GEOHYDROLOGIC EVALUATION OF THE UPPER PART OF THE MESAVERDE GROUP, NORTHWESTERN COLORADO

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ABSTRACT

Coal mining in Routt and Moffat Counties of northwestern Colorado has produced large areas of spoils and disturbed land that have the potential of degrading the surface and ground-water quality of the region. This investigation of the geology and hydrology of the bedrock aquifers in the area was undertaken to define the important characteristics of the hydrologic system and to evaluate the future impacts of mining on water quality.

Regional aquifers in the Trout Creek Sandstone Member of the Iles Formation and Twentymile Sandstone Member of the Williams Fork Formation and an important local aquifer are the principal water-yielding units in the 2,000-foot-thick sequence of shale, sandstone, and coal underlying the study area. The structural complexity of the region, coupled with rugged topography, cause the irregular outcrop of the aquifer units, primarily on the back slopes of the cuestas and elevated limbs of several anticlines. The aquifers are recharged by infiltration of precipitation in the elevated outcrops. Ground water generally moves at rates of 1 to 30 feet per year toward topographically low areas in Twentymile Park and the valleys of the Yampa River and its local tributaries. Discharge occurs by upward leakage through confining layers, lateral flow to stream valleys on low-lying outcrops, and evapotranspiration.

Solute-transport modeling indicates that movement of poor quality water from spoil aquifers will not significantly degrade the water quality in the bedrock aquifers. Mining primarily will affect surface-water quality through direct discharge of poor quality water into the streams from springs and seeps that develop in the spoil.

INTRODUCTION

Large reserves of bituminous to subbituminous coal are present in the upper members of the Cretaceous Mesaverde Group in northwestern Colorado (pl. 1). In the Williams Fork Mountains of Routt and Moffat Counties, coal production increased by 260 percent from 1970 to 1980, at a time when total coal production in the United States increased by about 50 percent. Three large open-pit mines and several smaller mines in Routt County produced 4 to7 million tons of coal per year from 1980 to 1986. Past mining activities in the county have produced in excess of 9,000 acres of mine spoils and disturbed land. The areal extent of these areas can be expected to increase in size as mining continues. Mine spoil and disturbed land have the potential to degrade ground-water and surface-water quality by providing increased potential for leaching of soluble minerals.

Private industry, Federal, State, and local regulatory agencies, and the general public are faced with growing needs for hydrologic information pertaining to the natural environment of coal producing regions and the effects of mining-imposed changes on the environment. A study by the U.S. Geological Survey, in cooperation with the Colorado Department of Natural

Resources, Mined Land Reclamation Division, the U.S. Office of Surface Mining Reclamation and Enforcement, and the U.S. Bureau of Land Management was done to meet such needs in Routt and Moffat Counties through an investigation of the geology and hydrology of the Williams Fork Mountain coal region (fig. 1). The study involved a detailed investigation of the ground-water hydrology of the eastern part of the area, where coal has been mined for almost a century and for which geohydrologic data are prevelant, and a more general overview of the geology and hydrology of the western part of the area, where mining has not been extensive and for which geohydrologic data are sparse.

The objectives of the more detailed investigation of the eastern part of the area include:

1. Defining the extent, thickness, lateral continuity, and structural configuration of the principal bedrock aquifers;
2. Mapping aquifer characteristics, potentiometric surfaces, and dissolved-solids concentrations in the principal bedrock aquifers;
3. Estimating the water budget and the rate and direction of groundwater movement for the area;
4. Defining dominant water-chemistry composition, dissolved-solids concentrations, and principal geochemical mechanisms; and
5. Estimating the effects of mining activities on ground-water levels and dissolved-solids concentrations in the bedrock aquifers by use of mathematical models of the aquifers.

Objectives of the general overview of the western part of the area include:

1. Defining the extent, thickness, and lateral continuity of the principal bedrock aquifers;
2. Determining the general hydrologic relations between components of the hydrologic system; and
3. Determining general directions of ground-water flow.

Purpose and Scope

This report describes the characteristics of the hydrologic system in the study area. The hydrologic characteristics are based on hydrologic data that consisted of approximately 400 lithologic or geophysical well logs, 2,400 water-level measurements made in cased wells, 1,600 chemical analyses of ground- and surface-water samples, and other published or unpublished documents, maps, and tables. Some of the data are proprietary and confidential. The majority of the data pertain to the eastern part of the study area. The availability of data affects the hydrologic interpretations that can be made and is the principal reason for the differences in study objectives for the eastern and western parts of the area. The hydrologic characteristics of the eastern part of the study area were corroborated and better defined by use of mathematical models of the ground-water flow and solute-transport systems.

