PREPARED IN COOPERATION WITH THE
COLORADO DEPARTMENT OF NATURAL
RESOURCES, DIVISION OF WATER RESOURCES,
OFFICE OF THE STATE ENGINEER

WATER-RESOURCES INVESTIGATIONS MAP REPORT 96-4166
GEOHYDROLOGY OF THE NORTH PARK AREA
Robson, S.G., and Graham, Glenn, 1996, Geohydrology of the North Park Area, Jackson County, Colorado

INTRODUCTION

Increasing population in rural and suburban areas of Colorado is causing greater reliance on ground water as a source of domestic supply. In the primarily rural area of Jackson County, for example, the number of registered water wells increased from about 100 in 1972 to about 500 in 1995. Most of the new wells were drilled after 1988 and supply water to ranches and summer homes.

In Jackson County, ground water is pumped from a series of shallow alluvial aquifers along principal stream valleys and from deeper, more extensive, bedrock aquifers. In much of the area, the alluvial aquifers are thin and can be dewatered by moderate water-level declines. Knowledge of the nature and extent of the alluvial and bedrock aquifers, the sources of recharge and discharge, and the effects of ground-water withdrawal on water levels in the aquifers is vital if management of the area's water resources is to ensure continued availability of a dependable water supply.

Purpose and Scope

This report presents the results of a study of the North Park area of Jackson County undertaken by the U.S. Geological Survey in 1995 in cooperation with the Colorado Department of Natural Resources, Division of Water Resources. The study was designed to provide information on the geology, extent, and thickness of various water-yielding formations; rate and sources of ground-water recharge and discharge; direction of ground-water movement; water quality of aquifers; and ground-water development.

Location of Study Area

The study area is in North Park in central Jackson County, Colorado. North Park is a broad intermountain valley consisting of flat to rolling sage and grassland ranging in altitude from about 8,000 to 9,000 ft. The valley is drained by the northward-flowing North Platte River and its principal tributaries, the Canadian, Michigan, and Illinois Rivers, and Grizzly Creek. Walden is the county seat and principal town in the 1,430-mi² study area.

North Park is surrounded and somewhat isolated by high, picturesque mountains. To the east and southeast, the valley is bordered by the Medicine Bow Mountains and the Never Summer Mountains. To the south and west, the valley is bordered by the Rabbit Ears Range and the Park Range, which are part of the Continental Divide. To the north, the valley is bordered by Independence Mountain and several lesser mountains. Mountain peaks generally range in altitude from 10,000 to 13,000 ft, and many are within wilderness areas or the Rocky Mountain National Park.

The North Park study area corresponds to the surface drainage area of the North Platte River upstream from the streamflow-gaging station near Northgate, Colorado. The study area includes all of central and southern Jackson County because the county boundaries in this area are defined by topographic divides.

Previous Investigations

Geologic mapping in the study area was begun in 1874 by A.R. Marvine of the Hayden Survey. However, Marvine died as a result of hardship and exposure during the fieldwork in North Park, and only a part of his work was published by Hayden (1877). More recent and detailed geologic mapping of the western part of North Park was completed in the 1960's by W.J. Hail, Jr. (1965, 1968). Surficial geologic mapping of the North Park area (Madole, 1991a, b) at 1:100,000 served as the principal geologic source for this investigation.

The ground-water resources of North Park were first described in a U.S. Geological Survey reconnaissance study of the area by P.T. Voegeli, Jr. (1965). Most subsequent descriptions of the area's hydrology have been site specific. For example, a number of unpublished reports describe the hydrology of local areas where permit applications have been filed for coal mining. A thesis by N.L. Barnes (1983) describes aquifer tests undertaken in the Coalmont area. A summary discussion of the geology and hydrology of North Park is contained in Kuhn and others (1983). Basic data pertaining to wells are contained in Voegeli (1965), Madden (1977a, b), and Bureau of Reclamation and others (1983).

GEOLOGY

Jackson County is underlain by rocks of Precambrian, Triassic, Jurassic, Cretaceous, and Tertiary age and by unconsolidated sediments of Quaternary age, all of which have some water-bearing potential (table 1). The oldest rocks are of Precambrian age and crop out in the high mountains to the northeast and west of North Park (fig. 1). Precambrian rocks primarily are crystalline metamorphic and igneous rocks consisting of schist, gneiss, and granite, which yield small volumes of water from rock fractures to seeps and springs. Precambrian rocks extend to great depth and underlie all younger rocks in North Park.

Rocks of Triassic, Jurassic, and Cretaceous age, which overlie the Precambrian rocks in North Park, were deposited as flat-lying sediments in ancient seas and streams long before the present Rocky Mountains were formed. Uplift of the Rocky Mountains during late Cretaceous and Tertiary time faulted, fractured, and deformed the formerly flat-lying rocks into a U-shaped structural depression (a syncline) that today is North Park. The upturned sides of the syncline are visible as outcrops and hogback ridges of Triassic, Jurassic, and Cretaceous rocks along most of the eastern and western margins of North Park (fig. 1). The Triassic, Jurassic, and Cretaceous rocks consist of interlayered marine shale, shaley limestone, siltstone, and sandstone. Porous or fractured sandstone is the principal water-yielding unit; shale, limestone, and siltstone generally do not yield water to wells. The rocks extend to great depth in most of North Park and yield small volumes of water to wells near outcrops.

During Tertiary time, the structural depression in North Park was being filled with sediments eroded from the adjacent, newly uplifted mountains (primarily the Park Range and Medicine Bow Mountains). Sand and gravel were deposited on alluvial fans that were prevalent near the margins of the depression; silt and clay were deposited in lakes and swamps that were prevalent near the center of the depression. These materials became the Coalmont Formation, which today consists of interlayered beds of poorly to moderately consolidated sandstone, conglomerate, siltstone, and shale with minable coal deposits in some areas. Sandstone and conglomerate are prevalent near the margins of North Park where they constitute 40 to 60 percent of the Coalmont Formation (fig. 2). In the central part of North Park, siltstone and shale predominate, and sandstone and conglomerate constitute less than 20 percent of the Coalmont. Coarse-grained, poorly consolidated sandstone and conglomerate are the principal water-yielding unit in the Coalmont Formation. As a result, the margins of the Coalmont have greater water-yielding potential than do the central parts of the Coalmont Formation where shale is prevalent.

