 m per km), respectively, as shown on Plate 20.

The bed ranges from 3 feet (0.9 m) to 10 feet (3.0 m) in thickness generally with the thickness increasing from west to east as shown on Plate 21 and has up to 2 partings totaling 41 feet (12.5 m) thick. The overburden ranges from 50 feet (15 m) to 400 feet (122 m) thick, as shown on Plate 20.

Chemical Analyses of the Local 3 Coal

No proximate and elemental analyses of the Local 3 coal have been made; it is assumed, however, that the coal is similar to other coal beds in the Fort Union Formation and is lignite in rank.

BEULAH-ZAP COAL BED

The Beulah-Zap coal bed overlies the Local 3 coal bed. It is separated from the Local 3 coal bed by approximately 35 feet (10.7 m) of rock. The Beulah-Zap coal bed underlies approximately 95 percent of the quadrangle. In the remainder of the quadrangle the Beulah-Zap coal bed has been removed by erosion. Records of 19 drill holes penetrating the Beulah-Zap coal bed in this quadrangle were found. Based upon these records and projections from adjacent quadrangles, the Beulah-Zap coal bed forms a gentle synclinal flexure, with a northwest trending axis and dips approximately 25 feet per mile (4.7 m per km) on the limbs as shown on Plate 23.

The bed ranges from 5 feet (1.5 m) to 15 feet (4.6 m) in thickness with the thickness increasing from center to the borders of the quadrangle, as shown on Plate 24. The overburden ranges from 50 feet (15 m) to 350 feet (107 m) thick, as shown on Plate 23. The interburden ranges from 5 feet (1.5 m) to 9 feet (2.7 m) thick, as shown on Plate 23.

Chemical Analysis of the Beulah-Zap Coal - Proximate and elemental analyses of the Beulah-Zap coal bed are presented in Tables A-1 and A-4, respectively. Analyses of coal samples in the Dunn Center quadrangle indicates the following: ash content varies between 4.9 and 8.0 percent; the sulfur content

varies between 0.4 and 1.16 percent; and the BTU/lb varies between 5910 and 7330. They show the Beulah-Zap coal is lignite in rank.

SCHOOLHOUSE COAL BED

The Schoolhouse coal bed is the uppermost mapped coal bed in the quadrangle. It is present in 85 percent of the quadrangle, the remainder having been removed by erosion along the north, east and west boundaries of the quadrangle. Where present, the bed overlies the Beulah-Zap coal bed and is separated from it by 80 feet (24.4 m) of rock. The bed forms a gentle synclinal flexure with a northwest trending axis, and limbs with dips of approximately 25 feet per mile (4.7 m per km), as shown on Plate 26.

Although the coal bed thickens and thins erratically over the entire quadrangle, where the bed is present, it ranges from 0 feet (0 m) to 11 feet (3.4 m) in thickness, as shown on Plate 27. The overburden ranges from 0 feet (0 m) to 300 feet (91.4 m) thick, as shown on Plate 26. The interburden ranges from 5 feet (1.5 m) to 11 feet (3.4 m) thick, as shown on Plate 26.

Chemical Analysis of the Schoolhouse Coal - Proximate and elemental analyses of the Schoolhouse coal bed are presented in Tables A-1 and A-5, respectively. Analysis of coal samples from the Schoolhouse coal bed near Center in Oliver County indicate the following: ash content varies between 5.7 and 6.6

percent, the sulfur content varies between 1.0 and 1.2 percent, and BTU/lb varies between 6720 and 6910. They show the Schoolhouse coal to be lignite in rank.

LOCAL COAL BEDS

In the Dunn Center NE quadrangle, seven local coal beds, ranging in thickness from 1 to 14 feet (0.3 to 4.3 m), occur in the Ludlow-Cannonball and the Sentinel Butte and Tongue River members of the Fort Union Formation. Two local coal beds, Local 3 and 4, are of reserve base thickness; derivative maps were constructed and coal resources and reserves were calculated. Generally, the other local coal beds are thin, usually less than 5 feet thick, and of limited extent. Derivative maps were not constructed and coal resources and reserves were not calculated for five local coal beds due to their lenticular nature, insufficient data, and thickness.

