Prepared in cooperation with the Bureau of Land Management

Hydrogeology, Groundwater Levels, and Generalized Potentiometric-Surface Map of the Green River Basin Lower Tertiary Aquifer System, 2010–14, in the Northern Green River Structural Basin, Wyoming

Scientific Investigations Report 2015–5090

U.S. Department of the Interior
U.S. Geological Survey

Cover. Background photograph: Cliff in upper part of photograph is composed of rocks of the Alkali Creek Tongue of the Wasatch Formation and the Farson Sandstone Member of the Green River Formation. Ridge on top of the bluff is composed of sandstone that is more resistant to weathering than other rocks composing the geologic formations. Sandstone beds in both geologic units are important aquifers in the Green River structural basin. Sagebrush in foreground of photograph rests on rocks composing the main body of the Wasatch Formation. Photograph by Jennifer Beck, U.S. Geological Survey.

Upper left photograph: Livestock drinking water from a small surface impoundment. Water in the impoundment was provided by a nearby stock well. Photograph by Michelle Taylor, formerly of the U.S. Geological Survey.

Lower left photograph: Stock well in protective corrugated steel culvert and associated solar panel. Electrical power generated by solar panels provides power to operate submersible pumps installed in many stock wells in the Green River structural basin. Green tape reel located to the left of the corrugated culvert holds the black electrical tape used to measure groundwater levels in wells. Photograph by Sarah Davis, U.S. Geological Survey.

Right photograph: Measurement of groundwater level in a stock well. Corrugated steel culvert has been used to surround and protect the wellhead. Water pumped from the well is delivered to the stock trough in the foreground via the two pipes coming out of the side of the corrugated culvert. Photograph by Kathy Foster, formerly of the U.S. Geological Survey.

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as °F = (1.8 × °C) + 32.

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as °C = (°F – 32) / 1.8.

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Hydrogeology, Groundwater Levels, and Generalized Potentiometric-Surface Map of the Green River Basin Lower Tertiary Aquifer System, 2010–2014, in the Northern Green River Structural Basin, Wyoming

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Abstract

In cooperation with the Bureau of Land Management, groundwater levels in wells located in the northern Green River Basin in Wyoming, an area of ongoing energy development, were measured by the U.S. Geological Survey from 2010 to 2014. The wells were completed in the uppermost aquifers of the Green River Basin lower Tertiary aquifer system, which is a complex regional aquifer system that provides water to most wells in the area. Except for near perennial streams, groundwater-level altitudes in most aquifers generally decreased with increasing depth, indicating a general downward potential for groundwater movement in the study area. Drilled depth of the wells was observed as a useful indicator of depth to groundwater such that deeper wells typically had a greater depth to groundwater. Comparison of a subset of wells included in this study that had historical groundwater levels that were measured during the 1960s and 1970s and again between 2012 and 2014 indicated that, overall, most of the wells showed a net decline in groundwater levels.

The groundwater-level measurements were used to construct a generalized potentiometric-surface map of the Green River Basin lower Tertiary aquifer system. Groundwater-level altitudes measured in nonflowing and flowing wells used to construct the potentiometric-surface map ranged from 6,451 to 7,307 feet (excluding four unmeasured flowing wells used for contour construction purposes). The potentiometric-surface map indicates that groundwater in the study area generally moves from north to south, but this pattern of flow is altered locally by groundwater divides, groundwater discharge to the Green River, and possibly to a tributary river (Big Sandy River) and two reservoirs (Fontenelle and Big Sandy Reservoirs).

Introduction

The Wyoming Landscape Conservation Initiative (WLCI) is a program created to "implement a long-term, science-based program of assessing, conserving, and enhancing fish and wildlife habitats while facilitating responsible energy and other development through local collaboration and partnerships" (Bowen and others, 2014, p. 2). The role of the U.S. Geological Survey (USGS) in the WLCI program is "to conduct science and perform technical-assistance activities that help to assess and monitor trends in overall ecosystem conditions, focal habitats, and species of concern; evaluate the effectiveness of habitat enhancement or restoration projects; and provide support to conservation planners and decision-makers" (Bowen and others, 2014, p. 2). The WLCI study area includes much of southwestern Wyoming, including all or parts of Lincoln, Sublette, Fremont, Sweetwater, and Carbon Counties (Bowen and others, 2014, fig. 1).

A study was completed as part of ongoing USGS contributions to the WLCI program with the objective to improve understanding of the primary groundwater resources used in a part of the northern Green River structural basin. Natural gas is currently (2015) extracted from tight (low permeability) gas reservoirs in a deep Late Cretaceous-age geologic formation (Lance Formation) (Law, 1984; Law and Spencer, 1989) that underlies the shallow groundwater resources that exclusively provide water to rural livestock, domestic, and industrial wells in the area (Clarey and others, 2010). Expansion of natural-gas development in the study area is expected in the future (EnCana Oil and Gas [USA], Inc., 2011; Bureau of Land Management, 2011). Drilling into the Lance Formation requires penetration of overlying aquifers that compose the regionally extensive and heterogeneous aquifer system contained within

Tertiary rocks (known as the Green River Basin lower Tertiary aquifer system) that supplies water to these wells. To improve understanding of this locally and regionally important aquifer system, the USGS, in cooperation with the Bureau of Land Management (BLM), completed the following: (1) measured groundwater levels in wells completed in the aquifer system, (2) evaluated measured groundwater levels and equivalent groundwater-level altitudes in relation to well depths and lithostratigraphic/hydrostratigraphic unit designation, (3) compared newly measured groundwater levels with historical groundwater levels where possible, and (4) constructed an updated generalized potentiometric-surface map.

Purpose and Scope

The purpose of this report is to describe groundwater levels and the generalized potentiometric-surface of the lower Tertiary aquifer system in the northern Green River structural basin. The hydrogeology of the area also is summarized. Construction of a generalized potentiometric-surface map of the regional Green River Basin lower Tertiary aquifer system in the northern Green River structural basin Wyoming was the conclusion of an effort by the USGS to measure groundwater levels during 2010–14 (Sweat, 2013). The complex geology in the Green River structural basin greatly influences groundwater levels and movement of groundwater in the lower Tertiary aquifer system. Nomenclature of the interfingering and intertonguing Tertiary lithostratigraphic units representing many different depositional environments (lithostratigraphy) is very complex and has been repeatedly revised in the northern Green River structural basin. Similarly, the classification of these lithostratigraphic units as hydrogeologic units (hydrostratigraphy) also is very complex and also has been repeatedly revised; consequently, a summary and synthesis of past and current science related to the lithostratigraphy and hydrostratigraphy of the northern Green River structural basin is provided herein.

Methods of Investigation

The methods used to inventory and select existing wells for measurement of groundwater levels in the study area are described in Sweat (2013). In general, existing wells were selected that included information about the depth of the well, the open or screen/perforated interval(s) of the well, the type of surface seal, and the groundwater level at the time of well completion (Sweat, 2013). Groundwater-level measurements were made during 2010–14 using a steel tape, electrical tape, or pressure gauge using protocols and quality-control procedures described in Cunningham and Schalk (2011).

Description of Study Area

The study area is described in this section of the report. Brief descriptions of the geographic setting, climate, and geologic setting in the vicinity of the study area are presented. A summary and synthesis of past and current science related to lithostratigraphy and hydrostratigraphy is provided in the following “Hydrogeology” section.

Geographic Setting and Climate

The study area is located in parts of Sublette, Lincoln, and Sweetwater Counties in western Wyoming about 68 miles (mi) northwest of Rock Springs, Wyoming, and about 18 mi south of Pinedale, Wyo. (fig. 1). Most land is administered by the BLM (fig. 1), and one of the primary land uses is livestock grazing. The study area is located in an area of increasing energy development and includes a current gas development project (Jonah Infill Development Project) and a developing natural gas project (Normally Pressured Lance Natural Gas Development Project) on the BLM lands.

Much of the study area is a rolling grass-, sagebrush-, and shrub-covered (greasewood-saltbrush) plain with intervening ridges, buttes, badlands, and ephemeral and perennial drainages. This vegetation is sparse in much of the study area and greatest near perennial streams. The study area includes critical habitat for the Greater Sage-Grouse (*Centrocercus urophasianus*), elk (*Cervus elaphus*), pronghorn (*Antilocapra americana)*, mule deer (*Odocoileus hemionus*), and feral horses (*Equus caballus*) (Duke and others, 2011).

Most of the study area is located east of the primary drainage in the Green River structural basin and drainage basin (Green River Basin), which is the perennial southward flowing Green River (fig. 1). Several prominent perennial tributaries to the Green River are present along the margins of the study area, including the south- and southwest-flowing New Fork and Big Sandy Rivers. Two reservoirs (Fontenelle and Big Sandy Reservoirs) are present in the southwestern and southeastern parts of the study area, respectively (fig. 1).

Climate in the study area is affected strongly by altitude and orographic effects of surrounding mountain ranges (Martner, 1986; Curtis and Grimes, 2004). In the southeastern part of the study area at Farson, Wyo. (fig. 1), the mean annual maximum temperature is about 55 degrees Fahrenheit (°F), and the mean annual minimum temperature is about 20 °F (period of record is January 1, 1915–December 31, 2005; Western Regional Climate Center, 2014a). Temperature in the northwestern part of the study area is similar, as the mean annual maximum temperature at Big Piney, Wyo., is about 53 °F, and the mean annual minimum temperature is about

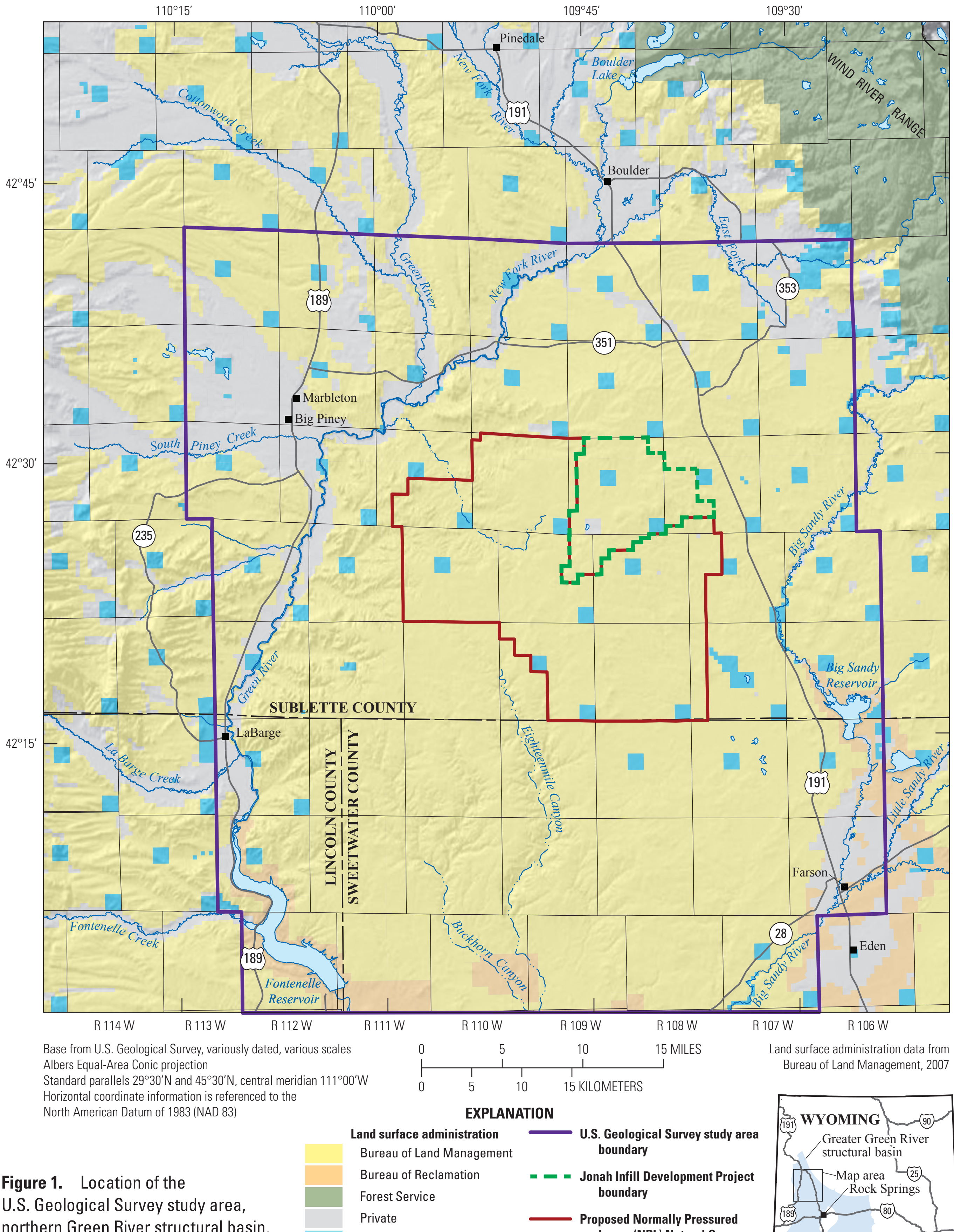


Figure 1. Location of the U.S. Geological Survey study area, northern Green River structural basin, Wyoming.

18 °F (period of record is August 1, 1948–March 31, 2013; Western Regional Climate Center, 2014b). Mean annual precipitation for the study area ranges from 6 to 15 inches (in.; Clarey and others, 2010, fig. 2–3, p. 2–33, period of precipitation record, 1971–2000) and, consequently, the climate is classified as arid to semiarid. Much of the study area receives less than 10 in. of precipitation per year (areas with mean annual precipitation of less than 10 in. in Wyoming are classified as desert; Martner, 1986). Precipitation increases substantially in areas north and northeast of the study area as altitude increases in the adjacent Wind River Range (Clarey and others, 2010, fig. 2–3, p. 2–33). Estimated mean annual pan evaporation and estimated mean annual potential evapotranspiration exceed mean annual precipitation throughout the study area (Martner, 1986; Curtis and Grimes, 2004).

Geologic Setting

The study area is located in the northern part of the Green River structural basin, a large (10,500 square miles; Roehler, 1992a) structural and topographic basin in southwestern Wyoming (identified as Green River structural basin on fig. 2). Tectonic activity formed the basin during the Laramide orogeny, a period of compressional mountain-building movements during the Late Cretaceous and early Tertiary. The structural basin is bounded by the Overthrust Belt to the west, the Wind River and Gros Ventre Ranges to the north, Rock Springs Uplift to the east, and the Uinta Mountains to the south (fig. 2). The structural basin also is located within the larger Green River drainage basin that is drained by the perennial southward flowing Green River and its tributaries, including the New Fork River in the north and Big Sandy River in the eastern parts of the study area (figs. 1 and 2). The Green River structural and drainage basins are located within part of the much larger multi-State Upper Colorado River drainage basin (fig. 2). The Greater Green River structural basin consists of four structural and topographic basins (Green River, Great Divide, Washakie, and Sand Wash structural basins; shaded in blue on fig. 2).

Lithostratigraphic units exposed at land surface in the study area and the locations of wells used for this study are shown in figure 3. Most of the exposed lithostratigraphic units in the study area are various members and tongues of the Green River and Wasatch Formations of early Tertiary age. Areal extent and thickness of both the Green River and Wasatch Formations vary substantially in the Green River structural basin, including the study area (Roehler, 1992b). Several different types of unconsolidated deposits of Quaternary age are present locally, most notably alluvium and terrace deposits along the Green, New Fork, and Big Sandy Rivers and associated tributaries (fig. 3).

Wells visited for this study were completed mostly in the Eocene-age Green River Formation and Eocene- and Paleocene-age Wasatch Formation (table 1; table 1–1 in appendix 1). The stratigraphy of both formations in the Green River structural basin is highly complex because it represents numerous interfingering/intertonguing lacustrine and fluvial lithologies deposited primarily as a result of lake-level fluctuations in an ancient lake environment (Bradley, 1926, 1959, 1964; Bradley and Eugster, 1969; Surdam and Stanley, 1979, 1980; Sullivan, 1980; Roehler, 1990, 1991a, 1991b, 1992a, 1992b, 1992c, 1993; Chetel and Carroll, 2010). The complex correlation and depositional environments of Eocene-age lithostratigraphic units (including the Green River and Wasatch Formations) across the central Green River structural basin and adjacent areas to the east is shown in figure 4 (reproduced from Roehler, 1992b, fig. 1).