The Eocene and Paleocene Coalmont Formation is in unconformable contact with the underlying Cretaceous Pierre Shale in most of North Park. The contact is difficult to identify on some geophysical logs because sandstone beds in the upper Pierre Shale, or erosional remnants of the Cretaceous Laramie Formation or Fox Hills Sandstone overlying the Pierre, are similar in appearance to the Coalmont. The approximate structure of the base of the Coalmont Formation (fig. 3) is based on an interpretation that grouped most sandstone near the Coalmont-Pierre contact with the Coalmont rather than with the predominantly shaley Pierre Shale. The irregular shape of the base of the Coalmont (fig. 3) is the result of the numerous faults and folds (synclines and anticlines) that are present in the underlying Triassic, Jurassic, and Cretaceous rocks. The altitude of the base of the Coalmont Formation ranges from 8,000 to 10,000 ft near the margins of the formation to less than 2,000 ft in the central part of the formation. The Coalmont Formation outcrops or subcrops in a 900-mi² area of North Park and is 6,000 to 6,500 ft thick in a large area south of Walden.

Oligocene and Miocene sediments of the White River Formation and the North Park Formation unconformably overlie the Coalmont Formation along the axis of the North Park syncline (fig. 3). Peterson Ridge and Owl Ridge are the erosional remnants of these formations, which once were widely distributed in North Park. The White River Formation consists of light gray tuffaceous siltstone and claystone; the North Park Formation consists of poorly consolidated sandstone, conglomerate, claystone, and volcanic ash. The sandstone, conglomerate, and ash likely are permeable; however, most of the White River and North Park Formations are above the level of the valley floor, are drained, and generally do not yield water to wells.

At Peterson Ridge, the outcrops of the White River Formation are higher on the south side of the ridge than on the north side. Impermeable beds in the White River, or impermeable shale at the top of the underlying Coalmont Formation, cause ground water in Peterson Ridge to flow northward and discharge at several springs located along the northern edge of the ridge. In the absence of these impermeable layers, most ground water in Owl and Peterson Ridges probably flows downward into the Coalmont Formation. A similar pattern of downward ground-water movement is likely in the Tertiary volcanic rocks that intrude or overlie the Coalmont Formation near Owl Mountain and Hyannis Peak (near the southern margin of the area).

Quaternary deposits consisting of alluvium, alluvial fans, terrace deposits, glacial drift, landslide deposits, and eolian deposits are widespread in North Park. Alluvium in stream valleys can be an important source of ground water; this unit is delineated in figure 1. The other Quaternary deposits in the area, which are not shown in figure 1, have lesser potential as sources of water because the deposits generally are thin, are located above the level of most streams, and are well drained. Alluvium, which consists of unconsolidated gravel, sand, and silt with some clay, generally is less than 25 ft thick, but exceeds 50 ft in a few areas. Thick alluvium near a perennial stream in a principal stream valley, such as that of the North Platte River, Canadian River, Michigan River, Illinois River, or Grizzly Creek, may yield 100 to 300 gal/min of water to wells (Voegeli, 1965). Alluvium in small valleys generally is thin and yields only small volumes of water to wells.

HYDROLOGY

Precipitation Runoff

The mean-annual precipitation in the North Park area is 19 in.; however, precipitation is much less in the valley than in the surrounding mountains (fig. 4). In the valley at Walden, for example, the 1951–80 mean-annual precipitation was about 11 in., while 23 mi to the west on the crest of the Park Range, mean-annual precipitation exceeded 50 in. On average, precipitation provides 1,450,000 acre-ft/yr of water to the 1,430-mi² North Park study area.

Almost all streamflow out of North Park passes the North Platte River near Northgate streamflow-gaging station at the northern end of North Park (fig. 1). The 1903–93 mean-annual streamflow at the Northgate gage was 314,000 acre-ft/yr; an additional 2,000 acre-ft/yr was diverted from North Park through two small irrigation ditches; therefore, total surface-water discharge from North Park was 316,000 acre-ft/yr. The difference between the average precipitation inflow to North Park (1,450,000 acre-ft/yr) and the average surface outflow (316,000 acre-ft/yr) from North Park is 1,134,000 acre-ft/yr. This 1,134,000 acre-ft/yr is the mean-annual volume of water that is lost by evapotranspiration in North Park because there is no other important means of water inflow or outflow from North Park. Thus, 78 percent of the precipitation in the North Park area is lost by evaporation from open water, snow, and ice and by transpiration from vegetation (evapotranspiration).

Ground Water

North Park is a closed ground-water basin; no ground water flows into or out of North Park through the margins of the basin, and local precipitation is the sole source of ground water in North Park. The geologic map (fig. 1) indicates that Precambrian rocks form a continuous border around the western, northern, and eastern parts of North Park. These rocks are essentially impermeable at depth and prevent ground-water flow through these margins of North Park. To the south, the Rabbit Ears Range primarily consists of permeable Coalmont Formation rocks; however, water-level data from wells (Voegeli, 1965) indicate that a ground-water divide exists along the crest of the Rabbit Ears Range, and ground water cannot flow into or out of North Park across the divide.

A ground-water divide has an effect on ground-water flow that is similar to the effect of a peaked house roof on rain runoff. Ground water flows in opposite directions away from a ground-water divide, just as rain runs off a roof in opposite directions away from the ridge of the roof. Rain that falls on one side of the ridge cannot run off the roof on the opposite side of the ridge. Similarly, rain that recharges the aquifer on one side of a ground-water divide cannot flow to the opposite side of the divide. Thus, ground water does not flow into or out of North Park across the ground-water divide under the Rabbit Ears Range.

Part of the precipitation that falls in North Park percolates through the soil and recharges the ground-water system. The ground water slowly flows through the formations from areas of recharge to areas of discharge where the water contributes to base flow in streams or is consumed by crops or phreatophytes growing along the valley bottoms. During October when frost has killed or defoliated most crops and phreatophytes, the base flow in streams is approximately equal to the rate of ground-water discharge. The rate of ground-water discharge is equal to the rate of ground-water recharge because no substantial change in the volume of ground water in storage has occurred in North Park. The 1904–93 mean-annual October flow in the North Platte River at Northgate is 117,000 acre-ft/yr and is the approximate mean-annual rate of ground-water recharge and discharge in North Park. The recharge and discharge occur in the alluvium, the Coalmont Formation, and in older rocks of Precambrian, Triassic, Jurassic, and Cretaceous age. No data are available to determine the rates of recharge and discharge in individual rock units.

