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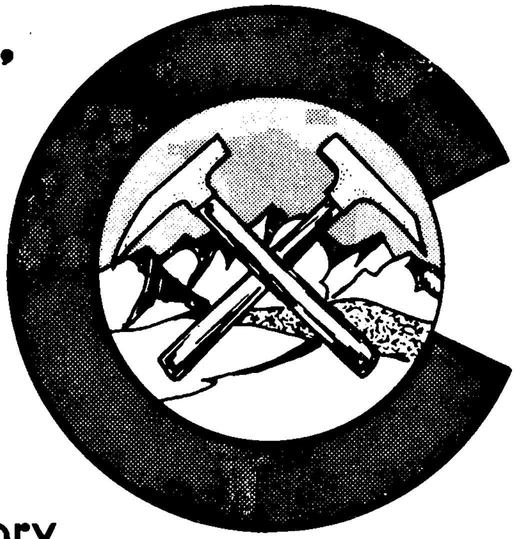
Hydrogeologic and Stratigraphic Data Pertinent to Uranium Mining, Cheyenne Basin, Colorado



by Robert M. Kirkham,
William O'Leary,
and James W. Warner

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO / 1980

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Colorado Geological Survey
Department of Natural Resources
State of Colorado
Denver, Colorado

1980

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*with the U.S. Geological Survey
Water Resources Division - Colorado District
Denver, Colorado

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ABSTRACT

Recoverable low-grade uranium deposits occur in the Upper Cretaceous Fox Hills Sandstone and Laramie Formation in the Cheyenne Basin, Colorado. One of these deposits, the Grover deposit, has been test mined on a pilot scale using in situ solution mining techniques. A second deposit, the Keota deposit, is currently being licensed and will produce about 500,000 lb/yr (227,000 kg/yr) of yellowcake also using in situ solution mining techniques. Other uranium deposits exist in this area and will also probably be solution mined, although open-pit mining may possibly be employed at a few locations in the Cheyenne Basin. One of the principle environmental impacts of this uranium mining activity is the potential affect on ground-water quality and quantity. In order to fully assess potential ground-water impacts, regulatory agencies and mine planners and operators must be familiar with regional geologic and hydrologic characteristics of the basin.

The Oligocene White River Group and Upper Cretaceous Laramie Formation, Fox Hills Sandstone, and Pierre Shale contain important aquifers which supply water for domestic, stock-watering, irrigation, and municipal purposes in the study area. Most water from the White River Group and Laramie Formation is produced from lenticular, locally thick, channel sandstones, although vertical fractures and clastic dikes locally influence water in the White River Group. The upper member of the Fox Hills Sandstone is a prolific water-producing, massive sandstone interpreted by Ethridge and others (1979) to have been deposited in a barrier bar system. The lower member of the Fox Hills Sandstone consists of numerous coarsening-upward, delta-front sandstones which yield moderate amounts of water. An aquifer within the upper part of the Pierre Shale, herein called the upper Pierre aquifer, is a thick sequence of siltstone and silty sandstone about 325 to 475 ft (97.5 to 142.5 m) below the base of the Fox Hills. This aquifer lies deep below the ground surface throughout most of the Cheyenne Basin and, for this reason, is not tapped by many wells in the study area. Should uranium mining seriously impact shallower aquifers, the upper Pierre and lower Fox Hills aquifers may become important sources of water.

Water samples collected and analyzed from over 100 wells during this investigation provide baseline water-quality data for much of the study area. These analyses indicate water quality is highly variable not only between aquifers, but also within a particular aquifer. Many of the wells yield water that exceeds U.S. Public Health drinking water standards for pH, TDS, sulfate, manganese, iron and selenium. Uranium, molybdenum, and vanadium concentrations are also high in many of these wells.

INTRODUCTION

Purpose

This report briefly describes the general hydrogeology, stratigraphy, and uranium resources of the Cheyenne Basin, Colorado. It also includes analyses of 104 water wells sampled during 1978 and 1979. The wells are located in the eastern part of the basin in an area containing known uranium deposits of economic interest. One of these deposits, the Grover deposit, has been tested on a pilot scale for amenability to in situ solution mining and restoration suitability. Power Resources Corporation and Union Oil Company of California plan to operate a full-scale solution mine at another deposit in the Cheyenne Basin, the Keota deposit. Additional solution mines are likely to be developed in the near future in the Cheyenne Basin, Colorado, and there is a possibility that open-pit mining may be used on certain deposits.

One of the principal environmental impacts of uranium mining is the potential affect on ground-water quality and quantity. Many agricultural activities in this part of Colorado are totally dependent upon water availability and any deterioration in quality or decrease in quantity could locally impair agricultural production. Because of this potential impact and because minimal information on existing ground-water conditions in the Cheyenne Basin is publicly available, a brief study of the area was conducted. This study included inventorying and sampling over 100 water wells to develop a better understanding of the regional geologic and hydrologic conditions related to ground water and uranium mining.

This report provides regional baseline ground-water data for much of the area likely to experience uranium development. It is of value to mineral exploration companies, mine operators, and governmental agencies in mineral exploration and in mine planning, design, operation, and restoration. Additional reports describing the potential environmental impacts of uranium mining in the Cheyenne Basin, the geologic and hydrogeologic setting, and methods of minimizing uranium development impacts are currently available from the Colorado Geological Survey (Kirkham, 1979) or are in preparation and will be available in the near future (Kirkham and Ladwig, 1980).

Location

The Cheyenne Basin, as defined in this report, is located in northeastern Colorado and southeastern Wyoming. The outline of the basin is based on the outcrop or subcrop of the base of the Fox Hills Sandstone. In several areas the basin margin can only be approximately located. Figure 1 illustrates the approximate outline of the Colorado part of the basin, the area studied for this report. It includes about 2,000 mi^2 (5,200 km^2) of northeastern Colorado and roughly is bordered by Greeley on the south, Fort Collins on the west, Fort Morgan on the southeast, and Sterling on the east.

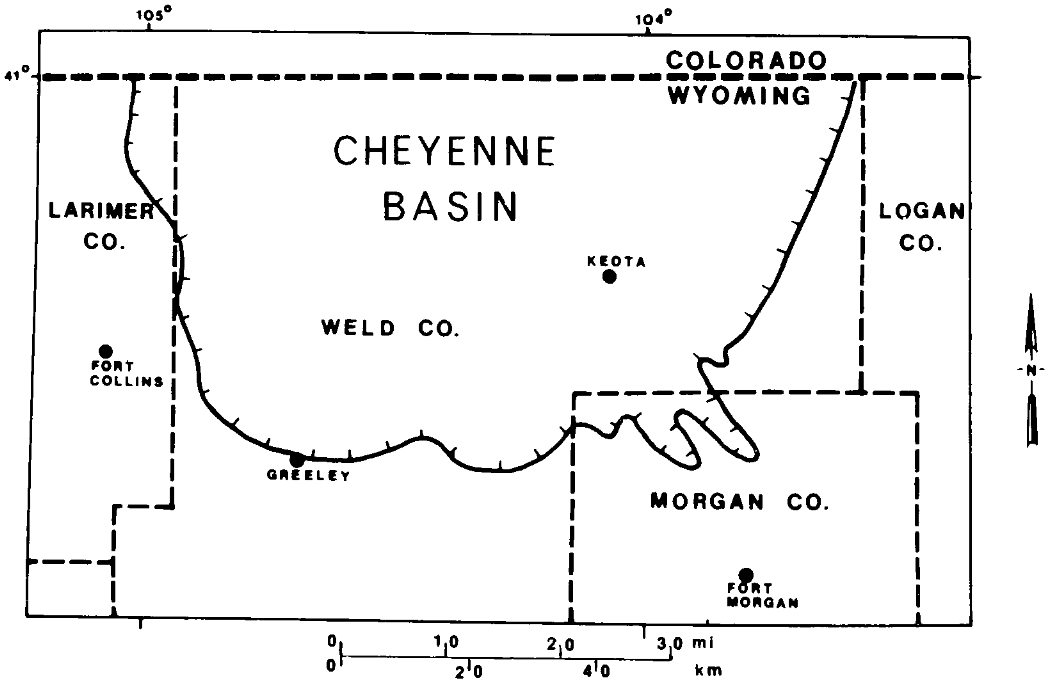


Figure 1. Approximate outline of the Cheyenne Basin, Colorado, based on the outcrop or subcrop of the base of the Fox Hills Sandstone.

Method of Well Location Determination

Water wells examined during this investigation are shown on Plate 1. Well locations listed in Appendix 1 indicate the township, range, section, and position within a section. Figure 2 illustrates the well numbering system utilized for this report. The first group of symbols indicates the township number and whether the township is north (N) or south (S) of the base line. Symbols of the second group represent the range number and whether the range is east (E) or west (W) of the principal meridian. The third group of symbols indicate the section number and position within the section. Position within the section is designated by the lower case numbers which follow the section number. The first letter indicates the quarter section, the second letter denotes the quarter-quarter section, and the third letter indicates the quarter-quarter-quarter section. Letters are assigned to each quarter within the section in a counter-clockwise direction beginning with "a" in the northeast quarter of the section. Each quarter-quarter and quarter-quarter-quarter section is assigned in a similar manner. For example, T.11 N., R.48 W., S. 20 dab, as shown in Figure 2, indicates a well in the northwest quarter of the northeast quarter of the southwest quarter of section 20, township 11 north, range 48 west.

Acknowledgments

This investigation was jointly conducted through a cooperative agreement by the Colorado Geological Survey and the Water Resources Division - Colorado District of the U.S. Geological Survey. Funding was also in part provided by the Geologic Division of the U.S. Geological Survey through U.S.G.S. Grant No. 14-08-0001-G-487, Study of Environmental Impacts of Energy Resource Development in the Denver Basin, Colorado. We thank the U.S. Geological Survey, in particular J. F. Blakey and J. D. Maberry, for their cooperation enabling the initiation and completion of this beneficial study. L. R. Ladwig, principal grant investigator for the project, supervised and directed this investigtion.

Refinement of our understanding of the Fox Hills and Laramie stratigraphy was accomplished through study of a number of selected geophysical logs supplied by Power Resources Corporation and the Colorado Oil and Gas Conservation Commission. We thank B. W. Conroy, S. L. Stinnette, R. L. Slyter, and D. Rogers for their assistance. Discussions with F. G. Ethridge, T. B. Thompson, and N. Tyler of Colorado State

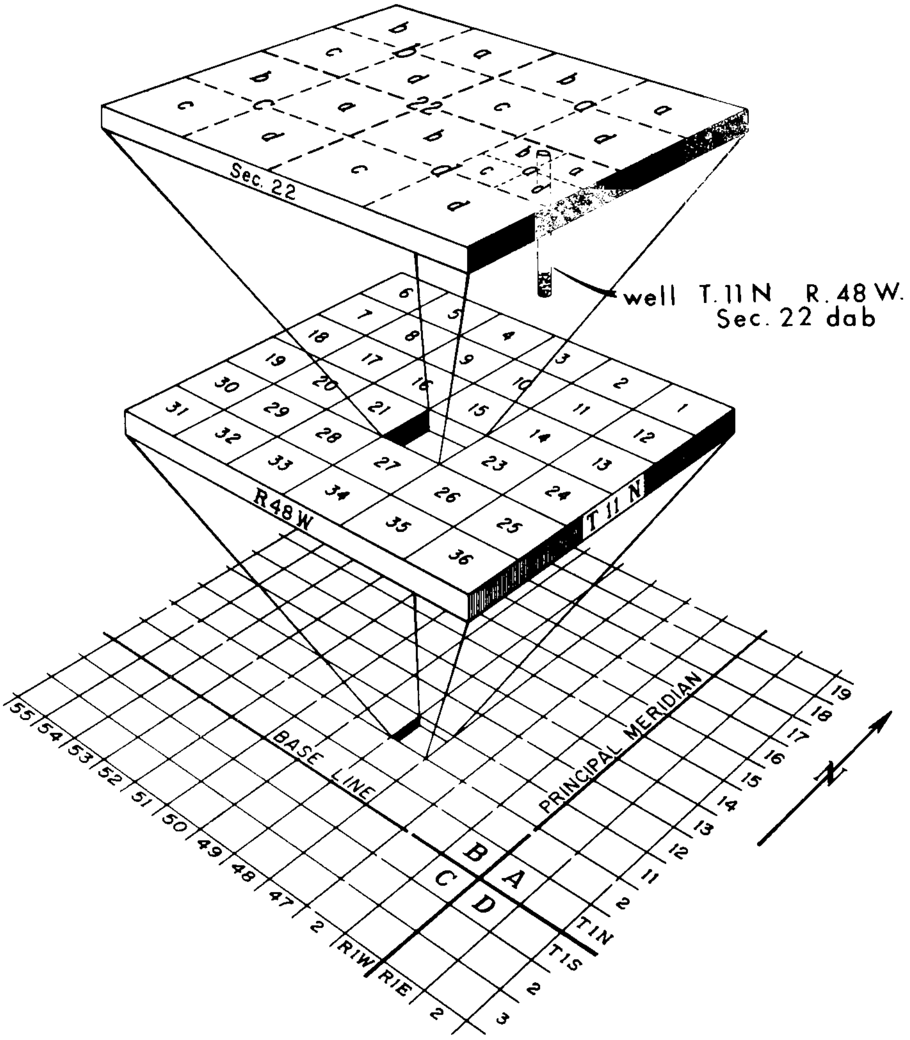


Figure 2. Well number system (from Weist, 1964).