The complex stratigraphic nomenclature of the various interfingering/intertonguing beds, tongues, and members of both the Green River and Wasatch Formations in the Green River structural basin and study area (figs. 4 and 5) have been repeatedly revised since originally named. Many new member and tongue names of both formations have been defined and abandoned, redefined, or their stratigraphic and geographic boundaries changed. Not all of these identified lithostratigraphic/lithofacies units (beds, tongues, and members) are present in the study area. Units identified in the vicinity of the study area are shown on figure 5. In this report, the nomenclature of Roehler (1991a, 1991b, 1992a, 1992b, 1992c, 1993) and Love and others (1993) generally was used in combination with various geologic maps of the study area (Oriel and Platt, 1980; Love and Christiansen, 1985; Sutherland and Scott, 2009; Sutherland and Luhr, 2011) to identify and name the various member and tongue names of both formations.

The Green River Formation in the Green River structural basin is divided into numerous different tongues, members, and beds representing many different depositional environments (figs. 4 and 5). The Laney Member of the Green River Formation consists of interbedded layers and lenses of oil shale; marlstone; tuffaceous sandstone and siltstone; and gray, tan, or green sandstone and mudstone (Roehler, 1991a, 1991b, 1992a, 1992b, 1992c). In some parts of the Green River structural basin, including much of the study area, the Laney Member has been divided into different beds (for example, LaClede and Sand Butte Beds; fig. 5, sections *B–B′* and *C–C′*) (Roehler, 1992b, figs. 8 and 9). The LaClede Bed contains the thickest oil-shale accumulation in the Green River Formation, and thickness in the study area ranges from 0 to less than 100 feet (ft; Roehler, 1992b, fig. 29). The Sand Butte Bed is present only in a small part of the study area, just southeast of Farson where thickness is less than 400 ft (Roehler, 1992b, fig. 30). The Wilkins Peak Member of the Green River

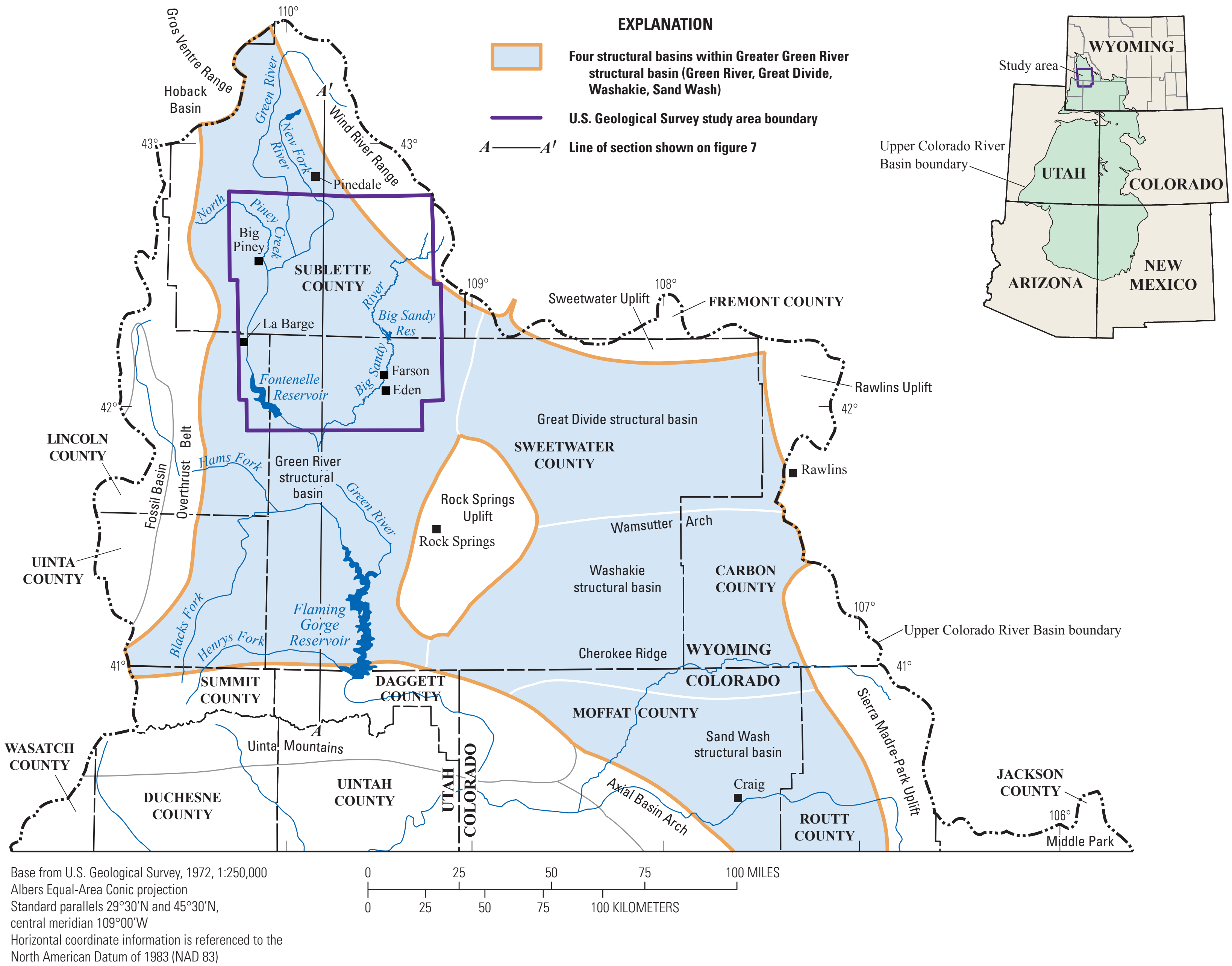
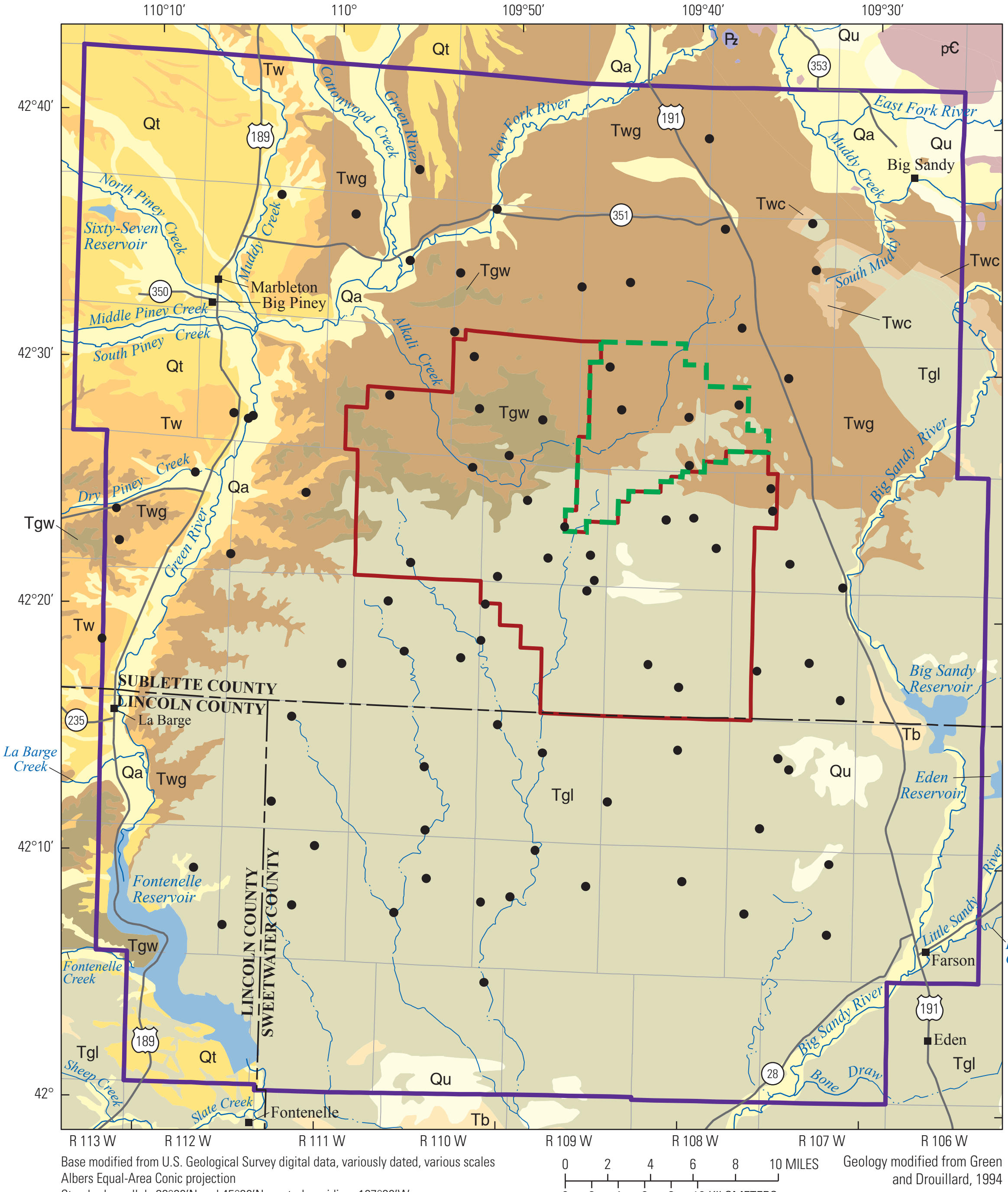


Figure 2. Location of study area in relation to principal tectonic features of the Greater Green River structural basin and adjacent areas (modified from Taylor and others,1986; Geldon, 2003a, 2003b).



EXPLANATION

Quaternary unconsolidated deposits

- Qa — Alluvium and colluvium
- Qt — Terrace deposits
- Qu — Quaternary deposits, undifferentiated (includes lacustrine, eolian, and glacial deposits)

Tertiary lithostratigraphic units

- Tb — Bridger Formation
- Tgl — Laney Member of the Green River Formation

Tertiary lithostratigraphic units—Continued

- Twc — Cathedral Bluffs Tongue of the Wasatch Formation
- Tgw — Wilkins Peak Member of the Green River Formation
- Twg — Alkali Creek Tongue of the Wasatch Formation and the Farson Sandstone Member of the Green River Formation
- Tw — Wasatch Formation (includes main body of the Wasatch Formation and Chappo Member)
- Pz — **Paleozoic rocks**
- p€ — **Precambrian rocks**

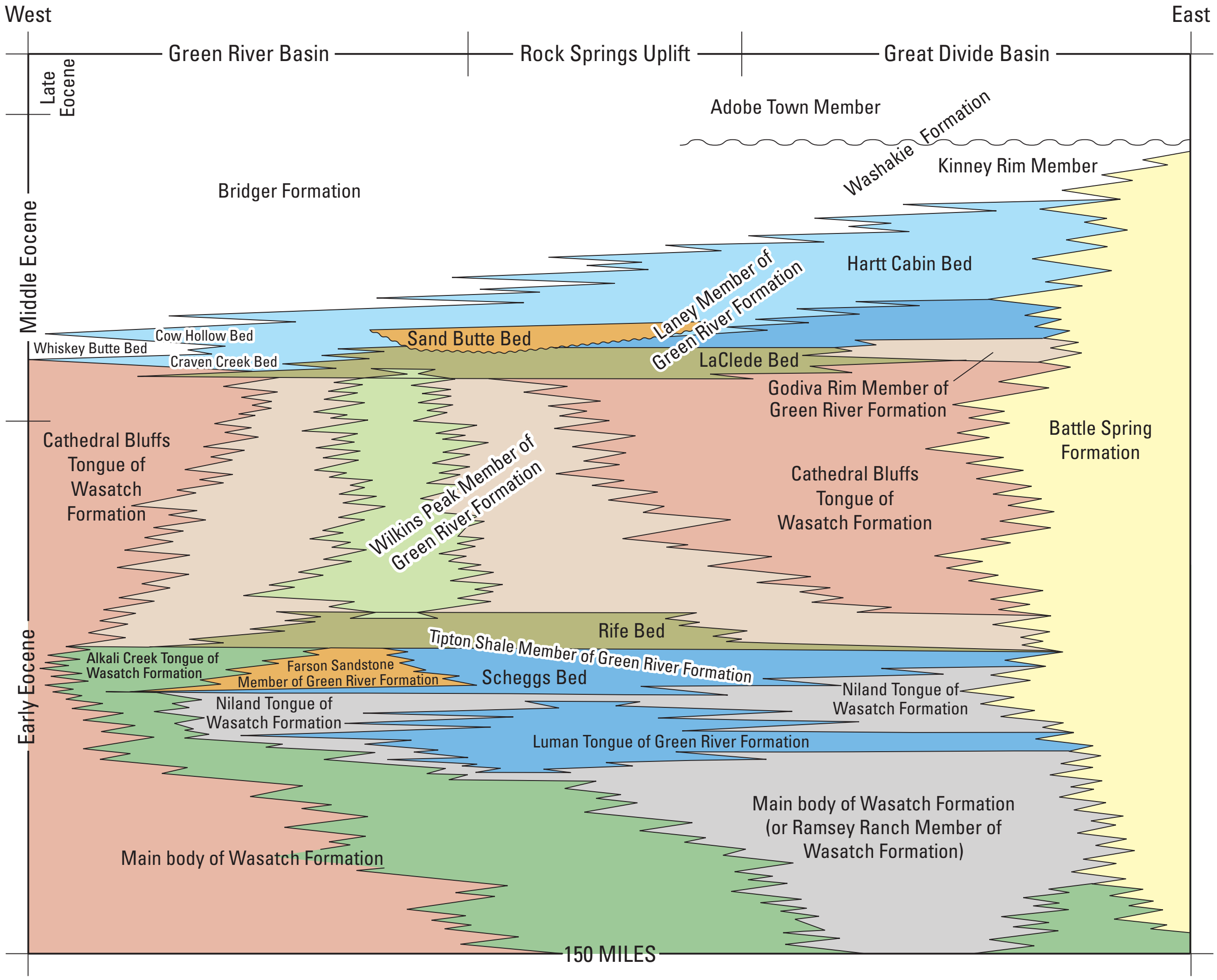
- **U.S. Geological Survey study area boundary**
- **Jonah Infill Development Project boundary**
- **Proposed Normally Pressured Lance (NPL) Natural Gas Development Project boundary**
- **Measured well**

Figure 3. Lithostratigraphic units and the location of measured study wells within the U.S. Geological Survey study area, northern Green River structural basin, Wyoming.

Table 1. Summary of groundwater-level measurements, groundwater-level altitudes, and well depths, in relation to lithostratigraphic and hydrogeologic units, northern Green River structural basin, Wyoming, 2010–14.

[--, no data or not applicable; NAVD 88, North American Vertical Datum of 1988]

Characteristic	Number of measured wells	Minimum	Median	Maximum
Quaternary alluvial aquifer (New Fork alluvium)				
Groundwater level, in feet below land surface	1	3.17	--	--
Groundwater-level altitude, in feet above NAVD 88	1	6,810	--	--
Well depth, in feet below land surface	1	16	--	--
Laney Member of the Green River Formation (Laney aquifer)				
Groundwater level, in feet below land surface	2	21.00	--	26.69
Groundwater-level altitude, in feet above NAVD 88	2	6,451	--	7,012
Well depth, in feet below land surface	2	25	--	65
Wilkins Peak Member of the Green River Formation (Wilkins Peak confining unit)				
Groundwater level, in feet below land surface	2	38.64	--	56.69
Groundwater-level altitude, in feet above NAVD 88	2	6,545	--	6,571
Well depth, in feet below land surface	2	190	--	190
Cathedral Bluffs Tongue of the Wasatch Formation (Wasatch zone of the Wasatch-Fort Union aquifer)				
Groundwater level, in feet below land surface	4	17.52	48.38	84.20
Groundwater-level altitude, in feet above NAVD 88	4	6,655	6,712	6,875
Well depth, in feet below land surface	4	80	139.25	177
Farson Sandstone Member of the Green River Formation and Alkali Creek Tongue of the Wasatch Formation (Farson Sandstone-Alkali Creek aquifer)				
Groundwater level, in feet below land surface (nonflowing wells)	47	5.89	120.66	482.82
Groundwater-level altitude, in feet above NAVD 88 (nonflowing and flowing wells)	50	6,589	6,846	7,227
Well depth, in feet below land surface	50	66	344.5	1,042
Main body of the Wasatch Formation (Wasatch zone of the Wasatch-Fort Union aquifer)				
Groundwater level, in feet below land surface (nonflowing wells)	19	13.00	130.62	484.66
Groundwater-level altitude, in feet above NAVD 88 (nonflowing and flowing wells)	27	6,622	6,791	7,231
Well depth, in feet below land surface	27	153	555	1,365
Undifferentiated Green River and Wasatch Formations				
Groundwater level, in feet below land surface (nonflowing wells)	3	19.81	27.18	171.20
Groundwater-level altitude, in feet above NAVD 88 (nonflowing and flowing wells)	3	7,002	7,107	7,191
Well depth, in feet below land surface	2	75	--	339



EXPLANATION

- Arkose (pediment) deposits
- Lacustrine sandstone deposits
- Red flood-plain deposits
- Gray and green flood-plain deposits
- Mixed freshwater lacustrine and gray and green flood-plain deposits
- Mudflat and some saltwater lacustrine oil shale deposits
- Cyclic saltwater lacustrine oil shale, evaporite, and mudflat deposits
- Saltwater lacustrine (rich) oil shale deposits
- Freshwater lacustrine (lean) oil shale deposits
- Paludal (coal-bearing) deposits
- Unconformity

Figure 4. Generalized west-east stratigraphic correlation and depositional environments of Eocene-age rocks across the central Wyoming Greater Green River structural basin (modified from Roehler, 1992b, fig. 1).

