RICHLAND COUNTY FOX HILLS AQUIFER WELL INVENTORY: ASSESSING CONDITIONS OF FLOWING ARTESIAN WELLS

Kevin Chandler, Jon Reiten, and Mark Wolfram

Montana Bureau of Mines and Geology

DNRC Resource Planning Grant

Sponsored by Richland Conservation District

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Cover: A Fox Hills–Hell Creek flowing well in Richland County, Montana. Photo by Mark Wolfram, MBMG.

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INTRODUCTION

Users of wells completed in the Fox Hills–Hell Creek (FHHC) aquifer in Richland County have noticed significant declines in production and shut-in pressure over the past several decades. Wells in the Sidney area have lost over 100 ft of pressure head since they were drilled in the late 1970s to early 1980s. To address this problem, the Richland County Conservation District (RCCD), in cooperation with the Montana Bureau of Mines and Geology (MBMG), completed an inventory of Richland County FHHC aquifer wells in 2015. The FHHC aquifer is a regional aquifer underlying the eastern one-third of Montana (fig. 1). The depth to the aquifer in Richland County ranges from near the land surface in the northwestern part of the county to more than 1,500 ft below surface along the North Dakota border.

Many flowing wells in this aquifer were completed with 2-in metal casing to depths of more than 1,000 ft. These small casing diameters prohibit use of submersible pumps. When flowing conditions cease, production can be extended by using a surface pump. However, surface pumps cannot lift water beyond approximately 26 ft below the pump level, rendering these wells unusable.

Water-level monitoring has documented head declines of 1 to 4 ft per year during the past 40 years in Richland County as well as in neighboring counties in North Dakota (Honeyman, 2007). As a result of these declines, some of the wells have stopped flowing. The decrease in head may be the result of an overall decrease in aquifer pressure due to groundwater use or uncontrolled discharge from flowing wells. Alternatively, groundwater leaking through corroded casing into overlying aquifers with lower-pressure head may cause some wells to cease artesian flow. Controlling discharges from FHHC wells may reduce or eliminate water-level decline, and may potentially restore aquifer pressure. Controlling discharge from flowing wells by installing below frost level control valves, well pits, and in some cases lining leaking casing requires well owner interest. Based on our previous work (Reiten,