University and A. Wacinski of the Colorado Division of Water Resources aided our stratigraphic interpretations. Editorial review by L. R. Ladwig, W. P. Rogers, D. B. Collins, A. L. Hornbaker, and F. G. Ethridge improved the content and style of the manuscript.

GENERAL GEOLOGIC SETTING

Bedrock Stratigraphy

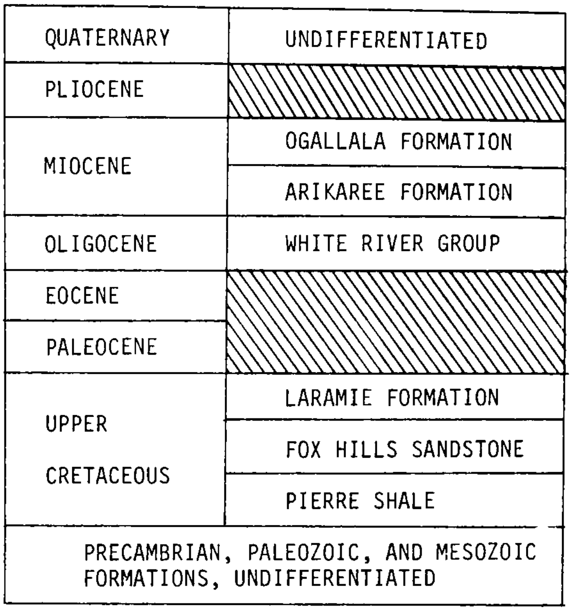
Known uranium deposits of economic importance are restricted to the

Upper Cretaceous Fox Hills Sandstone and younger rocks in the Cheyenne Basin, Colorado. For this reason, only the Fox Hills, overlying younger rocks, and underlying Pierre Shale will be discussed in this report. Refer to Kirkham and Ladwig (1979, 1980) for a description of the older rocks which are not discussed in this report.

Figure 3 is a generalized stratigraphic column for the Cheyenne Basin. The marine Upper Cretaceous Pierre Shale overlies a sequence of Paleozoic and Mesozoic sedimentary rocks of unknown total thickness. The Pierre Shale ranges in thickness from about 3,000 to 8,000 ft (900 to 2,400 m) and consists primarily of shale, claystone, and siltstone, with occasional thick sections of sandstone, silty sandstone, and siltstone that locally contain water, oil, and gas. Only the uppermost part of the Pierre Shale is of interest to this study. Kitely (1978) describes a sequence of sandstones and siltstones stratigraphically near the top of the Pierre and refers to them as the C, D, and unnamed sandstone members of the Pierre Shale. Interpretation of geophysical logs from oil and gas drill holes indicates this sequence of moderately permeable sediments, herein referred to as the upper Pierre aquifer, lies about 325 to 475 ft (97.5 to 142.5 m) below the Pierre Shale-Fox Hills Sandstone contact. The uppermost part of the Pierre Shale overlies this aquifer and is mostly shale and claystone with occasional thin limestone or carbonate-rich stringers.

The Upper Cretaceous Fox Hills Sandstone conformably overlies the Pierre Shale. The contact between these two units is transitional and in many cases must be arbitrarily picked. Since virtually all data on this particular stratigraphic interval comes from drill-hole geophysical logs, we have selected a contact readily identifiable on such logs. The contact is placed at the top of the thick shale section overlying the upper Pierre aquifer (the C, D, and unnamed sandstone members of Kitely, 1978) and at the base of a series of upward-coarsening sand units in the lower Fox Hills.

Thickness of the Fox Hills Sandstone ranges from about 200 to 450 ft (60 to 135 m). Typically, the Fox Hills consists of at least three to seven upward-coarsening sandstone beds overlain by as many as five massive



QUATERNARY	UNDIFFERENTIATED
PLIOCENE	▨
MIOCENE	OGALLALA FORMATION
	ARIKAREE FORMATION
OLIGOCENE	WHITE RIVER GROUP
EOCENE	▨
PALEOCENE	
UPPER CRETACEOUS	LARAMIE FORMATION
	FOX HILLS SANDSTONE
	PIERRE SHALE
PRECAMBRIAN, PALEOZOIC, AND MESOZOIC FORMATIONS, UNDIFFERENTIATED	

Figure 3. Generalized stratigraphic column of the Cheyenne Basin, Colorado (after Kirkham and Ladwig, 1979).

sandstones that appear "blocky" on geophysical logs (see Figure 5). Regional stratigraphic studies in the Cheyenne Basin by Ethridge and others (1979) suggest these two generalized sand units persist throughout much of the basin and warrant stratigraphic differentiation. The sequence of upward-coarsening sands constitute the lower member of the Fox Hills Sandstone and appear to be delta-front sands correlative to those described by Weimer (1973) and Kirkham and Ladwig (1979) in the Denver Basin. Shepard and Summer (1979) believe a wave-dominated delta model best fits surface and subsurface data on the lower member of the Fox Hills in the western part of the basin. The massive sands overlie the upward-coarsening sands in much of the basin and comprise the upper member of the Fox Hills. Ethridge and others (1979) believe the upper member was deposited in a barrier bar system.

Detailed local studies of stratigraphic and ground-water characteristics were conducted during this investigation. Our work in the Keota area suggests the Fox Hills can be divided into two members in a manner similar to that described by Ethridge and others (1979). Figure 4 schematically illustrates stratigraphic characteristics of the Fox Hills and other formations in the Keota area. The thick, massive Keota sandstone member of the upper Fox Hills ranges from 80 to 175-ft (24 to 52.5-m) thick. The Buckingham sandstone member splits from the top of the Keota member in the eastern part of the area. It consists of a number of lenticular sandstones and interbedded claystones ranging up to about 50-ft (15-m) thick. Base of the upper Fox Hills corresponds to the base of the Keota member.

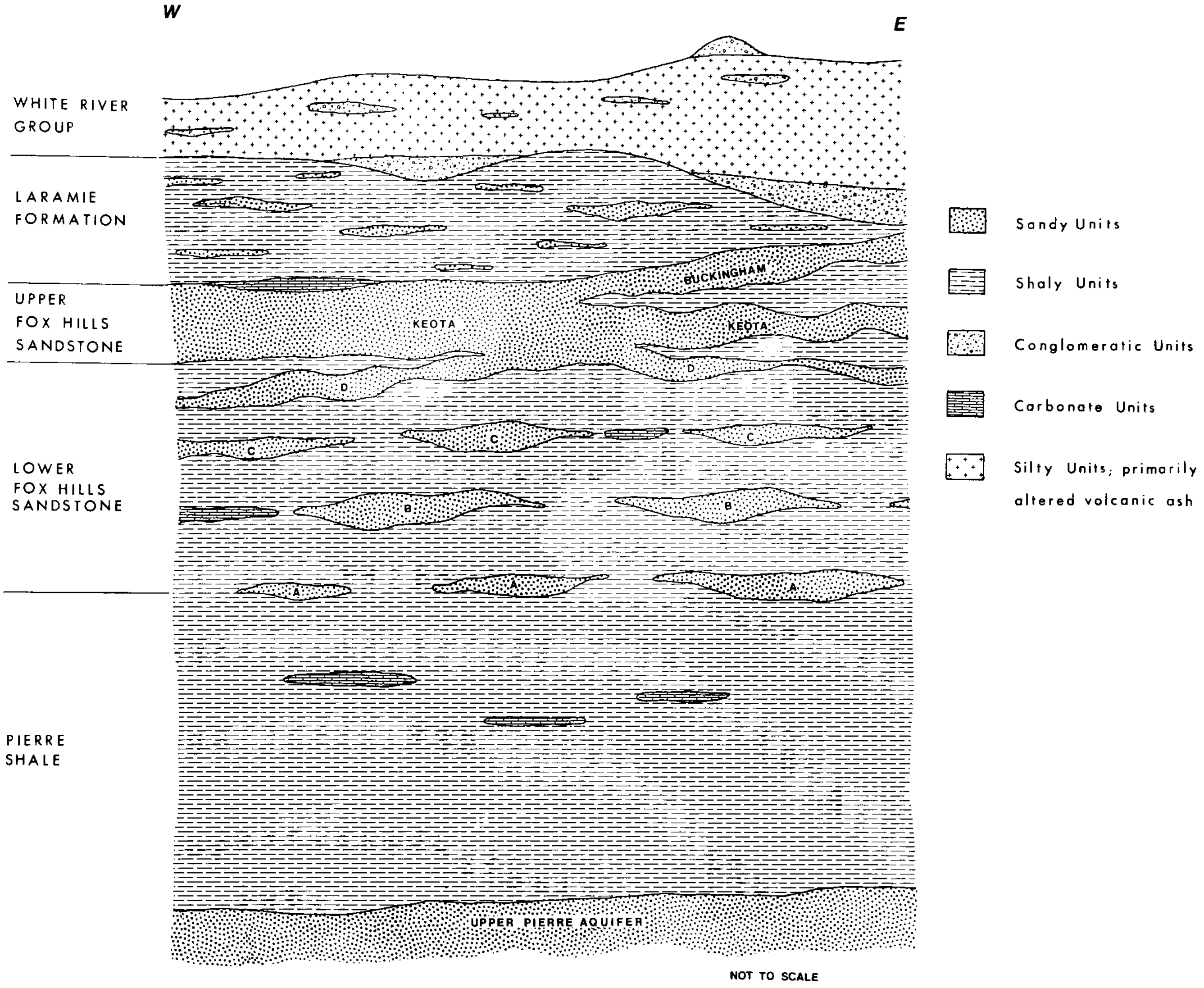


Figure 4. Schematic east-west cross section through the Keota area.

The lower member of the Fox Hills contains four coarsening-upward sand units in the Keota area which are interbedded with shale and claystone. About 30 to 40 percent of the lower Fox Hills is sandstone, whereas about 60 to 90 percent of the upper Fox Hills is sandstone. The four sand units of the lower Fox Hills in the Keota area are herein named, in ascending order, the A, B, C, and D sandstone members. All four units range up to about 55-ft (16.5-m) thick, coarsen upwards, and contain thin claystone beds and occasional carbonate-rich beds. The D sandstone member usually is separated from the Keota member by 5 to 25 ft (1.5 to 7.5 m) of claystone, but in the general vicinity of the proposed Keota mine, it appears to join the Keota member. In this area it is difficult to pick the contact between the upper and lower members. Recognition of this type of stratigraphic feature is necessary to assure successful excursion control at in situ solution mines.

The Upper Cretaceous Laramie Formation overlies the Fox Hills Sandstone. It consists of interbedded sandstone, shale, claystone, and coal. Many workers have studied the Laramie in the Denver Basin, but little information is published on the Laramie Formation of the Cheyenne Basin. There appear to be major differences between the Laramie Formation in the two basins. In many ways the Laramie Formation of the Cheyenne Basin is lithologically more similar to the Lance Formation of Wyoming than to the Laramie Formation in the Denver Basin. Future regional stratigraphic studies may conclude the Laramie in the Cheyenne Basin should be correlated with the Lance Formation. In the Denver Basin the Laramie can often be divided into an upper and lower part (Kirkham and Ladwig, 1979). The lower part contains numerous coal, shale, claystone, and lenticular, locally thick sandstone beds, whereas the upper Laramie is primarily shale and claystone. Total thickness of the Laramie Formation in the Denver Basin rarely exceeds 650 ft (195 m).

In the Cheyenne Basin the Laramie Formation, where intact and not eroded, is much thicker. Figure 5 is a geophysical log from an oil exploration drill hole near the deeper part of the Cheyenne Basin. The Laramie is about 1500-ft (450-m) thick at this location. Study of nearby, confidential logs indicate the Laramie may be over 1800-ft (540-m) thick in the deepest part of the basin. Numerous 10 to 125-ft (3.0 to 37.5-m)

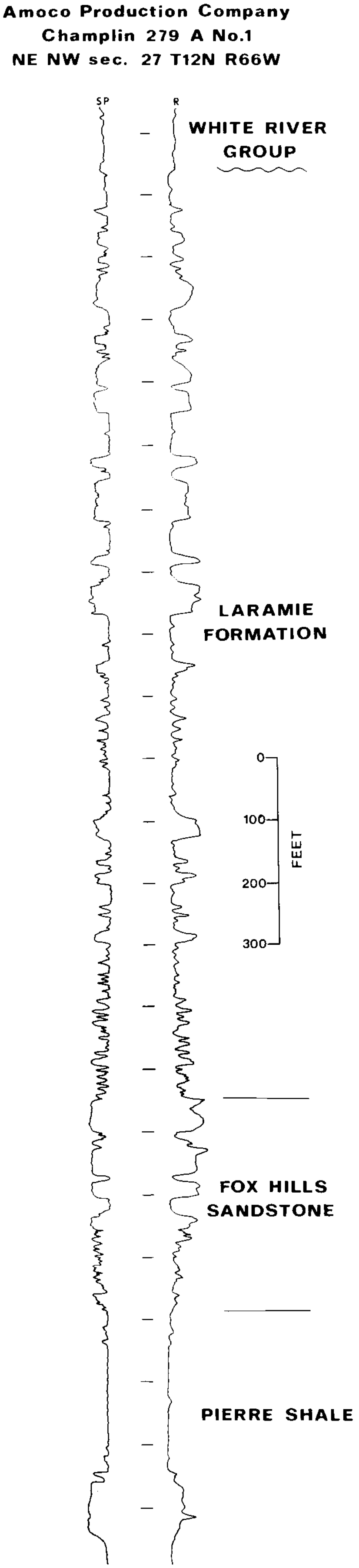


Figure 5. Geophysical log of an oil exploration drill hole in the deeper part of the Cheyenne Basin, Colorado (original log held by the Colorado Oil and Gas Conservation Commission).

thick sandstone beds, many of which fine-upward, occur throughout the Laramie in the Cheyenne Basin. In this particular log, thick sandstones are more abundant in the upper part of the Laramie. Several of the thicker and laterally more extensive Laramie sands have been informally named by the uranium industry. They include the Grover, Porter Creek, and Sand Creek sandstone members. Coal beds generally occur in the lower 400 ft (120 m) of the Laramie in the Cheyenne Basin. Thickness of coal beds in this zone range from less than 1 ft (0.3 m) to just over 5 ft (1.5 m).

