

EVALUATION OF GROUND-WATER-LEVEL CHANGES NEAR

GILLETTE,  
NORTHEASTERN WYOMING

INTRODUCTION

This study, done in cooperation with the Wyoming State Engineer, investigates the geohydrology in an area of about 220 mi<sup>2</sup> in northeastern Wyoming that includes the urbanized region near Gillette (fig. 1). Gillette is the county seat of Campbell County and the principal trading center in the northeastern part of the State.

Energy development in northeastern Wyoming caused dramatic population growth in Campbell County since about 1960 (fig. 2). The population growth rate in the study area is assumed to follow a trend similar to that shown in figure 2 because much of the population growth in Campbell County occurred in the vicinity of Gillette. The population of Gillette increased from 3,150 (Littleton, 1950, p. 1) in 1950 to about 15,000 in 1985.

Ground-water development in the study area includes wells for the Gillette public-water supply, for separate water supplies developed for many subdivisions, for waterflooded in oil fields, and for facilities at nearby surface coal mines. Also, there are many stock and domestic wells near Gillette.

Local water users are concerned that pumping may be causing water levels to decline, and some users are concerned that pumping of the deep wells may affect the water levels in the shallower aquifers. Water analysis and direct verification of the declines and, if declines are occurring, the areal extent of declines and identification of the stratigraphic zones in which the declines are occurring.

Purpose and Scope

The purpose of this report is to present concepts of ground-water flow in the Powder River structural basin in northeastern Wyoming based on investigations of the effects of pumping. Evaluation of water-level changes in the Fort Union Formation of Tertiary age is emphasized because much of the recent pumping near Gillette has been from wells completed in the Fort Union. There were insufficient data to estimate transmissivity from pumping and draw-down data.

Well records, driller's lithologic logs, and geophysical logs were used to determine the well-completion method and the water-yielding zones. Wells were inventoried, and water levels were measured periodically in wells that had air lines installed.

The records of about 100 wells near Gillette had data to define well construction, water level, and the lithology drilled. These wells were selected to be representative of all the wells completed in the principal aquifers (fig. 3).

Driller's lithologic logs and the depths of perforated intervals for the water wells were compared with geophysical logs of oil-test holes drilled in the area in order to determine which geologic formation yielded water to each well. The formations were differentiated using formation tops picked on geophysical logs by Norman Benson (U.S. Geological Survey, oral commun., 1985). Water wells are grouped according to total depth and depths of the perforated intervals. For identification in this report, the groups are designated as wells in the Wasatch Formation, upper and lower parts of the Fort Union Formation, and Lance Formation and Fox Hills Sandstone; however, perforated intervals in some wells were open to more than one formation.

Previous Investigations

Lowry, Wilson, and others (1986, p. 201) list more than 350 references that include numerous reports describing the geology and hydrology in the Powder River structural basin. In addition, records of wells, pumpage data, and some water-level data were filed with the Wyoming State Engineer's Office.

Several water-level contour maps have been published. The contour map prepared by King (1974) probably is representative of the altitude of the first water level that might be encountered when drilling a well in the study area. Annual reports published by the Gillette Area Groundwater Monitoring Organization (GAGMO) from 1983 to 1985 include potentiometric-surface maps and water-level-change maps for the Wasatch Formation and the underlying Wyodak coal bed in the Tongue River Member of the Fort Union Formation at most coal-mine sites. In addition, well location, aquifers in which wells are completed, and water levels are published annually by GAGMO. These water-level data are for wells completed in shallow aquifers, most of which are less than 500 ft deep. Hotchkiss and Levings (1986, figs. 8-12) and Daddow (1986) show contour maps of water levels for wells completed in deeper formations.

Well-Numbering System

Wells cited in this report are numbered by a method based on the U.S. Bureau of Land Management system of land subdivision in Wyoming (fig. 4). The first number indicates the township, the second the range, and the third the section in which the well is located. The capital or lowercase letters following the section number indicate the location of the well in the section. The first letter denotes the quarter section, the second letter the quarter-quarter section, and the third letter the quarter-quarter-quarter section (10-acre tract). The subdivisions of a section are lettered A, B, C, and D in a counterclockwise direction, starting in the northeast quarter. If more than one well is listed in a 10-acre tract, consecutive numbers starting with 1 follow the letters of the well number. If a section does not measure 1-mi square, it is treated as a full section with the southeast section corner serving as the reference point for the subdivision of the section.

Acknowledgments

The author thanks the many residents who provided information about wells and permitted U.S. Geological Survey personnel to measure water levels in their wells. The management personnel of several Gillette subdivisions provided access to their wells to measure water levels. The City of Gillette Water Department and Mr. Gerald Dickinson gave permission to install digital water-level recorders on wells.