Coalmont Aquifer

Potentiometric Surface

The principal areas of ground-water recharge and discharge in the Coalmont Formation are defined by the potentiometric surface of the Coalmont aquifer (fig. 5). Water-level measurements in wells define the ground-water altitude at a well. A surface drawn through many measurements of ground-water altitude is called a potentiometric surface. A potentiometric surface slopes from areas of ground-water recharge where the potentiometric surface is higher toward areas of ground-water discharge where the potentiometric surface is lower. Most wells in the Coalmont Formation in North Park range in depth from about 100 to a few hundred feet and are completed in the upper part of the Coalmont aquifer, which generally is unconfined. The altitude of the potentiometric surface was defined using water-level measurements in wells and the altitude of streams crossing the Coalmont Formation. The altitude of streams crossing the formation are indicative of the altitude of the potentiometric surface because the potentiometric surface of an unconfined aquifer cannot exceed the altitude of the stream. Historical water-level measurements in wells indicate that the altitude of the potentiometric surface has remained relatively constant during the past 40 or more years. As a result, the potentiometric surface based on historical water-level measurements and stream altitudes (fig. 5) depicts the long-term water-level conditions in the upper part of the Coalmont aquifer.

The potentiometric surface of the Coalmont aquifer ranges in altitude from more than 9,200 ft in the southern part of the area to less than 8,000 ft in the northern part of the area. The potentiometric surface generally is lower near the principal stream valleys than in the upland areas between stream valleys because greater precipitation and snowmelt in the upland areas percolate to depth and recharge the aquifer. Ground water flows laterally toward the principal stream valleys where it is discharged to the streams or to the alluvium and, subsequently, to the streams. The general direction of ground-water movement, as indicated by the arrows on figure 5, is perpendicular to the potentiometric contours.

In the north-central part of North Park, the potentiometric surface is much flatter (as indicated by widely spaced contours) than in the southern part of North Park (fig. 5). Base-flow analyses of streams tributary to the North Platte River near Walden indicate that only a small volume of ground-water discharge enters the North Platte River between Walden and the Northgate gaging station. The flat topography of the lower valley and the small percentage of permeable sandstone in the central Coalmont Formation probably force most ground water to the surface upgradient from Walden, and a flat potentiometric surface and minimal ground-water discharge occur downgradient from Walden. Thus, the principal areas of ground-water recharge in the Coalmont Formation are in the upland areas between stream valleys in the southern part of North Park where precipitation is greater. The principal areas of ground-water discharge are along the larger stream valleys primarily above the 8,200-ft potentiometric contour. The North Platte River and streams below the 8,200-ft potentiometric contour receive only small volumes of ground-water discharge from the Coalmont Formation.

The potentiometric surface in the upper part of the Coalmont Formation is unconfined in many areas; however, shale beds prevalent in the Coalmont Formation form confining layers, and the deeper parts of the aquifer are confined. Confined conditions are evident in several stream valleys where deeper wells flow, and the potentiometric surface of the Coalmont aquifer is above land surface. In the southern part of the aquifer, recharge in the steep topography of the Rabbit Ears Range likely causes large downward head gradients across confining layers in the Coalmont aquifer. This would cause the standing water level to be farther below land surface in deep wells than in shallow wells.

Ground-Water Storage

Large volumes of ground water are stored in the Coalmont aquifer. In North Park, the Coalmont aquifer contains about 120 million acre-ft of recoverable ground water in storage. However, the Coalmont Formation is as much as 6,500 ft thick, and water in the deeper parts of the formation likely is of poor chemical quality. In the upper 1,000 ft of the Coalmont, where water is of better quality, about 39 million acre-ft of recoverable ground water is in storage. Thirty-nine million acre-ft is a large volume of water; it is equivalent to all the water that would flow out of North Park in streams during a 125-year period. The estimated volume of ground water in storage was calculated using the area and thickness of the Coalmont aquifer, the percent sandstone in the Coalmont, and a mean specific yield of 0.18 based on the specific yield of similar Tertiary sandstone units in the Denver Basin (Robson, 1983).

Water Quality

Thirty chemical analyses of water samples from wells 100 to 800 ft deep in the Coalmont Formation were compiled primarily from the files of the U.S. Geological Survey. The analyses indicate that in most areas the ground water is of good chemical quality and meets the recommended and mandatory drinking-water regulations indicated in table 2. However, in areas affected by coal mining, or in areas where coal beds are near land surface, the ground-water quality is varied, and samples from some wells may contain concentrations of dissolved solids, sulfate, iron, or manganese that exceed the recommended drinking-water regulations. The Coalmont area 14 mi southwest of Walden and the east-central margin of North Park about 9 mi east of Walden are the two principal mined areas.

Beyond the two mined areas, ground water in the Coalmont Formation generally is of a sodium bicarbonate type with a median dissolved-solids concentration of about 400 mg/L. Dissolved-solids concentrations range from about 200 to 3,000 mg/L in this area, and the water generally is soft to moderately hard. In the Coalmont area, the ground water is a mixed sodium, calcium, bicarbonate, sulfate type with a median dissolved-solids concentration of about 700 mg/L; dissolved-solids concentrations range from 500 to 1,200 mg/L, and the water is moderately hard to hard. East of Walden, the ground water also is a mixed sodium, calcium, bicarbonate, sulfate type with a median dissolved-solids concentration of about 1,100 mg/L; dissolved-solids concentrations range from 400 to 7,000 mg/L, and the water is very hard.

Potential Well Yield

The Coalmont aquifer has the potential to yield large volumes of water to wells in some areas and minimal volumes of water in other areas. Well yield primarily is dependent on the capability of the aquifer to transmit and store water as measured by the aquifer characteristics transmissivity (T) and storage coefficient (S). T and S vary greatly across the Coalmont aquifer, and these variations produce corresponding large variations in potential well yield.