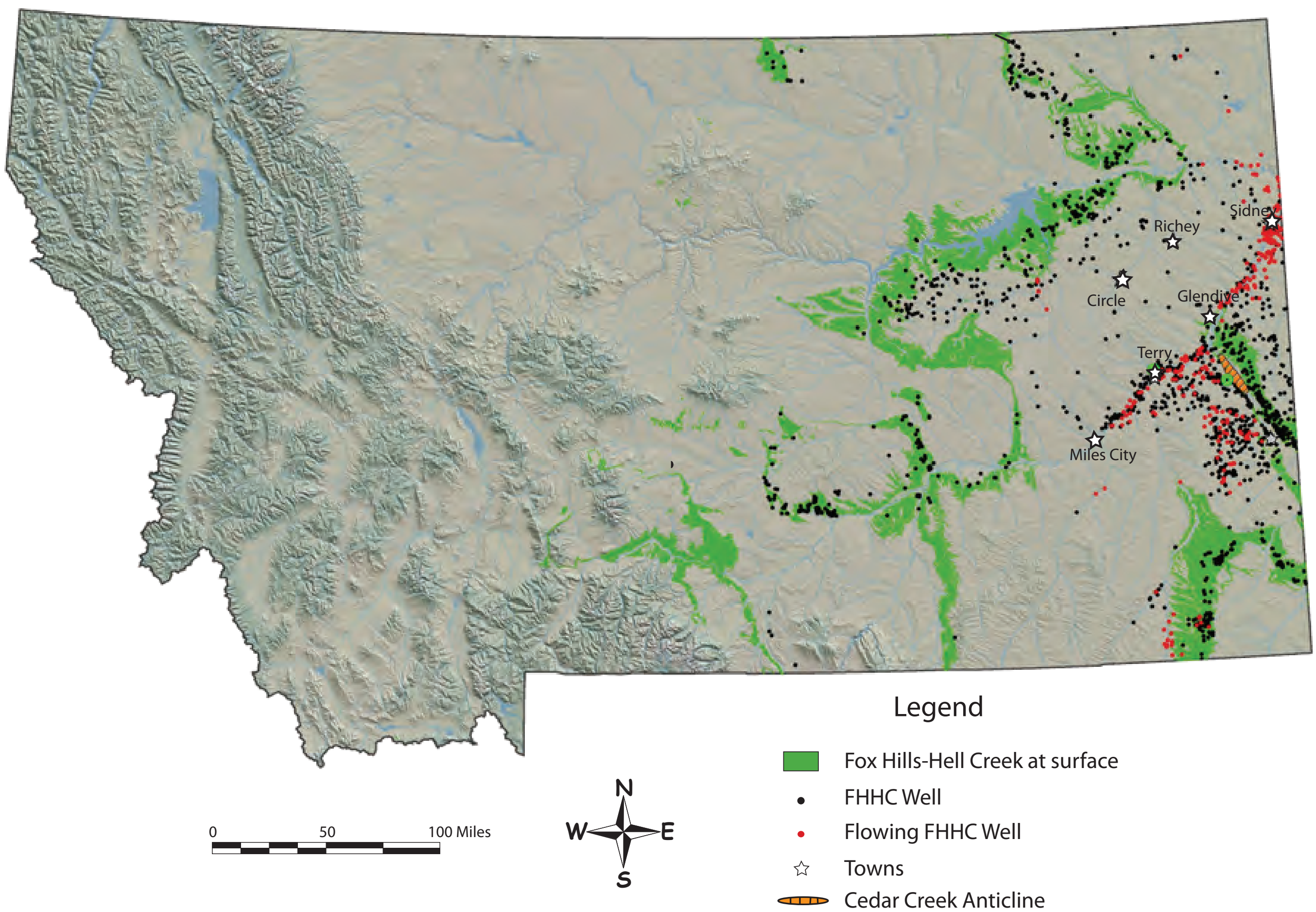

Figure 1. Location of outcrops of the FHHC aquifer in Montana. Wells and flowing wells completed in the FHHC are also shown.

unpublished report, 1995) controlling flowing wells in central Montana, well head pressure can recover and may make some FHHC wells in the higher elevation areas usable again.

Hydrogeologic Framework

The FHHC aquifer is typically found in the lower portion of the Late Cretaceous Hell Creek and Fox Hills Formations. Layers of loosely cemented sandstones in these formations act as a single confined aquifer with highly variable sandstone thickness, permeability, and potential water yield. A west-to-east cross section of the aquifer shows a simplified view of the stratigraphy with shale layers in the upper Hell Creek and the Fort Union Formations confining the aquifer material (fig. 2). The cross section represents approximately 220 mi from the Missouri River north of Jordan, Montana, through the Sidney area, and 60 mi into North Dakota. The blue line represents the approximate potentiometric surface, or the water level in wells completed in the aquifer. The cross section illustrates likely flowing well conditions where the potentiometric surface is above the land surface, such as in the Yellowstone River Valley.

Information from oil well geophysical logs provides better understanding of the variability of the aquifer structure. Geophysical logs were analyzed as part of an FHHC modeling project (Jay Gunderson, MBMG, written commun., 2013) Well logs show the FHHC aquifer is sandstone layers interbedded with clay and siltstone. The bottom of the aquifer is where the FH sandstone contacts the Bearpaw (Pierre) Shale. This contact is distinctive on the geophysical logs due to the massive and consistent nature of the Bearpaw (Pierre) Shale. The top of the aquifer is more difficult to pick due to the large changes in stratigraphy from well to well. Our well log analysis shows the geology is much more complex than the simplified stratigraphic model in the cross section (fig. 3).