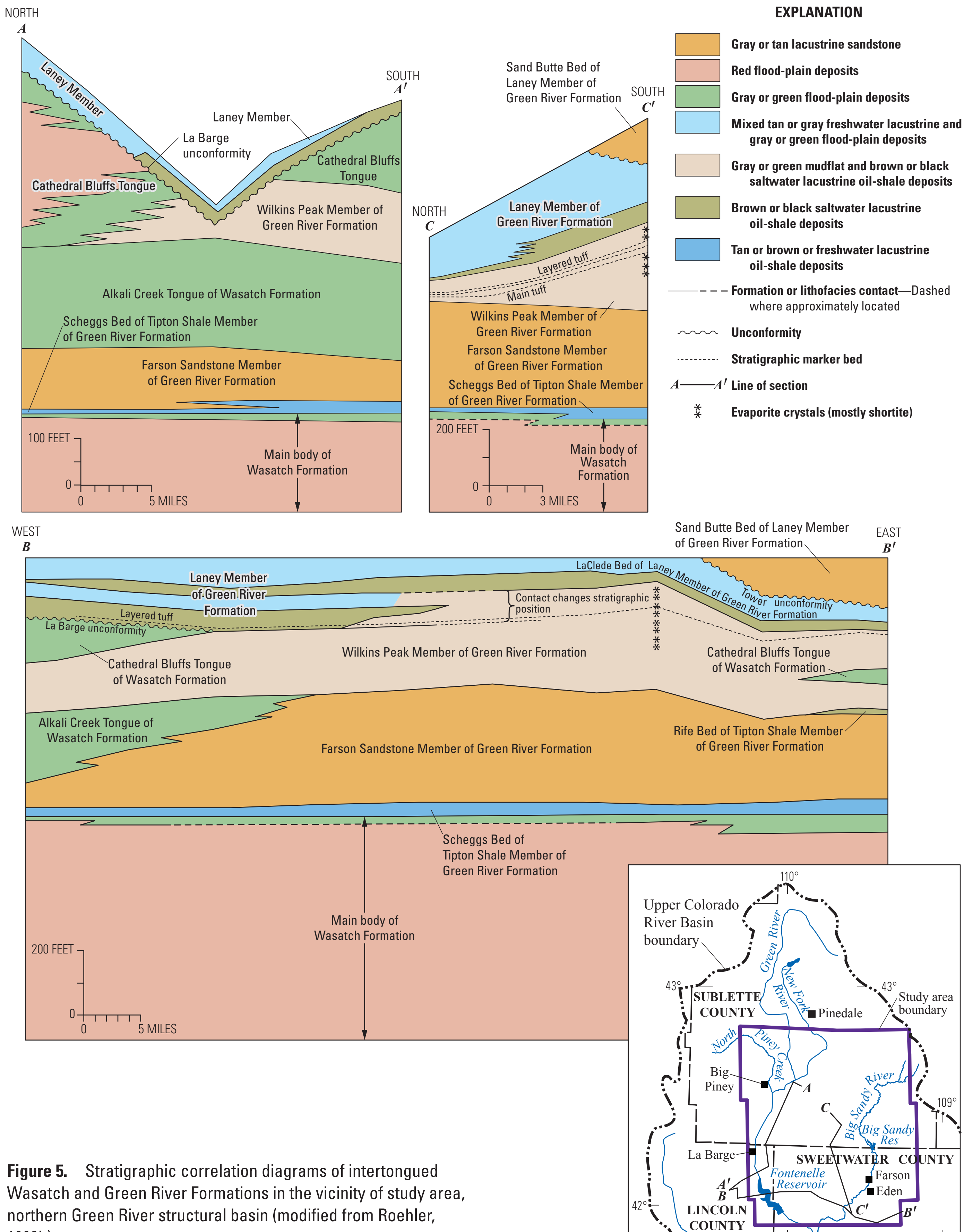


Figure 5. Stratigraphic correlation diagrams of intertongued Wasatch and Green River Formations in the vicinity of study area, northern Green River structural basin (modified from Roehler, 1992b).

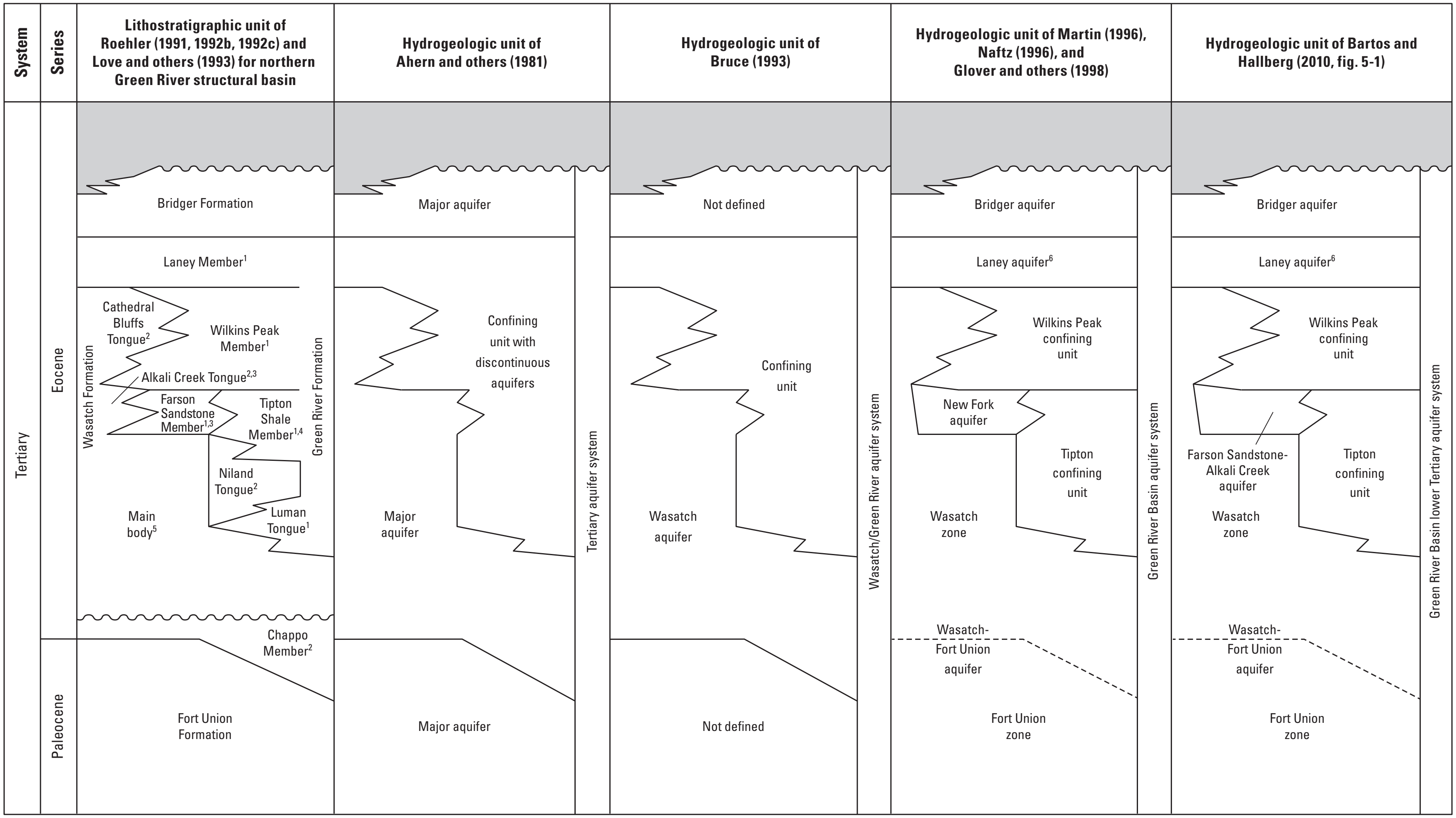
Stock well and associated windmill. The windmill is located directly above the well and provides the power to pump the well. Water removed from the well is pumped into the water storage device constructed of corrugated steel located right of the well. Rocks forming the cliff in the background of the photograph are composed of the Alkali Creek Tongue of the Wasatch Formation and the Farson Sandstone Member of the Green River Formation. The valley floor in foreground of photograph rests on rocks composing the main body of the Wasatch Formation. Sandstone beds in all three geologic units are important aquifers in the Green River structural basin. Photograph by Cheryl Miller, U.S. Geological Survey.

Formation consists of saline minerals and bedded trona deposits within interbedded sandstone, siltstone, mudstone, shale, and oil shale; beds of marlstone, algal limestone, and conglomerate are present locally (Bradley, 1964; Roehler, 1991a, 1991b, 1992a, 1992b, 1992c). The Wilkins Peak Member has been divided into lower, middle, and upper parts in the Green River structural basin; only the middle and upper parts are present in the study area (Roehler, 1992b). The thickness of the upper and middle parts of the Wilkins Peak Member in the study area ranges from 0 to 100 ft and 0 to 200 ft, respectively (Roehler, 1992b, figs. 25 and 26). The Tipton Shale Member of the Green River Formation (also known as the Tipton Tongue in parts of the basin) consists of interbedded layers and lenses of oil shale, sandstone, siltstone, and limestone; the member commonly is divided into the Rife and Scheggs Beds, which are less than 50 ft in thickness in the study area (fig. 5) (Roehler, 1992b, figs. 4, 8, and 9). The Rife and Scheggs Beds are composed mostly of tan, brown, or black oil shale in the study area.

Similar to the Green River Formation, the Wasatch Formation in the Green River structural basin is divided into numerous different tongues, members, and beds representing many different depositional environments (figs. 4 and 5). Where undivided in the Green River structural basin, the Wasatch Formation is identified as the “main body of the Wasatch Formation.” The main body of the Wasatch Formation consists of gray, green, and red mudstone and sandstone (Roehler, 1991a, 1991b, 1992a, 1992b, 1992c), and thickness in the study area ranges from 2,000 to 8,000 ft (Roehler, 1992b, fig. 15). The Cathedral Bluffs Tongue of the Wasatch Formation consists of red sandstone and mudstone, gray and green sandstone and mudstone, and variegated sandstone and mudstone; thickness in the study area ranges from 0 to less than 500 ft (Roehler, 1992b, fig. 27). The Alkali Creek Tongue of the Wasatch Formation consists of interbedded freshwater-deposited brown, green, and gray sandstone, siltstone, mudstone, and shale; and locally conglomeratic lenses (Roehler, 1991a, 1992a, 1992b, 1992c). Thickness of the Alkali Creek Tongue ranges from 0 to 300 ft in the study area (Roehler, 1992b, fig. 21). The laterally equivalent Farson Sandstone Member of the Green River Formation consists of gray, tan, and brown sandstone; thin interbedded, gray shale and siltstone of lacustrine origin; and locally occurring conglomerate. Thickness of the Farson Sandstone Member ranges from 0 to 400 ft in the study area (Roehler, 1992b, fig. 20).

Donavan (1950) and Lawrence (1963) assigned the rocks composing the Farson Sandstone Member to the Fontenelle Tongue of the Green River Formation. Oriel (1961) assigned the rocks to the New Fork Tongue of the Wasatch Formation, whereas Sullivan (1980) assigned the rocks to the Tipton Shale Member of the Green River Formation. Rocks composing the Alkali Creek Tongue of the Wasatch Formation were assigned to the New Fork Tongue of the Wasatch Formation by Oriel (1961), Lawrence (1963), and Sullivan (1980); and to the Fontenelle Tongue of the Green River Formation by Donavan (1950). Roehler (1991a) proposed assigning these rocks with these former names to the newly proposed Alkali Creek Tongue of the Wasatch Formation and Farson Sandstone Member of the Green River Formation, and abandoning the New Fork Tongue and Fontenelle Tongue names. The convention of Roehler (1991a) is used herein.

The Paleocene-age Fort Union Formation underlies the Wasatch Formation in the study area (fig. 6). Both formations are very similar lithologically, and differentiating the two formations in the subsurface is difficult (Martin, 1996). An unnamed Paleocene-age lithostratigraphic unit composed of interbedded conglomerate, sandstone, siltstone, and mudstone underlies the Fort Union Formation (Law, 1984).



[1]Of the Green River Formation.
[2]Of the Wasatch Formation.
[3]Farson Sandstone Member intertongues with and underlies the Alkali Creek Tongue in parts of Green River structural basin.
[4]Also known as the Tipton Tongue of the Green River Formation.
[5]Includes rocks above the Chappo Member formerly identified as the "La Barge Member" of the Wasatch Formation (Roehler, 1991a, 1992b, 1992c)
[6]Laney Member of Green River Formation is a confining unit where impermeable.

EXPLANATION

- **Rocks absent due to erosion or nondeposition**
- **Unconformity**
- **Division of Wasatch-Fort Union aquifer into the Wasatch and Fort Union zones**

Figure 6. Relation of lithostratigraphic units to hydrogeologic units, northern Green River structural basin, Wyoming (modified from Love and others, 1993; Ahern and others, 1981; Bruce, 1993; Martin, 1996; Naftz, 1996; Glover and others, 1998; and Bartos and Hallberg, 2010.)

Hydrogeology

Aquifers in layered sedimentary rocks of Tertiary (Paleocene and Eocene) age are used widely as sources of water in the Green River structural basin (fig. 2) because they are areally extensive, thick, and yield enough water with sufficient quality for many different uses (Clarey and others, 2010). These aquifers occur in numerous water-saturated geologic formations, members, and tongues (lithostratigraphic units). The hydrologic characteristics of the lithostratigraphic units or parts of the units have been used to name and define them in relation to their hydrogeologic function (aquifers or confining units, referred to as hydrogeologic units). Rocks in the Bridger, Green River, Wasatch, and Fort Union Formations containing these aquifers occur at, near, or below the surface in the basin. Because fluvial sediments (primarily sandstone) compose most of the permeable rocks (aquifers), hydraulic properties generally depend on the number, thickness, and lateral and vertical continuity of sandstone layers and lenses.

Hydraulic connection among the different hydrogeologic units and between individual sandstone aquifers composing an individual hydrogeologic unit varies locally because of intervening fine-grained rocks, but regionally the hydrogeologic units generally are in sufficient hydraulic connection to compose a heterogeneous regional aquifer system identified as the Tertiary aquifer system (Ahern and others, 1981), Wasatch/Green River aquifer system (Bruce, 1993), Green River Basin aquifer system (Martin, 1996; Naftz, 1996; Glover and others, 1998), or Green River Basin lower Tertiary aquifer system (Bartos and Hallberg, 2010) (fig. 6). Locally, some sandstone aquifers in these hydrogeologic units are perched and not hydraulically connected to the underlying Green River Basin lower Tertiary aquifer system (AMEC Environment and Infrastructure, Inc., 2012, 2013). 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 hydrogeologic characteristics that are best described and studied together. The nomenclature used to characterize and define these hydrogeologic units (fig. 6) differs among investigators and has changed over time because of new data and various interpretations. The last column in figure 6, modified from Bartos and Hallberg (2010, fig. 5–1), is the regional hydrogeologic (hydrostratigraphic) nomenclature used in this report.