Hydraulic conductivity, which can be used to calculate T, has been determined from aquifer tests on about 30 wells completed in the Coalmont aquifer (Voegeli, 1965; Barnes, 1983; Bureau of Reclamation and others, 1983; and unpublished coal mine permit applications on file at the Colorado Department of Natural Resources, Division of Minerals and Geology). Wells with small values of hydraulic conductivity primarily are located near the central part of North Park where there is less than 20 percent sandstone and conglomerate in the Coalmont Formation. Wells with large values of hydraulic conductivity primarily are located in areas where there is more than 40 percent sandstone and conglomerate in the Coalmont Formation. The geometric means of a group of 17 small hydraulic-conductivity values and a group of 3 large hydraulic-conductivity values are plotted in figure 6 with the corresponding arithmetic mean values of percent sandstone and conglomerate for each group. The mean hydraulic conductivity and percent sandstone and conglomerate found in similar Tertiary sediments in the Denver Basin (Robson, 1983) are shown in figure 6 to further define the shape of the line drawn through the data points. Figure 6 indicates that in North Park and in the Denver Basin, Tertiary sandstone and conglomerate beds tend to be more permeable in the parts of an aquifer that contain more sandstone and conglomerate than in the parts of an aquifer that contain less sandstone and conglomerate. The relation shown in figure 6 was used with the percent sandstone and conglomerate map (fig. 2) to estimate the hydraulic conductivity of the sandstone and conglomerate. T for the upper 1,000 ft of the Coalmont aquifer was calculated as:

$$T = 1{,}000\ P\ K \qquad (1)$$

where

T = transmissivity, in foot squared per day;
P = percent sandstone and conglomerate (from fig. 2); and
K = hydraulic conductivity (from fig. 6).

The T of the upper 1,000 ft of the Coalmont aquifer (fig. 7) is less than 20 ft²/d in the central part of North Park where there is less than 20 percent sandstone and conglomerate. T may exceed 3,000 ft²/d in the northern and southern parts of the Coalmont Formation where saturated thickness and percent sandstone and conglomerate are large. Storage coefficient (S) of the upper 1,000 ft of the Coalmont aquifer was estimated to range from 0.0002 to 0.001 based on a mean specific storage of 0.000002 per foot for similar aquifers in the Denver Basin (Robson, 1983), the percent sandstone and conglomerate map (fig. 2), and the following equation:

$$S = 1{,}000\ P\ S_s \qquad (2)$$

where

S = storage coefficient;
P = percent sandstone and conglomerate; and
S_s = mean specific storage.

Potential well yield can be calculated by use of equations developed by C.V. Theis in 1935 (Freeze and Cherry, 1979, p. 317) and the various values of T and S for the Coalmont aquifer. The potential well yields shown in table 3 are calculated for a hypothetical well 1,000 ft deep, 2 ft in diameter, with 100 ft of drawdown after 30 days of pumping. Potential well yields range from about 1,000 gal/min in the areas of high T and S in the northern and southern parts of the Coalmont aquifer to less than 10 gal/min in the area of low T and S in the central part of the aquifer. In those parts of the aquifer where data are more prevalent, potential well yields are less than 300 gal/min. Wells of lesser or greater depth can be expected to have a proportionally smaller or larger yield; for example, in a uniform aquifer, if a 1,000-ft-deep well yields 500 gal/min, a well half as deep could yield about half as much. However, potential well yields are not actual well yields. The actual yield of a well is affected by the thickness and permeability of the sandstone and conglomerate present near the well site; such local conditions cannot be determined from these basinwide analyses.

Alluvial Aquifer

The alluvium in North Park is much less extensive than the Coalmont Formation but is an important source of ground water in larger stream valleys. Although alluvium extends along the valleys of most streams (fig. 1), it is wide and thick enough to be an important source of water only in the larger valleys. In most of the larger valleys, the alluvium generally is less than one-half mile wide and attains widths of about 1 mi in only a few areas. The median thickness of the alluvium in the larger valleys is about 20 ft but is as much as 50 ft in a few areas along the North Platte River west of Walden. An aquifer test on a 35-ft-deep well completed in the alluvium of the Michigan River at Walden (Voegeli, 1965, p. 18) had a hydraulic conductivity of 330 ft/d, a T of 2,700 ft²/d, and yielded 113 gal/min. The hydrology and geology of the Michigan River alluvium seems to be similar to that of alluvium in other valleys in North Park, and similar alluvium in those valleys could be expected to yield comparable volumes of water to wells.

Ground water in the alluvium forms an alluvial aquifer. The alluvial aquifer is part of a stream-aquifer system in which water moves readily between the stream and the aquifer. When the water level in the aquifer is higher than the water level in the stream, water flows from the aquifer into the stream; when the water level in the aquifer is lower than in the stream, water flows from the stream into the aquifer. When pumping wells lower the water level in the aquifer, water from the stream may be induced to flow into the aquifer near the wells (induced recharge), or the rate of water flow from the aquifer to the stream may be diminished (captured discharge). Induced recharge and captured discharge diminish streamflow and reduce the rate of water-level decline in the aquifer caused by pumping. Induced recharge and captured discharge enable the thin alluvial aquifers near streams in North Park to support large rates of ground-water withdrawal. Aquifers near streams with intermittent flow receive less induced recharge and captured discharge and can sustain only small rates of withdrawal.

The alluvial aquifer is recharged from precipitation, irrigation, the Coalmont Formation, and streamflow; the aquifer discharges to streams and by evapotranspiration. Precipitation on the alluvium and water applied to irrigated fields on the alluvium are important sources of recharge to the alluvial aquifer. Ground water in the Coalmont Formation flows toward the stream valleys where the water enters the streams or the alluvium and becomes recharge to the alluvial aquifer. Streamflow also recharges the alluvial aquifer in areas where pumping or local conditions cause water to flow from the stream into the aquifer. However, the principal direction of water movement in the alluvium is toward the streams; as a result, the alluvial aquifer generally discharges to streams. Because of the shallow depth to water in many parts of the alluvium, some water is discharged from the aquifer directly by evapotranspiration through wetlands and vegetation. In North Park, water pumped from wells completed in the alluvial aquifer is a small component of the total discharge from the aquifer.

Water in the alluvial aquifer is of a mixed sodium, calcium, bicarbonate, sulfate type and has a median dissolved-solids concentration of about 250 mg/L. The hardness of the water ranges from soft to very hard.

