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OPEN-FILE REPORT 92-UR

HYDROGEOLOGIC ASSESSMENT OF THE HIGH PLAINS AQUIFER IN BENNETT COUNTY, SOUTH DAKOTA

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2011

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INTRODUCTION

This report summarizes the results of 7 years of an intensive field effort to assess the areal extent, thickness, hydraulic properties, and water-quality conditions of the High Plains aquifer in Bennett County, South Dakota. The High Plains aquifer includes about 174,000 square miles of the central United States east of the Rocky Mountains in the Great Plains. Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming are underlain by the High Plains aquifer as shown in figure 1 (Gutentag and others, 1984). The term "High Plains aquifer" is preferred to the "Ogallala aquifer" or "Arikaree aquifer" because the geologic units of Ogallala and Arikaree constitute only parts of this ground-water system.

Bennett County is located in southwest South Dakota and has an area of 1,191 square miles, all of which is underlain by the High Plains aquifer. Statewide, the High Plains aquifer covers an area of approximately 4,800 square miles in South Dakota. The High Plains aquifer is the principal source of water for irrigation, municipal, and domestic use in Bennett County.

Field work for this study began in October 2004 and continued through April 2010. The field work included the drilling of 40 test holes, 21 of which were completed as monitoring wells in the High Plains aquifer. Hydraulic properties of aquifer were determined by performing a pumping test from seven monitoring wells. Water samples were collected from 31 wells and 1 spring for laboratory analysis.

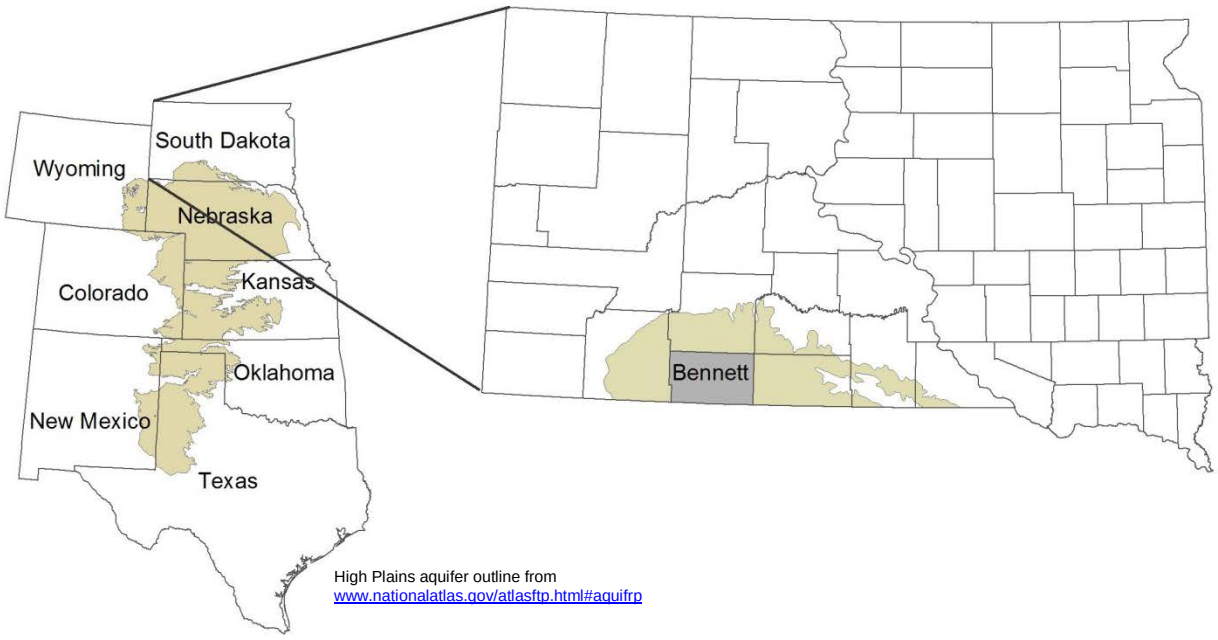

Figure 1. Map of the High Plains aquifer with index map showing the location of Bennett County, South Dakota.

METHODOLOGY

The general geology of the investigated area was determined using available geologic maps and test-drilling data, reviewing literature, and by drilling and logging new test holes and wells. This study included the assessment of 182 test holes and wells drilled in Bennett County for various projects (app. A).

The goal of drilling test holes in Bennett County was to penetrate the Tertiary sediments (Ogallala, Arikaree, and White River Groups) because the thickness of these sediments in Bennett County was unknown. However, the depth capabilities of the Geological Survey Program's drilling rigs caused most drilling to terminate in the Arikaree Group before the thickness of all Tertiary sediments could be determined.

Maps of surface geology at a uniform and sufficiently detailed scale did not exist for all of the study area. Unpublished maps of surface geology, at a scale of 1:250,000, in the files of the Geological Survey Program were used to estimate surface geologic boundaries for purposes of this report.

Water-level data were collected in September and October 2009 from 16 of the monitoring wells installed in the High Plains aquifer for this study and from 42 wells maintained by the Water Rights Program, Department of Environment and Natural Resources. The water levels were measured in the 42 "Water Rights" wells in December 2009 and January 2010. In April 2010, the water levels were measured in 16 of the monitoring wells installed in the High Plains aquifer for this study and 3 monitoring wells installed for previous studies. Five of the monitoring wells installed for this study could not be measured because they were dry. Additionally, two monitoring wells installed for this study were destroyed after 2007 (R2-2006-49 and R2-2006-50). Data from the U.S. Geological Survey (Carter and Heakin, 2007) were also used to construct a water-table map for this study.

The hydraulic properties of the High Plains aquifer in Bennett County were determined by seven, short, single-well pumping tests using seven different monitoring wells. Monitoring wells for this study were constructed with 2-inch diameter polyvinyl chloride (PVC) casing and screen. The pumping tests were conducted using four wells installed in sediments of the Arikaree Group and three installed in sediments of the Ogallala Group. The pumping rate ranged from 4.6 to 5.0 gallons per minute. The pumping tests were performed with the submersible Grundfos Redi-Flo2® pump. The duration of the pumping phase of each pumping test was 120 minutes and was also approximately 120 minutes for the recovery phase.

Pumping test data were processed using Aqtesolv software developed by HydroSOLVE, Inc. The methods used to estimate the hydraulic parameters were:

- the Theis solution for a confined aquifer,
- the Cooper-Jacob solution for a confined aquifer,
- the Theis solution for a recovery test in a confined aquifer,
- the Theis solution for an unconfined aquifer,

- the Cooper-Jacob solution for an unconfined aquifer, and
- the Neuman and Quick Neuman solutions for an unconfined aquifer.

Water samples were collected for analysis of general inorganic chemistry, trace metals, and radionuclides. The South Dakota Department of the Health Laboratory performed the analyses.

CLIMATE

The climate is typically continental, characterized by cold winters and hot summers. Average annual precipitation in Bennett County from 1971 to 2000 was approximately19 inches (Carter and Heakin, 2007). Mean annual evaporation in southern South Dakota as measured from class A evaporation pans is about 60 inches (Gutentag and others, 1984).

HIGH PLAINS AQUIFER

Geologic Description

In Bennett County, the High Plains aquifer is herein defined to consist of one or more hydraulically connected geologic units of Late Tertiary or Quaternary age. In ascending order, the Tertiary sediments considered to be part of the aquifer in Bennett County consist of the Arikaree Group, Batesland Formation, and Ogallala Group. Overlying Quaternary sediments consist of alluvial and eolian deposits (pl.1).

In south-central and southwestern South Dakota, the depositional surface during Tertiary time was composed of Cretaceous-age Pierre Shale. The Pierre Shale is predominately dark-gray to black throughout the study area; however, it is yellowish-brown to light-gray where weathered.

The Arikaree Group in the study area was deposited during the Oligocene and Miocene. Arikaree sediments in the study area were described by Weeks and Gutentag (1981) as consisting predominantly of pinkish-tan to red, greenish, brown massive very fine to fine sandstone with beds of volcanic ash, silty sand, siltstone, claystone, sandy clay, and limestone. Sediments having similar lithology and appearance were encountered in test holes and wells drilled for this investigation.

The Batesland Formation was deposited in Late Miocene time. This formation consists of light-greenish to light-gray very fine to fine sandstone with interbedded silt and clay. The Batesland Formation occurs at land surface in the western part of the study area (pl. 1).

The deposition of the Ogallala Group began in Late Miocene to Early Pliocene time and continued until Late Pliocene time when the climate became more arid and up-warping of the High Plains area caused deposition to cease and erosion to begin (North Plains Groundwater Conservation District - Texas, 2002). In South Dakota, the Ogallala Group has been divided into

three formations: Fort Randall (the basal unit), Valentine, and Ash Hollow (Fahrenbach and others, 2010). However, the Fort Randall unit was not recognized in the drilling performed for this project. The Valentine Formation consists of poorly consolidated, gray to olive-green, light-tan, fine to coarse sand and silt. Local lenses of olive to greenish silty clay are also present in the Valentine Formation. The Ash Hollow Formation consists of calcite- and silica-cemented, light-gray to olive-gray, fine sandstone, and siltstone.

Post Ogallala-age sediments consist of eolian deposits and alluvium. The eolian deposits consist of wind-blown sand, which is sometimes calcareous, that is derived from the Ash Hollow and Valentine Formations. In some cases, the contact between the Ogallala Group and younger sediments is not easily identified. The eolian deposits (Sand Hills) are present in southern part of Bennett County (pl. 1). Alluvium is present as fluvial floodplain and terraced sediments along the more active streams and rivers. The deposits consist of poorly sorted, often cross-bedded, gravel, sand, silt, and clay (Gutentag and others, 1984).