The ability of the aquifer to supply water to a well depends on the thickness of permeable sandstone and the continuity of the aquifer material. Gunderson (MBMG, written commun., 2013) developed estimates of aquifer sand thickness and net sand in the aquifer to illustrate spatial changes in aquifer properties. The interpolated sand thickness map (fig. 4) indicates a thinning of the aquifer sandstone to the north and east in the area with the greatest water-level decline rates.

History of Water-Level Declines

Well owners in Richland County have reported declining static water levels (SWL) in the FHHC aquifer for more than a decade. In addition to this inventory, we verified these observations by comparing current SWL to measurements recorded when the wells were drilled. Measurements on six Sidney area wells that originally flowed show current SWL below land surface (fig. 5). In some wells where the SWL have dropped below land surface, the wells are now unusable or owners installed surface pumps to boost the pressure. Other FHHC wells in the Sidney area were not inventoried, and likely ceased to flow. The residents have not reported problems since Sidney community water system supplies water to these households, and they no longer use their FHHC wells. Most of the impacted wells are located along the valley slopes at slightly higher elevations than wells completed in the valley bottom. Many are remotely located stock water wells without electrical service. Appendix A contains hydrographs of impacted wells.

The MBMG Ground Water Assessment Program (GWAP) inventoried selected FHHC wells in 1993 and 1995. Long-term declines were discussed for a well

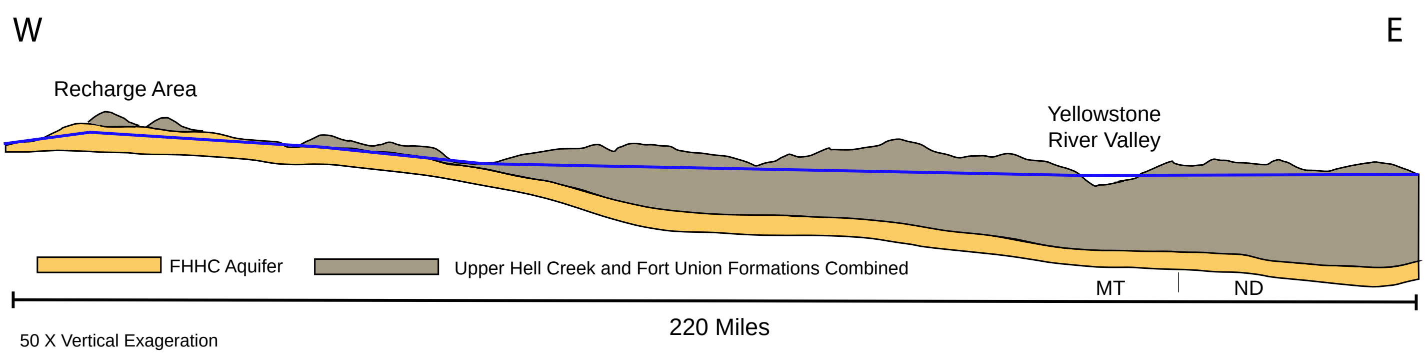

Figure 2. A two-layer stratigraphic model cross section shows the relative position of the FHHC aquifer, and the approximate potentiometric surface (blue line). The combined upper Hell Creek and Fort Union Formations are predominately mudstone confining layers.