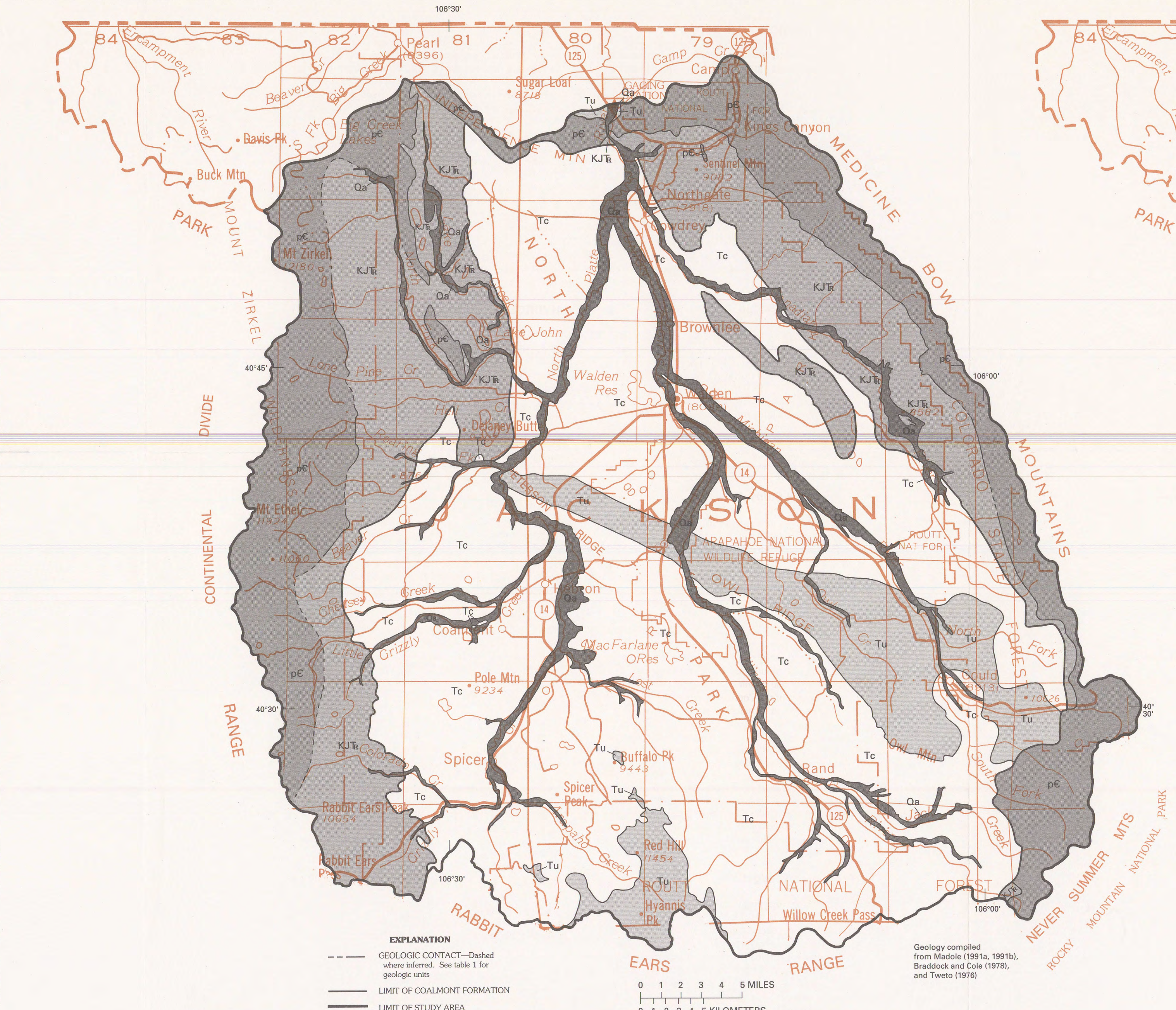


Figure 1. Generalized geology of North Park.