Hydrogeologic Setting

The High Plains aquifer in Bennett County consists of Arikaree Group, Batesland Formation, Ogallala Group sediments, alluvium, and eolian deposits which are hydraulically connected and are under primarily water-table conditions. The Arikaree Group is the most utilized geologic unit in the High Plains aquifer in Bennett County and underlies all of the study area. The White River Group is not considered to be part of the High Plains aquifer in Bennett County.

The Ogallala Group is the most productive part of the High Plains aquifer in Bennett County. Irrigation wells can yield approximately 1,000 gallons per minute from 200 feet of saturated thickness. Wells in the Arikaree Group generally do not yield large quantities of water. The largest yield from the Arikaree Group in Bennett County was found to be 76 gallons per minute (Carter and Heakin, 2007).

The thickness of the High Plains aquifer is primarily controlled by the topography of the underlying, eroded pre- and post-Arikaree surface. Hydrogeologic cross sections presented on plate 2 illustrate the subsurface of the area.

Recharge and Discharge

Precipitation is the principal source of recharge to the High Plains aquifer. As stated previously, the average annual precipitation from 1971 to 2000 was about 19 inches in the study area (Carter and Heakin, 2007) and mean annual evaporation in the study area as measured from class A evaporation pans is about 60 inches (Gutentag and others, 1984). A previous investigation of the High Plains aquifer in southern South Dakota has estimated recharge from precipitation to be 1.3 to 1.8 inches per year (Kolm and Case, 1983). The majority of the precipitation is dissipated through direct evaporation or is transpired by plants. Seepage from the aquifer through springs and to streams also occurs. Ground water is also discharged by artificial

processes including withdrawal of water for irrigation, domestic and public consumption, and livestock.

Saturated Thickness

The High Plains aquifer as defined in this report includes an area of about 1,185 square miles in Bennett County. The saturated thickness of the High Plains aquifer in the study area ranges from approximately 100 feet in the northwest to approximately 1,100 feet in southwest part of Bennett County (table 1; pls. 2 and 3). The saturated thickness differs greatly between these extremes for two reasons: (1) the contact between the Ogallala Group and the underlying Arikaree Group is an undulating, erosional surface resulting in large variations in the thickness of the Ogallala Group and Arikaree Group as determined by this study and by Rahn and Paul (1975) and, (2) eolian and fluvial processes have eroded parts or all of the Arikaree Group, Ogallala Group, and eolian deposits.

Water Table

Ground water in the High Plains aquifer generally is under unconfined conditions. In the period from September 2009 through April 2010 when data for this study were collected, the depth to water in the High Plains aquifer in Bennett County ranged from 6 to 158 feet below land surface. Data collected in this study indicate a variation in water level less than 1 foot to 1.4 feet (table 1). Data collected from 1979 through 2010 for selected wells measured by the Water Rights Program, Department of Environment and Natural Resources, show ground-water fluctuations from less than 5 feet to about 13 feet (fig. 2).

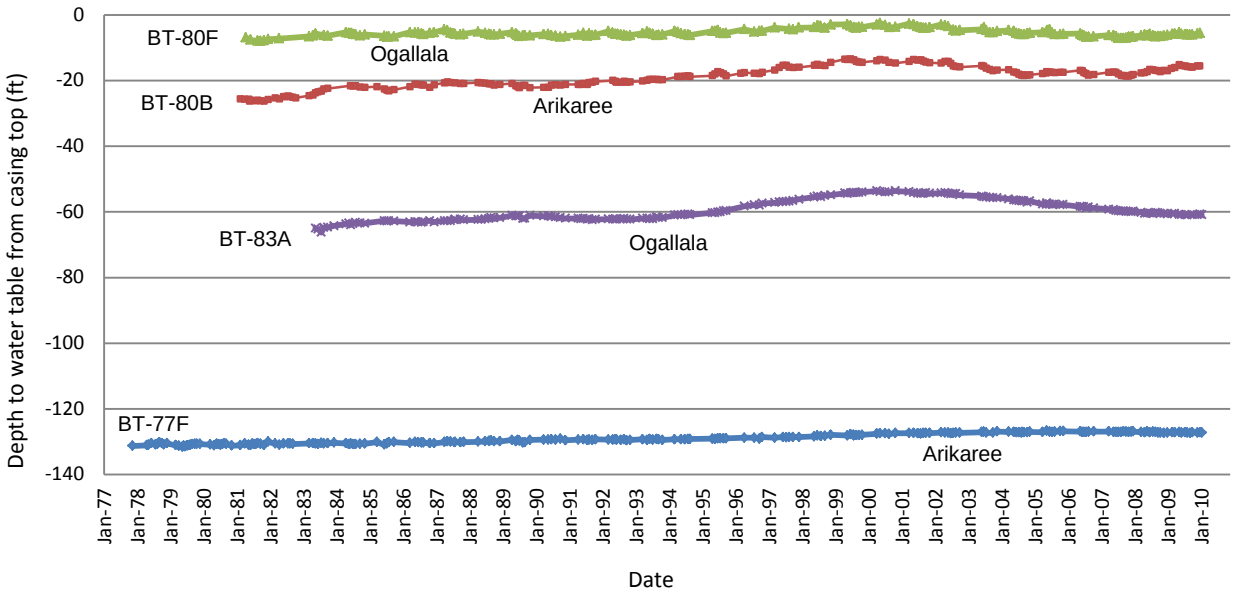

Figure 2. Hydrograph of wells BT-77F, BT-80B, BT-80F, and BT-83A.

Table 1. Ground-water elevation and saturated thickness of the High Plains aquifer in Bennett County, South Dakota

Well name	Legal location	Casing-top elevaton[1]	Date	Water elevation[1]	Date	Water elevation[1]	Date	Water elevation[1]	Estimated saturated thickness (ft)
R2-93-28	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.	3041.00	---	---	---	---	4/28/2010	3033.33	---
R2-93-29	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.	3041.00	---	---	---	---	4/28/2010	3033.15	---
R2-93-30	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.	3041.00	---	---	---	---	4/28/2010	3033.21	---
BT-83B[2]	NE¼ SW¼ SW¼ SE¼ sec. 18, T. 35 N., R. 35 W.	3230.50	9/29/2009	3220.39	1/11/2010	3220.60	---	---	720
BT-78D[2]	SE¼ NW¼ SE¼ NE¼ sec. 19, T. 35 N., R. 37 W.	3298.70	9/29/2009	3290.40	1/11/2010	3290.50	---	---	990
BT-80F[2]	SE¼ SW¼ SW¼ SW¼ sec. 31, T. 36 N., R. 33 W.	3053.00	9/23/2009	3047.00	12/21/2009	3047.50	---	---	614
R20-2009-10	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.	3004.00	9/24/2009	2974.18	---	---	4/28/2010	2974.85	---
M51-2009-05	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.	3004.00	9/28/2009	2975.73	---	---	4/28/2010	2976.70	609
BT-78I[2]	SW¼ SW¼ SW¼ SW¼ sec. 18, T. 36 N., R. 34 W.	3072.60	9/29/2009	3056.40	1/11/2010	3056.30	---	---	---
BT-83G[2]	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 36 N., R. 35 W.	3037.50	9/29/2009	2969.40	1/12/2010	2969.60	---	---	---
BT-83D[2]	NE¼ NE¼ NE¼ NW¼ sec. 4, T. 36 N., R. 35 W.	3036.60	9/29/2009	3021.00	12/21/2009	3021.10	---	---	---
BT-83I[2]	NE¼ NE¼ SE¼ NW¼ sec.11, T. 36 N., R. 35 W.	3054.00	9/29/2009	3010.50	11/23/2009	3010.40	---	---	661
BT-83E[2]	SW¼ SW¼ SW¼ SW¼ sec. 12, T. 36 N., R. 35 W.	3060.50	9/29/2009	3039.80	12/21/2009	3039.70	---	---	514
BT-80D[2]	SW¼ SW¼ SW¼ SW¼ sec. 15, T. 36 N., R. 35 W.	3100.00	9/29/2009	3068.80	12/21/2009	3069.00	---	---	---
BT-83C[2]	SE¼ NW¼ SE¼ SW¼ sec. 31, T. 36 N., R. 35 W.	3191.60	9/28/2009	3179.80	1/11/2010	3179.80	---	---	---
BT-78F[2]	SE¼ SE¼ SE¼ SE¼ sec. 22, T. 36 N., R. 36 W.	3069.50	9/28/2009	3060.00	12/21/2009	3060.70	---	---	---
BT-78E[2]	NW¼ NW¼ NW¼ NW¼ sec. 11, T. 36 N., R. 37 W.	3161.50	9/28/2009	3091.00	1/11/2010	3090.90	---	---	681
M51-2009-01	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.	3161.00	9/23/2009	3135.43	---	---	4/28/2010	3135.12	---
M51-2009-02	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.	3161.00	9/23/2009	3136.75	---	---	4/28/2010	3137.05	781
Johnson spring[3]	NE¼ NE¼ SW¼ SW¼ sec. 21, T. 36 N., R. 37 W.	---	9/29/2009	3117	---	---	---	---	---
BT-83A[2]	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.	3280.90	9/23/2009	3219.90	1/11/2010	3220.00	---	---	---
R2-2006-53	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.	3280.00	10/16/2009	3220.00	---	---	4/28/2010	3220.35	909

