

Oklahoma, South Dakota, Texas, and Wyoming (McGuire and others, 2003). Through irrigation of p. 6–11 to 6–14) modified parts of the potentiometric-surface map of Crist (1980) with more recent locally confining or semi-confining conditions occur in many places within Laramie County (for crops with groundwater from the High Plains aquifer system, the area that overlies the aquifer system has become one of the world's major agricultural regions. In addition, the aquifer system also serves as the primary source of drinking water for most residents of the region. In 2000, the High Plains aquifer system had an estimated 2,980 million acre-feet of drainable water (water in the aquifer system that would drain by gravity and generally can be withdrawn by wells) in storage, making it one of the largest aquifers or aquifer systems in the world (McGuire and others, 2003). The High Plains aquifer system underlies an area of 8,190 mi² in southeastern Wyoming (Gutentag and Weeks, 1980). Including Laramie County, the High Plains aquifer system is present in parts of five counties in southeastern Wyoming (see index map). The High Plains aquifer system underlies 8 percent of Wyoming, and 5 percent of the aquifer system is located within the State (Gutentag and Weeks, 1980). Based on withdrawals for irrigation, public supply, and industrial use in 2000, the High Plains aquifer system is the most utilized source of groundwater in Wyoming (Boughton and others, 2006, fig. 4). With the exception of the Laramie Mountains in western Laramie County (areas shaded with green, blue, and purple on map, indicating Mesozoic and older rocks), the High Plains aquifer system is present throughout Laramie County. In Laramie County, the High Plains aquifer system is the predominant groundwater resource for agricultural (irrigation), municipal, industrial, and domestic uses. Withdrawal of groundwater for irrigation (primarily in the eastern part of the county) is the largest use of water from the High Plains aquifer system in Laramie County and southeastern Wyoming (Boughton and others, 2006). Groundwater-level declines, associated with localized high-use areas in the High Plains aquifer system in Laramie County, have been noted as far back as the 1940s (Lowry and Crist, 1967). In fact, in response to groundwater-level declines (primarily due to irrigation withdrawals) in some areas in southeastern Wyoming, special "areas" of the aquifer system were selected for

increased groundwater regulation. In Laramie County, a specially regulated aquifer area known as the "Laramie County Control Area" was created in 1981 by the Wyoming Board of Control (JR Engineering LLC and others, 2008). The Laramie County Control Area (not shown) comprises much of the county, but generally includes the High Plains aquifer system from about Interstate 25 in west-central Laramie County eastward to the Wyoming-Nebraska State line. For the Laramie County Control Area, an Advisory Board reviews and makes water-administration recommendations to the Wyoming State Engineer's Office (WSEO) concerning any development of new wells, enlargements of existing permitted wells, or placement of new lands under irrigation within the Control Area. prompted a study by the U.S. Geological Survey (USGS) in cooperation with the WSEO to update the potentiometric-surface map of the aquifer system in Laramie County. Groundwater levels were measured in wells completed in the High Plains aquifer system and used to construct a map of the potentiometric surface of the High Plains aquifer system. The potentiometric surface of an aquifer is equal to the altitude at which water will rise in tightly cased wells open to a given point in that aquifer (Lohman and others, 1972). In areas where the aquifer is unconfined, the potentiometric

Purpose and Scope

The primary purpose of this map is to present the generalized potentiometric surface of the High Plains aquifer system in Laramie County, Wyoming. Groundwater levels used to construct he potentiometric surface were measured between March and June 2009, but most groundwater levels were measured between March and May. In addition, the hydrogeologic units of the High Plains aquifer system in Laramie County are briefly described, along with depth to water and estimated saturated-thickness maps created using the potentiometric-surface map presented herein.

surface is equal to the water-table altitude. The potentiometric-surface map provides a tool for

evaluating groundwater flow directions and hydraulic gradients in the High Plains aquifer system.