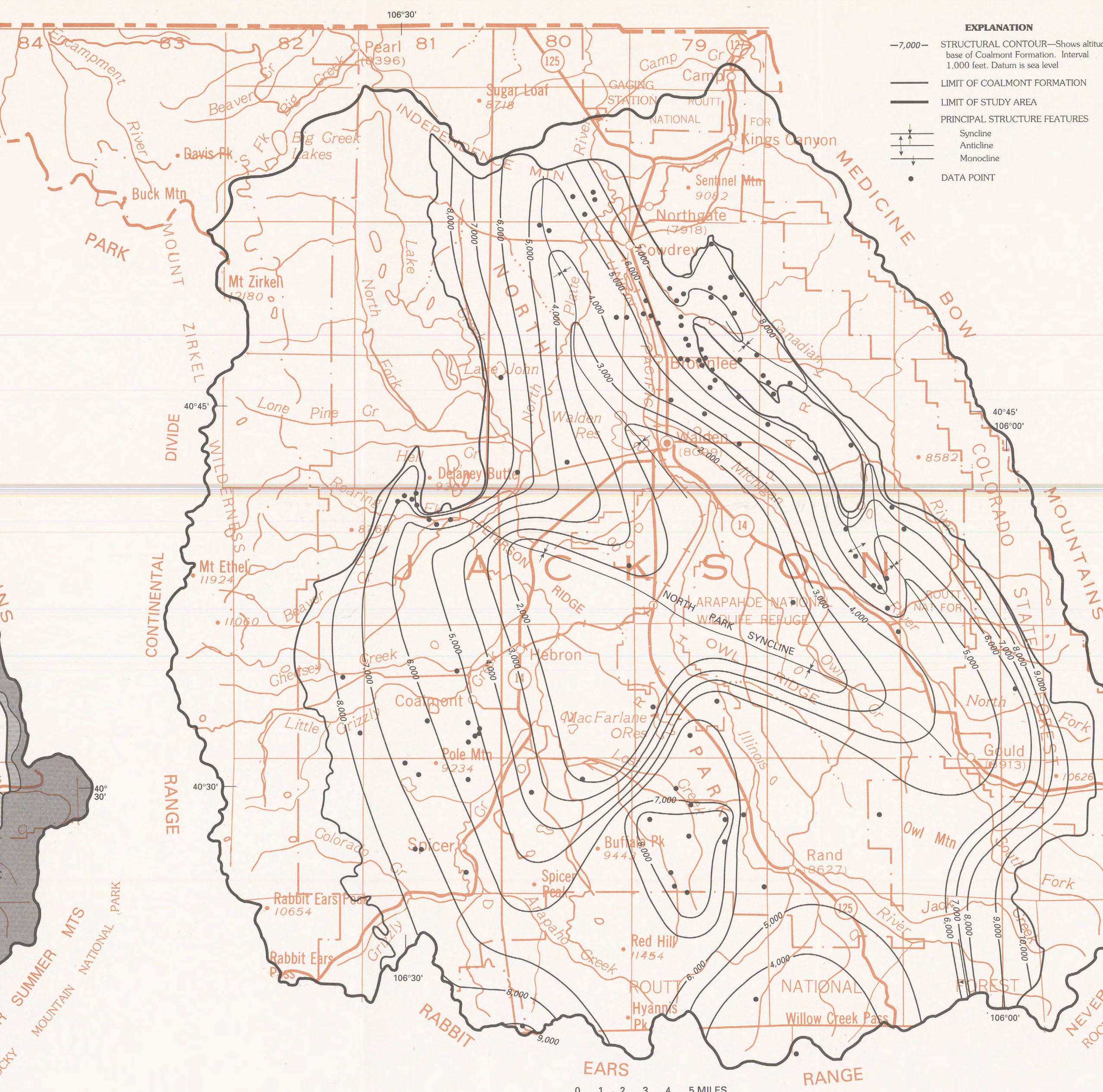


Figure 3. Approximate structure of the base of the Coalmont Formation.

Figure 4. Mean-annual precipitation, Jackson County, 1951–80.

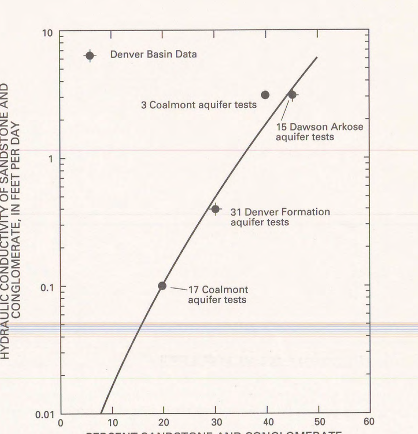


Figure 6. Approximate relation between hydraulic conductivity and percent sandstone and conglomerate in the Coalmont aquifer.

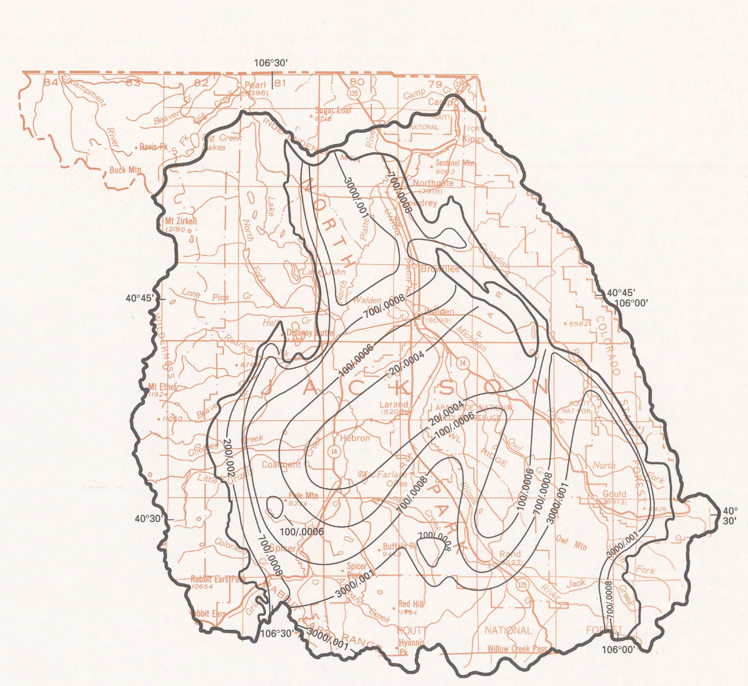


Figure 7. Estimated transmissivity and storage coefficient of the upper 1,000 feet of the Coalmont aquifer.