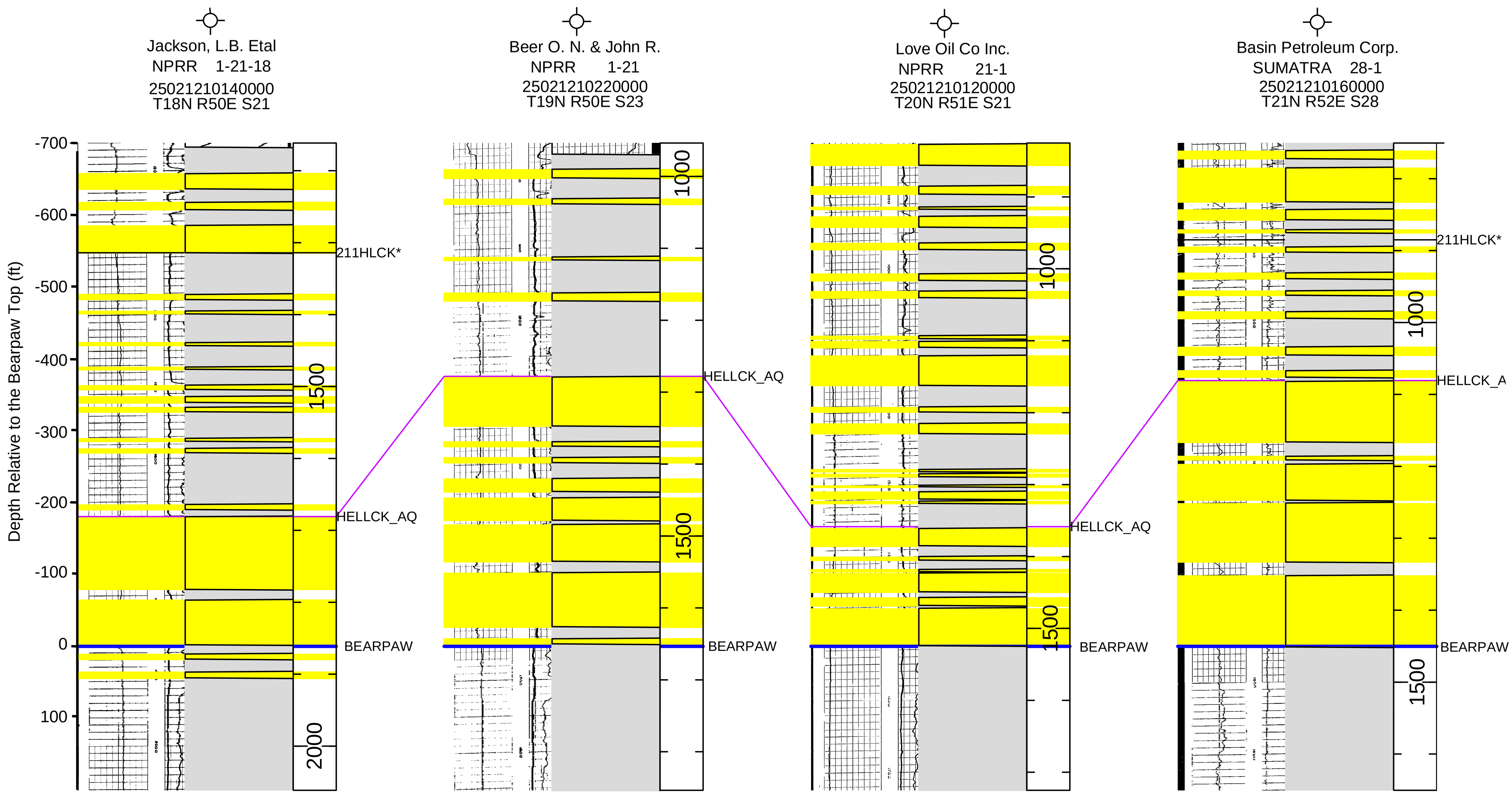

Figure 3. Oil well geophysical logs show the material variability in the FHHC aquifer. Sandstone intervals are colored yellow, and the logs leveled on the top of the Bearpaw (Pierre) Shale for comparison. (Well locations shown as blue line in fig. 4, Dawson County).