Table 1 — continued

Well name	Legal location	Casing-top elevaton[1]	Date	Water elevation[1]	Date	Water elevation[1]	Date	Water elevation[1]	Estimated saturated thickness (ft)
BT-76E[2]	SE¼ SW¼ SE¼ SE¼ sec. 1, T. 36 N., R. 38 W.	3202.80	9/28/2009	3143.00	1/11/2010	3143.40	---	---	713
BT-80C[2]	SW¼ SW¼ SW¼ SW¼ sec. 9, T. 36 N., R. 38 W.	3205.00	10/05/2009	3197.32	12/21/2009	3198.30	---	---	717
BT-77E[2]	SE¼ SE¼ SE¼ NE¼ sec. 10, T. 36 N., R. 38 W.	3197.50	9/28/2009	3175.10	1/11/2010	3176.50	---	---	730
R20-2009-04	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.	3237.00	9/24/2009	3216.58	---	---	4/28/2010	3217.55	
M51-2009-04	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.	3237.00	9/24/2009	3217.20	---	---	4/28/2010	3218.54	714
R2-2006-49[4]	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.	3322.00	5/30/2007	3313.10	---	---	---	---	---
R2-2006-50[4]	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.	3322.00	5/30/2007	3310.12	---	---	---	---	---
BT-78B[2]	NE¼ NE¼ NW¼ NE¼ sec. 2, T. 36 N., R. 40 W.	3298.30	9/28/2009	3296.30	1/11/2010	3296.70	---	---	716
BT-76C[2]	SW¼ SW¼ SW¼ SW¼ sec. 17, T. 37 N., R. 33 W.	3000.50	9/29/2009	2928.70	12/21/2009	2929.00	---	---	549
BT-80E[2]	NW¼ NW¼ NW¼ NW¼ sec. 32, T. 37 N., R. 33 W.	2955.00	9/28/2009	2894.33	12/21/2009	2894.80	---	---	514
BT-78KR[2]	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 37 N., R. 34 W.	3117.00	10/05/2009	2959.10	1/12/2010	2959.90	---	---	630
R2-2005-44	NE¼ NE¼ NE¼ NE¼ sec. 4, T. 37 N., R. 34 W.	3030.00	10/16/2009	2958.59	---	---	4/28/2010	2960.17	610
BT-76B[2]	SE¼ SE¼ SE¼ NE¼ sec. 9, T. 37 N., R. 34 W.	2977.70	9/29/2009	2947.60	12/21/2009	2950.50	---	---	---
BT-78J[2]	SE¼ SE¼ SE¼ SE¼ sec. 17, T. 37 N., R. 34 W.	2964.30	9/29/2009	2935.50	12/21/2009	2935.50	---	---	---
BT-79A[2]	NE¼ NE¼ NE¼ NE¼ sec. 20, T. 37 N., R. 34 W.	2962.00	9/29/2009	2936.30	12/21/2009	2936.40	---	---	---
BT-77G[2]	SW¼ SW¼ SW¼ SW¼ sec. 28, T. 37 N., R. 34 W.	2990.40	9/29/2009	2904.90	1/12/2010	2905.20	---	---	---
BT-83F[2]	SW¼ SW¼ SW¼ SW¼ sec. 28, T. 37 N., R. 34 W.	2990.60	9/29/2009	2904.50	1/12/2010	2904.80	---	---	---
BT-83H[2]	NW¼ NW¼ NW¼ NW¼ sec. 30, T. 37 N., R. 34 W.	2981.70	9/29/2009	2931.80	1/12/2010	2931.80	---	---	---
BT-57AR[2]	NW¼ NE¼ NE¼ SE¼ sec. 18, T. 37 N., R. 35 W.	2977.00	9/29/2009	2959.75	1/11/2010	2960.00	---	---	---
BT-76D[2]	SE¼ SW¼ SW¼ NW¼ sec. 20, T. 37 N., R. 35 W.	2997.60	9/29/2009	2973.87	1/11/2010	2974.30	---	---	604
BT-78H[2]	SE¼ SE¼ SE¼ SE¼ sec. 21, T. 37 N., R. 35 W.	2990.80	9/29/2009	2964.40	1/11/2010	2964.20	---	---	---
BT-78G[2]	NE¼ NE¼ NE¼ NE¼ sec. 31, T. 37 N., R. 35 W.	3001.40	9/28/2009	2992.50	1/11/2010	2993.00	---	---	610
R2-2007-03	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 36 W.	3070.00	10/16/2009	3033.87	---	---	4/28/2010	3034.63	---

Table 1 — continued

Well name	Legal location	Casing-top elevaton[1]	Date	Water elevation[1]	Date	Water elevation[1]	Date	Water elevation[1]	Estimated saturated thickness (ft)
BT-77F[2]	NE¼ NE¼ NE¼ NE¼ sec. 31, T. 37 N., R. 36 W.	3187.00	9/29/2009	3059.69	1/11/2010	3059.70	---	---	---
BT-78C[2]	NE¼ NE¼ NE¼ NE¼ sec. 28, T. 37 N., R. 38 W.	3269.40	9/28/2009	3236.40	12/21/2009	3236.50	---	---	---
R20-2009-05	NE¼ NE¼ NE¼ NE¼ sec. 3, T. 37 N., R. 39 W.	3430.00	9/29/2009	3300.69	---	---	4/28/2010	3301.32	600
BT-80B[2]	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 39 W.	3324.50	9/29/2009	3308.57	12/20/2009	3308.90	---	---	---
BT-78A[2]	SE¼ SE¼ SE¼ SE¼ sec. 17, T. 37 N., R. 39 W.	3338.00	9/28/2009	3307.90	12/20/2009	3308.60	---	---	---
BT-77D[2]	NW¼ NW¼ NW¼ NW¼ sec. 25, T. 37 N., R. 39 W.	3291.50	9/28/2009	3266.80	1/11/2010	3267.00	---	---	---
BT-77C[2]	NW¼ NW¼ NW¼ NW¼ sec. 34, T. 37 N., R. 39 W.	3286.90	9/28/2009	3265.80	---	3266.60	---	---	---
R20-2009-08	NE¼ NE¼ NE¼ NE¼ sec. 5, T. 37 N., R. 40 W.	3472.00	10/16/2009	3398.72	---	---	4/28/2010	3399.42	520
R2-2004-28	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.	3401.00	10/16/2009	3358.20	---	---	4/28/2010	3359.40	663
R2-2004-29	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.	3400.00	10/16/2009	3359.75	---	---	4/28/2010	3359.15	---
BT-76A[2]	SE¼ SE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 34 W.	3026.70	9/29/2009	2952.40	1/12/2010	2953.70	---	---	592
BT-77A[2]	SW¼ SW¼ SW¼ SW¼ sec. 16, T. 38 N., R. 35 W.	2938.00	9/29/2009	2907.90	12/21/2009	2909.30	---	---	530
BT-77B[2]	NE¼ NE¼ NE¼ NW¼ sec. 23, T. 38 N., R. 35 W.	2926.60	9/29/2009	2911.02	12/21/2009	2910.60	---	---	---
R20-2009-12	SE¼ SE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 36 W.	3047.00	9/28/2009	2991.90	---	---	4/28/2010	2992.69	592
R2-2007-06	SE¼ SE¼ SE¼ SE¼ sec. 35, T. 38 N., R. 36 W.	3027.00	10/16/2009	2977.75	---	---	4/28/2010	2978.35	---
BT-79C[2]	NW¼ NW¼ NW¼ SW¼ sec. 22, T. 38 N., R. 38 W.	3347.00	9/28/2009	3162.70	11/23/2009	3162.90	---	---	---
R20-2009-07	SW¼ SW¼ SW¼ SW¼ sec. 31, T. 38 N., R. 39 W.	3447.00	10/05/2009	3353.08	---	---	4/28/2010	3353.38	620
BT-80A[2]	NE¼ NE¼ NE¼ NE¼ sec. 19, T. 39 N., R. 34 W.	2823.00	9/29/2009	2758.70	12/21/2009	2759.10	---	---	---
BT-79B[2]	SW¼ NW¼ SE¼ SE¼ sec. 19, T. 39 N., R. 39 W.	3412.00	9/29/2009	3264.00	12/21/2009	3264.40	---	---	---

[1] Water elevation and casing top elevation are in feet above mean sea level.
[2] Well measured and maintained by the Water Rights Program, Department of Environmental and Natural Resources.
All other wells measured and maintained by the Geological Survey Program, Department of Environment and Natural Resources.
[3] Natural spring.
[4] Well destroyed, water table was measured on 5/30/2007.

The altitude and configuration of the water table of the High Plains aquifer in the study area are shown on plate 4. The configuration and slope of the water table are similar to the configuration and slope of the land surface. The general direction of ground-water flow is from the west to east.

Hydraulic Properties

Seven pumping tests were performed using four wells installed in sediments of Arikaree Group (R2-2004-28, R2-2005-44, R2-2006-50, and R2-2007-03) and three wells installed in sediments of Ogallala Group (R2-2006-49, R2-2006-53, and R2-2007-06). Locations of these seven wells that were pumped are shown on plate 4. Results of processing data from pumping tests are conservative and represent average values of hydraulic conductivity for both aquifer units.

The results of analyzing pumping-test data are as follows.