COAL RESOURCES

Coal resource classification, as used in this report, is based on the degree of geological assurance of the existence and economic minability of the coal bed. The criteria for resource classification is based on the distance from the data point. The resource categories are:

Identified

measured - within 1/4 mile radius of data point

indicated - between 1/4 and 3/4 mile radius of data point

inferred - between 3/4 and 3 mile radius of data point

Hypothetical - beyond 3 mile radius of data point

Coal resource/reserve calculations are made using data presented on isopach and overburden contour maps for all Federal Government coal land in the quadrangle. Where Federal coal ownership is restricted, the reserve base/reserve tonnage was multiplied by the appropriate ownership percentage.

In areas suitable for surface mining, Reserve Base and Reserve tonnages were calculated for identified coal resources. Reserves were not calculated for hypothetical coal resources.

In areas suitable for underground mining (coal bed thickness of 5 feet or greater and overburden from 200 to 1000 feet), Reserve Base tonnages are calculated for identified and hypothetical coal resources.

The resource tonnages were estimated by a computer algorithm which is interactive with an automated planimeter-digitizer. Each area was traced with a magnifying cursor and when a section is completed, a check was made to see that partial areas stored on diskettes sum to the area of the whole section.

The areas measured were converted by the algorithm using

given parameters (lignite = 1750 tons per acre foot (1750 tons per acre foot = 12871 metric tons per hectare meter); recovery factor for strippable coal is 85 percent which will yield Reserve Base and Reserves in millions of short tons per section for each class. Coal resource values for the H Lignite, and Garner Creek beds are shown in Plates 5, and 7, respectively. Reserve base and reserve values for the Meyer, HT Butte, and Local 4, Hazen, Local 3, Beulah-Zap and Schoolhouse beds are shown on Plates 10, 13, 16, 19, 22, 25 and 28, respectively. Reserve Base and Reserve values are rounded off to the hundredth of one million short tons.

Total Reserve Base and Hypothetical Resource data for the mine coal beds mapped in this quadrangle are shown on Plate 2.

COAL DEVELOPMENT POTENTIAL

Areas considered to have strip mining potential are assigned a high, moderate, or low development potential based on the mining ratio (cubic yards of overburden per ton of recoverable coal).

Coal outcrop traces were projected from structure contour maps and checked against previously projected outcrops (Law, 1977). An overlay of the structure contour and topographic maps provides data for computation of overburden thickness. The coal isopach map was overlain by the overburden isopach map

and a mining ratio was calculated using the following the formula:

$$MR = \frac{To\ (.922)}{Tc\ (.85)}$$

where:

MR = cubic yards of overburden per ton of recoverable coal

To = thickness of overburden

Tc = thickness of coal

0.922 = factor to convert thickness of overburden and thickness of coal to cubic yards per ton

0.85 = coal recovery factor (85%)

The Coal Development Potential (CDP) map is compiled by overlaying each mining ratio map for the quadrangle on the property base and noting for all Federal coal land whether each 40-acre tract contains Reserve Base coal in any of the mining ratio categories (Plate 29). 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. The highest rating for each tract is plotted on the CDP map. Areas beyond the outcrop are designated "not applicable" and areas of less than 5 feet coal thickness are designated "0" development potential. Mining ratios are not calculated where coal thicknesses are less than five feet or where overburden

thicknesses exceed 200 feet.

The coal development potential for subsurface mining is considered low in this quadrangle because no criteria for its classification have been established.

DEVELOPMENT POTENTIAL FOR SURFACE MINING METHODS

The coal development potential for surface mining methods (less than 200 feet (61 m) of overburden) is shown on Plate 29 and coal tonnages are summarized in Table 2.

The coal development potential in the Dunn Center NE quadrangle is high along the northern border of the map and in the central and southeastern areas due to the presence of Schoolhouse coal bed at depths of less than 100-150 feet, and thicknesses from 5 to 11 feet (1.5 to 3.4 m). It is below reserve base thickness (5 feet) in the southwestern 1/8 of the map, in a small area along the western border, and in a four square mile area in the northwest central portion of the quadrangle.

The Beulah-Zap bed which ranges up to 16 feet (4.9 m) thick, accounts for the high development potential in the southwestern quadrangle corner. The Beulah-Zap is under less than 200 feet of overburden and is greater than reserve base thickness over most of the quadrangle. It is below reserve base thickness in a narrow strip across the southeast corner of the map and in a broad oval area extending from the northeast

Table 2 - Strippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Dunn Center NE Quadrangle, Dunn County, North Dakota.