The large, areally extensive Green River Basin lower Tertiary aquifer system coincides with the boundary of the Green River structural basin and includes the study area (fig. 2). The regional aquifer system is thousands of feet thick in the Green River structural basin and consists of as many as four aquifers and two confining units, generally named after their respective lithostratigraphic units (fig. 6). Aquifers, from top to bottom, are the Bridger, Laney, Farson Sandstone-Alkali Creek, and Wasatch-Fort Union aquifers (fig. 6). The Bridger aquifer is only present in the southern part of the study area. The Wasatch-Fort Union aquifer is defined as an aquifer divided into two zones (Wasatch and Fort Union zones). Confining units are the Wilkins Peak and Tipton confining units; where impermeable, the Laney Member of the Green River Formation also is a confining unit. The Farson Sandstone-Alkali Creek aquifer was formerly named the “New Fork aquifer” (Martin, 1996) on the basis of earlier stratigraphic nomenclature identifying rocks composing the unit as the “New Fork and Alkali Creek Tongues of the Wasatch Formation,” and was used by Welder (1968, sheet 2). The base of the aquifer system is defined as the contact with underlying Late Cretaceous-age rocks in the Lance Formation, Fox Hills Sandstone, and Lewis Shale (Martin, 1996; Glover and others, 1998). Details about the Green River Basin lower Tertiary aquifer system, including descriptions of the physical and chemical characteristics of the hydrogeologic units (aquifers and confining units) composing the aquifer system, are provided in previous studies (Robinove and Cummings, 1963; Barker and Sapik, 1965; Welder, 1968; Dana and Smith, 1973a, 1973b; Dinwiddie, 1973; Price and Waddell, 1973; Dana, 1975; Ahern and others, 1981; Lowham and others, 1985 [1987]; Zimmerman and Collier, 1985; Teller and Chafin, 1986; Johnson-Fermelia Co., Inc., 1990; Chafin and Kimball, 1992; Bruce, 1993; Jorgensen Engineering and Land Surveying, and Hinckley Consulting, 1994; Martin, 1996; Naftz, 1996; Glover and others, 1998; Dynamac Corporation, 2002; JFC Engineers/Surveyors, 2002; HydroGeo, Inc., 2004; Geomatrix Consultants, Inc., 2008; AMEC Geomatrix, Inc., 2009; Bartos and Hallberg, 2010; Bartos and others, 2010; Trihydro Corporation, 2011, 2012; AMEC Environment and Infrastructure, Inc., 2012, 2013; Boughton, 2014).

Previous investigations indicate groundwater in the Green River Basin lower Tertiary aquifer system generally flows from high altitude recharge areas along the structural basin margin towards lower altitudes in the basin center and to the south (fig. 7; Ahern and others, 1981; Chafin and Kimball, 1992; Martin, 1996; Naftz, 1996; Glover and others, 1998; AMEC Environment and Infrastructure, Inc., 2012, 2013). Groundwater at shallow depths of the Green River Basin lower Tertiary aquifer system is moving primarily in local to intermediate (and more dynamic) flow systems with shorter groundwater-flow paths, whereas groundwater at greater depths is moving primarily in intermediate to regional groundwater-flow systems with longer groundwater-flow paths and greater residence times (fig. 7; Chafin and Kimball, 1992; Martin, 1996; Naftz, 1996; Glover and others, 1998). Groundwater in saturated unconsolidated deposits of Quaternary age (alluvium or alluvial aquifers) associated with major perennial streams is hydraulically connected to the aquifer system in much of the northern structural basin (Martin, 1996; Naftz, 1996; Glover and others, 1998; Dynamac Corporation, 2002; Geomatrix Consultants, Inc., 2008; AMEC Geomatrix, Inc., 2009; AMEC Environment and Infrastructure, Inc., 2012, 2013). Discharge from deep aquifers of the aquifer system is by upward leakage to the shallower aquifers, and ultimately to major streams such as the Green River and its tributaries and associated alluvial aquifers (fig. 7) (Martin, 1996; Naftz, 1996; Glover and others, 1998; Dynamac Corporation, 2002; Geomatrix Consultants, Inc., 2008; AMEC Geomatrix, Inc., 2009;

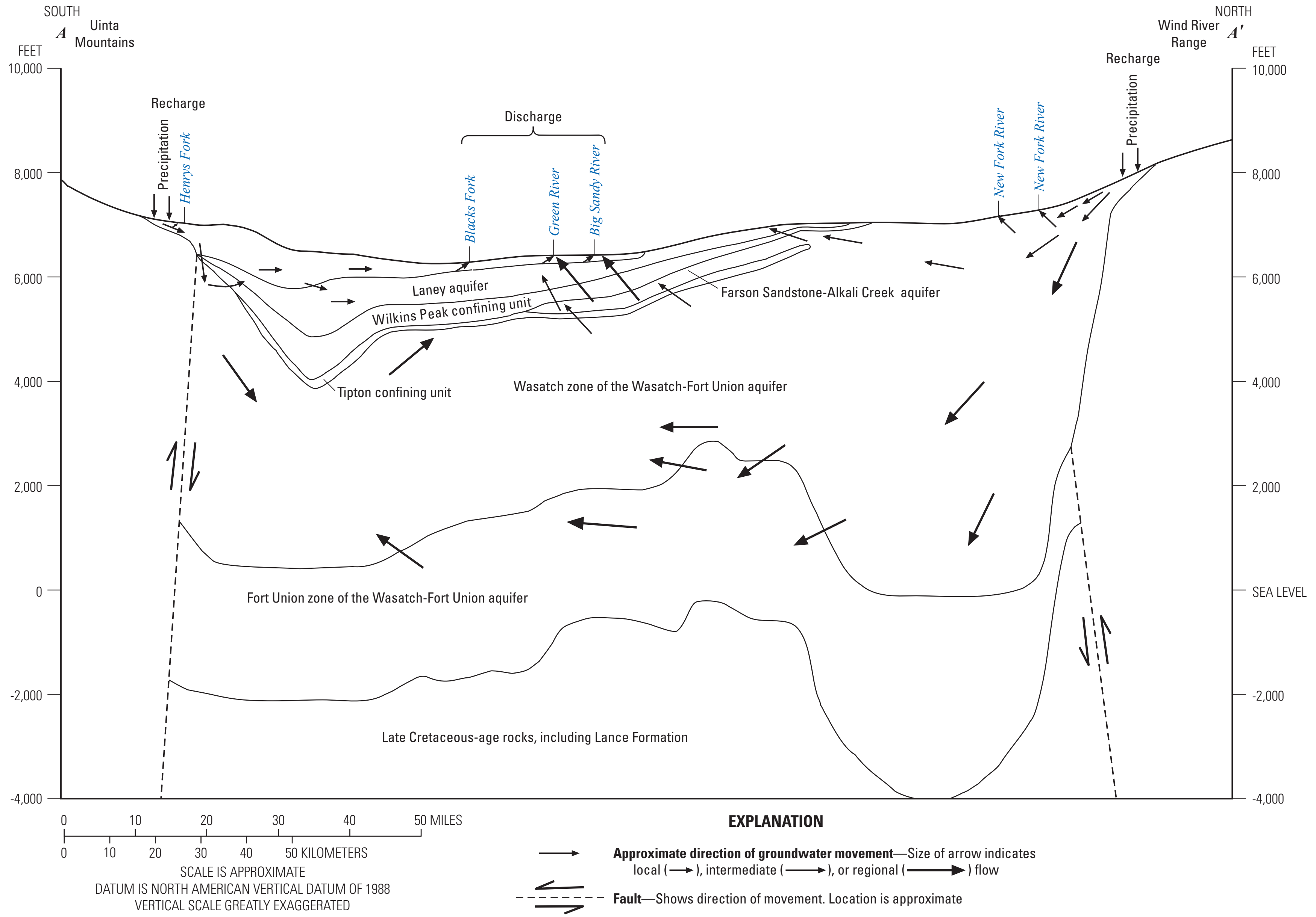


Figure 7. South-north diagrammatic cross-section summarizing groundwater recharge, discharge, and generalized groundwater-flow paths in the Green River Basin lower Tertiary aquifer system (modified from Martin, 1996). Line of section shown on figure 2.

AMEC Environment and Infrastructure, Inc., 2012, 2013). Smaller streams in some parts of the northern Green River structural basin likely receive discharge from shallow aquifers of the aquifer system with local groundwater-flow paths (Martin, 1996; AMEC Geomatrix, Inc., 2009; AMEC Environment and Infrastructure, Inc., 2012, 2013).

Wells completed in aquifers of the Green River Basin lower Tertiary aquifer system yield water primarily from permeable unfractured and fractured lenticular sandstone beds typically interbedded with much less permeable fine-grained rocks such as shale, mudstone, and siltstone; locally occurring conglomerate beds also yield water to wells (Ahern and others, 1981; Martin, 1996; Naftz, 1996; Glover and others, 1998; AMEC Environment and Infrastructure, Inc., 2012, 2013). Lenticular sandstone beds compose most of the aquifers and commonly are laterally and vertically discontinuous. The thickness and amount of sandstone at a given location generally depends on the distance from the sediment source area. Groundwater in the sandstone aquifers is under unconfined (water table) and confined (artesian) conditions. Because of the discontinuous nature of individual sandstone beds composing the aquifers, some investigators classified some aquifers in the northern Green River structural basin as semiconfined or leaky confined aquifers (AMEC Geomatrix, Inc., 2009; AMEC Environment and Infrastructure, Inc., 2012, 2013). Artesian pressure in the sandstone aquifers at some locations can be high enough to cause wells completed in the aquifer system to flow (for example, Welder, 1968; Jorgensen Engineering and Land Surveying, and Hinckley Consulting, 1994; Martin, 1996; Glover and others, 1998; AMEC Environment and Infrastructure, Inc., 2012, 2013). Locally, fine-grained rocks with small primary permeability may yield water to wells where fractured or solution channels have developed, most notably fine-grained lacustrine rocks in the Laney Member of the Green River Formation (Laney aquifer) near Big Sandy Reservoir (Martin, 1996; Glover and others, 1998).

The uppermost lower Tertiary aquifers of the Green River Basin lower Tertiary aquifer system commonly yield water of sufficient quantity and quality for stock use (Bartos and Hallberg, 2010; Bartos and others, 2010; Clarey and others, 2010). In fact, most wells in the study area are completed for stock use. Yields from the uppermost aquifers are sometimes sufficient for industrial use, as indicated by wells completed in the northern part of the basin (including study area) to facilitate natural gas well construction, development, and maintenance. Although groundwater quality in the study area is highly variable, wells completed in these uppermost shallow aquifers commonly yield freshwater (total dissolved solids concentrations less than 1,000 milligrams per liter) and are suitable for many uses (Bartos and others, 2010; Trihydro Corporation, 2011; Boughton, 2014).

Groundwater Levels

After selecting existing wells for measurement of groundwater levels in the study area using procedures described in Sweat (2013), a groundwater-level dataset was constructed using information obtained by visiting 93 wells during May to September from 2010 to 2014 (table 1–1). Groundwater levels measured in four wells (highlighted in gray in table 1–1) were removed from the groundwater-level dataset because of lack of information about open intervals in relation to hydrogeologic units (two wells), potential interference from well pumping at time of measurement (one well), and interference from an associated storage tank (one well) (table 1–1). Most (71) of the 89 wells utilized in the final groundwater-level dataset were used primarily for stock use. Of the remaining wells in the dataset, six wells were unused stock wells, three wells were used for primarily domestic use, two wells were used to supply water for oil and gas development, two wells were observation (monitoring) wells, four wells were unused oil and gas development water-supply wells, and one well was an unused well with unknown water use (table 1–1). The depths of the 89 selected wells ranged from 16 to 1,365 ft below land surface (table 1; table 1–1).

Stock well used for groundwater-level measurement. The groundwater level was measured using the steel tape located in front of the steel well casing. To measure the groundwater level in the well, the steel tape was lowered through the small opening between the top of the steel well casing and the round steel plate on the top of the well. The rectangular concrete apron around the steel well casing was poured to provide a surface seal. A round Bureau of Land Management benchmark is embedded in the lower left corner of the concrete surface seal. Photograph by Cheryl Miller, U.S. Geological Survey.

Of the 89 wells remaining in the dataset, 11 wells were flowing wells (no pump and artesian) (noted as "F" in table 1–1). A pressure gauge was used to measure 7 of 11 flowing wells, and those measurements were converted to feet above land surface as described in Cunningham and Schalk (2011). Groundwater levels in six of the flowing wells measured using a pressure gauge ranged from 9.12 to 14.95 ft above land surface, and the groundwater level in one well was 62.9 ft above land surface (table 1–1). For contouring purposes, groundwater-level measurements for the four unmeasured flowing wells were estimated to be 10 ft above land surface (marked with an "E" preceding the groundwater-level altitude in table 1–1), which is within the measured range of 9.12 to 14.95 ft above land surface for most (6 of 7) of the measured flowing wells (table 1–1).

Groundwater levels measured above or below land surface were converted to groundwater-level altitudes above the North American Vertical Datum of 1988 (NAVD 88); groundwater-level altitudes also are known as hydraulic heads. The distribution of hydraulic head in an aquifer or aquifer system can be represented with a potentiometric-surface map. Groundwater-level information (depth to groundwater and groundwater-level altitudes) and associated depths for the 89 wells used to construct the final groundwater-level dataset and evaluated to contour the potentiometric-surface map are summarized by hydrogeologic unit in table 1. Groundwater-level altitudes and depth-to-groundwater measurements obtained during this study, as well as ancillary information for all measured wells, are available from the Groundwater Site Inventory database of the USGS National Water Information System database at http://nwis.waterdata.usgs.gov/wy/nwis/inventory by using the site-identification numbers in table 1–1.

Groundwater levels were measured in wells completed in several different lithostratigraphic (and potentially different hydrogeologic units [aquifers]) of the Green River Basin lower Tertiary aquifer system (table 1–1; table 1). With the exception of one well completed in Quaternary alluvium, wells were assigned to Tertiary-age (Eocene) lithostratigraphic units by comparing available well-completion information (screen or open interval, well depth, and driller's logs) with contour maps showing the thickness of Tertiary lithostratigraphic units in the Green River structural basin (Roehler, 1992b) and geological maps (Oriel and Platt, 1980; Love and Christiansen, 1985; Sutherland and Scott, 2009; Sutherland and Luhr, 2011). Many of the wells (50 of 89) used to construct the potentiometric-surface map for this study were completed in the Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation or Alkali Creek Tongue of the Wasatch Formation). The remaining wells were completed in Quaternary alluvium (1 well), the Laney aquifer (Laney Member of the Green River Formation) (2 wells), the Wilkins Peak confining unit (Wilkins Peak Member of the Green River Formation) (2 wells), the Wasatch zone of the Wasatch-Fort Union aquifer (main body of the Wasatch Formation and Cathedral Bluffs Tongue of the Wasatch Formation) (31 wells), and 3 wells were completed in the undifferentiated Green River or Wasatch Formations (lithostratigraphic unit or units; table 1; table 1–1).

Relation between Depth to Groundwater and Well Depth

A relation between depth to groundwater and well depth can be used to evaluate overall potential for groundwater movement among aquifers in the study area. Well depth in the groundwater-level dataset generally reflects the screened or open interval of the well, although some wells have multiple open intervals (table 1–1), which could complicate the regional relation.

Depth to groundwater measured in nonflowing wells ranged from 3.17 to 484.66 ft below the land surface (table 1; table 1–1). Depth to groundwater generally increased with increasing well depth (fig. 8*A*), although three of the deepest wells (greater than 1,000 ft deep) had shallow groundwater levels of less than 100 ft. Two of the three deepest wells had multiple open intervals, and construction information about open intervals was not available for the third well. Except for near perennial streams, groundwater-level altitudes in most aquifers generally decreased with increasing well depth (fig. 8*B*), indicating a generally downward potential for groundwater movement in the study area. The greatest range of groundwater-level altitudes (about 856 ft for all measured wells and about 776 ft for wells used to construct potentiometric-surface map) is exhibited in the shallower wells with depths of less than 500 ft. Groundwater levels in wells deeper than or equal to 500 ft (500 to 1,365 ft) vary about 642 ft.

Temporal Groundwater-Level Changes

Differences in groundwater levels between the oldest groundwater-level measurement in a well and a measurement made in the same well during 2012–14 are listed in table 2 and shown in figure 9; the time span between measurements ranged from 36 to 49 years. The purpose of the comparison is to describe general patterns, as well as direct future studies of groundwater-level changes. No interpretation of why the changes have occurred is presented, and comparison of two points in time should not be interpreted as a trend.

A total of 27 wells had data available for comparison, and most were located in the southern part of the study area (fig. 9). Within individual wells the change in groundwater levels between the historic groundwater-level measurement (1960s to 1970s) and the most recent measurement (2012–14) ranged from an increase of 5.5 ft to a decrease of 86.9 ft. Groundwater levels for most of the wells (59 percent, 16 of 27) changed about 10 ft or less between the two measurement periods (table 2). Most of the wells (74 percent, 20 of 27) showed a decrease in groundwater levels with declines ranging from 0.1 to 86.9 ft; 41 percent (11 of 27) of the wells had a groundwater-level decline of more than 10 ft, which includes 3 wells with declines of more than 50 ft.