Most sandstone members of the Laramie generally are lenticular channel sandstones. An individual, locally thick sandstone often splits into several thinner sandstone units. Near the town of Grover, the base of the Grover sandstone member lies 200 to 350 ft (60 to 105 m) above the top of the Fox Hills Sandstone. Thickness of the Grover member ranges from less than 25 ft (7.5 m) to over 125 ft (37.5 m), including shale partings. In this same area the Porter Creek sandstone member varies from 15 to 75-ft (4.5 to 22.5-m) thick and is 8 to 55 ft (2.4 to 16.5 m) above the Grover member. The Porter Creek unit consists of one to three individual sandstone beds which irregularly split and rejoin. The shale interval between the Grover and Porter Creek member varies markedly. In some areas the two members may possibly join to form a single sandstone unit. The Sand Creek sandstone member has been studied in T9N, R63W. In this area the Sand Creek member is about 1000 ft (300 m) above the Fox Hills and averages about 50-ft (15-m) thick (Reade, 1978).

Most workers (Reade, 1976; Shepard and Summer, 1979; Ethridge and others, 1979; Kirkham and Ladwig, 1979) believe Laramie deposition in the Cheyenne Basin is primarily fluvial. Ethridge and others (1979) suggest the lower part of the Laramie generally represents a delta-plain environment and upper Laramie an alluvial-plain setting. Laramie depositional environments were only briefly studied in this investigation. Our cursory examination supports the conclusions of Ethridge and others (1979).

Thickness of the Laramie Formation in the Cheyenne Basin varies markedly, with the greatest formational thickness occurring in the deepest part of the basin. A major factor controlling preserved formation thickness is the angular unconformity which truncates the top of the Laramie Formation. A second factor, not yet fully documented, relates to depositional and structural history of the basin. During Laramie time, it is likely that the Cheyenne Basin was actively subsiding. This may have allowed for greater sediment accumulation in the deeper parts of the basin. Structure contour maps, isopach maps, and regional correlation of individual sandstone members within the Laramie Formation lend credence to this hypothesis.

A possible explanation of the thick Laramie section in the Cheyenne Basin, as compared to its thickness in the Denver Basin, may relate to the possible equivalency of the formation to the Lance Formation. Another factor may be related to our limited knowledge of the age of the rocks grouped into the Laramie Formation in the Cheyenne Basin. The upper part of the thick Laramie sequence in the Cheyenne Basin may possibly be equivalent to the Upper Cretaceous Arapahoe Formation, Upper Cretaceous-Paleocene Denver Formation, and Paleocene-Eocene Dawson Arkose of the Denver Basin. If this speculation holds true, the upper Laramie in the Cheyenne Basin is younger than Late Cretaceous and the unconformity which truncates the Laramie may approximately correlate chronologically with the late Eocene erosion surface described in the southern Rocky Mountains by Epis and Chapin (1975). Detailed study of this possible age problem may shed light on the relationships between the upper Laramie unconformity, the paleosols described by Soister (1978) and Pettyjohn (1966), and the structural and depositional histories of the Denver and Cheyenne Basins.

The only paleontological age control on the Laramie Formation in the Cheyenne Basin that the authors are aware of indicate a Late Cretaceous age. Carpenter (1979) describes a suite of amphibians, dinosaurs, mammals, and non-dinosaurian reptiles of Late Cretaceous (Maestrichtian) age from near Briggsdale. Our drill hole information indicates the fossils are from a section of strata at least 300 ft (90 m) above the top of the Fox Hills Sandstone. Robinson (1980, pers. comm.) describes additional fossils of a similar age that were collected near the Natural Fort rest area on interstate highway I-25 in section 5, T11N, R67W. These Laramie fossils are probably about 1,000 ft (300 m) above the top of the Fox Hills Sandstone, based on a structure contour map by Ethridge and others (1979). This data indicates the lower 1,000 ft (300 m) of the Laramie is of Late Cretaceous age, but no age control is yet available for the overlying 500 to 800 ft (150 to 240 m).

Differences in the depositional histories of the two basins during Laramie time may also in part explain the anomalous thickness variations. As previously described, the upper Laramie in the Denver Basin is dominantly claystone and shale, whereas in the Cheyenne Basin much of the formation contains thick sandstone beds. The major river channels draining the Front Range area may have passed through the Cheyenne Basin and only overbank areas extended into the Denver Basin. Differences in the amounts of sediment deposited and compaction ratios could explain the observed thickness changes.

The fluvial Oligocene White River Group overlies the unconformity cut on the Laramie, Fox Hills, and Pierre. The group contains two formations, the Upper and Middle Oligocene Brule Formation and the Lower Oligocene Chadron Formation. Scott (1978) describes the Brule as being 200 to 500-ft (60 to 150-m) thick and composed of light-colored, sandy or clayey, ashy siltstone. Lenticular channel sandstones or siltstones containing siltstone clasts and granitic gravel occur throughout the lower part of the Brule. The Chadron consists of 100 to 250 ft (30 to 75 m) of highly fractured, clayey, blocky, ashy siltstone and montmorillonitic claystone (Scott, 1978). Channels of calcite- and silica-cemented sandstone and conglomerate often occur at the base of the Chadron and are also scattered throughout the unit. These beds form resistant ledges in outcrop, such as those near Keota.

The fluvial Lower Miocene Arikaree Formation unconformably overlies part of the White River Group. In the study area the Arikaree occurs to a limited extent and only as channel sandstones and conglomerates ranging up to 80-ft (24-m) thick that are cut into the White River Group. To the east and north, the Arikaree is more of a blanket-type deposit.

The Miocene Ogallala Formation unconformably overlies the Arikaree and White River Formations, and where these rocks are absent, it overlies the Laramie and older rocks. The formation is 50 to 600-ft (15 to 180-m) thick and consists primarily of conglomerate and sandstone beds interbedded with siltstone, limestone, and volcanic ash (Scott, 1978).

Structure

The Cheyenne Basin, as defined by Kirkham and Ladwig (1979) and Childers (1974), is a structural element of a much larger basin, commonly known in the petroleum industry as the Denver, Denver-Cheyenne, D-J, or Denver-Julesburg Basin. The Cheyenne Basin roughly corresponds to the deepest part of the northern half of the larger basin. It is a doubly plunging, asymmetrical syncline with its structural axis in the western part of the basin (Figure 6). The town of Cheyenne lies near the deepest part of the basin and at this location, the top of the Precambrian is at an elevation of over 7,000 ft (2,100 m) below sea level. Structural dips on the northern, southern, and eastern flanks of the Cheyenne Basin typically range from less than 1° to about 5°. On the western flank of the basin in Colorado, rocks dip up to 45° eastward towards the basin center. A few relatively minor faults and folds occur within the basin, but these have not been adequately investigated. The Greeley Arch bounds the south flank of the Cheyenne Basin and separates it from the Denver Basin (Kirkham and Ladwig, 1979).

Figure 1 illustrates the approximate outline of the Colorado part of the Cheyenne Basin based on the outcrop or subcrop of the Fox Hills Sandstone. Figure 6 is a general structure contour map of the top of the lower Fox Hills for much of the Cheyenne Basin (from Ethridge and others, 1979). The deepest part of the basin appears to be in T12N, R66W where the top of the Fox Hills is less than 3900 ft (1170 m) above sea level. Regional dip of the Fox Hills, as calculated from Figure 6, averages about 8 1/2° eastward on the west flank of the basin, about 1/3° northward on the south flank, and about 1/5° northwestward from Keota to the center of the basin. Figure 7 illustrates structural details of the top of the Upper Fox Hills in the Keota area.

GENERAL HYDROGEOLOGIC SETTING

Bedrock Aquifers

Principal bedrock aquifers of the Cheyenne Basin include the Fox Hills, Laramie, White River, and Ogallala Formations. Minor amounts of water may be produced from the upper Pierre aquifer, which includes the C, D, and unnamed sandstone members described by Kitely (1978) and from the Arikaree. Generally, the upper Pierre aquifer lies too far below land surface in the study area to be economically significant, although it may become an important aquifer if uranium mining seriously impacts other, shallower aquifers. Existing water analyses suggest the upper Pierre aquifer contains water of variable quality. Locally, this water is high in sulfate and other ions which, unless it is the only available water, make it generally unacceptable for domestic use and undesirable for stock watering. The Arikaree occurs very discontinuously in the basin and, for this reason, is not considered a major aquifer.

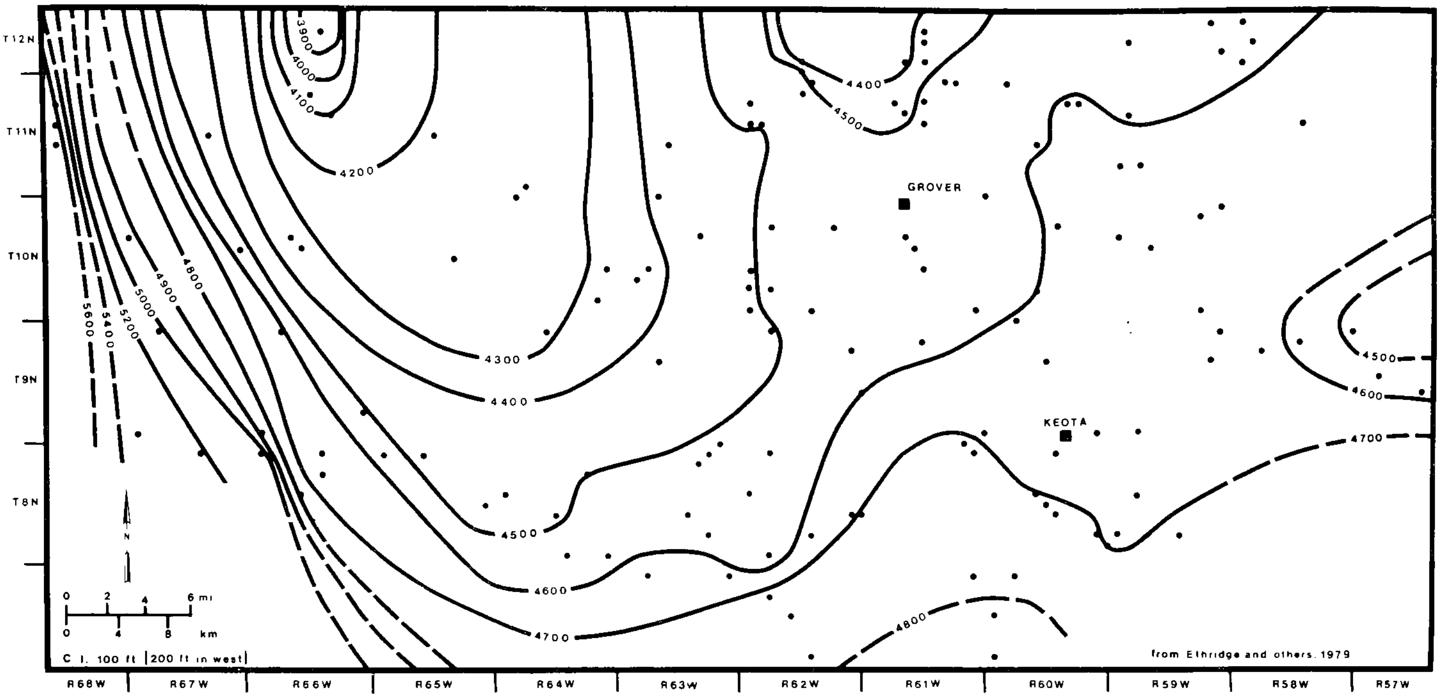


Figure 6. Structure contour map of the top of the lower Fox Hills Sandstone, Cheyenne Basin, Colorado (after Ethridge and others, 1979).