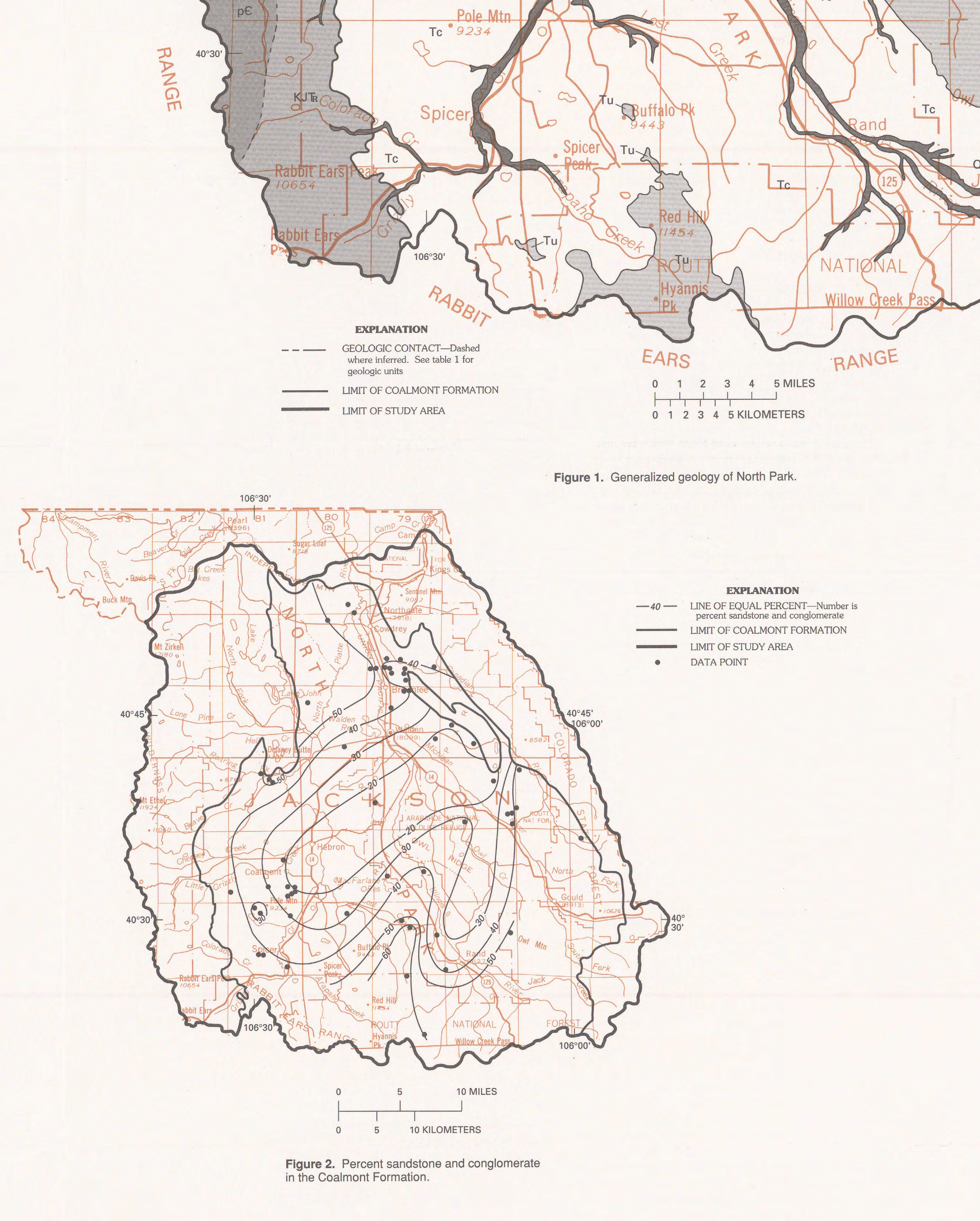


Figure 2. Percent sandstone and conglomerate in the Coalmont Formation.

Table 1. Description of geologic units and their physical and hydrologic characteristics

System	Series	Geologic unit	Map symbol (fig. 1)	Maximum thickness (feet)	Physical characteristics	Hydrologic characteristics
Quaternary	Holocene	Alluvium	Qa	50	Gravel, sand, silt, and small amounts of clay in stream valleys. Quaternary glacial, landslide, eolian, alluvial, and terrace deposits also are present in the area (Madole, 1991a, b), but are not shown in figure 1.	Thick segments can yield large volumes of water to wells near streams. Small-capacity wells are common. Potable water quality. Glacial, landslide, eolian, alluvial, and terrace deposits generally are well drained and are not a widespread source of water.
Tertiary	Pliocene	Undifferentiated volcanic rocks, North Park, and White River Formations	Tu	1,800	Volcanic flows and tuff breccia. Poorly consolidated tuffaceous sandstone, conglomerate, and siltstone with claystone and volcanic ash.	Breccia, sandstone, conglomerate, and ash yield water to springs. Few wells have been completed in unit.
	Miocene					
	Oligocene					
	Eocene	Coalmont Formation	Tc	6,500	Conglomerate, sandstone, and siltstone of fan alluvium, and shale, sandstone, and coal of interfan areas. Poorly to moderately consolidated. Predominantly shale in central North Park.	Poorly consolidated, coarse-grained sandstone and conglomerate can yield large volumes of potable water to wells. Where shale predominates, Coalmont has limited water-yielding potential. Water quality degrades with depth.
	Paleocene					
Cretaceous Jurassic Triassic		Undifferentiated Mesozoic rocks	KJTR	7,000 ?	Marine shale, shaley limestone, siltstone, and sandstone. Moderately to well consolidated.	Fractured sandstone yields potable water to springs and small-capacity wells. Shale, limestone, and siltstone generally yield little water.
Precambrian		Undifferentiated Proterozoic rocks	p€	--	Igneous and metamorphic rocks consisting of granite, gneiss, and schist.	Yields water from shallow fractures to springs and small-capacity wells. Potable water quality.

Table 2. Water-quality standards for selected constituents

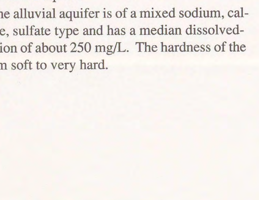
Water-quality constituent	National and Colorado drinking-water standards and regulations (U.S. Environmental Protection Agency, 1994; Colorado Department of Health, 1981)
Major inorganic constituents (mg/L)	
Sulfate	[1]250
Chloride	[1]250
Fluoride	[2]4.0
Dissolved solids	[1]500
Nitrate (as nitrogen)	[2]10
Trace elements (µg/L)	
Arsenic	[2]50
Barium	[2]2,000
Iron	[1]300
Lead	[2]15
Manganese	[1]50
Selenium	[2]50
Zinc	[1]5,000

[1]Secondary maximum contaminant level. These standards pertain to constituents in drinking water that primarily affect the esthetic qualities relating to the public acceptance of drinking water and are not federally enforceable but are intended as guidelines for the States.

[2]Primary maximum contaminant level. These regulations are the maximum permissible level of a contaminant in water at the tap; they are health related and are legally enforceable.

Table 3. Potential well yield and physical characteristics of various parts of the Coalmont aquifer

Potential well yield (gal/min)	Percent sandstone	Transmissivity (T) (ft²/d)	Storage coefficient
9	20	20	0.0004
50	30	100	.0006
300	40	700	.0008
1,000	50	3,000	.0010