Development potentials are based on mining ratios (cubic yards of overburden/ton of underlying coal). To convert short tons to metric tons multiply by 0.9072; to convert mining ratios in yd^3/ton coal to m^3/t, multiply by 0.842.

Coal Bed	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Schoolhouse	54.38	16.90	31.23	102.51
Beulah-Zap	60.16	52.56	41.94	154.66
Local 3	7.65	19.73	62.27	89.65
Hazen	0.66	0.85	18.39	19.90
Local 4	0.00	0.00	3.67	3.67
HT Butte	0.00	0.00	1.42	1.42
Meyer	0.05	0.04	0.42	0.51
Garner Creek	0.00	0.00	0.00	0.00
H Lignite	0.00	0.00	0.00	0.00
Total	122.90	90.08	159.34	372.32

to the center of the quadrangle. The overburden exceeds 200 feet in a strip across the northwest corner of the quadrangle.

The Local 3 and Hazen beds reach thicknesses of 9 (2.7 m) and 11 (3.4 m) feet respectively, but are under less than 200 feet of overburden in limited areas of the southeast and southwest corners of the map. Hazen is below reserve base thickness in the north, and the Local 3 is thinner than 5 feet in the northwest and southwest corners and along the north central east side of the quadrangle. These coals have no influence on the final coal development potential ratings for the Dunn Center NE quadrangle.

DEVELOPMENT POTENTIAL FOR UNDERGROUND MINING METHODS AND IN SITU GASIFICATION

The H Lignite coal bed, which is the lowest identified coal bed in the quadrangle, and the Garner Creek, Meyer, HT Butte, Local 4, Hazen, and Local 3 coal beds all have substantial quantities of non-strippable (greater than 200 feet of overburden) coal resources as shown in Table 3. The areal distribution of the coal resources is shown on Plates 5, 7, 10, 13, 16, 19 and 22, respectively.

The development potential for underground mining methods is considered low in this quadrangle because of probable economic and geologic constraints of underground mining of low rank coals. There are no active or planned underground mines

Table 3 - Nonstrippable Coal Reserve Base Data for Federal Coal Lands (in millions of short tons) in the Dunn Center NE Quadrangle, Dunn County, North Dakota.

To convert short tons to metric tons, multiply by 0.9072.

Coal Bed	High development potential	Moderate development potential	Low development potential	Total
Schoolhouse	0.0	0.0	0.0	0.0
Beulah-Zap	0.0	0.0	25.28	25.28
Local 3	0.0	0.0	58.02	58.02
Hazen	0.0	0.0	150.82	150.82
Local 4	0.0	0.0	28.49	28.49
HT Butte	0.0	0.0	19.56	19.56
Meyer	0.0	0.0	48.05	48.05
Garner Creek	0.0	0.0	1.29	1.29
H Lignite	0.0	0.0	1.67	1.67
Total	0.0	0.0	333.18	333.18

in the quadrangle, and no criteria for an underground mining classification have been established.

No criteria have been established for rating the development potential by in situ gasification of coal methods in this area.

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APPENDIX A

PROXIMATE AND ELEMENTAL ANALYSES

Table A-1 Proximate Analyses (as received)

Bed Name	No. of Samples	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur (Ultimate) %	Btu/lb*	Data Source
HT Butte	2	36.6	27.9	29.5	5.9	0.7	6970	Pollard et al., 1972
HT Butte	2	32.4	31.6	30.3	5.9	0.7	7024	Brant, 1953
HT Butte	3	35.5	28.6	31.1	4.9	0.5	7150	Johnson & Kunkel, 1959
Hazen	1	41.0	25.9	28.9	4.2	0.5	6290	Johnson & Kunkel 1959
Beulah-Zap	15	36.1	26.9	30.7	6.2	0.73	6890	Sondreal, Kube Elder, 1968
Beulah-Zap	3	34.0	29.0	29.0	8.0	0.8	6800	Pollard, et al., 1972
Beulah-Zap	1	39.5	28.3	25.3	6.9	0.4	5910	Johnson & Kunkel, 1959
Beulah-Zap	2	35.7	28.5	30.8	4.9	0.6	7018	Brant, 1953
Beulah-Zap	2	35.88	27.66	30.18	6.27	1.00	6566	Leonard, et al., 1925
Beulah-Zap	4	36.3	28.1	29.6	6.0	1.16	7028	USGS & Mont.Bur. of Mines & Geol. 1976
Beulah-Zap	10	29.6	29.6	34.2	6.7	0.5	7330	Swanson et al., 1976
Schoolhouse	1	35.8	26.9	31.7	6.6	1.0	6910	Pollard, et al., 1972
Schoolhouse	3	38.1	27.5	28.7	5.7	1.2	6720	Johnson & Kunkel 1959
Ave. Dunn Co.	-	40.6	-	-	7.0	0.6	6310	USDI, 1977
Ave. N.D.	-	36.0	28.0	29.0	6.0	0.7	6600	Leonard, et al., 1925

