Water-Quality Characteristics in the Black Hills Area, South Dakota

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ABSTRACT

This report summarizes the water-quality characteristics of ground water and surface water in the Black Hills area. Differences in ground-water quality by aquifer and differences in surface-water quality by water source are presented. Ground-water characteristics are discussed individually for each of the major aquifers in the Black Hills area, referred to herein as the Precambrian, Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers. Characteristics for minor aquifers also are discussed briefly. Surface-water characteristics are discussed for hydrogeologic settings including headwater springs, crystalline core sites, artesian springs, and exterior sites.

To characterize the water quality of aquifers and streams in the Black Hills area, data from the U.S. Geological Survey National Water Information System water-quality database were examined. This included samples collected as part of the Black Hills Hydrology Study as well as for other studies within the time frame of October 1, 1930, to September 30, 1998. Tables of individual results are not presented in this report, only summaries. Constituents summarized and discussed include physical properties, common ions, nutrients, trace elements, and radionuclides. Comparisons of concentration levels are made to drinking-water standards as well as beneficial-use and aquatic-life criteria.

Ground water within the Black Hills and surrounding area generally is fresh and hard to very hard. Concentrations exceeding various Secondary and Maximum Contaminant Levels may affect the use of the water in some areas for many aquifers within the study area. Concentrations that exceed Secondary Maximum Contaminant Levels (SMCL's) generally affect the water only aesthetically. Radionuclide concentrations may be especially high in some of the major aquifers used within the study area and preclude the use of water in some areas. The sodium-adsorption ratio and specific conductance may affect irrigation use for some wells.

High concentrations of iron and manganese are the only concentrations that may hamper the use of water from Precambrian aquifers. The principal deterrents to use of water from the Deadwood aquifer are the high concentrations of radionuclides as well as iron and manganese. Iron, manganese, and hardness may deter use of water from the Madison aquifer as well as dissolved solids and sulfate in downgradient wells (generally deeper than 2,000 feet). Iron, manganese, and hardness may also deter use of the Minnelusa aquifer. Water from the Minnekahta aquifer generally is suitable for all water uses although it is hard to very hard. High concentrations of dissolved solids, iron, sulfate, and manganese may hamper the use of water from the Inyan Kara aquifer. In the southern Black Hills, radium-226 and uranium concentrations also may preclude use of water from the Inyan Kara aquifer. Suitability for irrigation may be affected by high specific conductance and sodium-adsorption ratio for the Inyan Kara.

Surface-water quality within the Black Hills and surrounding area generally is very good but the water is hard to very hard. Concentrations of some constituents in the study area tend to be higher exterior to the Black Hills, primarily due to influences from the Cretaceous-age marine shales, including dissolved solids, sodium, sulfate, selenium, and uranium. Headwater springs have relatively constant discharge, specific conductance, dissolved solids, and concentrations of most other constituents.

Concentrations at crystalline core sites are very similar to those found in samples from Precambrian aquifers. Some high nitrate concentrations greater than the Maximum Contaminant Level (MCL) of 10 mg/L (milligrams per liter) have occurred at Annie Creek near Lead, which have been attributed to mining impacts. Trace elements generally are low with the exception of arsenic, for which 60 percent of samples exceed the proposed MCL of 10 µg/L (micrograms per liter) and one sample exceeds the current MCL of 50 µg/L. The SMCL's for iron and manganese also have been exceeded in some samples. Artesian springs have very constant discharge and specific conductance at each site but show some variability between sites. Dissolved solids concentrations exceeding the SMCL of 500 mg/L and sulfate concentrations exceeding the SMCL of 250 mg/L are common for these sites.

Low dissolved oxygen concentrations in surface waters only occur at sites exterior to the Black Hills where high temperature and low flow occasionally are problematic. About 66 percent of the samples from sites exterior to the Black Hills exceed 1,000 mg/L sulfate. Concentrations exceeding the arsenic MCL, the selenium aquatic-life criterion, and the iron and manganese SMCL's occasionally occur at these sites. Radionuclide data are limited, but higher uranium concentrations are found for the areas exterior to the Inyan Kara Group outcrop.

Occasionally very low pH levels are recorded immediately downstream from abandoned mine sites but generally are within acceptable ranges once they mix with additional stream water. Changes in specific conductance, sodium, and sulfate in Bear Butte Creek occurred after additional mining activities in a tributary basin. Bear Butte Creek also had exceedances of the acute and chronic copper aquatic-life criteria for several samples between 1992-94. Within-basin changes for Rapid Creek follow the general trend of increasing concentrations for most constituents. Nutrient levels are low but do show an increase, indicating that land-use practices, both urban and agricultural, may be affecting the stream.