The Fox Hills Sandstone underlies much of the Cheyenne Basin in an almost blanket-type manner. It is the most reliable ground-water source in the Cheyenne Basin. The upper part of the Fox Hills is the most prolific water-producing member of the formation, commonly yielding 20 to 100 gpm, and occasionally yielding over 200 gpm. The lower Fox Hills contains a greater amount of low permeability beds, primarily shale and claystone. Water-bearing sandstones do occur in the lower Fox Hills, but they possess variable hydraulic properties. In areas where the upper Fox

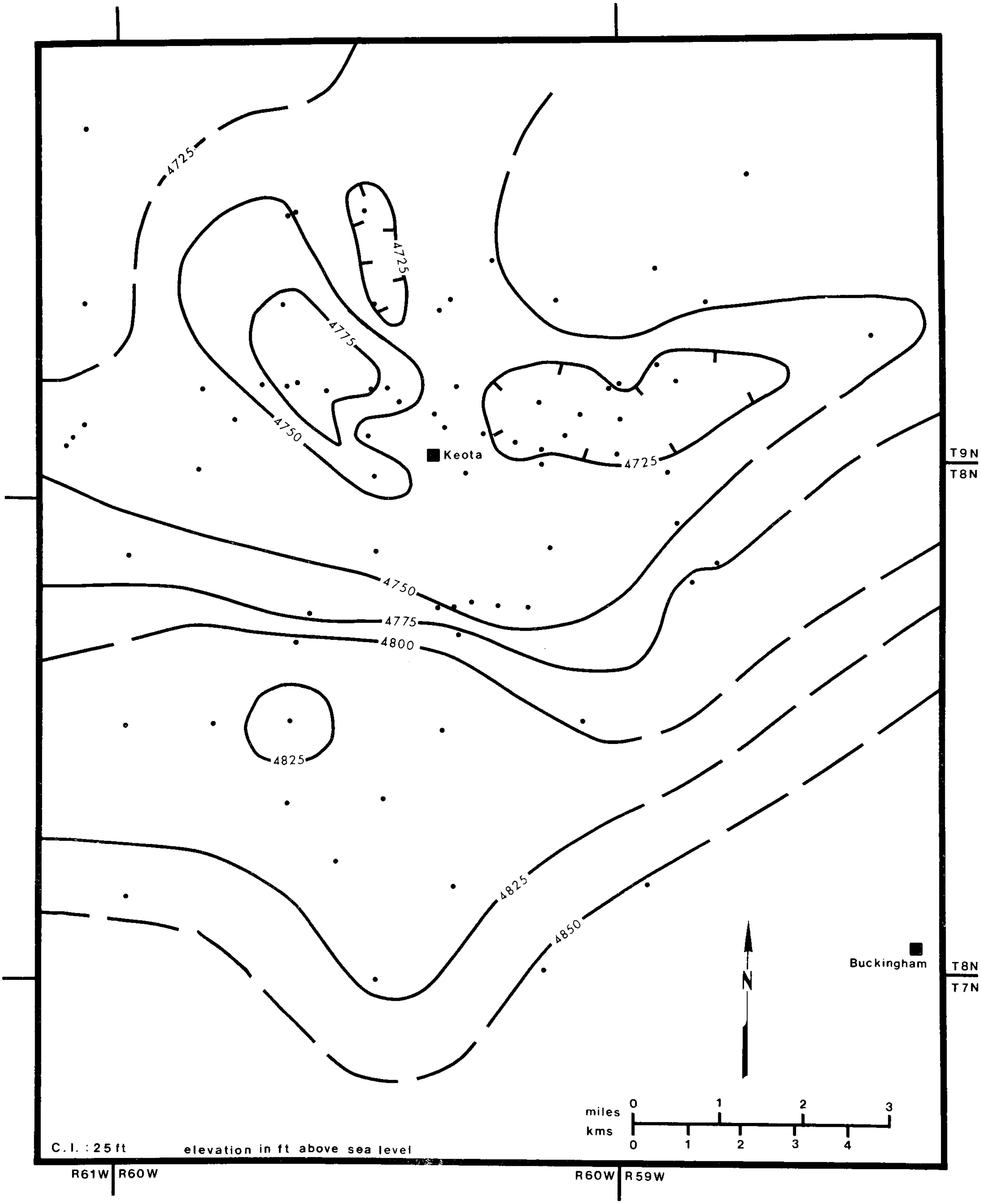


Figure 7. Detailed structure contour map of the top of the upper Fox Hills Sandstone in the Keota area.

Hills may be damaged by future uranium mining, the lower Fox Hills may become a significant aquifer which yields low amounts of water.

Numerous lenticular sandstone beds of varying thickness occur throughout the Laramie Formation. These sandstones provide a significant amount of the total ground water currently utilized in the Cheyenne Basin, primarily because the formation underlies much of the basin at shallow depths.

The White River Group consists largely of low permeability, ashy siltstone and claystone, but highly permeable, fluvial channels of sandstone and conglomerate occur occasionally in the formation. Some wells recover minor amounts of water from the ashy siltstone and claystone, but production is generally very low. The fluvial channels provide moderate to high quantities of ground water. Part of the porosity and permeability of the White River Group appears to be related to or at least influenced by vertical fractures and clastic dikes. Dikes serve as ground-water barriers and fractures provide conduits for vertical water movement. These factors are of great importance when considering potential excursion flow paths from solution mining operations.

Large quantities of water are produced from the Ogallala Formation throughout much of the High Plains. The Ogallala, however, occurs only to a limited extent in the Cheyenne Basin. Uranium-bearing host rocks occur at great depths in areas underlain by the Ogallala, therefore uranium exploration and development in the foreseeable future in these areas is unlikely. For these reasons, the Ogallala was not studied in detail for this report.

Very little is known about the direction and rate of ground-water flow in individual aquifers in the Cheyenne Basin. Figure 8 is a water-table elevation map of the study area. This map was prepared by contouring the elevation of water levels in wells tapping a variety of aquifers. The map suggests ground-water movement is to the south and southeast, towards the South Plate River. Wacinski (1979) reached a similar conclusion based on his work in the Crow Creek drainage. It is unknown if this direction of movement represents the actual flow path of water in individual aquifers. Distribution of springs in the basin suggests that this may be the general pattern.

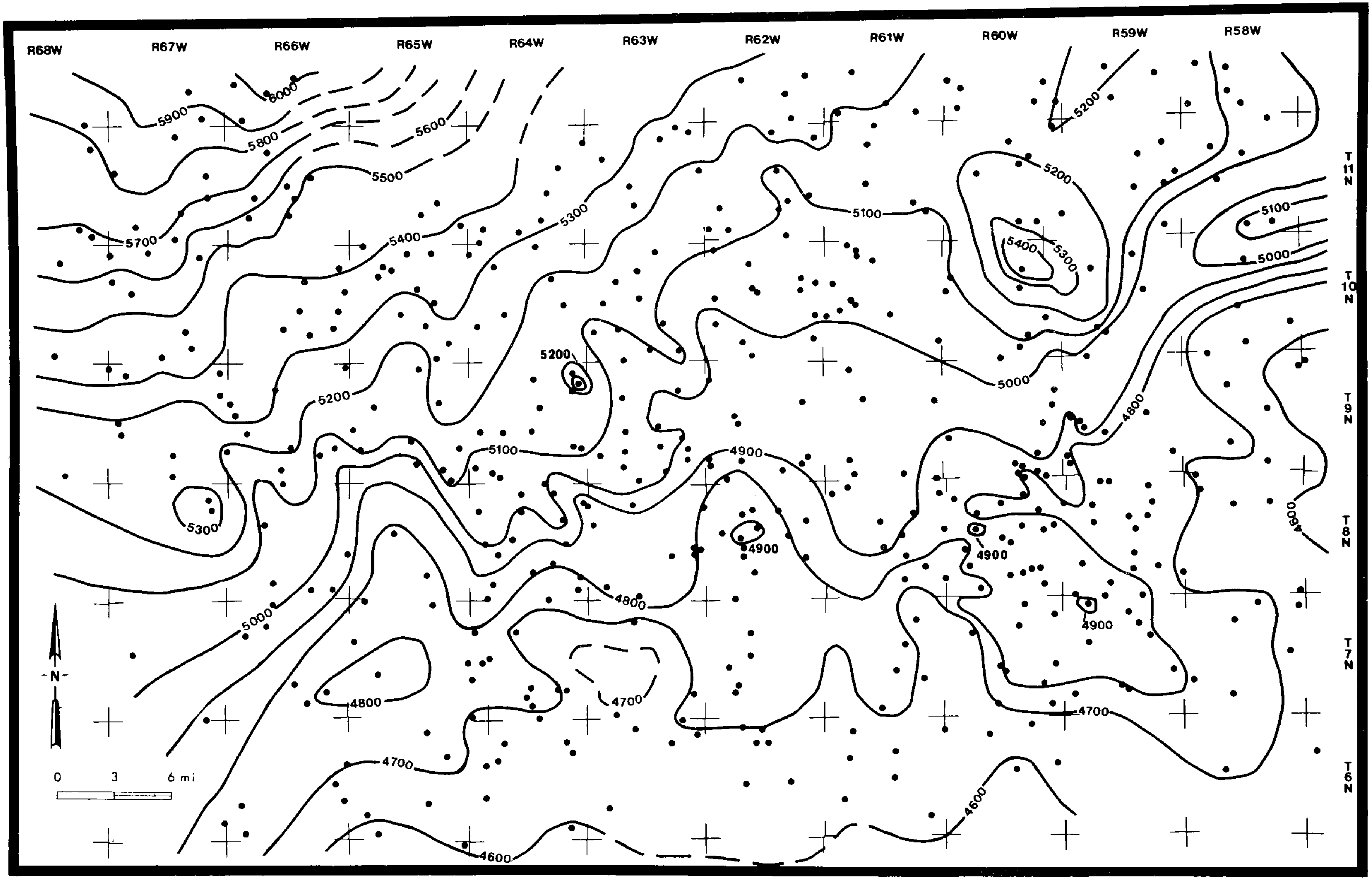


Figure 8. Water-table elevation map of the Cheyenne Basin, Colorado (prepared from data held by the Colorado State Engineer and from Appendix 1 of this report).

An attempt was made to prepare a potentiometric map from wells tapping only the Fox Hills Sandstone. The resulting map was unsatisfactory for several reasons: 1) only a limited number of wells extend to the Fox Hills and there are large areas in which no wells tap the Fox Hills, 2) a main source of water level data was the Colorado State Engineer's files, and the water levels in these records were measured at widely varying times using a variety of measuring methods, 3) recent mineral exploration drilling activities and water extraction from existing wells appear locally to have altered natural flow paths, 4) many wells which tap the Fox Hills are completed in such a way that it is impossible to remeasure water levels, and 5) several of the Fox Hills wells have been abandoned and plugged and are therefore unavailable for remeasurement.

Water Quality

Water samples from 104 domestic, irrigation, stock, municipal, and other types of wells were collected and analyzed as a part of this investigation. Wells inventoried and sampled were selected because of proximity to known uranium deposits, accessibility, and physical characteristics. Sampled wells tap the upper and lower Fox Hills Sandstone, Laramie Formation, and White River Group. Well locations are shown on Plate 1, well characteristics are described in Appendix 1, and the results of the analyses are contained in Appendix 2.

Water quality is highly variable in the sampled wells. The following ranges indicate the wide variation of certain parameters: total dissolved solids (TDS) - 227 to 4540 milligrams per liter (Mg/l), calcium - 1.3 to 516 Mg/l, alkalinity - 76 to 2070 Mg/l, sulfate - 11 to 2800 Mg/l, iron - 0 to 8300 micrograms per liter (Ug/l), selenium - 0 to 70 Ug/l, and uranium - 0.03 to 160 Ug/l. This variation occurs not only between aquifers, but also within a particular aquifer. In some cases wells which tap the same aquifer only a short distance apart may vary markedly in quality.

Much of the water sampled during this investigation is of very poor quality and exceeds drinking water standards of the U.S. Public Health Service. Of the 104 wells sampled, the water in 49 equals or exceeds recommended TDS values, 34 equal or exceed sulfate standards, 27 equal or exceed manganese standards, 18 equal or exceed iron standards, 9 equal or exceed selenium standards, and five equal or exceed pH standards. High uranium and vanadium concentrations are also a problem, but no drinking water standards are established for these parameters.

A cursory examination of the water analyses suggests the following relationships in the study area. Water high in uranium (dissolved and suspended) occurs in much of the study area in many of the major aquifers. There is a marked tendency for highest uranium values to occur near uranium deposits, but several wells that are moderately high in uranium are not geographically or stratigraphically near any known uranium deposits that the authors are aware of. All wells which are high in vanadium tap either the White River Group or alluvial aquifers which overlie the White River Group. Most wells high in vanadium are also at least moderately high in uranium.

All wells with high selenium contents are also high in uranium. High selenium values are not restricted to any one formation and there is no apparent correlation between high selenium and molybdenum or vanadium. The majority of wells high in molybdenum are in the Keota-Buckingham area and have either the White River Group or Fox Hills Sandstone as their principle aquifer.

All wells with pH values exceeding the U.S. Public Health Service drinking water standards tap the Fox Hills Sandstone. Almost all wells with high iron or manganese contents tap either the Laramie or Fox Hills. High iron values generally are associated with high manganese values, but the reverse of this is not always true.

URANIUM RESOURCES AND DEVELOPMENT

Numerous uranium and other radioactive elements occur in a variety of environments and formations throughout the Cheyenne Basin. Four significant uranium deposits in the Cheyenne Basin are described in published reports (Reade, 1976, 1978; Wyoming Mineral Corporation, 1978). All four are roll-front type deposits in either the Laramie Formation or upper member of the Fox Hills Sandstone. An additional 32 radioactive mineral occurrences are documented in the area (Nelson-Moore and others, 1978). Other significant uranium deposits have been discovered by industry, but this information is not yet publicly available. Known uranium deposits include the Grover, Keota, Pawnee, and Sand Creek deposits. Reade (1978) described three of these deposits, and Wyoming Mineral Corporation (1978) described a fourth deposit in a permit application. Much of the following characterizations are derived from these two sources.