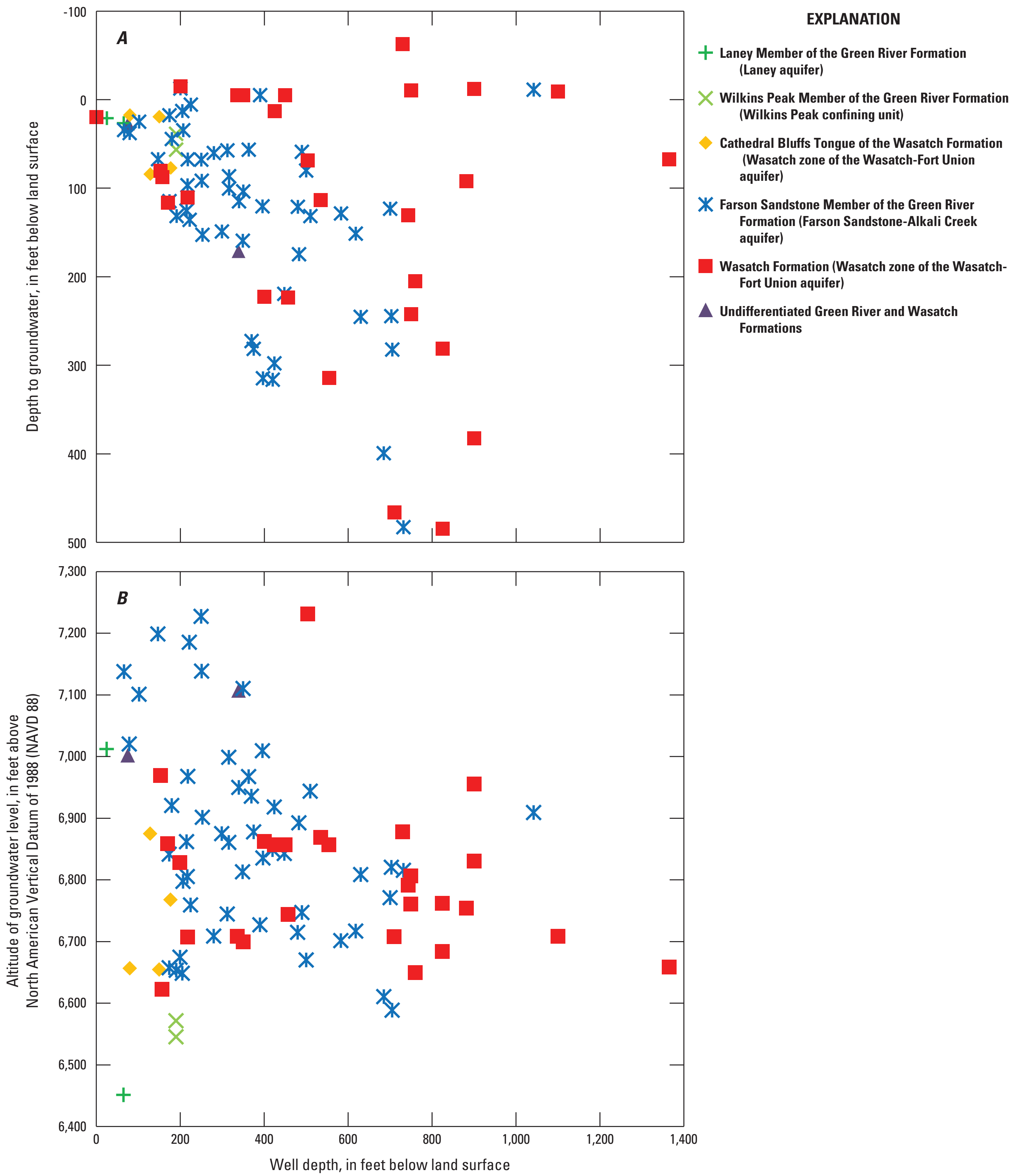


Figure 8. Depth to groundwater and groundwater-level altitude in relation to well depth, northern Green River structural basin, Wyoming. *A*, Relation between depth to groundwater and well depth; and *B*, relation between groundwater-level altitude and well depth.

Table 2. Groundwater-level changes in selected wells, northern Green River structural basin, Wyoming.

[USGS, U.S. Geological Survey; NWIS, National Water Information System (http://waterdata.usgs.gov/nwis); NAVD 88, North American Vertical Datum of 1988. Negative groundwater-level value (-) indicates groundwater level above land surface (shown in green). Negative groundwater-level change value (-) indicates a decrease in groundwater level between oldest and 2012–14 measurements.]

Site identifier (fig. 9)	USGS station name	USGS site-identification number	Depth of well (feet below land surface)	Oldest groundwater-level measurement in NWIS (feet below land surface)	Oldest groundwater-level altitude (feet above NAVD 88)	Date of oldest groundwater-level measurement in NWIS	Groundwater level used to construct potentiometric-surface map (feet below land surface)	Groundwater-level altitude used to construct potentiometric-surface map (feet above NAVD 88)	Date of groundwater-level measurement used to construct potentiometric-surface map	Change between the oldest and 2012–14 groundwater-level measurements (feet)
01cc 01	24-110-01cc 01	420513109504701	65	22.65	6,455	09/14/1964	26.69	6,451	08/03/2012	-4.04
02da 01	25-107-02da 01	421005109315901	200	-43	6,705	07/31/1976	-12.34	6,674	08/07/2013	-31
23ddc01	25-107-23ddc01	420710109315601	1,365	flowing	[1]6,736	07/28/1976	67.50	6,659	07/30/2012	-78
10dad01	25-108-10dad01	420915109403901	882	17	6,829	04/23/1965	92.24	6,754	07/31/2012	-75
04add01	25-109-04add01	421025109481901	205	6.18	6,655	06/09/1965	12.92	6,648	08/01/2012	-6.74
13baa01	25-109-13baa01	420901109460001	583	104.12	6,726	09/14/1964	128.71	6,701	08/01/2012	-24.59
17da 01	25-109-17da 01	421321109493502	190	58.52	6,543	06/09/1965	56.69	6,545	08/01/2012	1.83
15aab01	25-110-15aab01	420905109540901	500	49.66	6,700	06/09/1965	80.10	6,670	08/01/2012	-30.44
21cac01	25-110-21cac01	420757109555601	190	39.6	6,570	06/09/1965	38.64	6,571	08/01/2012	1.0
02dbc01	25-111-02dbc01	421045110002001	480	97.72	6,738	06/09/1965	121.28	6,715	07/07/2014	-23.56
22dbb01	25-111-22dbb01	420822110013201	760	155.85	6,698	06/09/1965	204.96	6,649	07/07/2014	-49.11
32abb01	26-107-32abb01	421127109354601	191	134.98	6,650	07/31/1976	131.69	6,653	06/25/2012	3.29
30bab01	26-108-30bab01	421219109433801	618	140.67	6,727	06/20/1965	151.40	6,717	06/21/2012	-10.73
10ccd01	26-109-10ccd01	421421109475001	312	61	6,741	08/19/1976	57.53	6,744	06/14/2012	3
15dca01	26-110-15dca01	421308109541901	316	70.82	6,876	06/09/1965	86.57	6,860	08/01/2012	-15.75
34dca01	26-110-34dca01	421051109543001	280	60	6,709	06/09/1965	60.45	6,709	06/20/2012	0
25cdc01	27-107-25cdc01	421633109310701	150	24.95	6,649	09/14/1964	19.45	6,655	06/12/2012	5.5
18cca01	27-109-18cca01	421847109512101	349	142.59	6,829	04/27/1965	159.33	6,813	06/14/2012	-16.74
23bcc01	28-109-23bcc01	422330109465201	218	69.1	6,966	06/21/1965	67.50	6,968	06/20/2012	1.6
01dcb01	28-110-01dcb01	422600109523501	180	42.99	6,922	06/21/1965	44.52	6,920	06/19/2012	-1.53
33acd01	28-110-33acd01	422202109553801	420	229.3	6,936	06/21/1965	316.24	6,849	07/17/2012	-86.9
19aca01	28-112-19aca01	422348110114501	153	80.5	6,970	06/22/1965	80.58	6,969	07/08/2014	-0.1
30dda01	28-112-30dda01	422243110114301	170	116.14	6,859	06/22/1965	116.51	6,858	07/08/2014	-0.37
10dad01	29-107-10dad01	422951109344501	102	22.59	7,103	06/12/1965	25.10	7,101	06/28/2012	-2.51
06ddb01	30-107-06ddb01	423539109382201	147	67.1	7,199	09/22/1964	67.26	7,199	06/27/2012	-0.2
32aca01	30-107-32aca01	423140109370301	222	135	7,186	10/01/1966	135.92	7,185	06/28/2012	-1
13daa01	31-108-13daa01	423913109392701	251	88.29	7,142	08/05/1966	91.7	7,138	07/09/2014	-3.41

[1]Groundwater-level assumed to be at least 10 feet above land surface altitude for flowing wells (see text).

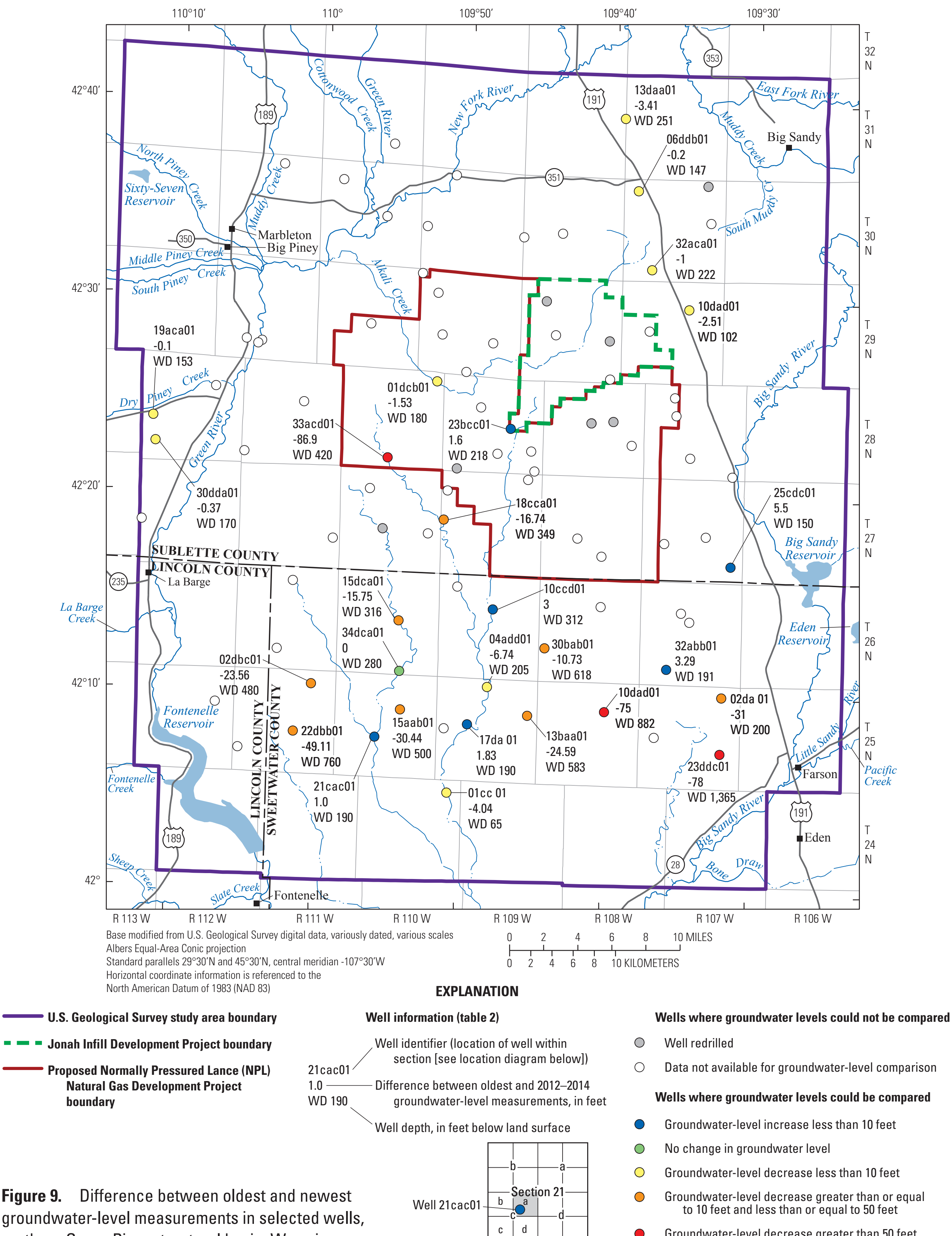


Figure 9. Difference between oldest and newest groundwater-level measurements in selected wells, northern Green River structural basin, Wyoming.

Measurement of groundwater level in a stock well. Green tape reel located next to the steel well casing holds the black electrical tape used to measure the groundwater level in this well. The black electrical tape has been lowered into the well through the small round opening located on the left side of the light-colored plate on the top of the well. The orange gasoline-powered generator located to the right of the steel well casing provides the electrical power to operate the submersible pump installed in the well. Photograph by Michelle Taylor, formerly of the U.S. Geological Survey.

Generalized Potentiometric Surface

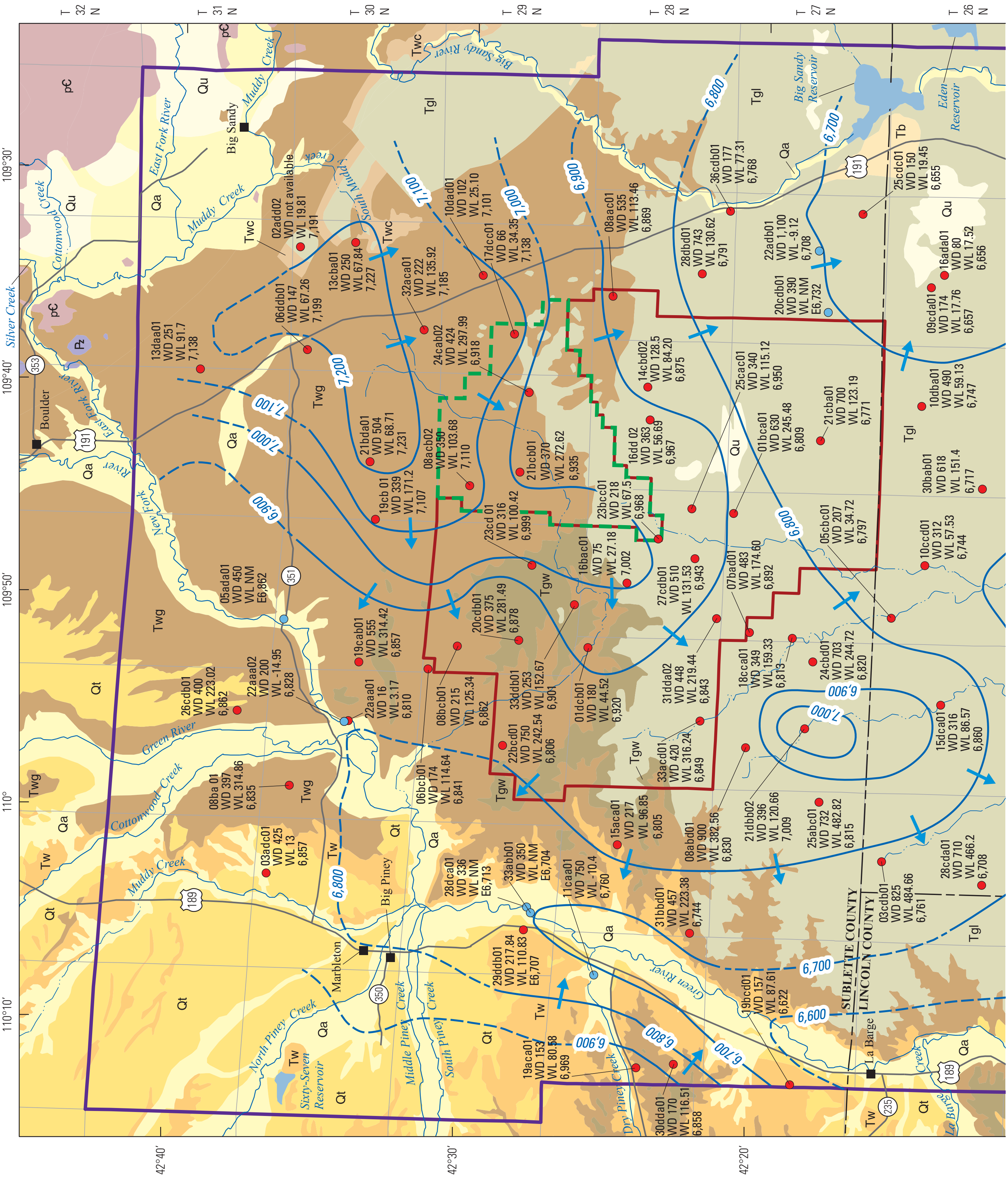
A generalized potentiometric surface of the uppermost aquifers in the Green River Basin lower Tertiary aquifer system in the northern Green River structural basin (fig. 10) was constructed on the basis of groundwater levels measured from 2010 to 2014 (table 1–1). The potentiometric surface represents groundwater-level altitudes in feet above the NAVD 88. Potentiometric contours are dashed where inferred or approximately located.