Geohydrology

The principal aquifers in the study area, in descending order, are the Wasatch and Fort Union Formations of Tertiary age, and the Lance Formation and the Fox Hills Sandstone of Cretaceous age. The alluvium is a generally thin aquifer and not extensive in the study area; wells completed in the alluvium were not included in this study. Aquifers deeper than the Fox Hills Sandstone are not utilized extensively in the study area. Gillette has municipal wells completed in the Madison Limestone of Mississippian age, but those wells are located about 30 mi east of Gillette and are outside the study area.

Most of the well data were obtained from records on file at the Wyoming State Engineer's Office. The records indicate that most wells have casing cemented from land surface to the bottom of the well. The casing is perforated at selected intervals after the water-level decline in place, thus all zones are sealed off except those perforated. In the wells used in this study, the casing was cemented to the bottom of the perforation ranges from about 10 to about 1,200 ft. The water level represents an average of the hydrostatic heads in the zones open to perforations. For most wells, the only available level data are the water levels reported when the well was drilled, hereafter referred to as the initial water levels.

The variation in hydraulic head is illustrated in the graph of initial water-level altitudes and the well-bottom altitudes for wells in the upper and lower parts of the Fort Union and wells in the Lance Formation and Fox Hills Sandstone (fig. 7). In those wells where perforated intervals are known, most perforations are in the bottom 100 feet, therefore, the altitude of the well bottom should be a reasonable representation of the altitude at which the head was measured. The distribution of data points shows poor correlation of hydraulic head with depth although there may be a slight trend of decreasing hydraulic head with depth for wells in the lower part of the Fort Union and Lance and Fox Hills. Decreasing hydraulic head with depth has also been noted by other investigators (Ground-Water Subgroup of Water Work Group Northern Great Plains Resource Program, 1974, p. 38) suggesting that vertical ground-water flow is downward and that the deeper aquifers potentially can be recharged from overlying beds. However, because of the interbedding of sandstone, shale, and coal, the discontinuous sandstone beds, and the wide range of hydraulic heads, vertical hydraulic connection probably is poor. It is possible that pumping water from the lower part of the Fort Union Formation and below may affect water levels in wells in the upper part of the Fort Union, but the effects will probably be small at such a slow rate it will be difficult to measure. In addition, the effects on water levels from pumping water from the lower part in the upper part of the Fort Union will mask the effects of pumping from the lower part. Further monitoring will be required to determine the effect.

Wells in the Wasatch Formation

The hydrographs for two observation wells completed in the Wasatch Formation at similar depths illustrate the effect of pumping other wells also completed in the Wasatch (fig. 8).

The hydrograph for well 50-72-20ABD, in the Wasatch Formation, which is near well 50-72-21ABA, illustrates water-level changes before and during the population growth at Gillette. Water levels were measured for 25 years (1911-74) in well 50-72-20ABD before it was destroyed in 1974 (Ringer, 1973 and 1974, and Balance and Freudenthal, 1975). The hydrograph (fig. 8) shows the water-level decline in the Wasatch Formation before the population of Gillette started increasing in about 1961. The declining water level from 1965 through 1974 probably resulted from increased pumping (although pumpage data are not available) associated with population growth (see fig. 2). No water-level data are available for wells in the Wasatch from 1975-82.

The hydrograph for well 50-72-21ABA in the Wasatch illustrates water-level recovery following a period of pumping. A digital water-level recorder has been operated by the Wyoming State Engineer's Office on this well since 1983. The hydrograph (fig. 8) shows a steady rise in the water level for the period of record. Continued pumping of water from the Wasatch Formation for Gillette municipal use after 1981 probably accounts for the rising water level. If pumping of water from the Wasatch by municipal wells does not occur and no new wells are drilled, the water level in well 50-72-21ABA probably will rise to a relatively steady level similar to that measured in well 50-72-20ABD prior to 1961.

Comparison between the hydrographs for wells 50-72-20ABD and 50-72-21ABA and annual precipitation (fig. 8) indicates that water levels in the Wasatch Formation may be partially affected by long-term changes in annual precipitation. It is unlikely that water-level changes resulting from differing recharge from precipitation could be identified in the deeper aquifers that are below the Wasatch Formation because low vertical permeability would restrict downward movement of recharge.