The Grover deposit, discovered in 1970, occurs in T10N, R61 and 62W, about four miles southwest of the town of Grover. Uranium mineralization occurs in the Grover sandstone member of the Laramie Formation. The Grover sandstone member ranges from about 25 to 125-ft (7.5 to 37.5- m) thick and lies about 200 to 350 ft (60 to 105 m) above the top of the Fox Hills Sandstone. Grade of the Grover deposit averages 0.14 percent eU308 with reserve estimates indicating a total of about 1 million lb (454,000 kg) eU308 using a cutoff grade of 0.05 percent.

A pilot-scale in situ solution mining project was conducted at the Grover deposit by Wyoming Mineral Corporation. The test initiated in June, 1977 and concluded in May, 1978. Restoration of the mined aquifer initiated in May, 1978 and terminated in February, 1979. By June, 1979, restoration stabilization was demonstrated (Wyoming Mineral Corporation, 1979). The project was primarily conducted to test various lixiviant capabilities, well field design, and restoration technology.

The Pawnee deposit, discovered in 1971, lies in secs. 25, 26, 27, and 28, T8N, R60W. Uranium mineralization occurs in the upper or Pawnee sandstone member of the Fox Hills Sandstone (Reade, 1978). A tentative correlation between the Keota and Pawnee sandstone members was demonstrated during this investigation. The roll-front is very linear, trending east-west, and its orientation and associated chemical alteration suggest southward ground-water movement during uranium deposition. Mineralization averages 0.07 percent eU308 and contains an estimated 1 million lbs (454,000 kg) eU308.

Uranium mineralization at the Keota deposit in secs. 35 and 36, T9N, R60W, occurs in several roll fronts in both the Keota and Buckingham members of the upper Fox Hills Sandstone. Power Resources Corporation plans to mine the Keota deposit using in situ solution mining techniques. Production during the first year should be on the order of 150,000 lbs (68,000 kg) of U308. Second-year production is anticipated at about 250,000 lbs (114,000 kg) U308 and about 500,000 lb (227,000 kg) of U308 should be annually recovered during the remaining life of the mine. Reserve estimates suggest the Keota deposit contains 5,000,000 to 10,000,000 lb (2,270,000 to 4,540,000 kg) U308.

The Sand Creek deposit lies in secs. 19, 20, and 29, T9N, R63W, just northeast of the Hyland pit where uranium was first discovered in Weld County. Uranium mineralization occurs in the Sand Creek sandstone member of the Laramie Formation, about 1,000 ft (300 m) above the top of the Fox Hills Sandstone. The roll-front is very narrow, generally less than 50-ft (15-m) wide, but is unusually rich in uranium for a sandstone deposit. Core samples indicate grades up to 0.41 percent U308 and an average of 0.21 percent. Reserve estimates indicate about 154,000 lbs (69,900 kg) eU308 with a cutoff grade of 0.05 percent.

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Appendix 1. Description of sampled wells.

I.D. NO.	LAND NET LOCATION	PERMIT NO.	OWNER	YEAR COMPLETED	WELL DEPTH (FT)	GEOLOGIC SOURCE[1]	TYPE LIFT AND POWER[2]	ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT	USE OF WATER[3]
U-1	T8N, R61W, S.25 DDA	32560	B.R. Criswell	12/04/67	241	K_f	S/E	4955	180	12/04/67	D
U-2	T8N, R63W, S.24 ADB	38123	USDAFS	07/00/61	446	K_f	S/E	4965	160.0	06/13/78	S
U-3	T8N, R63W, S.24 BDA	38124	USDAFS	07/00/61	459	K_f	P/W	4980	187.4	06/14/78	S
U-4	T8N, R64W, S.1 DDD	37172	USDAFS	05/19/51	217	K_l	P/W	5102	129.0	06/14/78	S
U-5	T8N, R63W, S.7 CCB	18750	USDAFS	02/00/64	400	K_f	S/E	5035	196.2	06/14/78	S
U-6	T8N, R62W, S.20 DAC	37174	USDAFS	00/00/38	302	K_f	S/E	4840	74.8	06/14/78	P
U-7	T8N, R61W, S.26 AAD	12377	O. Hill	07/28/62	295	K_f	S/E	4990	230	06/15/78	D
U-8	T8N, R61W, S.27 DDD	365	G. Speaker	10/02/57	420	K_f	S/E	5005	280	10/02/52	D
U-9	T8N, R61W, S.15 DAA	23214	J. Sievers	04/22/65	315	K_f	P/W	4976	121	06/15/78	S
U-10	T8N, R61W, S.21 AAC	23212	J. Sievers	04/21/65	315	K_f	P/W	4999	74.9	06/15/78	S
U-11	T8N, R61W, S.10 CAB	19333	K. Pierce	04/30/64	288	K_f	P/W	4950	176	06/16/78	S
U-12	T8N, R61W, S.17 ACB	20732	W. Sievers	05/14/64	288	K_f	P/W	4975	252	05/14/64	S
U-13	T9N, R61W, S.29 CCA	61296	R. Cochran	05/23/72	62	K_l	P/W	4929	9.1	06/19/78	S
U-14	T9N, R61W, S.34 ADD	620	R. Janitel	08/28/57	215	K_l	P/W	5015	102.8	06/19/78	S
U-15	T8N, R61W, S.11 BDC	23209	R. Janitel	04/20/65	195	K_l	P/W	4987	85	04/20/65	S
U-16	T8N, R60W, S.6 CDD	37170	USDAFS	00/00/51	247	K_l	P/W	4942	90	00/00/51	S
U-17	T9N, R62W, S.25 CBB	12014	Graefe	06/00/62	176	K_l	P/W	4996	100.1	06/20/78	I
U-18	T8N, R61W, S.6 BCC	8242	Graefe	04/20/61	177	K_l	P/W	4954	33.4	06/20/78	S
U-19	T8N, R62W, S.23 DAA	18032	C. Thomsen	06/00/63	300	K_f	S/E	5020	200	06/06/63	D
U-20	T9N, R62W, S.17 DAC	6587	D. Magnuson	08/27/60	102	K_l	P/W	4968	22	08/27/60	S
U-21	T9N, R62W, S.30 CCC	6589	D. Magnuson	08/25/62	68	K_l	P/W	4974	11.2	06/21/78	S
U-22	T9N, R62W, S.29 DDB	38125	USDAFS	12/00/59	225	K_l	P/W	4961	69.9	06/21/78	S
U-23	T8N, R62W, S.8 ADB	22760	State of Colo.	02/06/65	272	K_f	S/E	4882	107.7	06/21/78	S
U-24	T8N, R62W, S.16 BAB	62465	State of Colo.	09/29/72	95	K_l	S/E	4830	16.9	06/21/78	S
U-25	T8N, R62W, S.17 DBA	2691-F	D. Lahey	08/31/60	27.5	K_l	T/E	4840	6.71	08/31/60	I
U-26	T9N, R61W, S.12 DCC	43494	C. Bashor	10/27/70	91	K_l	S/E	5007	52.3	06/26/78	S
U-27	T9N, R61W, S.8 DDD	--	E. Dunbar	12/10/52	190	K_l	T/E	4980	33.27	06/26/78	D
U-28	T9N, R61W, S.5 BAD	58738	W. Bashor	05/31/72	150	K_l	P/W	5020	100	05/31/72	S
U-29	T10N,R61W, S.19 AAA	32124	D. Bashor	11/21/67	110	K_l	S/E	5045	44.6	06/27/78	D
U-30	T10N,R61W, S.17 DCC	12351	D. Bashor	07/10/62	192	K_l	P/W	5060	51.1	06/27/78	S
U-31	T10N,R61W, S.22 BCB	--	W. Bashor	00/00/53	80	T_{wr}	S/E	5025	10	06/27/78	D
U-32	T10N,R61W, S.5 ABB	11174-F	Tn of Grover	08/25/67	230	K_l	S/E	5075	137	06/27/78	P
U-33	T11N,R61W, S.32 CCC	12498	H. Knudsen	07/31/62	158	T_{wr}	P/W	5083	20	07/31/62	S
U-34	T10N,R62W, S.24 ACC	PM1*	Wyo. Min.C.	05/00/77	110	K_l	S/G	5040	35	06/28/78	Z
U-35	T10N,R62W, S.24 ADC	GM2*	Wyo. Min.C.	05/06/77	231	K_l	S/G	5050	39	06/28/78	Z

1) deepest aquifer tapped by well: K_f - Upper Cretaceous Fox Hills Sandstone; K_l - Upper Cretaceous Laramie Formation; T_{wr} - Oligocene White River Group; Q_a - Quaternary alluvium

2) LIFT: J - jet; P - piston; S - submergible; T-Turbine; U-unknown; Z - other. POWER: D-diesel; E - electric; G - gasoline; H - hand; W - windmill

3) water use: D - domestic; I - irrigation; P - public supply; S - stock; Z - other

*) monitor wells at Grover Test Site operated by Wyoming Mineral Corporation

**) uranium exploration drill hole

I.D. NO.	LAND NET LOCATION	PERMIT NO.	OWNER	YEAR COMPLETED	WELL DEPTH (FT)	GEOLOGIC SOURCE^1	TYPE LIFT AND POWER^2	ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT	USE OF WATER^3
U-36	T10N,R62W, S.24 ADD	FM2*	Wyo. Min.C	05/00/77	520	K_f	S/G	5060	249	06/28/78	Z
U-37	T10N,R62W, S.24 ADA	GM8*	Wyo. Min.C	10/06/77	185	K_l	S/G	5040	36	06/28/78	Z
U-38	T9N, R60W, S.34 AAC	14C**	Wyo. Min.C	09/19/77	263	K_f	S/G	4945	150	06/28/78	Z
U-39	T9N, R60W, S.34 ADB	H3**	Wyo. Min.C.	09/02/77	120	T_{wr}	S/G	4945	78.7	06/28/78	Z
U-40	T10N,R62W, S.12 DCB	43495	D. Bashor	10/24/70	78	T_{wr}	P/W	5055	14	10/24/70	S
U-41	T10N,R62W, S.25 BDA	68198	W. Bashor	06/15/73	125	K_l	P/W	5010	53	06/15/73	S
U-42	T10N,R62W, S.14 AAC	20606	H. Gracik	08/30/66	108	K_l	P/W	5055	20	08/30/66	S
U-43	T10N,R62W, S.11 ADA	49358	H. Gracik	10/20/71	38	T_{wr}	P/W	5065	11.4	07/06/78	S
U-44	T10N,R62W, S.18 CAA	37122	USDAFS	00/00/26	206	K_l	P/W	5120	56.7	07/06/78	S
U-45	T9N, R62W, S.6 BCD	29814	USDAFS	02/19/67	240	K_l	S/E	5075	76.5	07/06/78	S
U-46	T10N,R62W, S.28 DAD	--	G. Konig	10/20/54	180	K_l	S/E	5040	60	10/20/54	D
U-47	T10N,R63W, S.22 DDA	44139	G. Konig	01/07/71	130	K_l	P/W	5170	80	01/07/71	S
U-48	T10N,R62W, S.16 ABA	2038-F	G. Konig	05/01/59	12	Qa	T/D	5060	6.5	07/07/78	I
U-49	T10N,R62W, S.16 BAA	13276	G. Konig	10/00/62	190	K_l	P/H	5080	24	10/00/62	D
U-50	T10N,R63W, S.35 ABA	--	USDAFS	03/00/62	350	K_l	P/W	5101	54	07/07/78	S
U-51	T10N,R63W, S.34 BAA	37127	USDAFS	00/00/40	220	K_l	P/W	5116	54	00/00/40	S
U-52	T9N, R63W, S.11 ABB	29817	N. Magnuson	01/31/67	302	K_l	P/W	5080	60	01/31/67	S
U-53	T11N,R61W, S.16 CCA	66795	N.C.A.R.	01/24/73	421	K_l	S/E	5335	180	01/24/73	D
U-54	T12N,R61W, S.32 BCC	43057	J. Loyd	09/03/70	100	Qa	S/E	5260	63.4	07/11/78	I
U-55	T12N,R61W, S.24 DDA	23210	L. Nessen	04/15/65	75	T_{wr}	S/E	5190	28	07/11/78	D
U-56	T12N,R60W, S.31 AAA	25764	V. Tietmeyer	11/20/65	195	T_{wr}	T/D	5235	46	11/20/65	I
U-57	T11N,R61W, S.23 CAD	20733	B. Wilson	05/24/64	178	T_{wr}	P/W	5175	60	05/24/64	S
U-58	T12N,R62W, S.25 BBB	--	M. Loyd	10/22/53	140	T_{wr}	T/G	5293	34	07/11/78	I
U-59	T11N,R62W, S.32 BBA	28461	J. Burnett	09/01/66	118	T_{wr}	S/E	5165	28	09/01/66	D
U-60	T11N,R62W, S.30 ABA	24654	B. Reichley	07/16/65	133	T_{wr}	S/E	5190	27.7	07/11/78	D
U-61	T11N,R63W, S.13 AAB	32509	R. Burbach	12/11/67	110	T_{wr}	S/E	5225	43.5	07/11/78	D
U-62	T11N,R62W, S.27 AAA	--	H. Gracik	02/27/63	--	--	Z/Z	5120	11.1	07/12/78	I
U-63	T11N,R62W, S.35 BCA	--	O. Douglass	02/00/27	60	T_{wr}	T/E	5090	10.95	07/12/78	I
U-64	T12N,R62W, S.20 DDD	--	J. Loyd	12/08/52	100	Qa	T/E	5310	16	12/08/52	I
U-65	T12N,R62W, S.26 BCC	--	M. Hoke	--	110	Qa	S/E	5305	56.3	07/12/78	D
U-66	T12N,R62W, S.24 BCC	--	O. Land	10/14/52	157	Qa	T/E	5298	30	10/14/52	I
U-67	T12N,R62W, S.35 BBD	45197	V. Hnizdil	04/08/71	154	Qa	J/E	5260	25	04/08/71	I
U-68	T9N, R63W, S.30 ACB	38128	USDAFS	10/00/58	310	K_l	P/W	5201	177	07/18/78	S
U-69	T9N, R63W, S.29 AAD	37105	USDAFS	00/00/40	19	Qa	P/W	5091	10.3	07/18/78	S
U-70	T9N, R63W, S.15 CDA	38126	USDAFS	04/00/58	200	K_l	P/W	5170	175.4	07/18/78	S
U-71	T9N, R63W, S.34 AAA	36627	USDAFS	02/16/62	305	K_l	P/W	5115	110	07/18/78	S
U-72	T9N, R63W, S.23 ACC	37102	USDAFS	00/00/40	67	K_l	P/W	5055	21	00/00/40	S
U-73	T8N, R61W, S.1 BCC	14984	R. Janitell	05/17/63	300	K_l	S/E	5060	240	05/17/63	S
U-74	T9N, R61W, S.36 DBB	--	State of Colo.	04/18/65	215	K_l	P/W	4963	160	01/27/77	S
U-75	T9N,.R64W, S.24 DCD	37109	USDAFS	05/00/39	178	K_l	P/W	5205	67	05/00/39	S
U-76	T8N, R60W, S.11 ACA	42516	USDAFS	07/24/70	136	T_{wr}	S/E	4889	82.54	04/17/79	S
U-77	T9N, R59W, S.31 BBA	5911	D. Shull	07/00/60	60	T_{wr}	P/W	4875	40	07/00/60	S
U-78	T9N, R60W, S.34 DBA	--	D. Bivens	--	110	T_{wr}	S/E	4990	76.7	04/18/79	D
U-79	T8N, R59W, S.34 DDC	73733	D. Williams	04/05/74	158	T_{wr}	S/E	4918	35.84	04/25/79	S
U-80	T8N, R59W, S.8 BAB	37085	USDAFS	03/25/48	134	T_{wr}	P/W	4812	45	03/25/48	S