Previous Investigations

Excluding regional maps, two county-wide potentiometric-surface maps of the High Plains aquifer system in Laramie County have been constructed previously (Lowry and Crist, 1967, pl. 2; cally stacked on schematic diagram in fig. 2). Consequently, wells completed in the High Plains

groundwater levels to represent predevelopment (before 1943) and two later (1994 and 2004) time example, see Cooley and Crist, 1994). periods. In addition, numerous local-scale investigations within the county (not listed herein) have produced potentiometric-surface maps of the aquifer system for areas of small geographic extent. Acknowledgments The authors would like to thank all the people who assisted with this study, measured groundwater levels, and assisted with preparation of the report. Lisa Lindemann and John Harju of the WSEO are gratefully acknowledged for their support of this study. George Moser, Nick Leventis, James Neely, and Ben Running with the WSEO, and Greg Boughton, Mike Sweat, Seth Davidson, and Kathy Foster with the USGS measured groundwater levels throughout Laramie

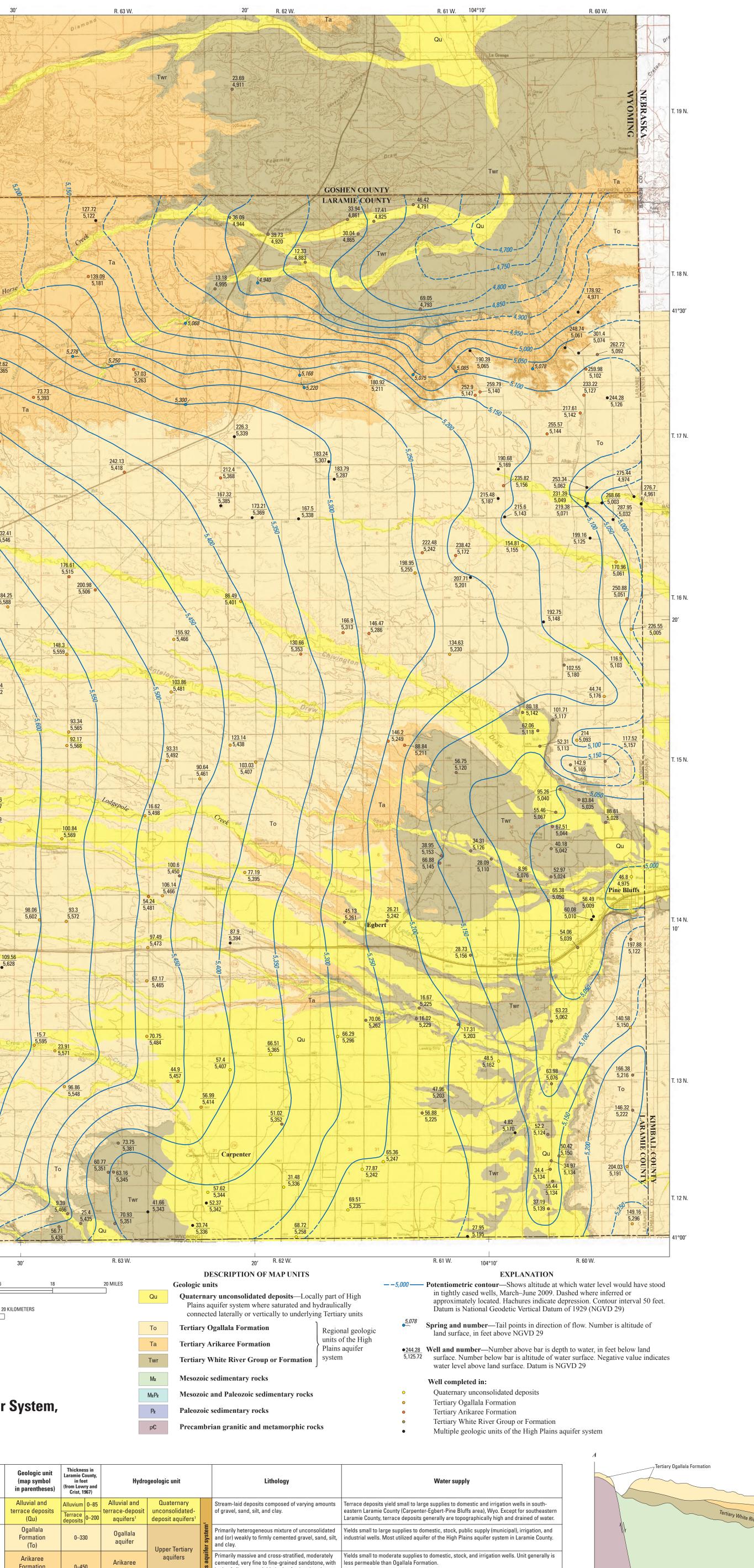
County. Special thanks are given to Victor Spencer of the Cheyenne Board of Public Utilities who kindly provided groundwater levels from monitoring wells located within the City of Cheyenne well fields. The authors thank the many public and private landowners of Laramie County who provided information and access to their water wells for measurements. Colleague reviews by Virginia McGuire (USGS) and Laura Bexfield (USGS) improved the quality of the manuscript. George Moser and Jeremy Manley (WSEO) provided helpful comments. Suzanne Roberts (USGS) is thanked for creating the illustrations and performing layout work. Description of Study Area Laramie County, in the southeastern corner of Wyoming, includes an area of 2,709 mi². The county includes parts of the southern Rocky Mountains physiographic province (Laramie Mountains that extend along the western edge of the county) and Great Plains physiographic province