Wells in the upper part of the Fort Union Formation

The water levels in wells in the upper part of the Fort Union Formation in 1985 were substantially lower than when the wells were drilled (fig. 9). The water levels in the upper part of the Fort Union in 1985 ranged from about 39 to about 455 ft lower than the initial reported water level. All but 2 of the 17 wells are used as production wells; therefore, some of the water levels measured during 1985 were lower because of residual drawdown resulting from pumping. It was usually not known how recently the well was pumped prior to the measurement.

To help define the water-level changes in the upper part of the Fort Union Formation, digital water-level recorders were installed on two wells in the upper part of the Fort Union. At well 50-72-20BBA, the water-level recorder was installed May 7, 1985. The water-level decline from May through October in this unused well (fig. 9) probably was caused by pumping Gillette municipal wells and public-supply wells in nearby subdivisions; both the pumping wells and the observation well are completed in the upper part of the Fort Union. A water-level measurement made in December 1985 indicated that the water level had stabilized, although there was no indication of water-level recovery in the observation well. At well 50-72-20CAB, the water-level recorder was installed in December 1985 (hydrograph not shown). Not enough data have been collected to establish a trend of the water level, although water-level measurements made from October 1985 to January 1986 indicate that the water level in this well has risen 17 ft during this short period. The recorder will be used on this well in future years as needed to help explain the water-level rise.

Anomalous differences were noted in the hydraulic heads in wells completed in the upper part of the Fort Union Formation. The lowest and highest hydraulic heads in all the wells evaluated in this study are determined from the water levels in wells in the upper part of the Fort Union (see fig. 7). The water-level altitudes range from 3,450 ft above sea level in well 50-72-20CAB to 4,590 ft in well 50-72-29CBB. These two wells are about 1 mi apart, and the top perforation in both wells is within 500 ft of the base of the Wyodak-Anderson coal bed. The well bottom in well 50-72-20CAB is 3,395 ft above sea level (altitude in well 50-72-29CBB (3,025 ft). The well with the higher water level is slightly down dip from the one with the lower water level. The formations dip about 1 foot per mile (generally about 90 ft per mi) to the west, however this much dip does not account for the 940 ft of difference in hydraulic head between the two wells. Well 50-72-29CBB has the higher water level and was drilled in 1979, more than 2 years after well 50-72-20CAB.

Some large differences in hydraulic head may be explainable. At nearby well 50-72-30CBB, the initial water-level altitude was 4,000 ft when the well was drilled in 1979 and was 4,278 ft on August 15, 1985. When measured in 1985, gas was escaping through the casing surface, and the water level seemed to fluctuate about 10 ft because of much bubbling action caused by the gas release. Comparison of the driller's lithologic log and geophysical logs of nearby wells indicates that the uppermost perforations in well 50-72-30CBB are probably in a clay shale. Perforations in the water could account for the relatively high initial water level as a result of partial gas lift. Dissipation of gas could account for part of the initial water-level decline since the well was drilled. Because the gas is still escaping and contributing to the hydraulic head in the well, the water level would most likely decline below its present level if the gas was sealed off.

Examination of the 17 hydrographs for wells completed in the upper part of the Fort Union Formation (see fig. 9) indicates that the average water-level decline in these wells is about 120 ft and has occurred from about 1972 to 1985; however, the average length of pumpage has been about 7 years. Very few water-level data are available from the time the wells were completed until 1985, and it is not possible to determine if the water-level decline has changed. More data are needed to determine the current trend of water-level changes.

A regional flow pattern of ground-water movement could not be determined for the upper part of the Fort Union Formation in the study area. The initial water levels reported at the time the wells were drilled were used as control for a potentiometric surface. An attempt to control the potentiometric surface resulted in a very unrealistic pattern of ground-water movement within the study area. The water levels reported in the Fort Union coal-bearing formations or below may affect water levels in wells in the upper part of the Fort Union, but the effects will probably be small at such a slow rate it will be difficult to measure. In addition, the effects on water levels from pumping water from the lower part in the upper part of the Fort Union will mask the effects of pumping from the lower part. Further monitoring will be required to determine the effect.

Wells in the lower part of the Fort Union Formation

Water-level changes in the lower part of the Fort Union Formation are not well documented because of the lack of water-level data. The hydrograph for this well (fig. 9) indicates that the water-level rise above the Wyodak-Anderson coal bed in December 1985. The water-level change represents recovery following intervals of pumping water from the lower part of the Fort Union. The water-level rise may occur in the summer after which the water level rises in the fall and winter. The data are insufficient to define a trend.