I.D. NO.	LAND NET LOCATION	PERMIT NO.	OWNER	YEAR COMPLETED	WELL DEPTH (FT)	GEOLOGIC SOURCE[1]	TYPE LIFT AND POWER[2]	ALTITUDE (FT)	DEPTH TO WATER (FT)	DATE OF MEASUREMENT	USE OF WATER[3]
U-81	T8N, R59W, S.22 CDB	11422	G. Castor	09/00/60	155	T_{wr}	S/E	4812	95	09/00/60	S
U-82	T7N, R59W, S.5 BAA	43592	D. Green	11/01/70	260	K_f	S/E	5005	99.84	04/25/79	S
U-83	T7N, R60W, S.1 CAA	35315	D. Green	09/28/68	291	K_f	P/W	4948	126.26	04/26/79	S
U-84	T8N, R60W, S.27 DAA	24413	H. Duell	06/25/68	168	K_f	S/E	4868	35.10	04/26/79	S
U-85	T8N, R60W, S.26 ADD	41866	H. Wilson	06/17/70	100	K_f	P/W	4865	49.98	04/26/79	S
U-86	T8N, R60W, S.35 AAD	--	State of Colo.	--	--	--	P/W	4885	70.16	05/01/79	S
U-87	T8N, R60W, S.24 BCD	8749	USDAFS	05/28/61	200	K_f	P/W	4922	107.64	05/01/79	S
U-88	T8N, R60W, S.22 BBB	14934	G. Doll	05/01/63	155	K_f	P/W	4916	69.05	05/01/79	S
U-89	T8N, R60W, S.27 CBA	37094	USDAFS	02/00/44	85	K_f?	P/W	4892	21.30	05/01/79	S
U-90	T8N, R59W, S.33 BBA	--	D. Williams	00/00/63	135	K_f	P/W	4920	108.16	05/07/79	S
U-91	T7N, R60W, S.3 AAA	10309	P. Weitzel	11/27/61	131	K_f	U/E	4925	91	11/27/61	S
U-92	T8N, R59W, S.30 ADA	--	P. Hnizdale	--	140	K_f-K_l	P/W	4900	81.05	05/08/79	S
U-93	T8N, R59W, S.31 DDD	2206	P. Hnizdale	10/20/58	261	K_f-K_l	S/E	5028	201.02	05/14/79	S
U-94	T8N, R60W, S.32 AAA	69080	USDAFS	08/07/73	310	K_f	S/E	4971	187.25	05/14/79	S
U-95	T8N, R60W, S.13 AAB	37091	USDAFS	06/00/51	90	K_f	P/W	4922	74.70	05/14/79	S
U-96	T8N, R59W, S.17 BAC	16117	USDAFS	07/07/63	180	K_f	P/W	4886	113.55	05/14/79	S
U-97	T8N, R60W, S.3 DBA	38118	USDAFS	02/05/58	207	K_l	S/E	4948	142.24	05/14/79	S
U-98	T8N, R60W, S.12 AAA	38119	USDAFS	05/00/58	248	K_f?	P/W	5002	201.21	05/15/79	S
U-99	T9N, R60W, S.35 DBC	--	H. Benner	--	70	T_{wr}	P/W	4926	28.76	05/15/79	S
U-100	T9N, R60W, S.26 CBB	--	N. Snader	--	55	T_{wr}	P/W	4954	45.23	05/15/79	S
U-101	T9N, R63W, S.29 DDC	29815	USDAFS	02/20/67	240	K_l	P/W	5165	133.20	05/15/79	S
U-102	T9N, R63W, S.20 AAA	37101	USDAFS	02/00/40	213	K_l	P/W	5159	111.09	05/15/79	S
U-103	T9N, R63W, S.8 ACA	37158	USDAFS	05/00/45	132	K_l	P/W	5162	90	05/00/45	S
U-104	T9N, R63W, S.18 BAA	37100	USDAFS	04/00/38	214	K_l	P/W	5255	--	--	S

Appendix 2. Chemical analyses of water from samp

SAMPLE I.D. NUMBER	SAMPLE DATE	FIELD pH (UNITS)	LAB SPECIFIC CONDUCTANCE (MICROMHOS)	TEMP °C	CALCIUM DISSOLVED (MG/L)	MAGNESIUM DISSOLVED (MG/L)	POTASSIUM DISSOLVED (MG/L)	SODIUM DISSOLVED (MG/L)	ALKA-LINITY (MG/L AS $CaCO_3$)	CHLORIDE DISSOLVED (MG/L)	SULFATE DISSOLVED (MG/L)	FLUORIDE DISSOLVED (MG/L)	NITROGEN NO2 + NO3 DISSOLVED (MG/L AS N)	NITROGEN AMMONIA DISSOLVED (MG/L AS N)	SILICA DISSOLVED (MG/L)	DISSOLVED SOLIDS, TOTAL (MG/L)
U-1	6/15/78	7.6	2120	17.5	61	21	9.1	390	190	160	620	1.0	0.02	0.37	12	1530
U-2	6/13/78	8.7	612	20.0	3.7	1.3	2.8	140	270	16	27	0.9	0.16	0.00	6.5	570
U-3	6/14/78	8.7	614	16.0	3.4	1.0	2.2	150	300	15	27	0.9	0.15	0.00	7.7	583
U-4	6/14/78	9.2	518	25.0	3.4	1.1	3.4	120	200	18	40	0.9	0.01	0.07	12	437
U-5	6/14/78	7.9	711	20.0	6.8	1.8	3.7	130	210	24	54	0.8	0.02	0.07	9.4	508
U-6	6/15/78	8.1	2238	16.5	1.3	2.5	1.5	180	270	13	79	0.9	0.32	0.00	10	645
U-7	6/15/78	7.9	1809	17.0	73	19	8.0	440	140	160	780	0.2	0.01	0.33	9.3	1680
U-8	6/15/78	7.6	1809	17.0	28	7.6	6.4	360	130	170	500	0.3	0.06	0.43	10	1250
U-9	6/15/78	7.7	1890	16.5	47	14	9.2	360	220	110	540	0.3	0.11	0.01	9.3	1390
U-10	6/15/78	7.3	1122	14.0	58	16	10	170	210	19	340	1.4	0.30	0.00	23	911
U-11	6/16/78	8.2	621	15.0	3.0	1.0	2.2	150	250	27	43	0.9	0.08	0.10	11	561
U-12	6/16/78	8.1	616	15.5	3.5	1.0	2.4	150	260	22	36	1.0	-	-	10	570
U-13	6/19/78	7.3	421	14.0	44	7.8	12	39	170	10	31	1.4	0.02	0.00	28	403
U-14	6/19/78	7.6	670	15.5	17	2.0	6.5	120	120	95	54	0.6	0.07	0.03	11	380
U-15	6/19/78	7.6	2065	15.5	110	20	13	310	90	330	450	0.3	0.47	0.00	8.8	1300
U-16	6/20/73	7.7	1620	14.0	78	13	11	250	98	320	250	0.3	0.16	0.01	11	1060
U-17	6/20/78	7.7	655	14.5	15	3.6	4.2	130	210	21	110	0.6	0.15	0.00	11	545
U-18	6/20/78	7.3	1585	13.5	100	34	18	230	160	42	630	0.6	0.26	0.00	13	1290
U-19	6/20/78	8.1	1203	15.5	20	4.4	3.6	250	230	33	320	0.7	0.08	0.26	11	948
U-20	6/20/78	7.3	2644	13.5	77	21	12	540	420	61	870	0.2	0.13	0.01	12	2150
U-21	6/21/78	7.2	1139	12.0	120	38	8.5	92	320	11	310	0.3	0.52	0.03	14	1020
U-22	6/21/78	7.5	1281	14.5	68	20	7.0	200	210	44	350	0.7	28	0.01	6.9	970
U-23	6/21/78	7.9	568	15.0	516	1.1	2.3	140	300	7.3	11	1.1	0.17	0.03	9.4	566
U-24	6/21/78	7.2	2413	13.0	180	58	12	360	400	100	830	0.9	0.02	0.06	28	2100
U-25	6/21/78	7.2	1877	11.0	120	35	12	120	2070	98	580	-	0.02	0.00	-	-
U-26	6/26/78	7.5	422	12.5	15	3.0	4.4	79	150	18	39	0.6	0.71	0.00	11	368
U-27	6/26/78	7.9	445	14.0	14	2.2	4.0	89	160	15	43	0.6	0.43	0.00	9.9	391
U-28	6/26/78	7.7	523	14.5	15	3.8	5.8	95	170	27	54	0.4	1.4	0.00	8.7	313
U-29	6/27/78	7.4	579	13.0	24	4.5	5.5	100	180	30	70	0.4	0.21	0.01	9.9	480
U-30	6/27/78	7.8	405	14.0	13	2.3	3.5	84	160	8.2	39	0.6	0.02	0.01	9.4	370
U-31	6/27/78	7.8	689	14.0	58	15	11	69	240	34	72	1.9	0.52	0.00	55	463
U-32	6/27/78	7.8	416	14.0	7.5	1.9	3.1	87	160	7.5	39	0.6	0.05	0.01	10	352
U-33	6/27/78	7.8	439	14.0	21	5.3	5.4	77	200	8.2	26	0.6	0.04	0.00	14	420
U-34	6/28/78	7.9	439	13.0	9.1	2.5	4.3	89	170	12	42	0.5	0.00	0.00	89	391
U-35	6/28/78	8.2	402	14.5	5.8	1.3	3.0	89	160	6.5	36	0.6	0.00	0.03	11	366
U-36	6/28/78	8.8	582	18.0	6.5	0.3	3.4	140	300	9.0	11	0.9	0.00	0.18	11	570
U-37	6/28/78	8.1	403	14.5	9.6	9.6	3.1	89	160	5.8	36	0.6	0.00	0.03	10	367
U-38	6/28/78	9.6	1065	15.0	3.5	0	22	220	210	39	230	0.7	-	-	9.0	803
U-39	6/28/78	8.5	516	14.5	7.5	0.9	13	110	260	14	49	0.6	-	-	9.0	496
U-40	7/05/78	8.0*	637	13.0	16	4.9	5.4	130	250	22	67	0.4	0.02	0.00	10	404
U-41	7/05/78	8.1*	660	14.5	100	3.9	5.8	120	190	57	59	0.4	0.85	0.00	9.6	387
U-42	7/05/78	7.7	494	13.0	17	4.9	5.7	92	210	19	31	0.4	0.08	0.00	9.6	303
U-43	7/06/78	7.4	1006	14.0	57	15	18	140	320	51	130	1.5	3.1	0.00	35	640
U-44	7/06/78	8.0*	428	15.0	43	9.6	6.9	28	160	22	31	0.9	3.8	0.00	21	261
U-45	7/06/78	8.0*	573	16.0	12	2.8	4.1	120	180	26	74	0.6	0.01	0.07	120	358
U-46	7/06/78	8.3*	422	17.0	11	2.2	3.8	87	170	7.3	34	0.7	0.00	0.01	11	261
U-47	7/06/78	7.7	718	13.0	45	7.7	7.4	94	150	83	73	0.5	4.4	0.01	13	413
U-48	7/07/78	7.9*	568	13.0	64	13	6.4	37	160	43	71	0.4	8.8	0.00	54	383
U-49	7/07/78	8.2*	535	13.0	37	13	8.4	46	76	97	40	0.3	0.05	0.11	5.8	294
U-50	7/07/78	8.3*	404	14.5	10	1.9	3.8	83	160	7.7	28	0.6	0.09	0.00	10	244
U-51	7/07/78	8.3*	502	14.5	11	2.3	3.6	100	170	27	47	0.6	0.12	0.00	9.5	305
U-52	7/07/78	7.4	624	14.0	19	4.6	5.3	130	300	26	15	0.6	0.03	0.79	7.8	390
U-53	7/11/78	7.9*	463	19.0	34	8.7	5.3	57	183	16	35	0.7	2.7	0.00	40	307
U-54	7/11/78	7.4	762	14.0	110	21	11	19	198	30	180	0.7	0.85	0.00	51	542
U-55	7/11/78	7.4	516	22.5	46	15	7.6	39	203	26	36	0.7	0.14	0.01	57	350
U-56	7/11/78	7.5	413	14.5	27	8.5	6.7	49	171	13	171	0.8	3.7	0.00	57	295
U-57	7/11/78	7.4	391	14.5	29	9.3	5.0	47	193	7.1	23	0.7	2.5	0.01	60	297
U-58	7/11/78	7.5	438	13.0	61	11	6.2	13	193	15	21	1.0	4.4	0.00	46	290
U-59	7/11/78	7.8*	435	20.0	30	5.6	6.1	59	160	14	37	0.5	1.9	0.00	16	265
U-60	7/11/78	7.7*	393	15.5	25	3.6	5.5	65	190	4.9	31	0.6	0.03	0.00	13	263