(most of the county) described by Fenneman (1946). The topography of the area east of the Laramie Mountains within the Great Plains physiographic province, which is most of the county, generally is a "high eastward-sloping" and "gently rolling surface of only moderate relief" underlain by Tertiary sedimentary rocks (Lowry and Crist, 1967, p. 6). Several prominent escarpments noticeably affect topography, particularly in the northern and southeastern parts of the county. Small eastward-flowing perennial, intermittent, and ephemeral streams drain the county, only two of which (Horse and Chugwater Creeks) are perennial throughout their courses (Lowry and Crist, 1967). The climate, which is characteristic of the northern Great Plains, is semiarid with large tem-Continued interest in groundwater levels in the High Plains aquifer system in Laramie County perature variations, cold winters, low precipitation, frequent winds, low humidity, and high evaporation. Mean annual precipitation (snow and rain) ranges from about 14 to 18 inches in the central and eastern parts of the county to as much as 24 inches in the Laramie Mountains on the western edge of the county (JR Engineering LLC and others, 2008, unnumbered figure, p. 4–1). Excluding the Laramie Mountains, land use/land cover is predominantly rangeland and agricultural land. The population of Laramie County in 2010 was 91,738 (U.S. Census Bureau, 2011).

drogeologic Setting

In Laramie County, the primary aquifers are the unconsolidated Quaternary alluvial and terrace deposits, the Tertiary Ogallala and Arikaree Formations, and the Tertiary White River Group or Formation; these aquifers are part of the High Plains aquifer system (fig. 1). An aquifer system consists of two or more aquifers, commonly vertically stacked, that are grouped together because of physical connection or sharing of similar geologic and hydrologic characteristics that are best described and studied together. Hydraulic connection among the Quaternary unconsolidateddeposit, Ogallala, and Arikaree aquifers, and the White River aquifer/confining unit varies locally, but regionally they are in sufficient hydraulic connection to compose a regional aquifer system (Crist, 1980; Cooley and Crist, 1981, 1994; Gutentag and Weeks, 1980; Avery and Pettijohn, 1984; Libra and others, 1981; Weeks and Gutentag, 1981; Gutentag and others, 1984). In many publications, the High Plains aquifer system in southeastern Wyoming is informally referred to as the "Tertiary aquifer" or "Tertiary aquifer system." The aquifers contained in Tertiary geologic units are vertically stacked, although not all are present throughout Laramie County due to erosion (see geologic units on map and shown verti-