- For sediments of Arikaree Group, the average hydraulic conductivity (K) was determined to be 2.70 feet per day (ft/day). That value of hydraulic conductivity is characteristic of fine sand or sandstone mix with silt and clay having relatively moderate permeability (U.S. Department of Interior, Bureau of Reclamation, 1985).

- For sediments of Ogallala Group, the average hydraulic conductivity was determined to be 14.40 ft/day. This value is characteristic of fine to coarse sand with high permeability (U.S. Department of Interior, Bureau of Reclamation, 1985).

The velocity of ground-water flow through the High Plains aquifer in Bennett County was calculated using the average hydraulic conductivities and the average horizontal hydraulic gradients in Arikaree Group and Ogallala Group sediments. The velocity of ground-water flow in the High Plains aquifer was calculated using Darcy's law. The equation is:

$$Vav = Kav(ft/day)(i)$$

Where:

Vav = average velocity of ground water in ft/day,
Kav = average hydraulic conductivity in ft/day,
i = hydraulic gradient (no units)

The average hydraulic gradient for the High Plains aquifer in Bennett County used in the calculation was 19 feet per mile, or 0.004.

The calculated average velocity of ground water (Vav) for sediments of the Arikaree Group is 0.011 ft/day, and for sediments of Ogallala Group is 0.057 ft/day.

The ground water level data from monitoring wells in the Arikaree and Ogallala Groups of the High Plains aquifer show that two units (groups) are hydraulically connected. The

hydrographs presented in figure 2 show that fluctuation of water levels in the selected monitoring wells is similar regardless of aquifer unit or depth of well.

Water Quality

To evaluate ground-water quality in the High Plains aquifer in Bennett County, chemical analyses were performed on water samples from 18 monitoring wells installed for this study, 13 wells which are part of the Water Rights Program, Department of Environment and Natural Resources, well network, and 1 spring. All 31 monitoring wells are completed in the High Plains aquifer.

All water samples were analyzed for general inorganic chemistry, trace metals, and radionuclides. A summary of analytical results from these 32 samples is presented in tables 2 and 3. Major-ion data indicate that water in the High Plains aquifer is a calcium-bicarbonate and calcium-sodium-bicarbonate type (pl. 5; fig. 3).

As indicated in tables 2 and 3, water collected from the monitoring wells generally is of good quality. The total dissolved solids generally range from 102 to 508 milligrams per liter (mg/L) (pl. 5), and hardness ranges in concentration from 14 to 286 mg/L. The exception is one sample taken from the Water Rights well BT-57AR installed in alluvium of the Little White River which has high concentrations of total dissolved solids (1,581 mg/L), hardness (911 mg/L), calcium, magnesium, potassium, and sulfate (table 2). Concentrations of nitrate plus nitrite as nitrogen in all 32 samples are less than the South Dakota Drinking Water Standard of 10 mg/L. All detected trace elements and radionuclides were at concentrations substantially less than their drinking water standard, except in the samples from monitoring wells M51-2009-02, R20-2009-04, BT-77B, BT-76D, and BT-57AR, which exceeded the drinking water standard of 15 picocuries per liter for gross alpha. Results of analyses of samples collected from monitoring wells R2-2005-44, R2-2006-50, M51-2009-01, M51-2009-04, BT-57AR, BT-80F, BT-77F, and BT-77B show that samples have equal or greater concentration of arsenic than the drinking water standard of 0.010 mg/L.

Table 2. Water-quality analyses for general inorganic constituents from the High Plains aquifer in Bennett County, South Dakota

			Parameter[1]															
Well name	Sample collection date	Location	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulfate	Bicarbonate	Carbonate	Iron	Manganese	Fluoride	Nitrate plus nitrite as nitrogen	Total dissolved solids	Hardness	Total alkalinity	pH
South Dakota Drinking Water Standard[2] (in row to the right)			---	---	---	---	---	---	---	---	---	---	4	10	---	---	---	---
R2-2004-28	11/17/2004	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R.40 W.	70.5	31.0	12.1	13.4	18.6	54.2	194	0	1.05	0.05	0.33	3.6	393	226	159	8.12
R2-2004-29	11/17/2004	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R.40 W.	43.9	<3	7.7	9.9	15.1	<10.0	205	0	0.86	0.03	0.44	1.2	255	141	168	8.18
R2-2006-50	11/21/2006	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.	4.4	4	0.7	8.7	103	24.1	226	10	<0.03	<0.02	1.17	0.3	369	14	209	8.63
R2-2006-53	5/30/2007	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.	21.4	<3	4	6.7	15.7	<10.0	127	0	<0.03	<0.02	0.5	<0.1	186	70	104	8.09
R2-2006-49	5/30/2007	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.	9.2	<3	1.6	4.3	2.7	<10.0	41	0	<0.03	<0.02	0.19	0.9	110	30	34	7.06
R2-2005-44	5/31/2007	NE¼ NE¼ NE¼ NE¼ sec. 4, T. 37 N., R. 34 W.	19.5	7	2.4	15.8	109	80	266	0	<0.03	<0.02	0.43	0.7	431	59	218	7.98
R2-2007-03	5/31/2007	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 36 W.	38.7	<3	4.7	7.79	11.4	41.1	234	0	<0.03	<0.02	0.32	1.2	350	116	192	7.79
R2-2007-06	5/31/2007	SE¼ SE¼ SE¼ SE¼ sec. 35, T. 38 N., R. 36 W.	46.1	7	10	14.2	28.8	27.1	227	0	<0.03	<0.02	0.25	1.0	324	156	186	7.72
M51-2009-01	9/23/2009	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.	21.4	<3	4.1	5.8	14.6	13.8	102	0	<0.03	<0.02	0.97	1.6	190	70	84	8.17
M51-2009-02	9/23/2009	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.	40.5	<3	5.8	14.1	70.2	81.3	255	0	<0.03	<0.02	0.38	1.1	408	125	209	7.92
BT-83A	9/23/2009	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.	11.7	<3	2.1	4.5	3.6	<10.0	55	0	<0.03	<0.02	0.2	1.2	111	38	45	7.64
M51-2009-04	9/23/2009	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.	23.1	8	3.9	11.5	85.4	86.4	224	0	0.07	<0.02	0.73	0.6	388	74	184	8.10
BT-80F	9/24/2009	SE¼ SW¼ SW¼ SW¼ sec. 31, T. 36 N., R. 33 W.	18.8	<3	3.3	4.3	7.0	<10.0	87	0	<0.03	<0.02	0.57	1.5	153	61	71	8.10
R20-2009-10	9/24/2009	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.	25.5	<3	3.2	5.8	5.6	<10.0	104	0	<0.03	<0.02	0.46	1.1	165	77	85	8.10
R20-2009-04	9/24/2009	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.	55.0	7	11.5	11.8	47.8	102	239	0	<0.03	0.07	0.60	0.4	403	185	196	8.10
M51-2009-05	9/28/2009	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.	31.4	<3	2.4	11.3	61.8	40.1	233	0	0.46	0.02	0.41	0.9	356	88	191	7.75
BT-80E	9/28/2009	NW¼ NW¼ NW¼ NW¼ sec. 32, T. 37 N., R. 33 W.	34.9	<3	2.9	8.5	3.9	<10.0	123	0	<0.03	<0.02	0.32	2.6	203	99	101	7.27
R20-2009-12	9/28/2009	SE¼ SE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 36 W.	27.9	<3	3.8	10.8	62.9	67.3	194	0	1.54	0.04	0.58	0.7	369	85	159	7.78
BT-83B	9/29/2009	NE¼ SW¼ SW¼ SE¼ sec. 18, T. 35 N., R. 35 W.	21.0	<3	3.2	5.8	3.6	<10.0	87	0	<0.03	<0.02	0.11	1.4	165	66	71	7.57
Johnson spring	9/29/2009	NE¼ NE¼ SW¼ SW¼ sec. 21, T. 36 N., R. 37 W.	8.9	<3	1.5	4.6	3.2	<10.0	41	0	<0.03	<0.02	0.23	1.3	102	28	34	7.42
BT-57AR	9/29/2009	NW¼ NE¼ NE¼ SE¼ sec. 18, T. 37 N., R. 35 W.	292	5	44.3	21.3	111	803	368	0	1.25	0.04	0.30	5.0	1581	911	302	7.48
BT-76D	9/29/2009	SE¼ SW¼ SW¼ NW¼ sec. 20, T. 37 N., R. 35 W.	82.3	10	17.7	14.1	51.0	75.4	395	0	0.05	<0.02	0.28	<0.2	506	278	324	7.41