* lab pH

HARDNESS (MG/L AS CACO$_3$)	HARDNESS NONCARB. (MG/L AS CACO$_3$)	BORON DISSOLVED (UG/L)	IRON DISSOLVED (UG/L)	MANGANESE DISSOLVED (UG/L)	MOLYBDENUM DISSOLVED (UG/L)	SELENIUM DISSOLVED (UG/L)	URANIUM DISSOLVED (UG/L)	VANADIUM DISSOLVED (UG/L)	GROSS ALPHA DISSOLVED URANIUM (UG/L)	GROSS ALPHA SUSPENDED URANIUM (UG/L)	GROSS BETA DISSOLVED SR-90 (PCI/L)	GROSS BETA SUSPENDED SR-90 (PCI/L)	GROSS BETA DISSOLVED CS-137 (PCI/L)	GROSS BETA SUSPENDED CS-137 (PCI/L)	SAMPLE I.D. NUMBER
240	7	230	0	50	4	0	0.05	4.0	<14	0.5	7.4	<0.4	7.9	<0.4	U-1
15	0	110	40	10	6	0	0.09	0.0	<3	<0.4	3.2	0.8	3.4	0.8	U-2
13	0	110	20	20	6	0	0.07	0.0	<3.7	0.7	4.1	0.6	4.3	0.6	U-3
13	0	90	10	10	5	0	0.05	0.0	<3.3	<0.4	3.1	0.9	3.3	0.9	U-4
24	0	80	0	5	7	0	0.14	0.0	<3.0	<0.4	2.7	<0.4	2.9	<0.4	U-5
14	0	150	0	10	6	0	0.07	0.0	<5.0	<0.4	<6.1	<0.4	<6.1	<0.4	U-6
260	85	110	0	110	5	0	0.09	3.0	<13	<0.4	5.9	<0.4	6.5	<0.4	U-7
100	0	160	0	10	5	0	0.05	3.0	<9.9	<0.4	<5.2	<0.4	<5.5	<0.4	U-8
180	0	110	0	90	12	0	0.7	1.0	19	<0.4	7.7	<0.4	8.3	<0.4	U-9
210	0	130	0	0	20	40	41	4.0	55	0.5	15	3.6	16	3.3	U-10
12	0	200	0	10	12	1	0.03	0.0	<1.8	<0.4	<2.0	<0.4	<2.1	<0.4	U-11
13	0	190	10	5	10	0	0.04	0.0	<3.8	<0.4	<1.8	<0.4	<1.9	<0.4	U-12
140	0	40	0	80	9	0	3.2	0.0	14	2.1	12	3.3	13	3.1	U-13
51	0	90	0	10	6	0	1.0	0.5	16	<0.4	8.3	0.4	8.8	<0.4	U-14
360	270	80	0	20	0	0	6.1	8.9	19	1.6	16	2.7	18	2.6	U-15
250	140	90	0	30	7	0	1.1	8.2	<13	1.9	12	2.7	13	2.6	U-16
52	0	80	90	30	4	0	0.07	6.0	<4.3	<0.4	2.9	<0.4	3.1	<0.4	U-17
390	180	180	580	610	26	2	45	1.7	64	56	21	22	22	24	U-18
68	0	140	40	50	6	0	0.06	1.5	<5.5	<0.4	<3.6	<0.4	<3.9	<0.4	U-19
280	0	120	10	50	0	0	0.12	0.0	<17	<0.4	<8.3	<0.4	<8.9	<0.4	U-20
460	61	80	200	160	0	1	9.2	0.0	<7.4	1.3	8.7	1.2	9.3	1.2	U-21
250	3	100	10	40	2	6	2.9	0.0	<9	<0.4	<3.7	<0.4	<4.0	<0.4	U-22
19	0	110	20	0	5	0	0.03	0.0	<3.2	<0.4	1.8	<0.4	1.9	<0.4	U-23
690	210	160	140	40	4	1	51	0.0	57	<0.4	16	1.3	17	1.2	U-24
440	7	200	10	2100	5	0	28	0.0	38	4.3	14	5.3	15	5.2	U-25
50	0	90	280	5	4	0	2.8	2.0	8.7	<0.4	3.4	<0.4	3.6	<0.4	U-26
44	0	80	0	0	3	0	0.45	0.0	<2.2	<0.4	4.5	<0.4	4.8	<0.4	U-27
53	0	90	100	0	4	0	7.1	2.5	20	<0.4	6.7	1.5	7.1	1.4	U-28
78	0	80	40	0	3	0	6.1	0.0	15	<0.4	5.4	1.1	5.7	1.0	U-29
42	0	70	120	10	4	0	0.70	0.0	5.1	<0.4	2.1	<0.4	2.3	<0.4	U-30
210	0	90	60	0	4	2	14	0.0	15	< 0.4	7.2	1.0	7.8	1.0	U-31
27	0	80	40	0	2	0	1.6	0.0	5.1	< 0.4	2.6	<0.4	2.7	<0.4	U-32
74	0	80	20	5	2	0	9.7	0.9	15	< 0.4	6.1	0.8	6.5	0.7	U-33
33	0	70	20	10	0	0	0.8	0.0	13	< 0.4	4.7	<0.4	5.0	<0.4	U-34
20	0	90	150	30	3	0	9.0	0.7	46	9.6	9.3	5.1	9.9	4.9	U-35
17	0	140	20	5	3	0	0.06	0.0	< 2.9	< 0.4	2.2	<0.4	2.3	<0.4	U-36
29	0	80	20	0	5	0	1.4	0.0	16	< 0.4	5.2	<0.4	5.6	<0.4	U-37
9	0	150	20	0	6	0	120	0.0	530	11	94	6.4	100	6.0	U-38
22	0	130	20	0	5	0	0.18	0.0	5.7	2.4	11	1.7	12	1.6	U-39
60	0	110	110	20	1	1	5.8	0.0	17	< 0.4	5.3	0.7	5.7	0.7	U-40
61	0	100	90	20	3	15	19	3.2	45	< 0.4	8.3	1.9	8.8	1.8	U-41
63	0	120	70	10	3	1	9.4	2.3	18	< 0.4	7.0	1.5	7.5	1.4	U-42
200	0	120	210	10	23	5	38	13	86	< 0.4	29	7.2	31	6.7	U-43
160	4	90	70	20	3	6	17	2.5	22	< 0.4	8.1	1.0	8.8	0.9	U-44
42	0	80	140	20	3	0	0.06	0.0	< 4.3	0.7	2.6	0.5	2.9	0.5	U-45
37	0	80	40	30	3	0	8.8	0.0	37	<0.4	5.8	0.9	6.3	0.9	U-46
140	0	100	50	50	3	17	18	0.0	19	2.0	7.6	4.1	8.1	4.1	U-47
210	58	90	20	20	3	5	17	9.0	23	<0.4	6.8	1.3	7.4	1.2	U-48
150	70	70	70	30	1	1	5.3	0.2	< 4.1	2.2	7.7	2.0	8.3	1.9	U-49
33	0	70	140	0	2	0	0.11	0.0	< 2.8	<0.4	2.0	<0.4	2.1	<0.4	U-50
37	0	80	100	20	3	0	7.4	0.0	< 5.4	<0.4	4.0	0.5	4.4	0.5	U-51
66	0	90	930	3200	1	0	0.03	1.0	< 3.9	<0.4	5.6	<0.4	6.0	<0.4	U-52
120	0	100	10	3	7.5	4	6.4	10	17	<0.4	5.8	0.6	6.2	0.5	U-53
360	160	60	60	70	13	14	37	1.5	42	<0.4	15	2.1	16	2.0	U-54
180	0	80	50	10	3	4	21	13	22	<0.4	12	1.9	13	1.8	U-55
100	0	80	60	0	3	3	15	15	12	<0.4	7.3	0.8	7.8	0.7	U-56
110	0	70	50	0	2	2	18	13	25	<0.4	7.3	1.0	7.9	0.9	U-57
200	5	40	20	0	3	2	7.6	7.7	7.0	<0.4	6.9	0.6	7.4	0.6	U-58
98	0	90	20	0	2	5	10	1.5	14	<0.4	7.0	0.4	7.4	<0.4	U-59
77	0	90	100	0	3	0	3.7	0.0	12	<0.4	6.2	0.9	6.6	0.9	U-60

SAMPLE I.D. NUMBER	SAMPLE DATE	FIELD pH (UNITS)	LAB SPECIFIC CONDUCTANCE (MICROMHOS)	TEMP °C	CALCIUM DISSOLVED (MG/L)	MAGNESIUM DISSOLVED (MG/L)	POTASSIUM DISSOLVED (MG/L)	SODIUM DISSOLVED (MG/L)	ALKA-LINITY (MG/L AS $CaCO_3$)	CHLORIDE DISSOLVED (MG/L)	SULFATE DISSOLVED (MG/L)	FLUORIDE DISSOLVED (MG/L)	NITROGEN $NO_2 + NO_3$ DISSOLVED (MG/L AS N)	NITROGEN AMMONIA DISSOLVED (MG/L AS N)	SILICA DISSOLVED (MG/L)	DISSOLVED SOLIDS, TOTAL (MG/L)
U-61	7/11/78	7.3	639	14.5	74	17	7.9	27	188	76	32	0.3	5	0.00	37	384
U-62	7/12/78	7.6	614	15.0	73	15	12	30	210	38	42	1.3	3.1	0.10	39	377
U-63	7/12/78	7.4	636	11.5	79	14	7.7	37	240	26	57	1.1	4.1	0.00	37	403
U-64	7/12/78	7.3	600	12.0	83	12	6.0	24	240	22	29	0.0	4.9	0.00	0.2	321
U-65	7/12/78	7.3	368	14.0	54	9.2	5.2	12	176	9.8	16	1.0	2.6	0.00	47	260
U-66	7/12/78	7.3	338	12.5	46	8.5	5.1	11	150	6.9	14	1.1	3.0	0.00	44	227
U-67	7/12/78	7.6*	386	14.0	51	9.7	6.7	14	170	11	16	1.0	3.9	0.00	51	263
U-68	7/18/78	7.2	577	14.0	26	5.8	6.3	89	190	19	62	0.7	0.06	0.00	11	334
U-69	7/18/78	7.8*	543	14.0	80	17	9.9	18	344	3.9	23	0.9	0.15	0.00	29	390
U-70	7/18/78	7.6	580	13.5	21	4.8	5.2	97	203	17	70	0.5	0.01	0.00	10	-
U-71	7/18/78	7.5	1030	15.0	84	26	7.7	110	254	33	270	0.6	13	0.00	7.2	691
U-72	7/18/78	7.2	1513	12.0	180	54	14	100	240	39	570	0.5	0.04	0.00	13	1120
U-73	7/19/78	7.5	2220	15.0	120	21	11	340	90	330	550	0.2	0.17	0.01	10	1440
U-74	7/19/78	7.7	1107	15.0	33	4.5	7	190	120	180	160	0.3	0.19	0.01	9.4	657
U-75	5/15/79	7.7*	563	14.0	43	14	7.5	46	230	6.8	46	0.8	1.5	0.02	12	315
U-76	4/17/79	7.2*	3321	12.5	390	61	37	350	130	14	1900	0.2	0.09	0.13	29	2860
U-77	4/18/79	7.6*	988	13.0	65	11	11	120	190	22	240	0.4	1.5	0.01	42	626
U-78	4/18/79	7.6*	1028	13.0	70	13	8.6	130	160	12	340	0.3	0.44	0.03	25	695
U-79	4/25/79	7.7*	503	12.5	23	10	10	67	200	3.6	38	3.6	1.4	0.01	23	299
U-80	4/25/79	7.5*	2043	11.5	52	12	12	380	99	88	760	0.3	0.06	0.51	5.8	1370
U-81	4/25/79	7.7*	1098	13.0	30	9.9	11	200	240	9.5	310	0.6	0.20	0.18	10	726
U-82	4/26/79	7.1*	1400	15.5	94	32	12	170	230	7.7	490	2.6	0.08	0.28	25	977
U-83	4/26/79	7.6*	812	13.5	34	11	7.1	130	290	5.7	150	1.3	0.01	0.22	13	528
U-84	4/26/79	7.3*	5387	12.0	250	190	28	920	520	15	2800	0.5	0.05	3.2	11	4540
U-85	4/26/79	7.0*	2309	12.0	230	130	26	140	380	7.9	1100	0.8	0.01	0.67	14	1880
U-86	5/01/79	7.4*	1208	13.0	36	16	12	220	460	6.6	160	2.1	0.16	0.57	14	744
U-87	5/01/79	7.6*	1998	13.5	130	31	24	280	170	58	780	0.3	0.12	0.04	9.6	1420
U-88	5/01/79	7.7*	2829	12.0	180	30	21	440	180	65	1300	0.4	0.23	0.22	7.8	2150
U-89	5/01/79	7.1*	3919	11.0	340	210	30	330	430	27	2000	0.9	2.1	0.57	21	3220
U-90	5/07/78	7.8*	413	12.5	44	14	7.3	26	150	7.0	23	3.0	3.1	0.05	24	239
U-91	5/07/79	8.1*	1297	12.0	71	24	8.0	12	350	16	320	1.1	0.22	0.38	12	853
U-92	5/08/79	7.9*	1436	10.5	83	31	14	200	290	9.5	470	1.2	0.23	0.04	12	996
U-93	5/14/79	7.6*	1031	14.5	59	21	9.0	140	290	4.8	250	2.1	0.03	0.29	26	688
U-94	5/14/79	7.8*	2270	15.0	79	22	12	410	230	34	890	0.7	0.04	0.47	8.8	1600
U-95	5/14/79	7.6*	3560	14.0	410	13	30	400	200	29	1700	0.2	0.21	0.08	21	2720
U-96	5/14/79	7.9*	2154	15.5	48	19	14	390	180	59	810	0.3	0.01	0.34	8.5	1460
U-97	5/14/79	8.1*	584	15.0	14	2.0	4.7	110	170	20	83	0.6	0.02	0.11	8.4	345
U-98	5/15/79	7.8*	2102	15.0	160	24	17	290	130	61	890	0.3	0.03	0.13	14	1540
U-99	5/15/79	7.8*	624	12.0	40	6.7	6.8	89	250	16	37	0.7	2.8	0.06	53	400
U-100	5/15/79	7.6*	668	12.5	47	9.4	7.6	83	170	12	150	0.3	0.04	0.03	18	430
U-101	5/15/79	8.0*	756	15.5	38	9.4	6.5	110	230	12	150	0.5	0.02	0.18	8.6	474
U-102	5/15/79	8.1*	504	15.0	17	3.9	4.4	87	170	6.6	70	0.5	0.04	0.15	8.2	300
U-103	5/15/79	7.9*	518	13.0	51	13	6.8	38	210	4.6	43	0.7	0.03	0.02	11	295
U-104	5/15/79	7.9*	518	14.0	48	11	6.9	46	210	4.6	48	0.8	0.05	0.03	11	303