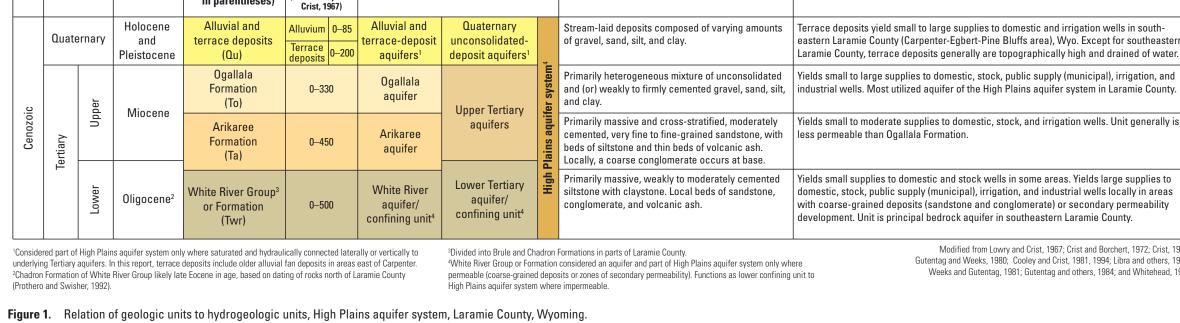
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Alternating episodes of deposition and erosion created the Cenozoic sedimentary geologic units composing the High Plains aquifer system. The thickness and lithology of these geologic units in Laramie County are summarized in figure 1. Quaternary unconsolidated deposits (alluvium and terrace deposits) were deposited by eastward-flowing streams. Alluvium was deposited from the erosion of the uplift to the west or in-place erosion of Tertiary geologic units composing the High Plains aquifer system. Terrace deposits are erosional remnants of alluvium that were deposited along former or current stream valleys. The Ogallala Formation is a complex sequence of cuts and fills composed mostly of stream-laid sediments with minor amounts of volcanic ash (Stanley, 1976; Diffendal, 1984, and references therein; Swinehart and others, 1985, and references therein). In contrast, the Arikaree Formation and White River Group or Formation are mostly composed of valley fills of windborne volcanic material transported into Wyoming from volcanoes in States located predominantly to the west (Stanley, 1976; Swinehart and others, 1985, and references therein). Some stream-laid sediment also occurs in the fills, most commonly at the bases of these two geologic units. Paleosols (fossil soils) occur in all three Tertiary geologic units. All three Tertiary geologic units slope gently to the east with dips of no more than 1 to 2 degrees (Ver Ploeg and others, 1998, 2000). Unconsolidated sand and gravel beds of the Ogallala Formation yield water more readily than the sandstone beds in the Arikaree Formation. The consolidated siltstone and sandstone beds of the White River Group or Formation yield highly variable volumes of water; yields are greatest where the permeability of the geologic unit has been increased by secondary permeability development from fractures, joints, and solution openings (Lowry, 1966; Lowry and Crist, 1967; Crist and Borchert, 1972). The Ogallala and Arikaree Formations generally are permeable and defined as aquifers throughout Laramie County, whereas the White River Group or Formation is only permeable and defined as an aquifer in areas with coarse-grained deposits or secondary permeability development. Where impermeable, the White River Group or Formation is defined as a basal confining unit to the High Plains aquifer system (fig. 1).

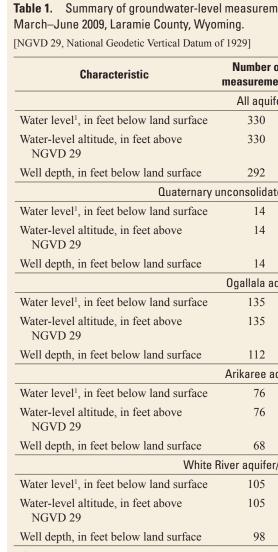
Potentiometric Surface The generalized potentiometric surface of the High Plains aquifer system in Laramie County, shown on the map, was constructed on the basis of groundwater levels measured in wells during March–June 2009. Groundwater levels in wells located within irrigation areas in Laramie County generally were measured first, prior to the beginning of the 2009 irrigation season. The potentiometric surface represents water-level altitudes and feet above the National Geodetic Vertical Datum of 1929 (NGVD 29). The potentiometric surface of the High Plains aquifer system was mapped by contouring altitudes of groundwater levels measured in 330 wells completed in Quaternary and Tertiary geologic units composing the aquifer system (see map; table 1). Of the 330 wells for which a groundwater level was used to construct the potentiometric surface, 94 were used primarily for domestic use; 83 were primarily for stock use; 55 were primarily for irrigation use; 41 were unused; 31 were for monitoring purposes; and the remaining 26 wells were used for other miscellaneous purposes. The land-surface altitude of a spring in an outcrop area is approximately equal to (or slightly higher than) the water-table altitude at that location, and thus several spring locations also were used to construct the potentiometric surface. The altitudes of perennial streams and associated perennial reaches known to be in hydraulic connection with the High Plains aquifer system (as identified by Lowry and Crist, 1967; Crist and Borchert, 1972; Crist, 1980; and Cooley and Crist, 1981) also were used as control for mapping the potentiometric surface. The geologic unit(s) of the High Plains aquifer system that a measured well was completed in were estimated based on well location, well depth, geologic or well logs, and comparisons with information in previous publications; the unit(s) are indicated on the map by use of different colored symbols. Groundwater levels measured to construct the potentiometric surface and available well depths for measured wells are summarized by aquifer in table 1; groundwater levels and depths measured for wells

completed in multiple geologic units of the High Plains aquifer system (see map) were assigned to one primary geologic unit (aquifer) for summary purposes in table 1. The water-level altitudes and depth to water measurements shown on the map, as well as additional ancillary information for all valleys and other topographically low areas.