The potentiometric surface was mapped by hand contouring altitudes of groundwater levels (hydraulic heads) in the final groundwater-level dataset consisting of 89 wells completed at different depth intervals, within different aquifers of the aquifer system, and measured at different times (2010–2014) (table 1; table 1–1); therefore, this potentiometric-surface map is considered to be generalized. Water levels in most wells were completed in the Farson Sandstone-Alkali Creek aquifer or the Wasatch zone of the Wasatch-Fort Union aquifer (table 1; table 1–1). Martin (1996) indicated that, in general, these aquifers are in hydraulic connection in the northern Green River structural basin that includes the study area; thus, groundwater flowing in this area moves horizontally and vertically between aquifer contacts and leaks through the confining units (semiconfining units). Because of this, groundwater-level altitudes from the different aquifers composing the aquifer system in this area were grouped together for contouring purposes; however, the sandstone aquifers composing the multi-aquifer system commonly are lenticular, discontinuous, and interbedded with intervening fine-grained rocks, resulting in locally variable groundwater-level altitudes (hydraulic heads) and differing amounts of hydraulic connection and confinement. Consequently, caution should be used when using the map to evaluate local (site-specific) horizontal and vertical hydraulic connections between the individual sandstone aquifers and site-specific groundwater-flow direction.

Groundwater-level altitudes from 5 of 89 wells in the dataset did not reasonably fit between appropriate contours without introducing improbable bends or unlikely placement of contours; therefore, data from these wells were not used to contour the potentiometric surface on figure 10 because the groundwater-level altitudes (hydraulic heads) of these 5 wells (highlighted in orange in table 1–1) are likely representative of aquifers not hydraulically connected to the contoured aquifer system.

The altitudes of the Green, New Fork, and Big Sandy Rivers also were used as control for mapping the potentiometric surface because these perennial streams are in hydraulic connection with the groundwater-flow system in the shallow parts of the northern Green River Basin lower Tertiary aquifer system (Martin, 1996; AMEC Geomatrix, Inc., 2009; AMEC Environment and Infrastructure, Inc., 2012, 2013). In fact, analysis of streamflow records indicates that these streams generally gain water from groundwater discharge from the Green River Basin lower Tertiary aquifer system throughout the northern Green River structural basin although some stream reaches may lose water to the aquifer system, particularly during certain times of the year (Martin, 1996; AMEC Environment and Infrastructure, Inc., 2012, 2013).

Groundwater moves from high altitudes (high hydraulic heads) to low altitudes (low hydraulic heads), generally in a direction that is perpendicular to the potentiometric-surface contours, and generally in the direction of the slope of the potentiometric surface (hydraulic gradient). Hydraulic gradients typically were less than 70 feet per mile, but hydraulic gradients vary depending on location. The potentiometric-surface map indicates that regional groundwater flow generally is from north to south, but this pattern of flow is altered locally by groundwater divides and groundwater discharge to the Green River, and possibly to the Big Sandy River and two reservoirs (Fontenelle and Big Sandy Reservoirs; fig. 10). For the contoured area, the altitude of the potentiometric surface declines from about 7,200 ft in the northeast to about 6,600 ft in the south. Although some parts of the study area have some minor differences, the generalized potentiometric-surface map constructed as part of this study generally resembles earlier maps created by Martin (1996) using older groundwater-level data.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Big Sandy River
Big Sandy Reservoir
Eden Reservoir
Big Sandy
Boulder
Marbleton
Big Piney
La Barge
Muddy Creek
East Fork River
Cottonwood Creek
Silver Creek
South Muddy Creek
New Fork River
Green River
North Piney Creek
Middle Piney Creek
South Piney Creek
Dry Piney Creek
Sixty-Seven Reservoir
La Barge Creek
SUBLETTE COUNTY
LINCOLN COUNTY
7,200
7,100
7,000
6,900
6,800
6,700
6,600
02add02 WD not available WL 19.81 7,191
13daa01 WD 251 WL 91.7 7,138
06ddb01 WD 147 WL 67.26 7,199
13cba01 WD 250 WL 67.84 7,227
32aca01 WD 222 WL 135.92 7,185
10dad01 WD 102 WL 25.10 7,101
17dcc01 WD 66 WL 34.35 7,138
08aac01 WD 535 WL 113.46 6,869
36cdb01 WD 177 WL 77.31 6,768
22adb01 WD 1,100 WL -9.12 6,708
20cdb01 WD 390 WL NM E6,732
25cdc01 WD 150 WL 19.45 6,655
16ada01 WD 80 WL 17.52 6,656
09cda01 WD 174 WL 17.76 6,657
24cab02 WD 424 WL 297.99 6,918
14cbd02 WD 128.5 WL 84.20 6,875
25cac01 WD 340 WL 115.12 6,950
21bda01 WD 504 WL 68.71 7,231
08acb02 WD 350 WL 103.68 7,110
21bcb01 WD 370 WL 272.62 6,935
16dd 02 WD 363 WL 56.69 6,967
01bca01 WD 630 WL 245.48 6,809
21cba01 WD 700 WL 123.19 6,771
10dba01 WD 490 WL 59.13 6,747
19cb 01 WD 339 WL 171.2 7,107
23bcc01 WD 218 WL 67.5 6,968
30bab01 WD 618 WL 151.4 6,717
23cd 01 WD 316 WL 100.42 6,999
05ada01 WD 450 WL NM E6,862
16bac01 WD 75 WL 27.18 7,002
27cdb01 WD 510 WL 131.53 6,943
07bad01 WD 483 WL 174.60 6,892
05cbc01 WD 207 WL 34.72 6,797
10ccd01 WD 312 WL 57.53 6,744
19cab01 WD 555 WL 314.42 6,857
20cdb01 WD 375 WL 281.49 6,878
26cdb01 WD 400 WL 223.02 6,862
22aaa02 WD 200 WL -14.95 6,828
22aaa01 WD 16 WL 3.17 6,810
08bcb01 WD 215 WL 125.34 6,862
33ddb01 WD 253 WL 152.67 6,901
01dcb01 WD 180 WL 44.52 6,920
31dda02 WD 448 WL 219.44 6,843
18cca01 WD 349 WL 159.33 6,813
24cbd01 WD 703 WL 244.72 6,820
15dca01 WD 316 WL 86.57 6,860
08ba 01 WD 397 WL 314.86 6,835
06bcb01 WD 174 WL 114.64 6,841
22bcd01 WD 750 WL 242.54 6,806
33acd01 WD 420 WL 316.24 6,849
21dbb02 WD 396 WL 120.66 7,009
03adc01 WD 425 WL 13 6,857
15aca01 WD 217 WL 96.85 6,805
08abd01 WD 900 WL 382.56 6,830
25abc01 WD 732 WL 482.82 6,815
28cda01 WD 710 WL 466.2 6,708
28dca01 WD 336 WL NM E6,713
33abb01 WD 350 WL NM E6,704
11caa01 WD 750 WL -10.4 6,760
31bbd01 WD 457 WL 223.38 6,744
03cdb01 WD 825 WL 484.66 6,761
29ddb01 WD 217.84 WL 110.83 E6,707
19bcd01 WD 157 WL 87.61 6,622
19aca01 WD 153 WL 80.58 6,969
30dda01 WD 170 WL 116.51 6,858
28dbd01 WD 743 WL 130.62 6,791
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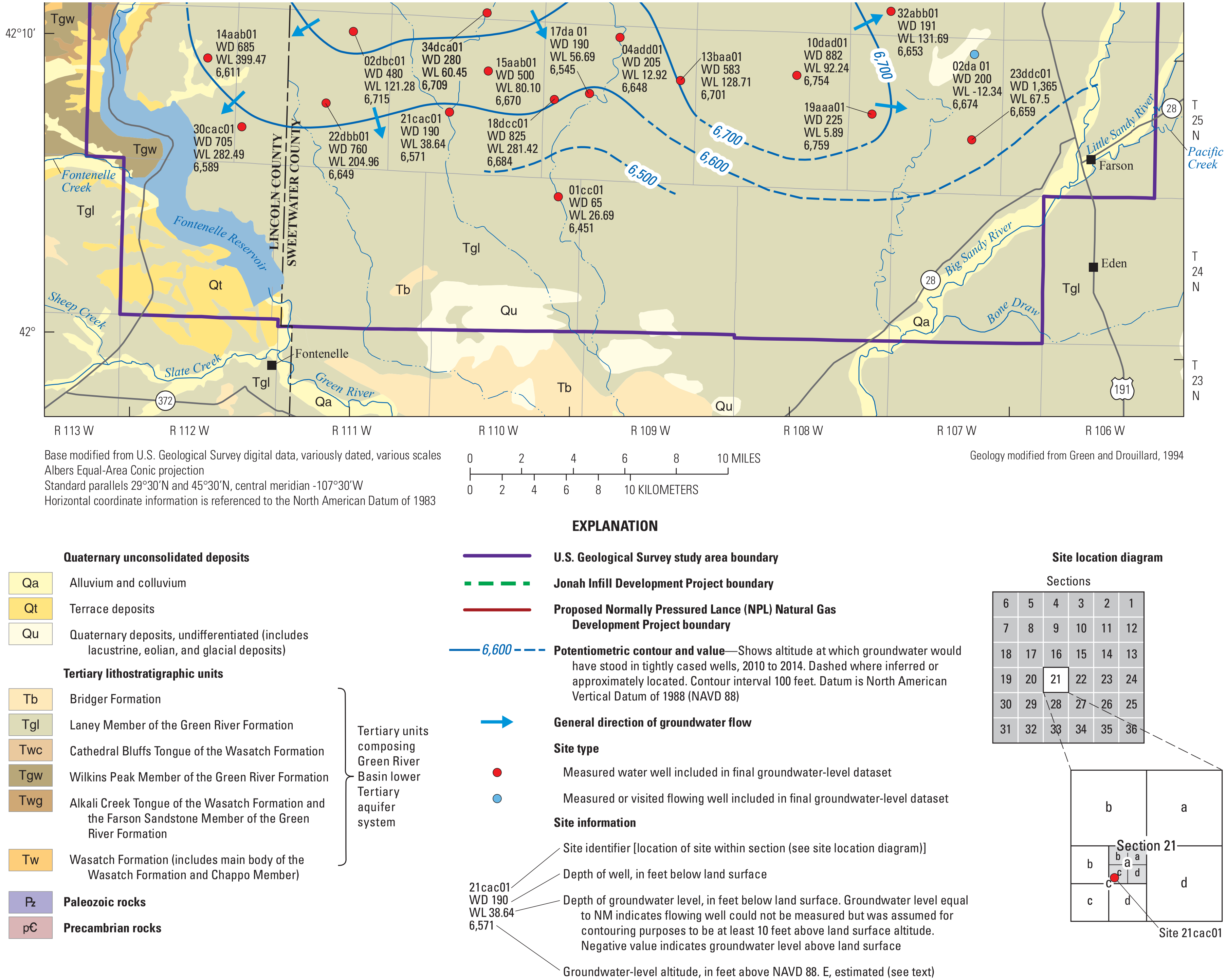

Figure 10. Generalized potentiometric surface of the Green River Basin lower Tertiary aquifer system, 2010–14, northern Green River structural basin, Wyoming.

Summary

In cooperation with the Bureau of Land Management, groundwater levels in wells located in the northern Green River Basin in Wyoming, an area of ongoing energy development, were measured by the U.S. Geological Survey from 2010 to 2014. The wells were completed in the uppermost aquifers of the Green River Basin lower Tertiary aquifer system, which is a complex regional aquifer system that provides water to most wells in the area. Except for near perennial streams, groundwater-level altitudes in most aquifers generally decreased with increasing well depth, indicating a general downward potential for groundwater movement in the study area. Drilled depth of the wells was observed as a useful indicator of depth to groundwater, such that deeper wells typically had a greater depth to groundwater.

A subset of 27 wells included in this study had historical groundwater levels that were measured during the 1960s and 1970s and again between 2012 and 2014. Overall, a comparison of the historical and more recent groundwater levels measured in individual wells ranged from a net rise of 5.5 feet to a decline of 86.9 feet. Most of the wells (20 of 27) showed a net decline in groundwater levels, and 3 wells had declines of greater than 50 feet.

The groundwater-level measurements were used to construct a generalized potentiometric-surface map of the Green River Basin lower Tertiary aquifer system. Groundwater-level altitudes measured in nonflowing and flowing wells used to construct the potentiometric-surface map ranged from 6,451 to 7,307 feet (excluding four unmeasured flowing wells used for contour construction purposes). The potentiometric-surface map indicates that groundwater in the study area generally moves from north to south, but this pattern of flow is altered locally by groundwater divides, groundwater discharge to the Green River, and possibly groundwater discharge to a tributary river (Big Sandy River) and two reservoirs (Fontenelle and Big Sandy Reservoirs).

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Appendix 1

Table 1–1. Wells evaluated for construction of generalized potentiometric-surface map, northern Green River structural basin, Wyoming.

[USGS, U.S. Geological Survey; DMS, degrees, minutes, seconds; NAVD 88, North American Vertical Datum of 1988; --, no data or not applicable; NA, not available; negative value (-) indicates groundwater level or well casing is above land surface; E, groundwater-level altitude estimated to be 10 feet above land-surface elevation for contouring purposes only (see text). Use of water abbreviations: STO, livestock; UNSTO, unused, formerly used for livestock; STO/MIN, stock and mining (used for drilling oil and gas wells); MIN, mining (oil and gas well drilling); UNMIN/STO, unused, formerly used for drilling oil and gas wells and livestock; UNMIN, unused, formerly used for drilling oil and gas wells; WS, water supply; UNUSED, former use not determined; DOM, domestic; DOM/STO, domestic and livestock; OBS, observation. Lithostratigraphic unit abbreviations: LNEY, Laney Member of Green River Formation; FRSO, Farson Sandstone Member of the Green River Formation; EOCN, undifferentiated Green River or Wasatch Formations; WSTC, Wasatch Formation; WKPK, Wilkins Peak Member of the Green River Formation; CDBF, Cathedral Bluffs Tongue of Wasatch Formation; ALVM, Quaternary alluvial deposits. Hydrogeologic unit abbreviations: LA, Laney aquifer; FSAC, Farson Sandstone-Alkali Creek aquifer; UND, undefined part of the lower Tertiary aquifer system in the Green River Basin; WZWA, Wasatch zone of Wasatch-Fort Union aquifer; WPCU, Wilkins Peak confining unit; QA, Quaternary alluvial aquifers. Groundwater-level status abbreviations: A, atmospheric pressure; F, flowing; P, pumping; R, recently pumped. Casing material abbreviations: S, steel; P, polyvinyl chloride (PVC); Z, other material (see footnote); N, PVC with glued joints; I, iron; G, galvanized iron; K, PVC with threaded joints; R, stainless steel. Type of openings abbreviations: X, open hole (no casing); P, perforated, porous, or slotted; Z, other, described in footnote; R, wire-wound screen. Blue shaded rows, flowing wells used to create potentiometric-surface map; gray shaded rows, wells removed from groundwater-level dataset before potentiometric-surface map compiled (see text); orange shaded rows, removed from groundwater-level dataset after potentiometric-surface map compiled (see text)]