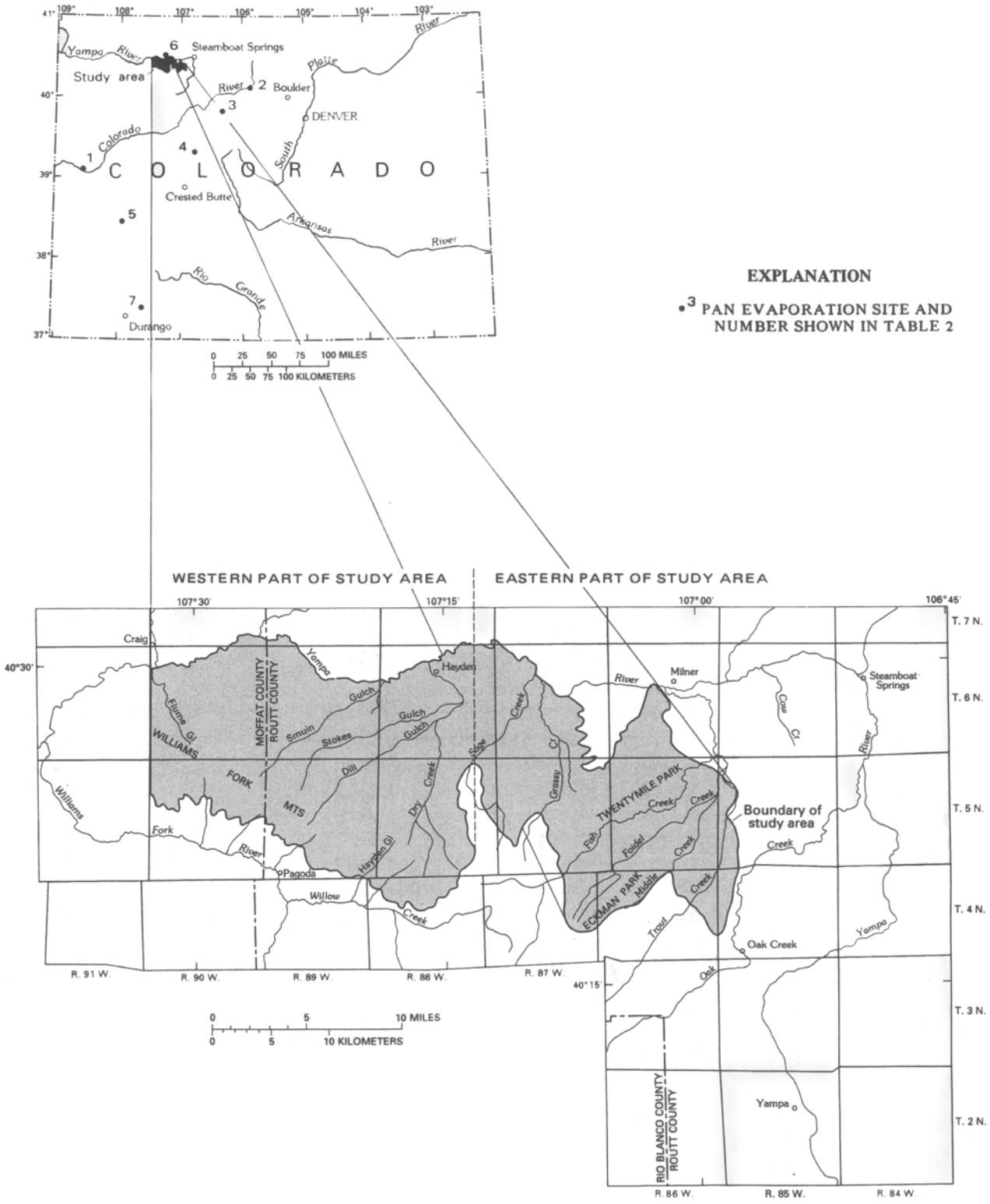

Figure 1.--Location of the study area.