HARDNESS (MG/L AS CACO$_3$)	HARDNESS NONCARB. (MG/L AS CACO$_3$)	BORON DISSOLVED (UG/L)	IRON DISSOLVED (UG/L)	MANGANESE DISSOLVED (UG/L)	MOLYBDENUM DISSOLVED (UG/L)	SELENIUM DISSOLVED (UG/L)	URANIUM DISSOLVED (UG/L)	VANADIUM DISSOLVED (UG/L)	GROSS ALPHA DISSOLVED URANIUM (UG/L)	GROSS ALPHA SUSPENDED URANIUM (UG/L)	GROSS BETA DISSOLVED SR-90 (PCI/L)	GROSS BETA SUSPENDED SR-90 (PCI/L)	GROSS BETA DISSOLVED CS-137 (PCI/L)	GROSS BETA SUSPENDED CS-137 (PCI/L)	SAMPLE I.D. NUMBER
250	67	60	30	10	3	3	10	6.8	9.5	<0.4	8.9	<0.4	9.6	<0.4	U-61
240	34	80	20	10	3	1	4.1	11	26	<0.4	18	0.9	20	0.9	U-62
260	15	100	70	10	3	2	5.5	7.0	26	<0.4	9.4	<0.4	10	<0.4	U-63
260	17	80	20	10	2	1	18	9.3	16	<0.4	8.9	1.5	9.4	1.4	U-64
170	0	40	10	0	3	1	6.1	10	5.1	<0.4	5.4	<0.4	5.8	<0.4	U-65
150	0	30	10	0	4	1	4.3	9.0	12	<0.4	5.7	<0.4	6.2	<0.4	U-66
170	0	30	20	10	3	2	6.2	11	15	<0.4	6.6	0.6	7.1	0.6	U-67
89	0	100	120	0	4	1	26	0.0	42	<0.4	11	2.4	12	2.3	U-68
270	0	120	1500	310	4	0	160	0.0	160	<0.4	37	11	39	10	U-69
72	-	100	150	40	2	1	0.12	0.0	<3.1	<0.4	5.6	<0.4	5.9	<0.4	U-70
320	63	100	70	20	3	70	36	0.0	44	<0.4	13	3.3	14	3.1	U-71
670	430	130	1700	660	1	0	22	0.0	34	<0.4	14	1	16	1	U-72
390	300	110	170	70	5	0	0.07	6.0	<14	<0.4	13	<0.4	14	<0.4	U-73
100	0	110	40	40	8	1	1.3	2.7	<6.8	<0.4	7.7	<0.4	8.1	<0.4	U-74
170	0	130	20	30	6	26	46	0.2	48	<0.4	12	2.5	13	2.3	U-75
1200	1100	130	1600	140	25	7	64	2	90	<0.4	33	4.1	40	3.5	U-76
210	18	150	60	4	<10	24	98	27	92	<0.4	29	4.2	33	3.6	U-77
230	68	120	140	30	<10	1	9.1	0.4	16	<0.4	6.0	0.8	6.7	0.7	U-78
99	0	260	10	1	28	11	24	0.6	19	<0.4	13	<0.4	14	<0.4	U-79
180	80	200	2300	160	4	0	0.21	1.4	<24	1.4	<7.8	1.5	<8.7	1.4	U-80
120	0	230	10	30	<10	-	0.80	0.0	<12	0.5	11	<0.4	12	<0.4	U-81
370	140	330	4600	180	<10	0	0.60	0	<16	1.0	9.9	0.7	11	0.7	U-82
130	0	210	1400	40	<10	0	0.80	1	<8.4	<0.4	6.3	<0.4	6.8	<0.4	U-83
1400	890	780	8300	290	7	0	5.6	0	< 100	6.9	24	2.3	29	2.3	U-84
1100	730	540	1200	340	0	0	21	2	100	11	26	6.2	32	6.3	U-85
160	0	300	590	30	11	0	3.2	0	19	9.3	11	7.6	12	7.3	U-86
450	280	270	1700	50	<10	0	2.8	1	<27	1.0	19	1.6	21	1.5	U-87
570	390	180	450	120	0	6	4.1	0.7	<41	5.4	<13	2.4	<14	2.5	U-88
1700	1300	660	380	2200	0	1	24	0.0	<82	<0.4	24	<0.4	28	<0.4	U-89
170	18	160	90	20	11	2	2.1	0	3.4	<0.4	5.4	0.9	5.7	0.9	U-90
280	0	260	50	20	4	0	0.18	0	<13	<0.4	8.9	<0.4	9.6	<0.4	U-91
340	45	340	60	10	0	43	18	0.0	<19	<0.4	14	<0.4	15	<0.4	U-92
230	0	260	920	60	8	0	0.09	0.1	<8.3	<0.4	6.7	0.4	7.2	0.4	U-93
290	58	260	40	120	3	0	0.14	0.0	< 25	<0.4	<9.5	<0.4	<10	<0.4	U-94
1100	880	110	340	510	8	5	57	0	120	1.2	26	7.9	29	7.5	U-95
200	18	220	800	80	6	0	0.09	0	< 23	<0.4	10	<0.4	11	<0.4	U-96
43	0	150	90	30	6	0	0.11	0.0	<4.3	<0.4	4.8	<0.4	5.1	<0.4	U-97
500	370	190	420	70	9	0	5.8	0.4	< 26	<0.4	18	0.8	20	0.7	U-98
130	0	130	20	0	3	5	65	7	92	<0.4	17	4.3	18	4.0	U-99
160	0	160	130	20	6	0	2.0	0.1	<5.7	<0.4	6.5	0.5	7.0	<0.4	U-100
130	0	170	100	60	0	0	10	0.0	< 8.0	<0.4	5.5	0.5	5.8	0.5	U-101
59	0	100	20	40	1	0	0.29	0.0	< 3.7	<0.4	3.3	<0.4	3.6	<0.4	U-102
180	0	110	160	40	3	5	17	0	24	<0.4	10	11	0.9	0.9	U-103
170	0	120	40	40	4	0	51	0	68	<0.4	16	4.8	17	4.5	U-104

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LOCATION MAP OF SAMPLED WATER WELLS, CHEYENNE BASIN, COLORADO
BY
R. M. KIRKHAM, W. J. O'LEARY, J. W. WARNER

DEPARTMENT OF NATURAL RESOURCES
COLORADO GEOLOGICAL SURVEY
JOHN W. ROLD, DIRECTOR

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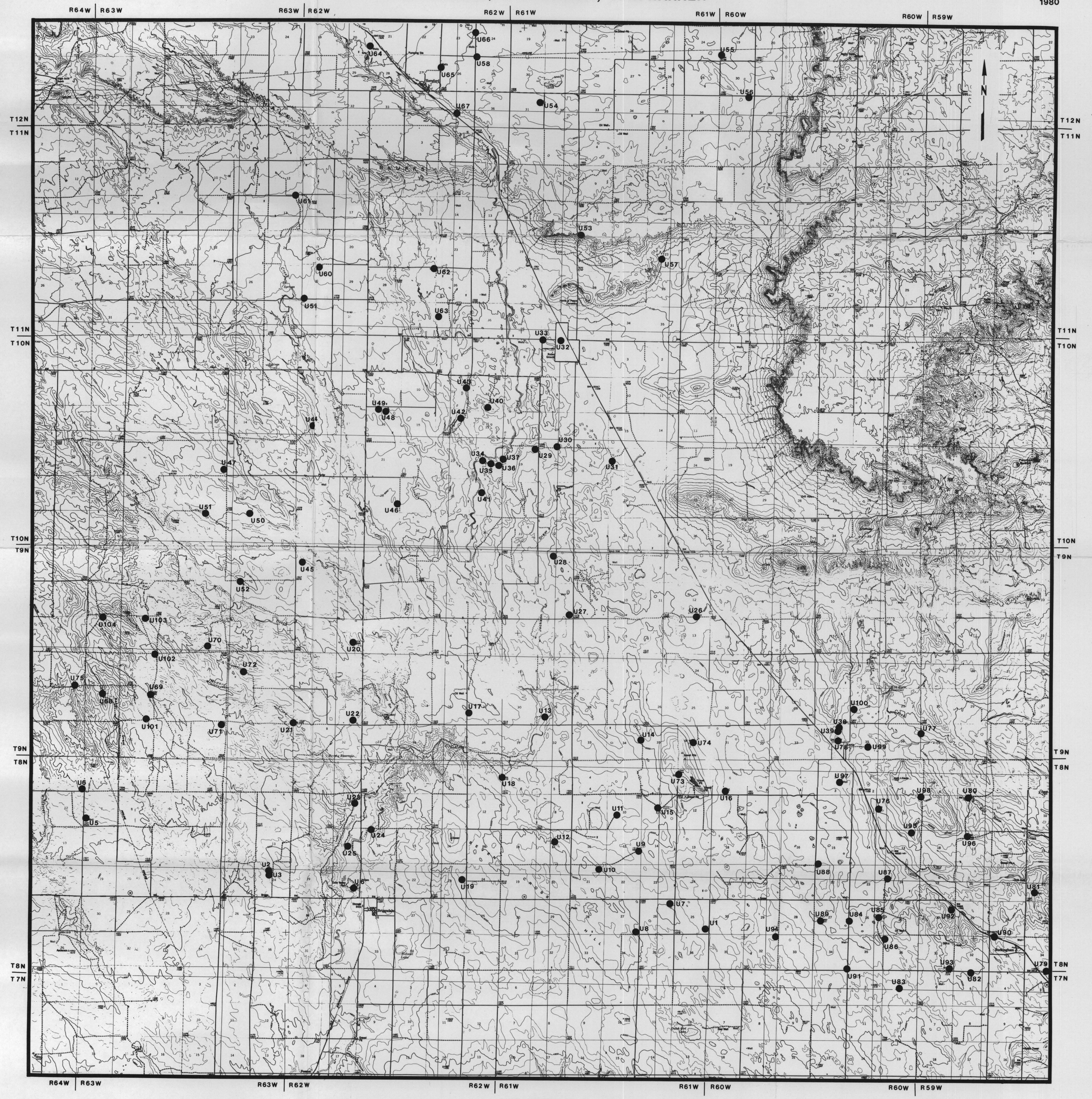

EXPLANATION

● U31 Sampled water well with I.D. number; Refer to Appendices 1 and 2 for well descriptions and chemical analyses

SCALE 1:100 000

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

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