Table 2 — continued

Well name	Sample collection date	Location	Parameter[1] Calcium	Chloride	Magnesium	Potassium	Sodium	Sulfate	Bicarbonate	Carbonate	Iron	Manganese	Fluoride	Nitrate plus nitrite as nitrogen	Total dissolved solids	Hardness	Total alkalinity	pH
South Dakota Drinking Water Standard[2] (in row to the right)			---	---	---	---	---	---	---	---	---	---	4	10	---	---	---	---
BT-77F	9/29/2009	NE¼ NE¼ NE¼ NE¼ sec. 31, T. 37 N., R. 36 W.	46.0	3	9.2	9.9	18.3	18.6	218	0	0.57	0.04	0.42	0.4	281	153	179	7.79
R20-2009-05	9/29/2009	NE¼ NE¼ NE¼ NE¼ sec. 3, T. 37 N., R. 39 W.	42.6	<3	7.8	8.9	19.6	12.9	207	0	0.14	0.02	0.53	0.5	262	138	170	7.90
BT-80B	9/29/2009	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 39 W.	85.6	54	17.6	14.9	9.8	50.0	199	0	0.09	<0.02	0.23	11.2	500	286	163	7.44
BT-77B	9/29/2009	NE¼ NE¼ NE¼ NW¼ sec. 23, T. 38 N., R. 35 W.	57.3	23	7.3	13.1	67.7	116	239	0	0.03	<0.02	0.43	3.4	508	173	196	7.82
BT-80A	9/29/2009	NE¼ NE¼ NE¼ NE¼ sec. 19, T. 39 N., R. 34 W.	58.2	11	5.8	8.4	33.1	34.4	234	0	0.22	<0.02	0.39	2.0	354	169	192	7.76
BT-79B	9/29/2009	SW¼ NW¼ SE¼ SE¼ sec. 19, T. 39 N., R. 39 W.	16.7	<3	1.8	8.0	1.0	<10.0	77	0	1.93	0.24	<0.06	<0.2	107	49	63	6.90
BT-80C	10/5/2009	SW¼ SW¼ SW¼ SW¼ sec. 9, T. 36 N., R. 38 W.	9.7	<3	2.0	5.5	2.9	<10.0	62	0	0.11	<0.02	0.18	1.1	110	32	51	7.35
BT-78KR	10/5/2009	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 37 N., R. 34 W.	36.6	<3	6.9	5.9	4.4	<10.0	161	0	0.36	0.03	0.26	1.0	187	120	132	7.81
R20-2009-08	10/5/2009	NE¼ NE¼ NE¼ NE¼ sec. 5, T. 37 N., R. 40 W.	36.8	<3	6.1	9.8	26.7	22.2	201	0	0.06	<0.02	0.64	0.3	255	117	165	7.94
R20-2009-07	10/5/2009	SW¼ SW¼ SW¼ SW¼ sec. 31, T. 38 N., R. 39 W.	57.0	5	10.8	10.2	24.4	30.1	270	0	0.17	0.51	0.44	<0.2	328	187	221	7.64

[1] All concentrations are in milligrams per liter with the exception of pH which is has no units.
[2] South Dakota Drinking Water Standards; Administrative Rules of South Dakota (ARSD) 74:04:12.

Table 3. Water-quality analyses for trace metals and radionuclides from the High Plains aquifer in Bennett County, South Dakota

			Parameter[1]												
Well name	Sample collection date	Location	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Thallium	Gross alpha
South Dakota Drinking Water Standard[2] (in row to the right)			0.006	0.01	2	0.004	0.005	0.1	1.3	0.015	0.002	0.1	0.05	0.002	15
R2-2004-28	11/17/2004	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.	<0.0004	0.008	0.139	<0.0004	<0.0002	0.0056	0.0035	0.002	<0.0001	0.0025	0.0067	<0.0001	20±5
R2-2004-29	11/17/2004	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.	<0.0004	0.006	0.194	<0.0004	<0.0002	0.0053	0.0015	0.0018	<0.0001	0.0013	<0.0006	<0.0001	12.3±3.4
R2-2006-50	11/21/2006	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.	0.0003	0.02	0.0428	<0.0001	<0.0001	0.0067	0.0035	0.0006	<0.0001	0.001	0.0011	<0.0001	7.4±1.6
R2-2006-53	5/30/2007	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.	<0.0002	0.007	0.062	<0.0002	<0.0002	0.0015	0.001	<0.0001	<0.0001	<0.0001	<0.0005	<0.0001	<0.6±1.7
R2-2006-49	5/30/2007	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.	<0.0002	<0.001	0.0621	<0.0002	<0.0002	0.0011	0.0004	<0.0001	<0.0001	0.0005	<0.0005	<0.0001	<0.6±0.1
R2-2005-44	5/31/2007	NE¼ NE¼ NE¼ NE¼ sec. 4, T. 37 N., R. 34 W.	<0.0002	0.011	0.0354	<0.0002	<0.0002	0.0066	0.002	<0.0001	<0.0001	0.0013	<0.0005	<0.0001	9.4±1.8
R2-2007-03	5/31/2007	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 36 W.	<0.0002	0.007	0.0574	<0.0002	<0.0002	0.0074	0.001	<0.0001	<0.0001	0.0019	0.0019	<0.0001	6.5±1.3
R2-2007-06	5/31/2007	SE¼ SE¼ SE¼ SE¼ sec. 35, T. 38 N., R. 36 W.	<0.0002	0.006	0.080	<0.0002	<0.0002	0.0048	0.0005	<0.0001	<0.0001	0.0022	0.0025	<0.0001	6.6±1.1
M51-2009-01	9/23/2009	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.	<0.0002	0.016	0.0699	<0.0002	<0.0002	0.0022	<0.0002	<0.0001	<0.0001	0.0009	<0.0005	<0.0001	0.7±0.4
M51-2009-02	9/23/2009	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.	<0.0002	0.007	0.0737	<0.0002	<0.0002	0.0023	<0.0002	<0.0001	<0.0001	0.0014	<0.0005	<0.0001	19.6±2.7
BT-83A	9/23/2009	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.	<0.0002	0.003	0.0590	<0.0002	<0.0002	0.0019	<0.0002	<0.0001	<0.0001	0.0009	0.0013	<0.0001	<0.6±0.2
M51-2009-04	9/23/2009	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.	<0.0002	0.016	0.0580	<0.0002	<0.0002	0.0022	<0.0002	<0.0001	<0.0001	0.0014	0.0012	<0.0001	8.3±0.1
BT-80F	9/24/2009	SE¼ SW¼ SW¼ SW¼ sec. 31, T. 36 N., R. 33 W.	<0.0002	0.010	0.0472	<0.0002	<0.0002	0.0024	<0.0002	<0.0001	<0.0001	0.0013	<0.0005	<0.0001	1.2±0.7
R20-2009-10	9/24/2009	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.	<0.0002	0.008	0.108	<0.0002	<0.0002	0.0026	<0.0002	<0.0001	<0.0001	0.0017	<0.0005	<0.0001	4.7±1.3
R20-2009-04	9/24/2009	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.	<0.0002	0.007	0.0687	<0.0002	<0.0002	0.0022	<0.0002	<0.0001	<0.0001	0.0027	0.0011	<0.0001	15.3±2.4
M51-2009-05	9/28/2009	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.	<0.0002	0.009	0.0673	<0.0002	<0.0002	0.0013	<0.0002	<0.0001	<0.0001	0.0025	0.0010	<0.0001	10.9±2.0
BT-80E	9/28/2009	NW¼ NW¼ NW¼ NW¼ sec. 32, T. 37 N., R. 33 W.	<0.0002	0.004	0.0906	<0.0002	<0.0002	0.0066	<0.0002	<0.0001	<0.0001	0.0021	0.0016	<0.0001	1.5±0.6
R20-2009-12	9/28/2009	SE¼ SE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 36 W.	<0.0002	0.009	0.0827	<0.0002	<0.0002	0.0013	<0.0002	<0.0001	<0.0001	0.0016	0.0012	<0.0001	12.0±2.1
BT-83B	9/29/2009	NE¼ SW¼ SW¼ SE¼ sec. 18, T. 35 N., R. 35 W.	<0.0002	<0.001	0.0590	<0.0002	<0.0002	0.0011	<0.0002	<0.0001	<0.0001	0.0012	<0.0005	<0.0001	<0.6±0.3