USGS station name	Site identifier (fig. 10)[1]	USGS site-identification number	Latitude (DMS)	Longitude (DMS)	County	Use of water	Lithostratigraphic unit	Hydrogeologic unit	Date of well construction (month/day/year)	Land-surface altitude (feet above NAVD 88)	Depth of well (feet below land surface)
24-110-01cc 01	01cc 01	420513109504701	42°04′58.5″	109°50′44.4″	Sweetwater	STO	LNEY	LA	11/15/1956	6,478	65
25-107-02da 01	02da 01	421005109315901	42°10′03.9″	109°31′55.0″	Sweetwater	STO	FRSO	FSAC	01/01/1976	6,662	200
25-107-06cda01	06cda01	420957109370901	42°09′56.7″	109°37′08.7″	Sweetwater	STO	EOCN	UND	NA	6,745	NA
25-107-19aaa01	19aaa01	420759109363201	42°07′59.4″	109°36′31.5″	Sweetwater	STO	FRSO	FSAC	06/18/1980	6,765	225
25-107-23ddc01	23ddc01	420710109315601	42°07′12.2″	109°31′57.7″	Sweetwater	STO	WSTC	WZWA	11/30/1972	6,726	1,365
25-108-10dad01	10dad01	420915109403901	42°09′14.5″	109°39′59.8″	Sweetwater	STO	WSTC	WZWA	08/30/1961	6,846	882
25-109-04add01	04add01	421025109481901	42°10′22.3″	109°48′06.7″	Sweetwater	STO	FRSO	FSAC	09/10/1957	6,661	205
25-109-13baa01	13baa01	420901109460001	42°08′58.1″	109°45′17.3″	Sweetwater	STO	FRSO	FSAC	09/03/1959	6,830	583
25-109-17da 01	17da 01	421321109493502	42°08′27.8″	109°49′25.6″	Sweetwater	STO	WKPK	WPCU	08/15/1959	6,602	190
25-109-18dcc01	18dcc01	420814109510201	42°08′13.8″	109°51′02.0″	Sweetwater	STO	WSTC	WZWA	10/23/2004	6,965	825
25-110-15aab01	15aab01	420905109540901	42°09′08.1″	109°54′04.6″	Sweetwater	STO	FRSO	FSAC	10/11/1961	6,750	500
25-110-21cac01	21cac01	420757109555601	42°07′43.2″	109°55′48.2″	Sweetwater	STO	WKPK	WPCU	09/09/1957	6,610	190
25-111-02dbc01	02dbc01	421045110002001	42°10′20.5″	110°00′16.3″	Sweetwater	STO	FRSO	FSAC	10/10/1959	6,836	480
25-111-22dbb01	22dbb01	420822110013201	42°07′54.9″	110°01′26.1″	Sweetwater	STO	WSTC	WZWA	10/10/1959	6,854	760
25-111-30cac01	30cac01	420703110051501	42°07′02.9″	110°05′14.6″	Lincoln	STO	FRSO	FSAC	09/11/1981	6,871	705
25-112-14aab01	14aab01	420919110065301	42°09′19.6″	110°06′53.1″	Lincoln	STO	FRSO	FSAC	09/09/1981	7,010	685
26-107-09cda01	09cda01	421418109345001	42°14′18.0″	109°34′50.3″	Sweetwater	UNSTO	FRSO	FSAC	11/20/1979	6,675	174
26-107-16ada01	16ada01	421351109341501	42°13′51.4″	109°34′14.7″	Sweetwater	STO	CDBF	WZWA	06/10/2012	6,674	80
26-107-32abb01	32abb01	421127109354601	42°11′27.1″	109°35′46.2″	Sweetwater	STO	FRSO	FSAC	09/20/1969	6,785	191
26-108-10dba01	10dba01	421433109402301	42°14′32.9″	109°40′23.4″	Sweetwater	STO	FRSO	FSAC	09/19/1981	6,806	490
26-108-30bab01	30bab01	421219109433801	42°12′24.2″	109°44′12.1″	Sweetwater	STO	FRSO	FSAC	10/20/1961	6,868	618
26-109-05cbc01	05cbc01	421515109501801	42°15′24.9″	109°50′20.3″	Sweetwater	STO	FRSO	FSAC	07/07/1959	6,832	207
26-109-10ccd01	10ccd01	421421109475001	42°14′18.6″	109°47′50.6″	Sweetwater	STO	FRSO	FSAC	11/25/1960	6,802	312
26-110-15dca01	15dca01	421308109541901	42°13′38.8″	109°54′17.7″	Sweetwater	STO	FRSO	FSAC	07/20/1959	6,947	316
26-110-34dca01	34dca01	421051109543001	42°11′05.0″	109°54′12.0″	Sweetwater	STO	FRSO	FSAC	09/04/1957	6,769	280
26-111-03cdb01	03cdb01	421532110014301	42°15′32.5″	110°01′43.2″	Sweetwater	STO	WSTC	WZWA	09/15/1981	7,246	825
26-111-28cda01	28cda01	421208110025801	42°12′05.0″	110°02′42.2″	Sweetwater	STO	WSTC	WZWA	09/09/1969	7,174	710
27-107-20cdb01	20cdb01	421749109360601	42°17′49.1″	109°36′05.6″	Sublette	STO/MIN	FRSO	FSAC	12/03/2001	6,722	390
27-107-22adb01	22adb01	421811109331401	42°18′10.7″	109°33′14.1″	Sublette	STO	WSTC	WZWA	12/17/2007	6,699	1,100
27-107-25cdc01	25cdc01	421633109310701	42°16′41.9″	109°31′28.3″	Sublette	STO	CDBF	WZWA	01/01/1964	6,674	150
27-108-21cba01	21cba01	421800109420701	42°17′59.5″	109°42′06.8″	Sublette	STO	FRSO	FSAC	05/03/1977	6,894	700

Table 1–1. Wells evaluated for construction of generalized potentiometric-surface map, northern Green River structural basin, Wyoming.—Continued

Depth to groundwater (feet below land surface)	Groundwater-level altitude rounded to nearest foot (feet above NAVD 88)	Groundwater-level status	Date of groundwater-level measurement	Depth hole drilled (feet below land surface)	Screened or open interval (feet below land surface)	Length of open interval (feet)	Diameter of casing material in screened or open interval (inches)	Casing material in screened or open interval	Type of openings in interval	Cased interval (feet above or below land surface)	Diameter of casing material in interval (inches)	Casing material in interval
26.69	6,451	--	08/03/2012	72	57–72	15	--	--	X	-0.21–57	6	S
-12.34	6,674	F	08/07/2013	200	150–190	40	6	S	P	-0.62–200	6	S
--	--	F	07/30/2012	NA	NA	--	--	--	--	NA	--	--
5.89	6,759	P	07/30/2012	228	204–225	21	6	S	P	-0.6–225	6	S
67.50	6,659	P	07/30/2012	1,365	[2]687–1,334	[2]108	4	S	P	-1.88–1,364	4	S
92.24	6,754	--	07/31/2012	882	756–882	126	--	--	X	-0.17–756	6	--
12.92	6,648	--	08/01/2012	205	102–205	103	--	--	X	0–102	6.63	S
128.71	6,701	--	08/01/2012	583	NA	--	--	--	--	-0.16–583	7	S
56.69	6,545	--	08/01/2012	193	NA	--	--	--	--	-0.31–193	6	S
281.42	6,684	--	08/03/2012	825	662–822	160	5	P	P	-2.25–664	7	S
80.10	6,670	--	08/01/2012	500	[3]211–500	[3]289	4	Z[3]	Z[3]	0–211	6.62	S
38.64	6,571	--	08/01/2012	190	[4]43–190	[4]106	6.62	Z[4]	Z[4]	40–100	[4]6.62	S[4]
121.28	6,715	--	07/07/2014	480	NA	--	--	--	--	-0.25–480	7	S
204.96	6,649	--	07/07/2014	775	615–760	145	--	--	X	-0.16–615	6	S
282.49	6,589	--	08/02/2012	705	646–705	59	6	S	P	-0.98–705	6	S
399.47	6,611	--	08/02/2012	685	625–685	60	6	S	P	-1.99–685	6	S
17.76	6,657	--	06/29/2012	200	130–180	50	6.62	P	P	-0.97–200	6.62	P
17.52	6,656	--	07/30/2012	80	60–80	20	5	N	P	-3.33–80	5	N
131.69	6,653	P	06/25/2012	200	160–200	40	6.62	S	P	-2.03–200	6.62	S
59.13	6,747	--	06/21/2012	490	469–490	21	6	S	P	-1.5–490	6	S
151.40	6,717	--	06/21/2012	618	[5]170–618	[5]158	6	S	P	-0.7–618	6	S
34.72	6,797	--	06/14/2012	210	49–210	161	--	--	X	-0.03–49	6.63	S
57.53	6,744	--	06/14/2012	312	[6]60–310	[6]50	7	S	P	-0.14–312	7	S
86.57	6,860	--	08/01/2012	316	[7]190–316	[7]66	6	S	P	-0.2–316	6	S
60.45	6,709	--	06/20/2012	285	NA	--	--	--	--	-1.55–NA	4	P
484.66	6,761	R	07/18/2012	825	785–825	40	6	S	P	-1.26–825	6	S
466.20	6,708	--	08/02/2012	710	570–710	140	6.62	S	P	-1.47–710	6.62	S
--	E6,732	F	06/22/2012	390	270–390	120	6.62	S	P	-2–390	6.62	S
-9.12	6,708	F	08/07/2013	1,100	[8]75–1,100	[8]175	6.62	S	P	-3–1,100	6.62	S
19.45	6,655	--	06/12/2012	NA	NA	--	--	--	--	-0.88–NA	6	S
123.19	6,771	--	06/26/2012	700	320–400	80	6	P	P	-0.3–700	6	P

Table 1–1. Wells evaluated for construction of generalized potentiometric-surface map, northern Green River structural basin, Wyoming.—Continued

USGS station name	Site identifier (fig. 10)[1]	USGS site-identification number	Latitude (DMS)	Longitude (DMS)	County	Use of water	Lithostratigraphic unit	Hydrogeologic unit	Date of well construction (month/day/year)	Land-surface altitude (feet above NAVD 88)	Depth of well (feet below land surface)
27-108-27db 01	27db 01	421706109402501	42°17′06.1″	109°40′24.7″	Sublette	STO	WSTC	WZWA	01/26/1981	6,815	730
27-109-01bca01	01bca01	422054109453601	42°20′54.3″	109°45′36.5″	Sublette	MIN	FRSO	FSAC	08/22/1998	7,054	630
27-109-07bad01	07bad01	422016109511001	42°20′16.2″	109°51′10.4″	Sublette	UNMIN/ STO	FRSO	FSAC	08/15/1978	7,067	483
27-109-18cca01	18cca01	421847109512101	42°18′47.8″	109°51′22.8″	Sublette	STO	FRSO	FSAC	12/14/1961	6,972	349
27-110-08abd01	08abd01	422017109563301	42°20′18.0″	109°56′33.1″	Sublette	STO	WSTC	WZWA	03/27/1981	7,213	900
27-110-21dbb02	21dbb02	421817109553601	42°18′17.2″	109°55′35.8″	Sublette	STO	FRSO	FSAC	NA	7,130	396
27-110-24cbd01	24cbd01	421804109522801	42°18′04.5″	109°52′28.0″	Sublette	UNMIN	FRSO	FSAC	05/27/1982	7,065	703
27-111-25abc01	25abc01	421749109585701	42°17′44.1″	109°59′01.4″	Sublette	STO	FRSO	FSAC	09/18/1969	7,298	732
27-112-19bcd01	19bcd01	421829110121701	42°18′28.7″	110°12′16.8″	Sublette	STO	WSTC	WZWA	10/21/1985	6,710	157
28-107-08aac01	08aac01	422513109353401	42°25′12.6″	109°35′33.7″	Sublette	STO	WSTC	WZWA	11/24/1997	6,982	535
28-107-17adb01	17adb01	422408109350001	42°24′18.2″	109°35′26.5″	Sublette	STO	WSTC	WZWA	1953	6,943	900
28-107-28dbd01	28dbd01	422210109342501	42°22′09.9″	109°34′25.2″	Sublette	STO	WSTC	WZWA	10/26/1999	6,922	743
28-107-36cdb01	36cdb01	422115109312801	42°21′15.0″	109°31′28.1″	Sublette	STO	CDBF	WZWA	03/30/2010	6,845	177
28-108-08ddb01	08ddb01	422446109423501	42°24′46.0″	109°42′35.3″	Sublette	WS	FRSO	FSAC	09/16/2008	7,108	600
28-108-14cbd01	14cbd01	422357109394601	42°23′56.7″	109°39′46.1″	Sublette	STO	EOCN	UND	NA	6,956	NA
28-108-14cbd02	14cbd02	422357109394801	42°23′56.7″	109°39′47.5″	Sublette	UNSTO	CDBF	WZWA	NA	6,959	128.5
28-108-16dd 01	16dd 01	422351109411901	42°23′50.7″	109°41′19.0″	Sublette	UNSTO	FRSO	FSAC	NA	7,024	299
28-108-16dd 02	16dd 02	422351109411902	42°23′50.9″	109°41′19.0″	Sublette	STO	FRSO	FSAC	12/02/2002	7,024	363
28-108-25bab01	25bab01	422245109383001	42°22′45.2″	109°38′30.2″	Sublette	STO	FRSO	FSAC	10/04/1980	6,898	1,042
28-109-16bac01	16bac01	422431109490001	42°24′30.9″	109°48′59.5″	Sublette	STO	EOCN	UND	1937	7,029	75
28-109-23bcc01	23bcc01	422330109465201	42°23′28.4″	109°46′53.6″	Sublette	STO	FRSO	FSAC	12/01/1949	7,035	218
28-109-25cac01	25cac01	422221109452701	42°22′21.0″	109°45′26.8″	Sublette	STO	FRSO	FSAC	09/06/1978	7,065	340
28-109-27cdb01	27cdb01	422212109474701	42°22′11.6″	109°47′46.7″	Sublette	MIN	FRSO	FSAC	06/23/1995	7,075	510
28-109-31dda02	31dda02	422125109503401	42°21′24.7″	109°50′33.6″	Sublette	STO	FRSO	FSAC	NA	7,062	448
28-109-36dcb02	36dcb02	422120109451201	42°21′20.2″	109°45′11.8″	Sublette	UNUSED	LNEY	LA	NA	7,033	25
28-110-01dcb01	01dcb01	422600109523501	42°25′47.3″	109°52′03.8″	Sublette	STO	FRSO	FSAC	06/30/1949	6,965	180
28-110-33acd01	33acd01	422202109553801	42°21′53.0″	109°55′22.4″	Sublette	STO	FRSO	FSAC	06/01/1953	7,165	420
28-111-15aca01	15aca01	422452110013101	42°24′36.6″	110°01′15.3″	Sublette	UNSTO	FRSO	FSAC	06/21/1965	6,902	217
28-111-31bbd01	31bbd01	422203110051801	42°22′03.0″	110°05′18.5″	Sublette	UNMIN/ STO	WSTC	WZWA	NA	6,967	457
28-112-11caa01	11caa01	422520110222001	42°25′18.2″	110°07′23.5″	Sublette	STO	WSTC	WZWA	06/19/1959	6,750	750
28-112-19aca01	19aca01	422348110114501	42°23′45.7″	110°11′40.7″	Sublette	STO	WSTC	WZWA	11/01/1956	7,050	153
28-112-30dda01	30dda01	422243110114301	42°22′29.1″	110°11′28.4″	Sublette	STO	WSTC	WZWA	11/30/1965	6,975	170
29-107-10dad01	10dad01	422951109344501	42°29′40.8″	109°34′42.6″	Sublette	STO	FRSO	FSAC	07/06/1963	7,126	102
29-107-17dcc01	17dcc01	422840109372101	42°28′33.6″	109°37′26.1″	Sublette	STO	FRSO	FSAC	01/01/1963	7,172	66
29-108-08acb02	08acb02	422959109443601	42°29′58.9″	109°44′36.1″	Sublette	STO	FRSO	FSAC	NA	7,214	350
29-108-21bcb01	21bcb01	422812109435001	42°28′15.9″	109°43′54.9″	Sublette	STO	FRSO	FSAC	03/28/1974	7,208	370
29-108-24cab02	24cab02	422801109401001	42°28′01.2″	109°40′10.3″	Sublette	STO	FRSO	FSAC	04/04/1987	7,216	424
29-108-36cdb01	36cdb01	422615109395001	42°26′04.8″	109°40′05.7″	Sublette	UNSTO	FRSO	FSAC	NA	7,058	79
29-109-06bcb01	06bcb01	423055109530501	42°31′15.2″	109°53′15.1″	Sublette	STO	FRSO	FSAC	11/01/1966	6,956	174
29-109-08bcb01	08bcb01	423016109520801	42°30′16.5″	109°52′07.8″	Sublette	STO	FRSO	FSAC	08/25/1978	6,987	215
29-109-20cdb01	20cdb01	422811109514701	42°28′10.0″	109°51′47.2″	Sublette	STO	FRSO	FSAC	06/17/1988	7,159	375

Table 1–1. Wells evaluated for construction of generalized potentiometric-surface map, northern Green River structural basin, Wyoming.—Continued