INTRODUCTION

The Black Hills area is an important resource center for the State of South Dakota. The Black Hills provide an economic base for western South Dakota through tourism, agriculture, the timber industry, and mineral resources. In addition to these resources, one of the most important natural resources in the Black Hills is water. Water originating from the area is used for municipal, industrial, agricultural, and recreational purposes throughout much of western South Dakota and is important recharge for aquifers in the northern Great Plains.

Population growth and resource development have the potential to affect the quantity, quality, and availability of water within the Black Hills area. Because of this concern, the Black Hills Hydrology Study was initiated in 1990 to assess the quantity, quality, and distribution of surface water and ground water in the Black Hills area of South Dakota (Driscoll, 1992). This long-term study is a cooperative effort between the U.S. Geological Survey (USGS), the South Dakota Department of Environment and Natural Resources (DENR), and the West Dakota Water Development District, which represents various local and county cooperators.

Ground-water quality in the area is heavily influenced by the mineralogy of the specific geologic unit containing the aquifer. Surface-water quality is heavily influenced by underlying geology and streamflow. Both ground-water and surface-water quality may be influenced by human effects related to land use. An assessment of the quality of ground and surface water is important for managing the water resources in the Black Hills area and providing a baseline for comparison of future water-quality data.

Purpose and Scope

The purpose of this report is to summarize the water-quality characteristics of ground water and surface water in the Black Hills. Comparisons of water quality by aquifer and comparisons of surface-water quality by water source are presented. Ground-water-quality characteristics are discussed individually for each of the major aquifers in the Black Hills area, referred to in this report as the Precambrian, Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers. Characteristics for minor aquifers, referred to in this report as the Spearfish, Sundance, Morrison, Pierre, Graneros, Newcastle, and alluvial aquifers, are discussed briefly. Surface-water-quality characteristics are discussed for various hydrogeologic settings including headwater springs, crystalline core basins, artesian springs, and exterior basins (down-gradient of the outcrop of the Inyan Kara Group). For some comparisons or descriptions, surface-water characteristics are discussed for selected basins, groups of sites, or selected sites. Comparisons are made for physical properties, major-ion chemistry, nutrients, trace elements, and radionuclide concentrations. Where sufficient data are available, spatial variations are presented.

Description of Study Area

The study area consists of the topographically defined Black Hills and adjacent areas located in western South Dakota (fig. 1). The generalized outer extent of the Inyan Kara Group, which approximates the outer extent of the Black Hills area, also is shown in figure 1. About 32 percent of the study area is within the boundaries of the Black Hills National Forest, which was created in 1897. The Black Hills are situated between the Cheyenne and Belle Fourche Rivers. The Belle Fourche River is the largest tributary to the Cheyenne River. The study area includes most of the larger communities in western South Dakota and contains about one-fifth of the State's population.

Physiography and Climate

The Black Hills uplift formed as an elongated dome about 60 to 65 million years ago (DeWitt and others, 1986). The dome trends north-northwest and is about 120 miles long and 60 miles wide. Elevations range from 7,242 feet above sea level at Harney Peak to about 3,000 feet in the adjacent plains. Most of the higher elevations are heavily forested with ponderosa pine, which is the primary product of an active timber industry. White spruce, quaking aspen, paper birch, and other native trees and shrubs are found in cooler, wetter areas (Orr, 1959). The lower elevation areas surrounding the Black Hills primarily are urban, suburban, and agricultural. Numerous deciduous species such as cottonwood, ash, elm, oak, and willow are common along stream bottoms in the lower elevations. Rangeland, hayland, and winter wheat farming are the principal agricultural uses for dryland areas. Alfalfa, corn, and vegetables are produced in bottom lands and in irrigated areas. Various other crops, primarily for cattle fodder, are produced in both dryland areas and in bottom lands.

Beginning in the 1870's, the Black Hills have been explored and mined for many commodities including gold, silver, tin, tungsten, mica, feldspar, bentonite, beryl, lead, zinc, uranium, lithium, sand, gravel, and oil (U.S. Department of Interior, 1967). Mines within the study area have utilized placer mining, small surface pits, underground mines, and open-pit mines.