Table 3 — continued

Well name	Sample collection date	Location	Parameter[1] Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Thallium	Gross alpha
South Dakota Drinking Water Standard[2] (in row to the right)			0.006	0.01	2	0.004	0.005	0.1	1.3	0.015	0.002	0.1	0.05	0.002	15
Johnson spring	9/29/2009	NE¼ NE¼ SW¼ SW¼ sec. 21, T. 36 N., R. 37 W.	<0.0002	0.002	0.0564	<0.0002	<0.0002	0.0009	<0.0002	<0.0001	<0.0001	0.0005	<0.0005	<0.0001	0.6±0.3
BT-57AR	9/29/2009	NW¼ NE¼ NE¼ SE¼ sec. 18, T. 37 N., R. 35 W.	<0.0002	0.010	0.0664	<0.0002	<0.0002	<0.0002	<0.0002	<0.0001	<0.0001	0.0156	0.0132	<0.0001	123±14.3
BT-76D	9/29/2009	SE¼ SW¼ SW¼ NW¼ sec. 20, T. 37 N., R. 35 W.	<0.0002	0.009	0.0767	<0.0002	0.0004	<0.0002	<0.0002	0.0003	<0.0001	0.0045	<0.0005	<0.0001	17.9±2.8
BT-77F	9/29/2009	NE¼ NE¼ NE¼ NE¼ sec. 31, T. 37 N., R. 36 W.	<0.0002	0.012	0.0783	<0.0002	0.001	0.0011	<0.0002	0.0003	<0.0001	0.0021	<0.0005	<0.0001	6.1±1.3
R20-2009-05	9/29/2009	NE¼ NE¼ NE¼ NE¼ sec. 3, T. 37 N., R. 39 W.	<0.0002	0.008	0.138	<0.0002	<0.0002	0.0022	<0.0002	<0.0001	<0.0001	0.0022	<0.0005	<0.0001	7.5±1.4
BT-80B	9/29/2009	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 39 W.	<0.0002	0.006	0.154	<0.0002	<0.0002	0.0007	<0.0002	<0.0001	<0.0001	0.0047	0.0079	<0.0001	12.5±2.1
BT-77B	9/29/2009	NE¼ NE¼ NE¼ NW¼ sec. 23, T. 38 N., R. 35 W.	<0.0002	0.011	0.0250	<0.0002	<0.0002	0.0022	<0.0002	<0.0001	<0.0001	0.0022	0.0042	<0.0001	21.1±3.6
BT-80A	9/29/2009	NE¼ NE¼ NE¼ NE¼ sec. 19, T. 39 N., R. 34 W.	<0.0002	0.007	0.143	<0.0002	<0.0002	0.0004	<0.0002	<0.0001	<0.0001	0.0034	0.0045	<0.0001	10.2±1.8
BT-79B	9/29/2009	SW¼ NW¼ SE¼ SE¼ sec. 19, T. 39 N., R. 39 W.	<0.0002	<0.001	0.069	<0.0002	<0.0002	<0.0002	<0.0002	0.0004	<0.0001	0.0032	<0.0005	<0.0001	4.0±0.8
BT-80C	10/5/2009	SW¼ SW¼ SW¼ SW¼ sec. 9, T. 36 N., R. 38 W.	<0.0002	<0.001	0.0278	<0.0002	<0.0002	0.006	<0.0002	<0.0001	<0.0001	0.0009	<0.0005	<0.0001	2.3±0.5
BT-78KR	10/5/2009	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 37 N., R. 34 W.	<0.0002	0.003	0.105	<0.0002	<0.0002	0.0006	<0.0002	<0.0001	<0.0001	0.0026	<0.0005	<0.0001	8.4±1.2
R20-2009-08	10/5/2009	NE¼ NE¼ NE¼ NE¼ sec. 5, T. 37 N., R. 40 W.	<0.0002	0.008	0.152	<0.0002	0.0009	0.0005	<0.0002	<0.0001	<0.0001	0.0031	<0.0005	<0.0001	7.1±0.1
R20-2009-07	10/5/2009	SW¼ SW¼ SW¼ SW¼ sec. 31, T. 38 N., R. 39 W.	<0.0002	0.004	0.248	<0.0002	0.0021	<0.0002	<0.0002	<0.0001	<0.0001	0.0052	<0.0005	<0.0001	9.9±1.8

[1] All concentrations are in milligrams per liter with the exception of gross alpha, which is expressed in picocuries per liter.
[2] South Dakota Drinking Water Standards; Administrative Rules of South Dakota (ARSD) 74:04:12.

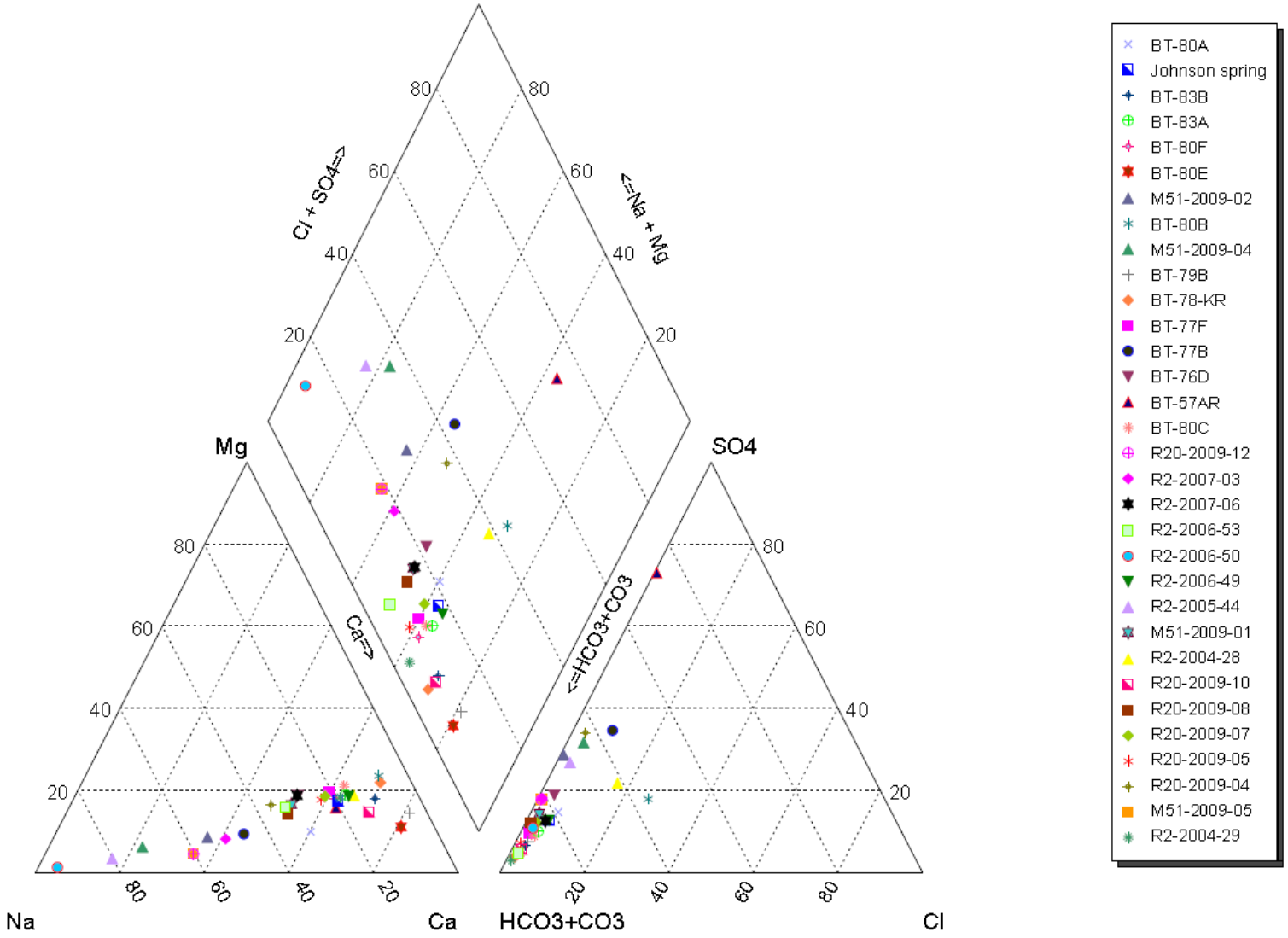

Figure 3. Trilinear diagram showing major ions in water sampled from the High Plains aquifer in Bennett County, South Dakota.

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the hydrogeology of the High Plains aquifer in Bennett County. The major water resource of this county is ground water from the High Plains aquifer.

The surface geology of Bennett County consists of fluvial and eolian deposits. The High Plains aquifer in this South Dakota county is comprised primarily of the Arikaree Group, Ogallala Group, eolian sediments (Sand Hills), and recent alluvium. Sediments of the White River Group directly underlie the aquifer in Bennett County.

Sediments of the High Plains aquifer are present in all of Bennett County (1,191 square miles). The aquifer is the thickest in southwest Bennett County and is under unconfined conditions. From September 2009 through April 2010, when data for this study were collected, water-level fluctuations ranged from a few inches to 1.4 feet. Monitoring of selected wells over 30 years indicates a water-level fluctuation of approximately 5 to 13 feet. Recharge to the High Plains aquifer is by infiltration of precipitation. Discharge from the High Plains aquifer is through evapotranspiration, loss to streams and springs, and withdrawals from domestic, public, and irrigation wells. The hydraulic conductivity of the High Plains aquifer was calculated separately for sediments of the Arikaree Group and sediments of the Ogallala Group. The average hydraulic conductivity for Arikaree Group sediments was calculated to be 2.70 ft/day, and 14.4 ft/day for Ogallala Group sediments. Those results show that Ogallala Group sediments have a hydraulic conductivity approximately 5 times greater than Arikaree Group sediments. This is consistent with water yield from production wells installed (domestic and irrigation) in these two High Plains aquifer units in Bennett County. The average velocity of ground-water flow in Arikaree Group sediments was calculated to be 0.011 ft/day and 0.057 ft/day in Ogallala Group sediments. The average horizontal hydraulic gradient in the High Plains aquifer in Bennett County was calculated to be 0.004.

The quality of water in the High Plains aquifer in Bennett County meets South Dakota Drinking Water Standards with the exception of arsenic concentrations equal to or greater than 0.010 mg/L in eight wells and gross alpha concentrations of greater than 15 picocuries per liter in five wells. The High Plains aquifer in the study area has a concentration of total dissolved solids ranging from 102 to 508 mg/L with one exception. The exception is well BT-57AR with concentration of the total dissolved solids of 1,581 mg/L. Calcium, sodium, and bicarbonate are the dominant ions in the ground water throughout the study area.