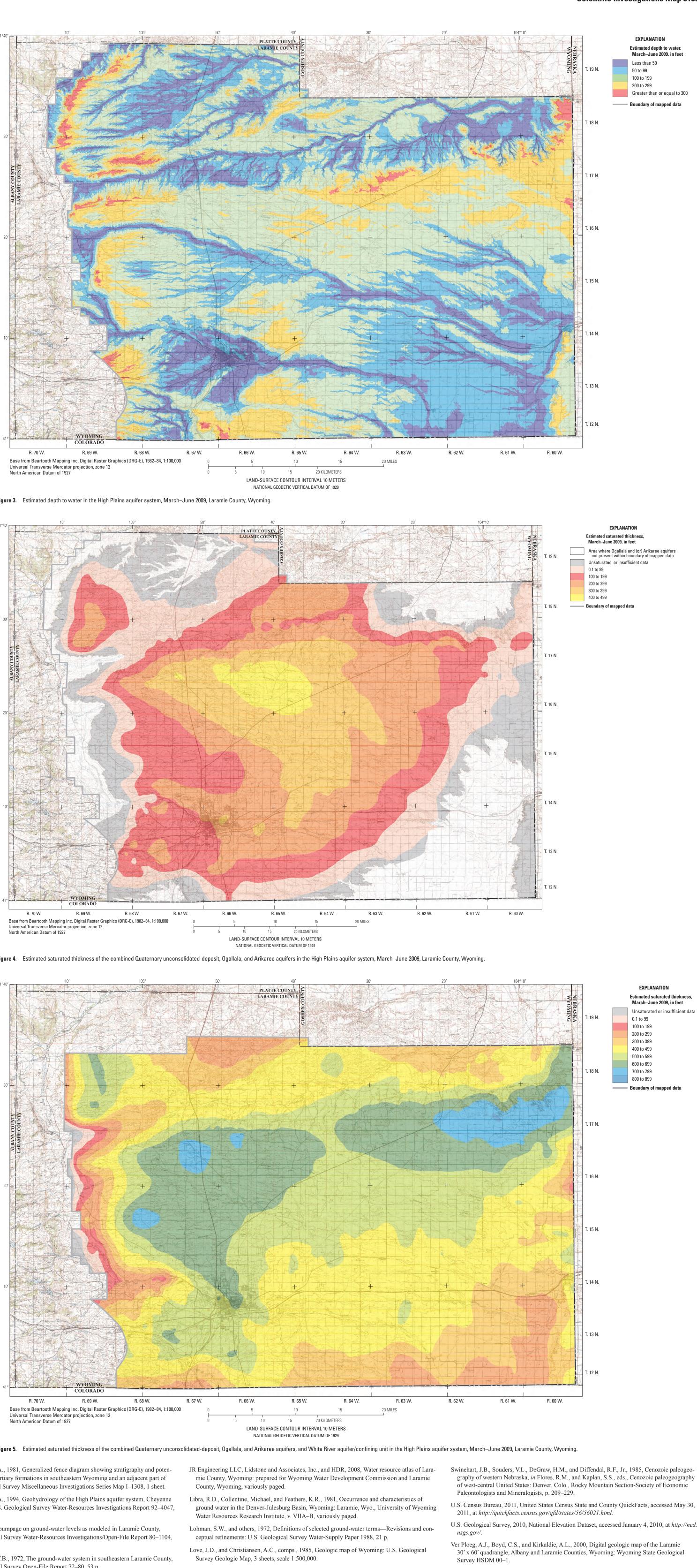
measured wells, are available from the Groundwater Site Inventory database of the USGS National Water Information System database at http://waterdata.usgs.gov/wy/nwis/gw. Groundwater moves from high altitudes to lower altitudes and generally in a direction that is perpendicular to the potentiometric contours in the direction of the slope of the potentiometric surface (hydraulic gradient). In the High Plains aquifer system in Laramie County, groundwater generally moves from west to east, but this pattern of flow is altered locally by groundwater divides, and by groundwater discharge to streams (see map). The altitude of the potentiometric surface declines from about 6,800 feet (ft) in western Laramie County to about 5,000 ft in eastern Laramie County. Discharge is by the movement of water to seeps and springs, streams, evapotranspiration, and withdrawal from wells. Some groundwater also flows out of the county as underflow, especially in the Quaternary unconsolidated-deposit aquifers (Rapp and others, 1953; Bjorklund, 1959; Lowry and Crist, 1967). Several surface-drainage systems locally affect the configuration of the potentiometric surface, most notably Chugwater Creek, Horse Creek, Lodgepole Creek, and the upper reaches of Crow Creek (see map). Potentiometric contours in the immediate vicinity of streams can indicate gaining streams by pointing in an upstream direction (potentiometric surface above water in the stream) or losing streams by pointing in a downstream direction (potentiometric surface below water in the stream). Chugwater and Horse Creeks generally gain water from the High Plains aquifer system throughout their reaches, and both are the only streams perennial throughout their courses in the county; all other streams are intermittent, many alternating between gaining or losing water to the aquifer system (Lowry and Crist, 1967; Cooley and Crist, 1981). Depending upon the reach, Lodgepole Creek either gains water from or loses water to the High Plains aquifer system (Lowry and Crist, 1967). Water-level contours along Crow Creek show that the stream generally gains water from the High Plains aquifer system west of Cheyenne and loses water to the aquifer system in the reaches east of the city.