The overall climate of the study area is continental, with generally low precipitation, hot summers, cold winters, and extreme variations in both precipitation and temperatures (Johnson, 1933). Local climatic conditions are affected by topography, with generally lower temperatures and higher precipitation at the higher elevations. The average annual precipitation for the study area (1931-98) is 18.61 inches, and has ranged from 10.22 inches for water year 1936 to 27.39 inches for water year 1995 (Driscoll, Hamade, and Kenner, 2000). The largest precipitation amounts typically occur in the northern Black Hills near Lead, where average annual precipitation (1950-98) exceeds 29 inches. Annual averages (1931-98) for counties within the study area range from 16.35 inches for Fall River County to 23.11 inches for Lawrence County. The average annual temperature is 43.9°F (U.S. Department of Commerce, 1999) and ranges from 48.7°F at Hot Springs to approximately 37°F near Deerfield Reservoir. Average evaporation generally exceeds average annual precipitation throughout the study area. Average pan evaporation for April through October is about 30 inches at Pactola Reservoir and about 50 inches at Oral.

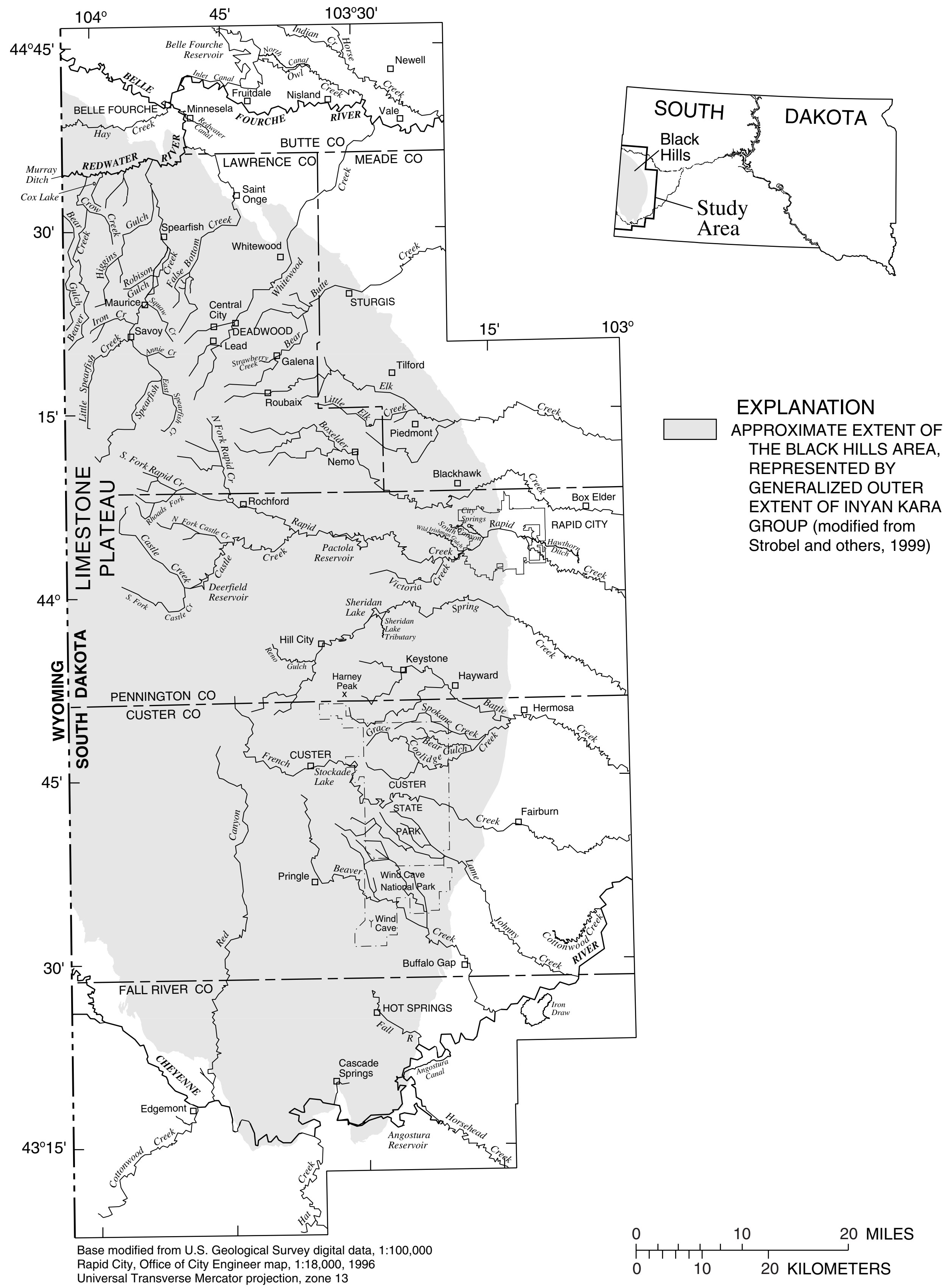

Figure 1. Area of investigation for the Black Hills Hydrology Study.