* To convert Btu/lb to Kilojoules/Kilogram, multiply by 2.326

Table A-2 -- Elemental Analysis of HT Butte Coal Bed

Element	Concentration in % Sample No.* D-80824	Sample No.* D-80825	Sample No.* D-80823
Sulphur	0.6	0.4	0.4
Hydrogen	6.8	6.9	6.9
Carbon	41.5	43.1	42.3
Nitrogen	0.7	0.6	0.7
Oxygen	44.0	45.0	45.5

*Johnson and Kunkel, 1959.

Table A-3 -- Elemental Analysis of Hazen Coal Bed

Element	Concentration-in % Sample No.* D-55178	Sample No.* 49875
Sulphur	0.5	
Hydrogen	7.0	
Carbon	38.0	
Nitrogen	0.6	
Oxygen	49.7	
U		0.0001
Ge**		ND
Ga**		0.002
V**		0.005
Cu**		0.004
Cr**		0.002
Zn**		0.01
Ni**		0.005
Co**		0.002
Be**		0.0003
Y**		0.01
La**		0.02
Mo**		ND

* Johnson and Kunkel, 1959
** Results in percent of ash

Table A-4 -- Elemental Analysis of Beulah-Zap Coal Bed

Element	Concentration in % Sample No.* 49879	Sample No.*** ND-KR-Bu	Sample No.**** ND-TT-DS	Sample No.***** D175930 to D17539
Sulphur				0.5
Hydrogen				6.2
Carbon				44.6
Nitrogen				0.7
Oxygen				41.3
U	0.0003			0.00005
Ge**	ND	0.001	ND	ND
Ga**	0.002	0.002	0.004	0.0015
V**	0.008	0.005	0.007	0.0035
Cu**	0.005	0.007	0.02	0.0055
Cr**	0.006	0.005	0.004	0.0025
Zn**	ND	ND	ND	0.0025
Ni**	0.005	0.003	0.006	0.0020
Co**	0.002	0.001	0.002	0.0010
Be**	0.0002	0.0008	0.0008	0.0003
Y**	0.01	0.004	ND	0.0025
La**	0.01	0.004	ND	0.01
Mo**	ND	0.002	0.004	0.0010
B**		0.24		0.110
Ti**		0.2		0.70******
Sn**		ND		---

* Johnson and Kunkel, 1959
** Results in percent of ash
*** Zubovic et al., 1961, average of 4 samples
**** Zubovic et al., 1961, average of 2 samples
***** Swanson et al., 1976
****** as TiO_2

Table A-5 - Elemental Analaysis of Schoolhouse Coal Bed

	Concentrations in %				
Element	Sample No.* D-55179	Sample No.* D-55176	Sample No.* D-55175	Sample No.* 49874	Sample No.* 49880
Sulphur	0.9	0.5	2.1		
Hydrogen	7.1	6.9	6.7		
Carbon	39.9	40.4	39.2		
Nitrogen	0.6	0.6	0.6		
Oxygen	46.4	47.4	43.6		
U				0.0001	0.0001
Ge**				ND	ND
Ga**				0.002	0.002
V**				0.01	0.006
Cu**				0.02	0.004
Cr**				0.007	0.005
Zn**				0.7	0.06
Ni**				0.002	0.003
Co**				0.001	0.001
Be**				0.001	0.0007
Y**				0.01	ND
La**				0.02	ND
Mo**				ND	ND

* Johnson and Kunkel, 1959
** Results in percent of ash