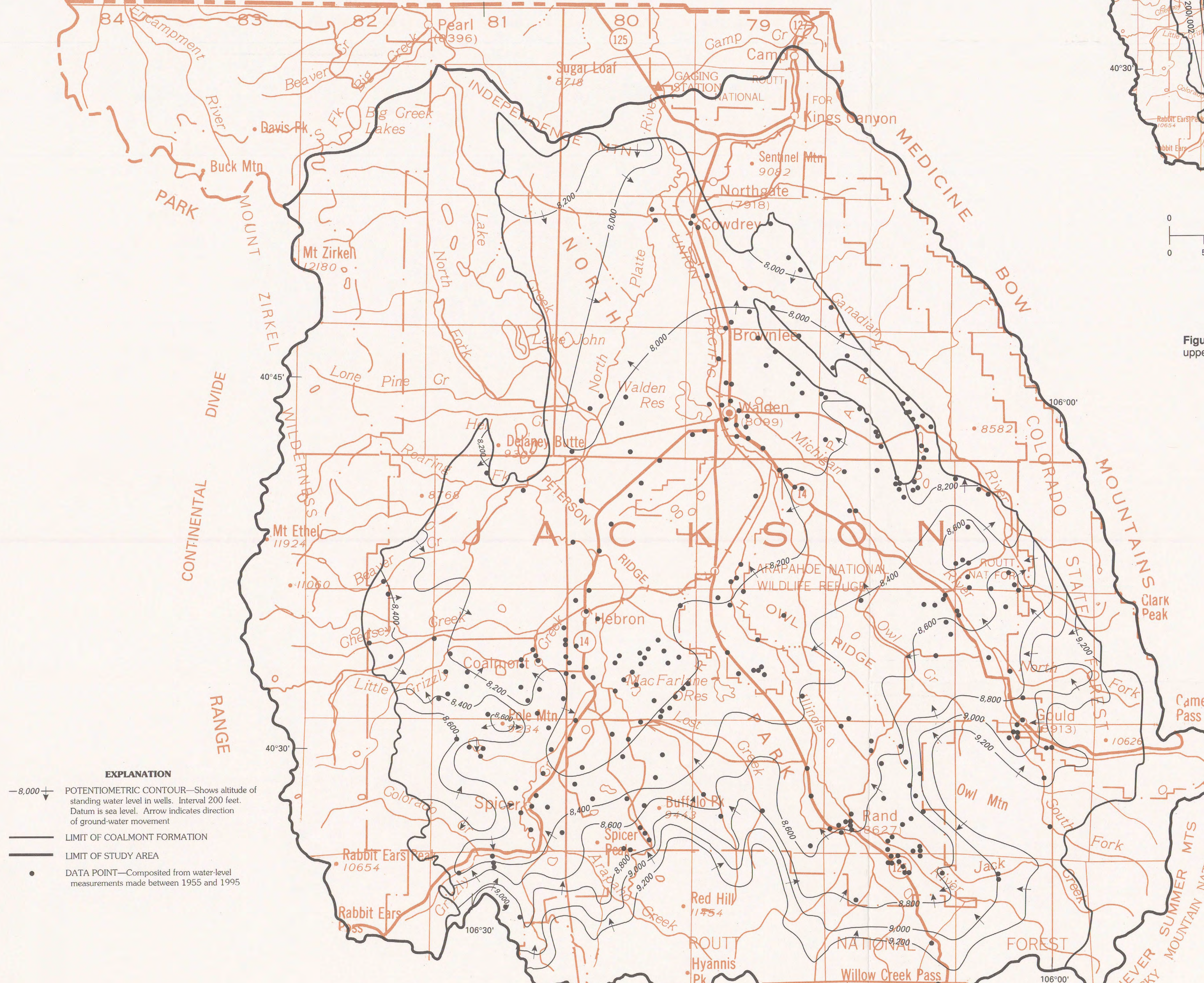


Figure 5. Potentiometric surface of the Coalmont aquifer.

EFFECTS OF WATER LAW ON DEVELOPMENT OF GROUND WATER IN NORTH PARK

By Glenn Graham, Colorado Division of Water Resources

Colorado water law and the system for regulating the waters of the State originally were developed to preserve and administer the distribution of surface water. As a result, the law is based on the principle of prior appropriation which assigns water rights based on a first-in-time, first-in-right, priority system (Vranesh, 1987). When it later became apparent that pumping wells also could diminish streamflow, regulations were implemented to assign water rights to large wells based on the priority system. Thus, the first diversion of water from a stream for beneficial use is assigned the senior water right on the stream, and later surface diversions (or large pumping wells) are assigned more junior water rights based on their date of first diversion. The senior water rights on the North Platte River and its tributaries in North Park date from the early 1880's. In North Park, the earliest priority date for a well is 1890, and only four wells have priority dates earlier than 1900; most wells have priority dates after 1940. Small-capacity wells for domestic and stock use are exempt from the water rights system, and permits for construction of these wells are granted based on water-use considerations. Colorado water law and regulations are administered by the Colorado Division of Water Resources, and permits are required for construction of all water wells in Colorado.

The legal availability of ground water in Colorado is determined on the basis of a site-specific evaluation of the aquifer and nearby streams. An "overappropriated" stream has a burden of legal rights for more water than the flow of the stream; a stream that is "not overappropriated" has water available for diversion. For example, the entire main stem of the North Platte River in North Park is "not overappropriated," and surface water is presently (1995) available for stream diversion or withdrawal from nearby wells. Well permits can be granted within the priority system for wells in the nearby alluvium or Coalmont aquifer if pumping will not deplete streamflow enough to infringe on existing water rights. However, other streams in North Park, such as the Illinois River, Michigan River, Canadian River, and their tributaries, are "overappropriated." Additional ground-water withdrawal from the alluvium or Coalmont in these drainage areas would deplete streamflow and thus infringe on existing water rights.

If there is no water available for appropriation, then the anticipated use of the ground water can be considered in evaluating a well permit application. If the well is to be used to supply water for domestic, stock, or individual residential use, the statutory requirements for an "exempt use" classification may be met, and the well permit can be granted under a statutory presumption of non-injury to existing water rights. If the intended use of ground water is for "non-exempt" use, then the party seeking a well permit must first determine the effect of the proposed use on existing water rights and must acquire water rights, usually surface-water rights, which would be used to develop a plan of augmentation to replace to the affected stream the depletions caused by the proposed use.

In addition to State limitations on development of ground water in North Park, there are obligations imposed on the use of the waters of the North Platte River in Colorado by the terms and conditions of the 1945 decision of the U.S. Supreme Court in *Nebraska* v. *Wyoming* as amended in 1953. Within Colorado, use of the waters of the North Platte River are restricted to: irrigation of not more than 145,000 acres, storage for irrigation purposes not to exceed 17,000 acre-ft/yr, and water exports from the basin not to exceed 60,000 acre-ft in any consecutive 10-year period. Use of water for ordinary and usual domestic, municipal, and stock-watering purposes is not restricted. To date (1995), Colorado has not approached any of the limits set by the court.

Additional constraints on use of the waters of the North Platte River, and by association, ground water tributary to the North Platte River, may result from ongoing discussions between the States of Colorado, Wyoming, and Nebraska, the U.S. Forest Service, and the U.S. Fish and Wildlife Service with regard to endangered species issues along the Platte River in Nebraska.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft³/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft²/d)	0.09292	meter squared per day
per foot	3.281	per meter
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
square mile (mi²)	2.59	square kilometer

Other abbreviations used:

microgram per liter (µg/L)
milligram per liter (mg/L)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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GEOHYDROLOGY OF THE NORTH PARK AREA, JACKSON COUNTY, COLORADO

By
S.G. Robson and Glenn Graham

1996

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