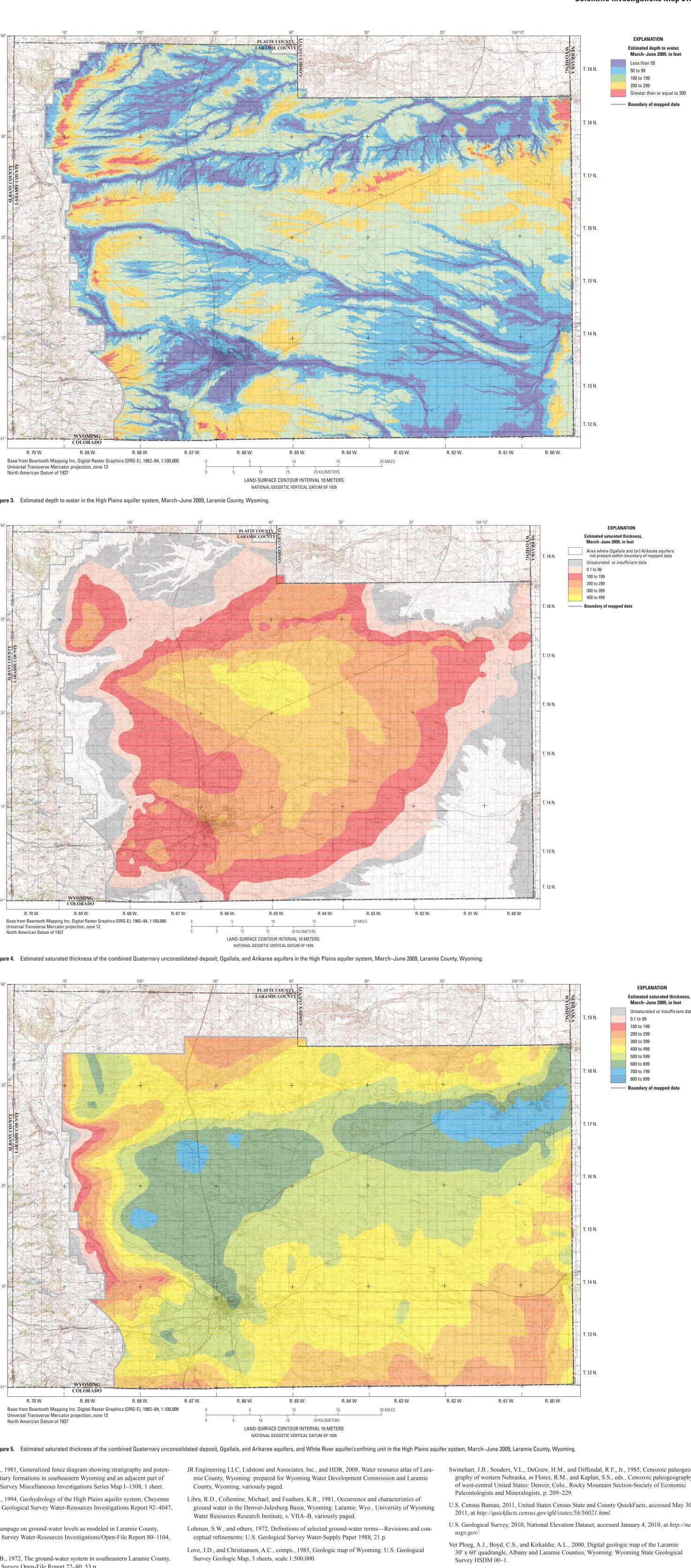
Depth to Water A map showing the estimated depth to water in the High Plains aquifer system in Laramie County during March-June 2009 (fig. 3) was constructed using a geographic information system to determine the vertical distance between the land-surface altitude (U.S. Geological Survey, 2010) and the potentiometric-surface altitude. Depth to water in the High Plains aquifer system ranged from less than 50 ft to more than 300 ft. Depth to water was shallowest (0 to 50 ft) beneath stream