Wells in the Lance Formation and Fox Hills Sandstone

Water-level changes were analyzed for eight wells completed in either the Lance Formation or the Fox Hills Sandstone, or in both formations. One well probably yields most of its water from the Lance, and one well is completed in both the Lance and the Fox Hills. The other six wells were reported to be yielding water from the Fox Hills, but records are not available to verify this. No water-level data are available for wells in the Wasatch from 1975-82.

Well 49-70-31BHB, completed in the Lance and Fox Hills, is used as an observation well to monitor water-level changes. A digital water-level recorder has been operated by the Wyoming State Engineer's Office on the well since September 1983. The hydrograph (fig. 10) shows that the water level has declined about 9 ft since the well was drilled in 1981, the initial water level was reported to be at 490 ft below land surface. The water-level decline probably is the result of pumpage for industrial use because there are 14 oil-field waterflood operations withdrawing water from the Fox Hills Sandstone within a radius of about 10 mi of the observation well.

Water-level data were too few to map a realistic potentiometric surface for the Lance Formation and the Fox Hills Sandstone within the study area. Initial water levels in the eight wells in the Lance and Fox Hills used in this study indicate that the gradient of the potentiometric surface is northward, which is similar to the direction of flow indicated by the regional potentiometric surface shown by Henderson (1985, fig. 33, p. C 44) for the Lance and Fox Hills.

SUMMARY AND CONCLUSIONS

Ground-water-level changes were evaluated in an area of about 220 mi<sup>2</sup> in northeastern Wyoming, including the urbanized region near Gillette, where ground-water development is most concentrated. Local water users are concerned that water levels are declining.

The principal aquifers in the study area, in descending order, are the Wasatch and Fort Union Formations of Tertiary age and the Lance Formation and Fox Hills Sandstone of Cretaceous age. Wells in alluvium were not included in this study. Gillette has municipal wells completed in the Madison Limestone of Mississippian age, but those wells are located about 30 mi east of Gillette and are outside of the study area. Aquifers in the Fort Union Formation are most likely to be developed for future ground-water supplies because the best quality of water is obtained from this formation. About 100 wells were selected to be representative of all wells completed in aquifers below the Wasatch.

Wells completed below the Wasatch Formation were completed in the upper and lower parts of the Fort Union Formation and in the Lance Formation or the Fox Hills Sandstone, or both. Most of the wells are completed in the upper part of the Fort Union between the base of the Wyodak-Anderson coal bed and 750 ft below the base of the coal bed. Other wells are completed in the zone from 750 ft below the base of the coal bed to the top of the Lance. Because of the discontinuity of lenses in the Fort Union, it was difficult to determine if wells are completed in the same sequence of lenses that would permit hydraulic connection between wells. In addition, perforations in wells are open to more than one sandstone lens, and the wells are drilled to different depths resulting in water levels in wells representing possibly a composite of different hydraulic heads.

Water-level data from 1949 to 1985 from a well completed in the Wasatch Formation indicate that the water level was relatively stable prior to 1961 when the population of the Gillette area started to increase. From about 1965 through 1974, the water level declined about 9 ft. No water-level data are available from 1975 to 1985. The water level in another well completed in the Wasatch Formation is equipped with a digital water-level recorder has been rising since 1983, probably because Gillette stopped pumping water from the Wasatch Formation for municipal use after 1981.

Data obtained from 18 observation wells completed in aquifers below the Wasatch Formation indicate that most wells in the Pumpage for municipal use by Gillette and for public supply by the subdivisions is the principal cause of water-level decline that averaged about 120 ft from about 1972 to 1985 for 16 wells in the upper part of the Fort Union Formation between the immediate vicinity of Gillette. A water-level decline of about 9 ft in a well in the Lance and Fox Hills from September 1983 to December 1985 probably results from pumpage for oil-field waterflood operations.

A regional flow pattern of ground-water movement could not be determined for the Fort Union Formation, Lance Formation, and Fox Hills Sandstone. A potentiometric surface prepared using initial reported water levels in wells in the upper part of the Fort Union indicated unrealistic patterns of ground-water movement. The water levels used for control probably were composite water levels resulting from hydraulic heads of more than one potentiometric surface. It was concluded that data were too few to define local flow systems or how the local systems merge into a regional flow pattern. Water-level data were too few to map a potentiometric surface for the lower part of the Fort Union Formation, the Lance Formation, and the Fox Hills Sandstone.