Depth to groundwater (feet below land surface)	Groundwater-level altitude rounded to nearest foot (feet above NAVD 88)	Groundwater-level status	Date of groundwater-level measurement	Depth hole drilled (feet below land surface)	Screened or open interval (feet below land surface)	Length of open interval (feet)	Diameter of casing material in screened or open interval (inches)	Casing material in screened or open interval	Type of openings in interval	Cased interval (feet above or below land surface)	Diameter of casing material in interval (inches)	Casing material in interval
-62.90	6,878	F	08/21/2013	730	520–720	200	6.62	P	P	0–730	6.62	P
245.48	6,809	R	06/14/2012	630	[9]435–585	[9]80	6	S	P	-1.78–630	6	S
174.60	6,892	--	06/14/2012	490	NA	--	--	--	--	-1.03–490	6	P
159.33	6,813	--	06/14/2012	349	260–349	89	6.88	S	P	-0.11–349	6.88	S
382.56	6,830	R	07/17/2012	900	[10]520–860	[10]180	6.62	S	P	-1.59–900	6.62	S
120.66	7,009	R	07/18/2012	NA	NA	--	--	--	--	-0.31–NA	6	S
244.72	6,820	--	07/20/2012	712	[11]480–660	[11]100	6.62	S	P	-0.2–20	14	S
482.82	6,815	R	07/17/2012	732	490–732	242	6.62	S	P	-1.37–732	6.62	S
87.61	6,622	--	07/08/2014	157	107–147	40	5	P	P	[12]0–157	[12]6.62; 5	S; P[12]
113.46	6,869	--	06/13/2012	587	210–587	377	6	S	P	-2.39–587	6	S
-12.31	6,955	F	08/19/2013	NA	NA	--	--	--	--	-3–NA	6	S
130.62	6,791	P	06/26/2012	750	630–750	120	6.62	S	P	-2–750	6.62	S
77.31	6,768	P	06/12/2012	180	160–170	10	5	P	P	-1.97–180	5	P
328.62	6,779	P	08/20/2013	1,000	475–525	50	6	S	P	-1.51–545	6	S
97.76	6,858	--	06/13/2012	NA	NA	--	--	--	--	-0.73–NA	6	S
84.20	6,875	--	06/13/2012	NA	NA	--	--	--	--	-1.49–NA	4	S
149.11	6,875	--	07/17/2012	NA	NA	--	--	--	--	-0.87–NA	4	S
56.69	6,967	--	06/27/2012	363	[13]270–330	[13]40	4.5	P	P	0–363	4.5	P
-11.00	6,909	F	07/10/2014	1,042	NA	--	--	--	--	[14]-2–1,042	[14]7; 4.5	S
27.18	7,002	--	06/20/2012	NA	NA	--	--	--	--	-0.61–75	6	S
67.50	6,968	--	06/20/2012	218	[15]190–NA	--	--	--	Z[15]	[15]-0.62–190	6.62	S
115.12	6,950	--	06/13/2012	340	290–340	50	6.62	S	P	-1.39–340	6.62	S
131.53	6,943	--	06/20/2012	510	290–490	200	6	S	P	-2.1–510	6	S
219.44	6,843	R	06/14/2012	NA	NA	--	--	--	--	-2.4–NA	6	S
21.00	7,012	--	07/17/2012	NA	NA	--	--	--	--	-1.7–NA	6	S
44.52	6,920	P	06/19/2012	200	NA	--	--	--	--	-1.1–200	6	S
316.24	6,849	--	07/17/2012	420	NA	--	--	--	--	[16]-0.96–420	6	Z[16]
96.85	6,805	--	08/02/2012	217.5	[17]100–215	[17]60	6.62	S	P	-0.17–215	6.62	S
223.38	6,744	--	07/18/2012	NA	NA	--	--	--	--	-2.61–NA	6	S
-10.4	6,760	F	07/09/2014	4,909	NA	--	--	--	--	[18]-2.5–NA	[18]7	S
80.58	6,969	--	07/08/2014	153	90–153	63	6	S	P	-1–153	6	S
116.51	6,858	--	07/08/2014	170	143–160	17	6	S	P	-1–170	6	S
25.10	7,101	P	06/28/2012	102	55–102	47	6.62	S	P	-0.1–102	6.62	S
34.35	7,138	--	06/28/2012	92	NA	--	--	--	--	-0.95–92	6.62	S
103.68	7,110	P	07/31/2012	NA	NA	--	--	--	--	-1.15–NA	6	S
272.62	6,935	--	07/31/2012	370	[19]283–365	[19]27	7	S	P	-1–370	7	S
297.99	6,918	--	07/31/2012	450	325–345	20	7	S	P	-0.3–450	5	S
37.90	7,020	--	07/31/2012	--	--	--	--	--	--	-0.85–NA	6	S
114.64	6,841	--	08/02/2012	174	145–170	25	6	S	P	-1–174	6	S
125.34	6,862	--	06/18/2012	220	[20]140–220	[20]60	6.62	S	P	-1.13–220	6.62	S
281.49	6,878	--	07/17/2012	375	[21]280–365	[21]40	4	P	P	[21]-1.45–375	[21]6; 4	S; P[21]

Table 1–1. Wells evaluated for construction of generalized potentiometric-surface map, northern Green River structural basin, Wyoming.—Continued

USGS station name	Site identifier (fig. 10)[1]	USGS site-identification number	Latitude (DMS)	Longitude (DMS)	County	Use of water	Lithostratigraphic unit	Hydrogeologic unit	Date of well construction (month/day/year)	Land-surface altitude (feet above NAVD 88)	Depth of well (feet below land surface)
29-109-23cd 01	23cd 01	422747109481601	42°27′46.9″	109°48′15.7″	Sublette	STO	FRSO	FSAC	05/25/1995	7,099	316
29-109-33ddb01	33ddb01	422618109500401	42°26′17.9″	109°50′04.1″	Sublette	STO	FRSO	FSAC	11/17/1992	7,054	253
29-110-22bcd01	22bcd01	422838109564501	42°28′37.9″	109°56′45.0″	Sublette	UNMIN	WSTC	WZWA	11/24/2003	7,049	750
29-111-28dca01	28dca01	422740110041701	42°27′39.8″	110°04′17.3″	Sublette	STO	WSTC	WZWA	12/22/1970	6,703	336
29-111-29ddb01	29ddb01	422745110052201	42°27′45.3″	110°05′21.5″	Sublette	DOM	WSTC	WZWA	08/03/1995	6,818	217.84
29-111-33abb01	33abb01	422726110042901	42°27′31.8″	110°04′33.0″	Sublette	DOM/ STO	WSTC	WZWA	04/07/1947	6,694	350
30-107-02add02	02add02	423557109333501	42°35′57.2″	109°33′35.0″	Sublette	STO	EOCN	UND	2014	7,211	NA[25]
30-107-06ddb01	06ddb01	423539109382201	42°35′39.5″	109°38′23.4″	Sublette	STO	FRSO	FSAC	12/06/1960	7,266	147
30-107-13cba01	13cba01	423408109331501	42°34′04.4″	109°33′18.3″	Sublette	UNSTO	FRSO	FSAC	07/05/1941	7,295	250
30-107-24bdb01	24bdb01	423328109330901	42°33′27.5″	109°33′09.0″	Sublette	STO	CDBF	WZWA	05/08/2007	7,355	150
30-107-32aca01	32aca01	423140109370301	42°31′40.4″	109°37′20.8″	Sublette	STO	FRSO	FSAC	10/14/1966	7,321	222
30-108-19cb 01	19cb 01	423312109461701	42°33′11.5″	109°46′16.6″	Sublette	STO	EOCN	UND	NA	7,278	339
30-108-21bda01	21bda01	423325109433501	42°33′25.3″	109°43′35.5″	Sublette	STO/MIN	WSTC	WZWA	NA	7,300	504
30-109-05ada01	05ada01	423622109510301	42°36′14.9″	109°51′04.1″	Sublette	STO	WSTC	WZWA	01/01/1960	6,852	450
30-109-19cab01	19cab01	423320109525701	42°33′38.5″	109°52′59.7″	Sublette	STO	WSTC	WZWA	03/27/1974	7,171	555
30-110-08ba 01	08ba 01	423555109584701	42°35′54.5″	109°58′52.7″	Sublette	STO	FRSO	FSAC	07/15/1971	7,150	397
30-110-22aaa01	22aaa01	423405109554901	42°34′05.1″	109°55′48.6″	Sublette	OBS	ALVM	QA	08/24/2010	6,813	16
30-110-22aaa02	22aaa02	423405109554902	42°34′05.1″	109°55′48.7″	Sublette	OBS	WSTC	WZWA	08/25/2010	6,813	200
30-111-03adc01	03adc01	423638110030101	42°36′37.7″	110°03′01.0″	Sublette	DOM	WSTC	WZWA	NA	6,870	425
31-108-13daa01	13daa01	423913109392701	42°39′18.4″	109°39′24.1″	Sublette	STO	FRSO	FSAC	06/30/1967	7,230	251
31-110-26cdb01	26cdb01	423733109552401	42°37′46.5″	109°55′24.7″	Sublette	STO	WSTC	WZWA	06/15/1965	7,085	400

[1]Figure 10 shows only 84 of 93 wells listed in appendix 1 (see text).

[2]Four open intervals in well, 687–720; 1,012–1,044; 1,173–1,206; and 1,324–1,334 feet.

[3]Plan to set 4-inch liner 211–500 feet noted on 6/9/1965; originally open interval was not cased.

[4]Original well completion had 6.62-inch steel casing to 100 feet, which was perforated from 43 to 59 feet. The remaining 90 feet of the hole, 100–190 feet, was not cased. At some point, 4-inch diameter PVC casing was added, the extent and open interval of that casing is unknown.

[5]Two open intervals in well, 170–190 and 480–618 feet.

[6]Two open intervals in well, 60–80 and 280–310 feet.

[7]Two open intervals in well, 190–220 and 280–316 feet.

[8]Six open intervals in well, 75–100, 175–200, 275–300, 475–500, 775–800, and 1,050–1,100 feet.

[9]Three open intervals in well, 435–455, 500–520, and 545–585 feet.

[10]Two open intervals in well, 520–580 and 740–860 feet.

[11]Five open intervals in well, 480–500, 520–540, 560–580, 600–620, and 640–660 feet.

[12]Surface casing is 6.62-inch steel from 0–98 feet; 5-inch PVC casing is installed from 97 to 157 feet.

[13]Two open intervals in well, 270–290 and 310–330 feet.

[14]Casing is 7-inch steel from -2 to 409 feet and 4.5-inch steel from 105 to 1,042 feet.

[15]1956 well form indicates first opening at 190 feet; 1965 form indicates open hole 190–218 feet. Permit indicated well cased to 219 feet with gravel pack and unknown perforations.

[16]Casing from 230 to 420 is recorded as 6-inch diameter "pumping pipe."

Table 1–1. Wells evaluated for construction of generalized potentiometric-surface map, northern Green River structural basin, Wyoming.—Continued

Depth to groundwater (feet below land surface)	Groundwater-level altitude rounded to nearest foot (feet above NAVD 88)	Groundwater-level status	Date of groundwater-level measurement	Depth hole drilled (feet below land surface)	Screened or open interval (feet below land surface)	Length of open interval (feet)	Diameter of casing material in screened or open interval (inches)	Casing material in screened or open interval	Type of openings in interval	Cased interval (feet above or below land surface)	Diameter of casing material in interval (inches)	Casing material in interval
100.42	6,999	R	08/21/2013	NA	280–310	30	5.5	P	P	-0.41–310	5.5	P
152.67	6,901	P	06/20/2012	254	234–254	20	5.5	P	P	[22]-1.13–254	[22]8.62; 5.5	S; P[22]
242.54	6,806	--	06/21/2012	750	404–698	294	6	S	P	-0.31–740	6	S
--	E6,713	F	06/21/2012	336	280–336	56	4	I	P	[23]0–336	[23]6; 4	I
110.83	6,707	R	09/15/2010	--	[24]130–211	[24]60	4.5	P	P	[24]-1.16–211	[24]9.5; 4.5	S; P[24]
--	E6,704	F	07/09/2014	350	NA	--	--	--	--	0–NA	4	G
19.81	7,191	--	07/10/2014	NA	NA	--	--	--	--	-1.1–NA	6	P
67.26	7,199	--	06/27/2012	153	[26]80–153	[26]23	7	S	P	-1–153	7	S
67.84	7,227	--	07/10/2014	260	[27]168–260	[27]92	6	S	P; X[27]	-0.35–188	6	S
[28]48.11	[28]7,307	P	06/27/2012	150	80–100	20	4.5	N	P	0–150	4.5	N
135.92	7,185	--	06/28/2012	233	199–228	29	6	S	P	-0.5–233	6	S
171.2	7,107	--	06/27/2012	NA	NA	--	--	--	--	-2–NA	6	S
68.71	7,231	--	07/10/2014	NA	NA	--	--	--	--	-1.1–NA	6	S
--	E6,862	F	07/09/2014	NA	NA	--	--	--	--	0–NA	4	S
314.42	6,857	--	06/28/2012	555	[29]325–550	[29]25	[29]7; 5.5	S	P	[29]-0.78–555	[29]7; 5.5	S
314.86	6,835	--	07/09/2014	397	375–395	20	--	S	P	-0.65–395	7	S
3.17	6,810	A	07/09/2014	22	6–16	10	4	K	P	0–16	4	K
-14.95	6,828	F	09/27/2010	210	160–200	40	4	R	R	0–160	4	S
13.00	6,857	R	09/13/2010	NA	NA	--	--	--	--	6–NA	6	S
91.7	7,138	--	07/09/2014	251	[30]92–250	[30]69	6	S	P	-1.2–251	6	S
223.02	6,862	R	07/09/2014	400	365–388	23	6	S	P	-0.55–400	6	S

[17]Two open intervals in well, 100–110 and 165–215 feet.

[18]Originally had 4,310 feet of 7-inch casing, cut and pulled 2,235 feet. Set plugs at 2,450 and 750 feet. Hole probably open from 193 to 750 feet. Released as flowing well 6/16/1961. Wyoming Oil and Gas Conservation Commission record for gas well has completion date of 6/19/1959, 10.75-inch casing to 200 feet, plugged back to 4,274 feet.

[19]Two open intervals in well, 283–295 and 350–365 feet.

[20]Two open intervals in well, 140–160 and 180–220 feet.

[21]Surface casing is 6-inch steel from -1.45 to 270 feet. 4-inch PVC casing is installed from 255 to 375 feet with two open intervals (280–300 and 345–365 feet).

[22]Surface casing is 8.62-inch steel from -1.13 to 15 feet. 5.5-inch PVC casing is installed from 3 to 254 feet.

[23]Upper casing is 6-inch iron from 0 to 280 feet, and lower casing is 4-inch iron from 280 to 36 feet.

[24]Surface casing is 9.5-inch steel from -1.16 to 79 feet. 4.5-inch PVC casing is installed from 15 to 211 feet with two open intervals (130–150 and 171–211 feet).

[25]Original well 65-feet deep; well redrilled 2014 (new completion information not filed).

[26]Two open intervals in well, 80–90 and 140–153 feet.

[27]The casing is perforated from 168 to 188 feet. There is no casing from 188 to 260 feet.

[28]The well was pumping on arrival, no check meaurement was made. There is possible backflow from tank.

[29]Casing diameter changes. Upper part of well is 7-inch steel casing from -0.78 to 500 feet, perforated from 325 to 330 feet. Lower part is 5.5-inch steel casing from 490 to 555 feet, perforated from 530 to 550 feet.

[30]Three open intervals in well, 92–112, 160–190, and 231–250 feet.

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Back cover. Upper left photograph: Measurement of groundwater level in a stock well. The windmill is located directly above the well and provides the power to operate the pump in the well. Water removed from the well is pumped into the water storage device constructed of corrugated steel located left of the well. Photograph by Sarah Davis, U.S. Geological Survey.

Upper right photograph: Flowing stock well providing water to livestock. Photograph by Sarah Davis, U.S. Geological Survey.

Lower right photograph: Measurement of groundwater level in a stock well. Corrugated steel culvert has been used to surround and protect the wellhead. Water pumped from the well is delivered to the stock trough on the left side of the photograph via the steel pipe coming out of the left side of the corrugated culvert. Photograph by Michelle Taylor, formerly of the U.S. Geological Survey.

Bottom center photograph: Stock well, stock troughs, and storage tank. Water from many stock wells in the Green River structural basin is pumped into storage tanks to provide water for later use. Hillside in the background of the photograph is composed of fine-grained rocks of the Laney Member of the Green River Formation. Photograph by Michelle Taylor, formerly of the U.S. Geological Survey.

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