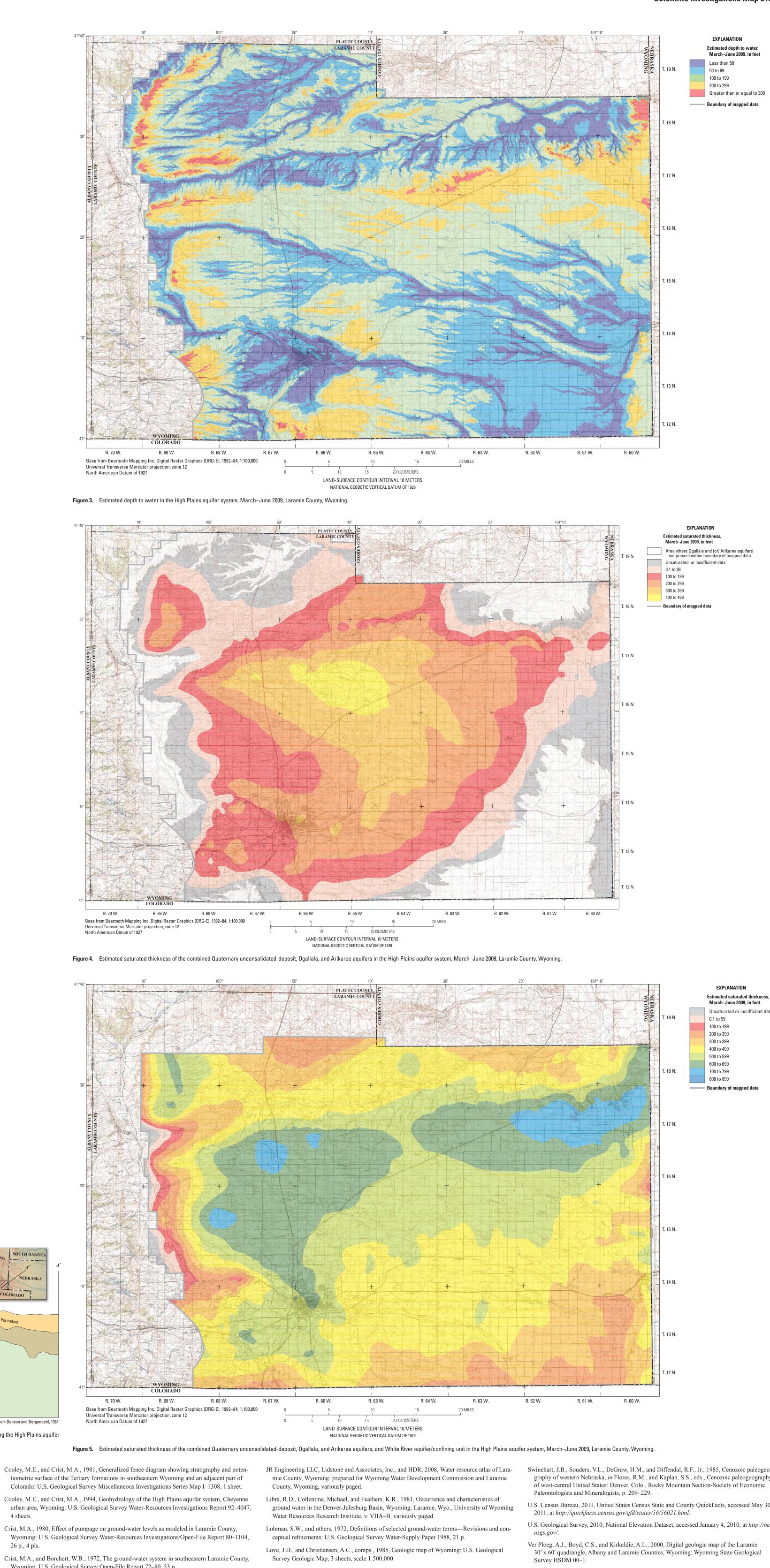


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²Negative value indicates water level above land surface.







NGVD 29, National Geodetic Vertical Datum of 1929]				
Characteristic	Number of measurements	Minimum	Median	Maximum
	All aquifers			
Water level ¹ , in feet below land surface	330	² -0.91	93.50	304.54
Water-level altitude, in feet above NGVD 29	330	4,790.58	5,499.60	6,793.02
Well depth, in feet below land surface	292	15.5	200	815
Quaternary	unconsolidated-de	posit aquifers		
Water level ¹ , in feet below land surface	14	4.82	57.51	77.87
Water-level altitude, in feet above NGVD 29	14	4,975.20	5,277.00	5,639.92
Well depth, in feet below land surface	14	30	93.50	205
	Ogallala aquifer			
Water level ¹ , in feet below land surface	135	² -0.91	98.69	298.40
Water-level altitude, in feet above NGVD 29	135	4,973.56	5,888.81	6,793.02
Well depth, in feet below land surface	112	15.5	208	575
	Arikaree aquifer			
Water level ¹ , in feet below land surface	76	20.95	168.95	287.95
Water-level altitude, in feet above NGVD 29	76	4,961.30	5,366.49	6,100.31
Well depth, in feet below land surface	68	55	268.26	500
White	River aquifer/confi	ning unit		
Water level ¹ , in feet below land surface	105	6.56	60.08	304.54
Water-level altitude, in feet above NGVD 29	105	4,790.58	5,215.62	6,788.98
Well depth, in feet below land surface	98	22	132.50	815

with coarse-grained deposits (sandstone and conglomerate) or secondary permeability

Modified from Lowry and Crist, 1967; Crist and Borchert, 1972; Crist, 1980;

Weeks and Gutentag, 1981; Gutentag and others, 1984; and Whitehead, 1996

Gutentag and Weeks, 1980; Cooley and Crist, 1981, 1994; Libra and others, 1981;

development. Unit is principal bedrock aquifer in southeastern Laramie County.

Saturated Thickness

granitic and