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
Foot (ft)	0.3048	meter
mile (mi)	1,609	kilometer
acre	4,047	square meter
square mile (mi <sup>2</sup> )	2,590	square kilometer
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second
foot squared per day (ft <sup>2</sup> /d)	0.09290	meter squared per day
acre-foot per year	1,233	cubic meter per year
gallon per minute (gal/min)	0.0006309	liter per second

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

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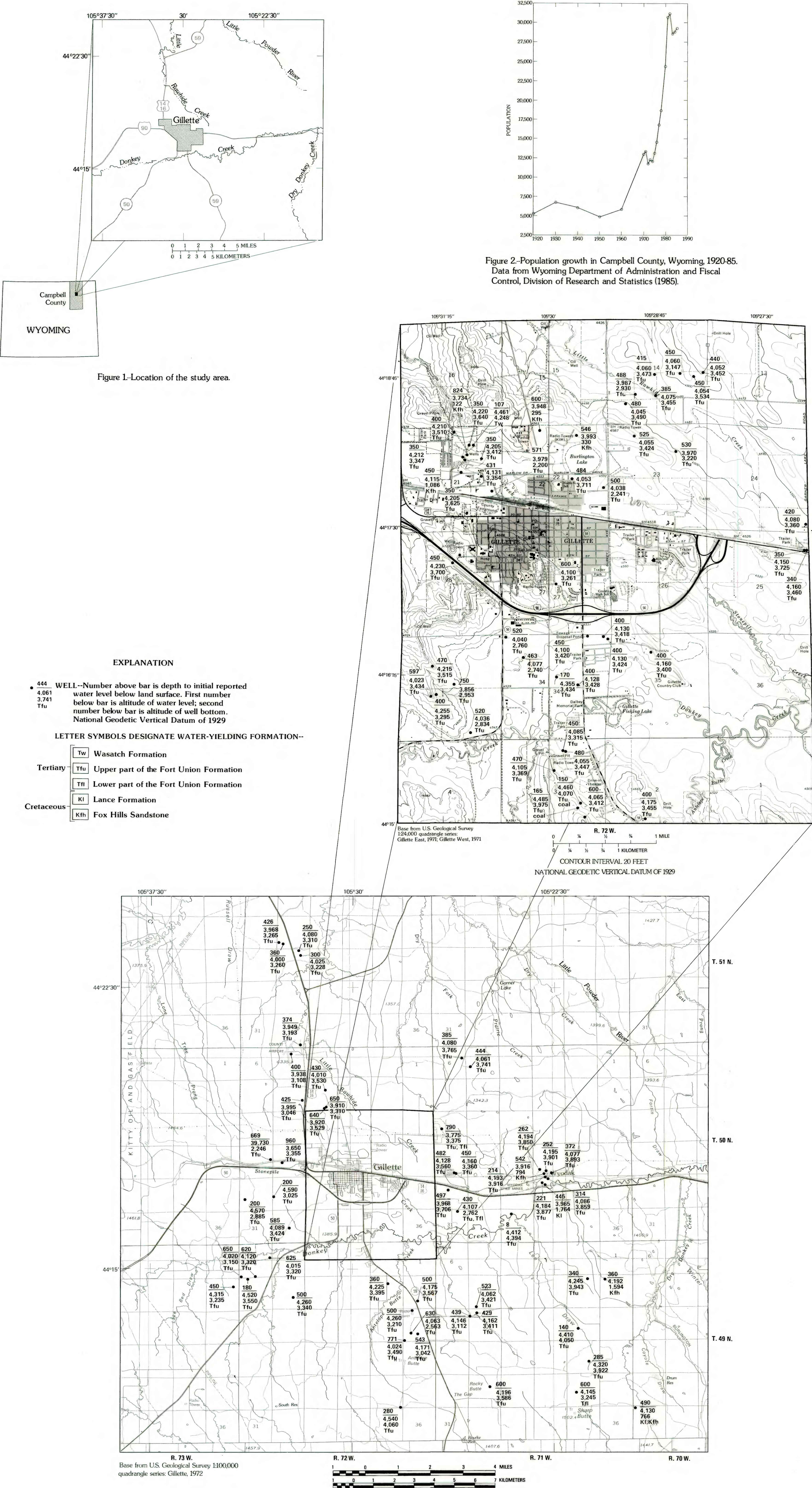


Figure 1—Location of the study area.

EXPLANATION

- 44. WELL—Number above bar is depth to initial reported water level; number below bar is altitude of water level; second number below bar is altitude of well bottom. National Geodetic Vertical Datum of 1929
- TW Wasatch Formation
- TU Upper part of the Fort Union Formation
- TL Lower part of the Fort Union Formation
- KL Lance Formation
- KN Fox Hills Sandstone

CONTOUR INTERVAL, 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

CONTOUR INTERVAL, 20 FEET

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Figure 3—Well data and locations of wells completed in formations of Tertiary and Cretaceous age.

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By

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1991