Location

The 280-mi^2 study area is located in Routt and Moffat Counties in northwestern Colorado (fig. 1). The area is east of Craig and is bounded on the north by the Yampa River and on the northeast and south by the outcrop of the Trout Creek Sandstone Member of the Iles Formation. The Williams Fork Mountains have altitudes of more than 8,300 ft and extend from south of Craig to the southern margins of Twentymile Park (a broad intermountain valley in the eastern part of the area). The study area is drained by numerous ephemeral or discontinuous perennial streams. Trout Creek and its tributaries, Fish, Foidel, and Middle Creeks, are the principal perennial streams in the area.

Previous Research

Previous research within the area generally concerned evaluation of coal, oil, and gas reserves. Extensive coal reserves in the Williams Fork Mountains have attracted the attention of geologists since the 19th century. Coal investigations in the Williams Fork Mountains through the early 1920's are described in Bass and others (1955):

> The general region was traversed and mapped geologically by S.F. Emmons (1887), geologist with the 40th parallel survey in 1872, 4 years before Colorado was granted statehood. A geologic description, including a map, is given in his report on the region. Four years later the region was visited by C.A. White (1878 and 1889), a geologist with the Hayden survey. Topographic and geologic maps and descriptions, which are contained in reports of that survey, call attention to the extensive coal deposits.
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> In the late eighties and early nineties, rumors that a railroad would be built into this region stimulated exploration, immigration, and settlement. Geologists and mining engineers employed by the proposed Denver, Northwestern Pacific (later the Moffat) Railroad investigated the resources of the area. From 1886 to 1905 several articles about coal in the area were published. These included papers by F.F. Chisholm (1886), L.S. Storrs (1902, p. 435–436), G.C. Hewett (1889, p. 376), R.C. Hills (1893, p. 354–358), H.F. Parsons and C.A. Liddell (1903), and W. Weston (1904, 1909, and 1914). A geologic report describing the coal deposits of the area was published by the U.S. Geological Survey in 1906 (Fenneman and Gale, 1906). Exploitation of the coal on a relatively large scale followed the arrival of the railroad in 1906. The coal in and near Twentymile Park was described by Campbell (1923).

Following Campbell's report, little work pertaining to coal was done within the area until the mid-1950's and the publication of a U.S. Geological Survey Bulletin by Bass and others (1955). Later investigations of coal reserves include work done by Horn (1959), Miller (1975), and Ryer (1977). In 1977–78, the U.S. Geological Survey Conservation Division conducted an extensive drilling program and published geological and geophysical information pertaining to all the holes (Brownfield, 1978a, 1978b; Bronson, 1979). In 1979–80, Dames and Moore prepared several quadrangle coal-resource maps that were published by the U.S. Geological Survey (Dames and Moore, 1979, 1980 a–h).

Investigations of oil and gas reserves began in the 1920's with studies on anticlines in the area (Crawford and others, 1920; Willson, 1920; Collins, 1921). Later, Sears (1924) published a report on the geology and gas prospects in the area. Parts of the Williams Fork Mountains were included in oil and gas investigation maps by Bradley (1945) and Dyni (1966).

Numerous theses have been written about parts of the area, including the works of Willson and Collins mentioned above. Blackmer (1939), Beattie (1958), Kerr (1958), Kucera (1962), Lauman (1965), Buffler (1967), Masters (1967), and Kiteley (1980) all wrote geological theses pertaining to parts of the study area.

Examination of surface and subsurface hydrology did not begin until the mid-1970's. Brogden and Giles (1977) published a reconnaissance ground-water hydrology report about a large area of Routt and Moffat Counties, which included most of the study area. Hounslow and Fitzpatrick (1978) and McWhorter and others (1979) published reports containing hydrologic information collected within the area. A regional environmental impact statement (U.S. Department of the Interior, 1976) contained some regional hydrologic information, while several unpublished site-specific studies for permit applications examined the hydrology of areas likely to be affected directly by mining activity. Warner and Dale (1981) made the first attempt to model the area in order to predict effects of mining on ground-water quality; however, their results were compromised by lack of data.

Acknowledgments

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Most of the results of this study that pertain to the western part of the study area were compiled and developed by the coauthor in 1978–80 (Stewart, 1983) while he was employed by the U.S. Geological Survey. Stewart's work was done in cooperation with the U.S. Bureau of Land Management. In addition, Mr. Robert S. Williams and Dr. Keenan Lee aided in field-data collection or provided guidance and ideas invaluable to the completion of the report.