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APPENDIX A

Test holes and wells used for the assessment of the High Plains aquifer in Bennett County, South Dakota

Test hole or well	Legal location
	T. 35 N., R. 33 W.
R2-93-27	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.
R2-93-28	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.
R2-93-29	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.
R2-93-30	NW¼ NW¼ SW¼ NE¼ sec. 20, T. 35 N., R. 33 W.
	T. 35 N., R. 35 W.
Private	NE¼ NE¼ sec. 3, T. 35 N., R. 35 W.
R20-94-28	SW¼ SW¼ SE¼ NW¼ sec. 7, T. 35 N., R. 35 W.
BT-83B	NE¼ SW¼ SW¼ SE¼ sec. 18, T. 35 N., R. 35 W.
	T. 35 N., R. 37 W.
BT-78D	SE¼ NW¼ SE¼ NE¼ sec. 19, T. 35 N., R. 37 W.
R2-2006-51	SE¼ NW¼ SE¼ NE¼ sec. 19, T. 35 N., R. 37 W.
	T. 35 N., R. 39 W.
Private	SE¼ NW¼ sec. 7, T. 35 N., R. 39 W.
	T. 35 N., R. 40 W.
Private	SE¼ NW¼ sec. 16, T. 35 N., R. 40 W.
	T. 36 N., R. 33 W.
R2-92-50	SE¼ SW¼ NE¼ NW¼ sec. 17, T. 36 N., R. 33 W.
R2-92-53	SE¼ SW¼ NE¼ NW¼ sec. 17, T. 36 N., R. 33 W.
R2-92-54	SE¼ SW¼ NE¼ NW¼ sec. 17, T. 36 N., R. 33 W.
R2-92-55	SE¼ SW¼ NE¼ NW¼ sec. 17, T. 36 N., R. 33 W.
BT-80F	SE¼ SW¼ SW¼ SW¼ sec. 31, T. 36 N., R. 33 W.

Appendix A — continued

Test hole or well	Legal location
	T. 36 N., R. 34 W.
R20-2008-02	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.
R20-2009-10	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.
M51-2009-05	SE¼ NE¼ NE¼ NE¼ sec. 7, T. 36 N., R. 34 W.
BT-78I	SW¼ SW¼ SW¼ SW¼ sec. 18, T. 36 N., R. 34 W.
Private	NW¼ NW¼ sec. 30, T. 36 N., R. 34 W.
	T. 36 N., R. 35 W.
BT-83G	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 36 N., R. 35 W.
BT-83D	NE¼ NE¼ NE¼ NW¼ sec. 4, T. 36 N., R. 35 W.
BT-83I	NE¼ NE¼ SE¼ NW¼ sec. 11, T. 36 N., R. 35 W.
BT-83E	SW¼ SW¼ SW¼ SW¼ sec. 12, T. 36 N., R. 35 W.
BT-80D	SW¼ SW¼ SW¼ SW¼ sec. 15, T. 36 N., R. 35 W.
BT-83C	SE¼ NW¼ SE¼ SW¼ sec. 31, T. 36 N., R. 35 W.
	T. 36 N., R. 36 W.
Private	NE¼ NW¼ NE¼ SW¼ sec. 1, T. 36 N., R. 36 W.
Private	NE¼ NE¼ SW¼ NE¼ sec. 12, T. 36 N., R. 36 W.
BT-78F	SE¼ SE¼ SE¼ SE¼ sec. 22, T. 36 N., R. 36 W.
Private	SW¼ SW¼ sec. 26, T. 36 N., R. 36 W.
	T. 36 N., R. 37 W.
BT-78E	NW¼ NW¼ NW¼ NW¼ sec. 11, T. 36 N., R. 37 W.
M51-2009-03	NE¼ NW¼ NW¼ NE¼ sec. 19, T. 36 N., R. 37 W.
M51-2009-01	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.
M51-2009-02	NW¼ NW¼ NW¼ NW¼ sec. 20, T. 36 N., R. 37 W.
Private	SW¼ NE¼ SW¼ SW¼ sec. 21, T. 36 N., R. 37 W.
BT-83A	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.
R2-2006-52	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.
R2-2006-53	SE¼ SE¼ SE¼ SW¼ sec. 32, T. 36 N., R. 37 W.

Appendix A — continued

Test hole or well	Legal location
	T. 36 N., R. 38 W.
BT-76E	SE¼ SW¼ SE¼ SE¼ sec. 1, T. 36 N., R. 38 W.
Private	NE¼ SE¼ NE¼ sec. 8, T. 36 N., R. 38 W.
BT-80C	SW¼ SW¼ SW¼ SW¼ sec. 9, T. 36 N., R. 38 W.
BT-77E	SE¼ SE¼ SE¼ NE¼ sec. 10, T. 36 N., R. 38 W.
R20-97-32	SE¼ SE¼ SE¼ NE¼ sec. 10, T. 36 N., R. 38 W.
R20-97-33	SE¼ SE¼ SE¼ NE¼ sec. 10, T. 36 N., R. 38 W.
Private	NW¼ SE¼ sec. 15, T. 36 N., R. 38 W.
	T. 36 N., R. 39 W.
R20-2009-04	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.
M51-2009-04	SW¼ SW¼ SW¼ SE¼ sec. 1, T. 36 N., R. 39 W.
R20-2007-23	SE¼ SW¼ SE¼ SE¼ sec. 1, T. 36 N., R. 39 W.
BT-79-3	SE¼ SE¼ SE¼ SW¼ sec. 5, T. 36 N., R. 39 W.
R2-2006-48	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.
R2-2006-49	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.
R2-2006-50	SW¼ NW¼ SE¼ SW¼ sec. 7, T. 36 N., R. 39 W.
Private	NE¼ NW¼ sec. 9, T. 36 N., R. 39 W.
BT-78B	NE¼ NE¼ NW¼ NE¼ sec. 2, T. 36 N., R. 40 W.
	T. 36 N., R. 40W.
Private	NE¼ NE¼ sec. 23, T. 36 N., R. 40 W.
Private	NE¼ SE¼ sec. 33, T. 36 N., R. 40 W.
	T. 37 N., R. 33 W.
Private	SE¼ NW¼ NW¼ sec. 7, T. 37 N., R. 33 W.
Private	NE¼ SW¼ NE¼ sec. 7, T. 37 N., R. 33 W.
Private	SE¼ SW¼ sec. 16, T. 37 N., R. 33 W.
Private	SE¼ NW¼ sec. 17, T. 37 N., R. 33 W.
BT-76C	SW¼ SW¼ SW¼ SW¼ sec. 17, T. 37 N., R. 33 W.
R2-2005-42	SW¼ SW¼ SW¼ SW¼ sec. 18, T. 37 N., R. 33 W.

Appendix A — continued

Test hole or well	Legal location
	T. 37 N., R. 33 W. — continued
Private	NW¼ SE¼ sec. 20, T. 37 N., R. 33 W.
Private	NE¼ NW¼ sec. 32, T. 37 N., R. 33 W.
BT-80E	NW¼ NW¼ NW¼ NW¼ sec. 32, T. 37 N., R. 33 W.
	T. 37 N., R. 34 W.
BT-78KR	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 37 N., R. 34 W.
R2-2005-41 B	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 37 N., R. 34 W.
Private	NE¼ NE¼ sec. 4, T. 37 N., R. 34 W.
R2-2005-43	NE¼ NE¼ NE¼ NE¼ sec. 4, T. 37 N., R. 34 W.
R2-2005-44	NE¼ NE¼ NE¼ NE¼ sec. 4, T. 37 N., R. 34 W.
Private	NE¼ SW¼ SW¼ sec. 4, T. 37 N., R. 34 W.
Private	NE¼ SE¼ sec. 4, T. 37 N., R. 34 W.
Private	SW¼ SW¼ SW¼ sec. 5, T. 37 N., R. 34 W.
Private	NE¼ NE¼ sec. 9, T. 37 N., R. 34 W.
BT-76B	SE¼ SE¼ SE¼ NE¼ sec. 9, T. 37 N., R. 34 W.
Private	NW¼ SE¼ sec. 13, T. 37 N., R. 34 W.
BT-78J	SE¼ SE¼ SE¼ SE¼ sec. 17, T. 37 N., R. 34 W.
R20-94-30	SE¼ SE¼ SE¼ SE¼ sec. 17, T. 37 N., R. 34 W.
R20-94-31	SE¼ SE¼ SE¼ SE¼ sec. 17, T. 37 N., R. 34 W.
Private	NW¼ NW¼ SW¼ sec. 19, T. 37 N., R. 34 W.
BT-79A	NE¼ NE¼ NE¼ NE¼ sec. 20, T. 37 N., R. 34 W.
BT-77G	SW¼ SW¼ SW¼ SW¼ sec. 28, T. 37 N., R. 34 W.
BT-83F	SW¼ SW¼ SW¼ SW¼ sec. 28, T. 37 N., R. 34 W.
BT-83H	NW¼ NW¼ NW¼ NW¼ sec. 30, T. 37 N., R. 34 W.
	T. 37 N., R. 35 W.
BT-57AR	NW¼ NE¼ NE¼ SE¼ sec. 18, T. 37 N., R. 35 W.
BT-76D	SE¼ SW¼ SW¼ NW¼ sec. 20, T. 37 N., R. 35 W.
Private	SE¼ SE¼ NW¼ sec. 21, T. 37 N., R. 35 W.
BT-78H	SE¼ SE¼ SE¼ SE¼ sec. 21, T. 37 N., R. 35 W.
Private	SE¼ NW¼ sec. 27, T. 37 N., R. 35 W.