Two maps were constructed showing the estimated saturated thickness of different combinations of geologic units composing the High Plains aquifer system in Laramie County during March–June 2009. The saturated thickness is the vertical distance between the potentiometric surface and the base of the geologic units composing the individual aquifers within the system or the entire aquifer system. The first map (fig. 4), showing the estimated saturated thickness of the combined Quaternary unconsolidated-deposit, Ogallala, and Arikaree aquifers, was constructed using a geographic information system to determine the vertical distance between the altitude of the potentiometric surface of the aquifer system and the altitude of the base of the Arikaree Formation (modified and updated from contours showing the top of the White River Formation in Lowry and Crist, 1967, pl. 2). The estimated saturated thickness of the combined Ogallala and Arikaree aquifers ranged from less than 1 foot to almost 500 ft. The second map (fig. 5), showing the estimated saturated thickness of the combined Quaternary unconsolidated-deposit, Ogallala, and Arikaree aquifers, and the White River aquifer/ confining unit (all units composing the High Plains aquifer system), was constructed by using a geographic information system to determine the vertical distance between the altitude of the potentiometric surface of the aquifer system and the altitude of the base of the White River Group or Formation (modified and updated from Crist, 1980, pl. 2). The estimated saturated thickness of the combined Quaternary unconsolidated-deposit, Ogallala, and Arikaree aquifers, and the White River aquifer/confining unit ranged from less than 1 foot to almost 900 ft.

system, southeast Wyoming to Nebraska panhandle (A–A').

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Not to scale

Figure 2. Simplified schematic showing relation of Tertiary geologic units composing the High Plains aquifer

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