Appendix A — continued

Test hole or well	Legal location
	T. 37 N., R. 35 W. — continued
Private	SE¼ SE¼ sec. 28, T. 37 N., R. 35 W.
Private	NE¼ SE¼ NW¼ SW¼ sec. 30, T. 37 N., R. 35 W.
BT-78G	NE¼ NE¼ NE¼ NE¼ sec. 31, T. 37 N., R. 35 W.
Private	NE¼ NW¼ SW¼ sec. 32, T. 37 N., R. 35 W.
	T. 37 N., R. 36 W.
R2-2007-02	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 36 W.
R2-2007-03	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 36 W.
Private	NE¼ SE¼ sec. 28, T. 37 N., R. 36 W.
Private	SE¼ NW¼ sec. 30, T. 37 N., R. 36 W.
BT-77F	NE¼ NE¼ NE¼ NE¼ sec. 31, T. 37 N., R. 36 W.
	T. 37 N., R. 37 W.
Private	NE¼ NE¼ sec. 6, T. 37 N., R. 37 W.
Private	SW¼ NW¼ NE¼ NW¼ sec. 9, T. 37 N., R. 37 W.
Private	SE¼ SW¼ sec. 17, T. 37 N., R. 37 W.
Private	SW¼ SE¼ sec. 17, T. 37 N., R. 37 W.
1	SW¼ NE¼ sec. 18, T. 37 N., R. 37 W.
Private	NE¼ SE¼ sec. 19, T. 37 N., R. 37 W.
	T. 37 N., R. 38 W.
Private	SE¼ SE¼ sec. 3, T. 37 N., R. 38 W.
Private	SE¼ SE¼ SE¼ sec. 3, T. 37 N., R. 38 W.
Private	NE¼ SE¼ sec. 18, T. 37 N., R. 38 W.
BT-78C	NE¼ NE¼ NE¼ NE¼ sec. 28, T. 37 N., R. 38 W.
	T. 37 N., R. 39 W.
R20-2009-05	NE¼ NE¼ NE¼ NE¼ sec. 3, T. 37 N., R. 39 W.
BT-80B	SE¼ SE¼ SE¼ SE¼ sec. 16, T. 37 N., R. 39 W.
BT-78A	SE¼ SE¼ SE¼ SE¼ sec. 17, T. 37 N., R. 39 W.

Appendix A — continued

Test hole or well	Legal location
	T. 37 N., R. 39 W. — continued
BT-77D	NW¼ NW¼ NW¼ NW¼ sec. 25, T. 37 N., R. 39 W.
Private	SW¼ SW¼ sec. 26, T. 37 N., R. 39 W.
BT-77C	NW¼ NW¼ NW¼ NW¼ sec. 34, T. 37 N., R. 39 W.
	T. 37 N., R. 40 W.
BT-78-1	NE¼ NE¼ NE¼ NE¼ sec. 1, T. 37 N., R. 40 W.
R20-2009-08	NE¼ NE¼ NE¼ NE¼ sec. 5, T. 37 N., R. 40 W.
R2-2004-30	NE¼ NE¼ NE¼ NE¼ sec. 7, T. 37 N., R. 40 W.
R2-2004-27	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.
R2-2004-28	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.
R2-2004-29	NW¼ SW¼ SW¼ SW¼ sec. 32, T. 37 N., R. 40 W.
	T. 38 N., R. 33 W.
Private	SE¼ NW¼ sec. 18, T. 38 N., R. 33 W.
Private	NW¼ NE¼ SE¼ sec. 18, T. 38 N., R. 33 W.
BIA	NW¼ NW¼ sec. 30, T. 38 N., R. 33 W.
	T. 38 N., R. 34 W.
BIA	NE¼ SW¼ sec. 7, T. 38 N., R. 34 W.
BIA	NE¼ NE¼ sec. 10, T. 38 N., R. 34 W.
Private	SE¼ NW¼ sec. 20, T. 38 N., R. 34 W.
Private	NE¼ NE¼ SW¼ sec. 23, T. 38 N., R. 34 W.
Private	SE¼ SE¼ sec. 31, T. 38 N., R. 34 W.
Private	NE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 34 W.
BT-76A	SE¼ SE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 34 W.
	T. 38 N., R. 35 W.
Private	NE¼ NW¼ sec. 16, T. 38 N., R. 35 W.
BT-77A	SW¼ SW¼ SW¼ SW¼ sec. 16, T. 38 N., R. 35 W.

Appendix A — continued

Test hole or well	Legal location
	T. 38 N., R. 35 W. — continued
BT-77B	NE¼ NE¼ NE¼ NW¼ sec. 23, T. 38 N., R. 35 W.
R2-2007-01	SW¼ SW¼ SW¼ SW¼ sec. 33, T. 38 N., R. 35 W.
	T. 38 N., R. 36 W.
Private	SE¼ SE¼ sec. 1, T. 38 N., R. 36 W.
Private	NE¼ SE¼ sec. 5, T. 38 N., R. 36 W.
R20-97-31	NE¼ NE¼ SE¼ NE¼ sec. 13, T. 38 N., R. 36 W.
R20-97-34	NE¼ NE¼ SE¼ NE¼ sec. 13, T. 38 N., R. 36 W.
Private	SE¼ NW¼ sec. 27, T. 38 N., R. 36 W.
Private	SW¼ SW¼ NW¼ SW¼ sec. 32, T. 38 N., R. 36 W.
R20-2009-12	SE¼ SE¼ SE¼ SE¼ sec. 32, T. 38 N., R. 36 W.
R2-2007-05	SE¼ SE¼ SE¼ SE¼ sec. 35, T. 38 N., R. 36 W.
R2-2007-06	SE¼ SE¼ SE¼ SE¼ sec. 35, T. 38 N., R. 36 W.
R2-2007-07	SE¼ SE¼ SE¼ SE¼ sec. 35, T. 38 N., R. 36 W.
	T. 38 N., R. 37 W.
Private	SW¼ SE¼ sec. 4, T. 38 N., R. 37 W.
Private	SW¼ SE¼ SE¼ SE¼ sec. 21, T. 38 N., R. 37 W.
Private	SE¼ NE¼ NE¼ NE¼ sec. 33, T. 38 N., R. 37 W.
Private	NE¼ NW¼ NW¼ NE¼ sec. 33, T. 38 N., R. 37 W.
	T. 38 N., R. 38 W.
Private	NE¼ SE¼ NE¼ NW¼ sec. 1, T. 38 N., R. 38 W.
BT-79C	NW¼ NW¼ NW¼ SW¼ sec. 22, T. 38 N., R. 38 W.
	T. 38 N., R. 39 W.
Private	SE¼ NW¼ SE¼ NE¼ sec. 9, T. 38 N., R. 39 W.
R20-2009-07	SW¼ SW¼ SW¼ SW¼ sec. 31, T. 38 N., R. 39 W.

Appendix A — continued

Test hole or well	Legal location
	T. 38 N., R. 40 W.
Private	NW¼ SE¼ sec. 9, T. 38 N., R. 40 W.
BIA	SW¼ NE¼ sec. 12, T. 38 N., R. 40 W.
R2-2004-31	NW¼ NW¼ NW¼ NW¼ sec. 29, T. 38 N., R. 40 W.
	T. 39 N., R. 34 W.
BT-80A	NE¼ NE¼ NE¼ NE¼ sec. 19, T. 39 N., R. 34 W.
	T. 39 N., R. 35 W.
Private	SW¼ SW¼ sec. 17, T. 39 N., R. 35 W.
Private	NE¼ SW¼ sec. 23, T. 39 N., R. 35 W.
Private	SW¼ SE¼ sec. 28, T. 39 N., R. 35 W.
Private	NW¼ SW¼ SW¼ sec. 29, T. 39 N., R. 35 W.
Private	SE¼ SW¼ NE¼ sec. 33, T. 39 N., R. 35 W.
	T. 39 N., R. 36 W.
Private	SW¼ NE¼ NW¼ sec. 3, T. 39 N., R. 36 W.
BIA	SE¼ SE¼ sec. 5, T. 39 N., R. 36 W.
BIA	NW¼ NW¼ sec. 23, T. 39 N., R. 36 W.
	T. 39 N., R. 37 W.
Private	SE¼ SE¼ sec. 13, T. 39 N., R. 37 W.
BIA	SW¼ SE¼ sec. 28, T. 39 N., R. 37 W.
	T. 39 N., R. 38 W.
BIA	SE¼ SE¼ sec. 8, T. 39 N., R. 38 W.
Private	SE¼ NE¼ sec. 14, T. 39 N., R. 38 W.
BIA	NW¼ NW¼ sec. 15, T. 39 N., R. 38 W.
BIA	SE¼ SE¼ sec. 18, T. 39 N., R. 38 W.

Appendix A — continued

Test hole or well	Legal location
	T. 39 N., R. 39 W.
BIA	SW¼ SW¼ sec. 6, T. 39 N., R. 39 W.
Private	NW¼ SW¼ sec. 9, T. 39 N., R. 39 W.
Private	SE¼ SE¼ sec. 10, T. 39 N., R. 39 W.
BIA	SE¼ NW¼ sec. 15, T. 39 N., R. 39 W.
Private	NE¼ SW¼ SW¼ SE¼ sec. 17, T. 39 N., R. 39 W.
BIA	SW¼ SW¼ sec. 18, T. 39 N., R. 39 W.
BT-79B	SW¼ NW¼ SE¼ SE¼ sec. 19, T. 39 N., R. 39 W.
Private	SE¼ NE¼ SW¼ SW¼ sec. 33, T. 39 N., R. 39 W.
Private	NE¼ SW¼ sec. 35, T. 39 N., R. 39 W.
	T. 39 N., R. 40 W.
Private	NW¼ SW¼ SE¼ NE¼ sec. 6, T. 39 N., R. 40 W.
Private	NE¼ SE¼ SW¼ SE¼ sec. 6, T. 39 N., R. 40 W.
R20-2008-01	NW¼ NW¼ SW¼ NW¼ sec. 27, T. 39 N., R. 40 W.