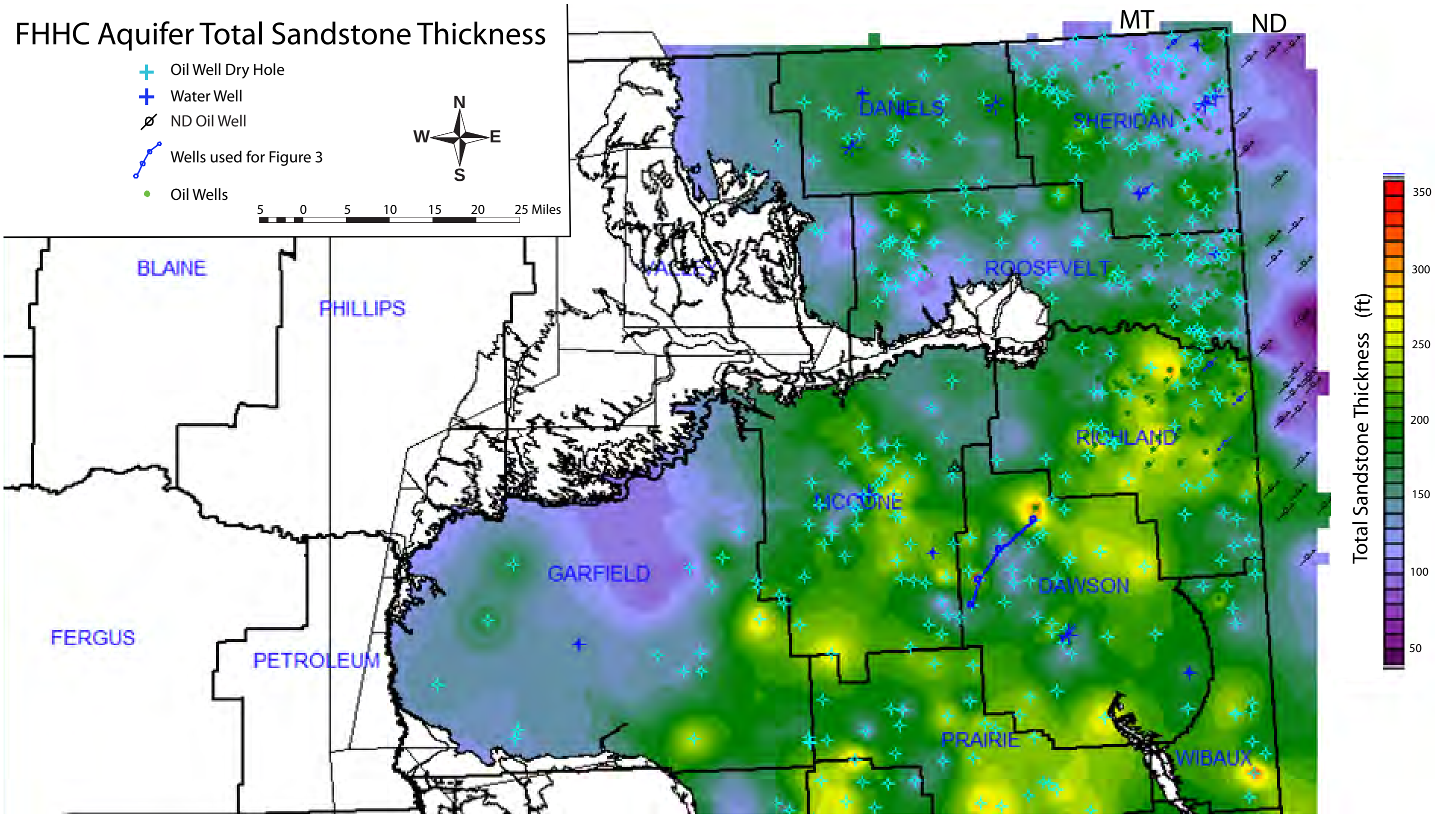

Figure 4. Total sand thicknesses in the FHHC aquifer, interpolated from oil well geophysical logs.

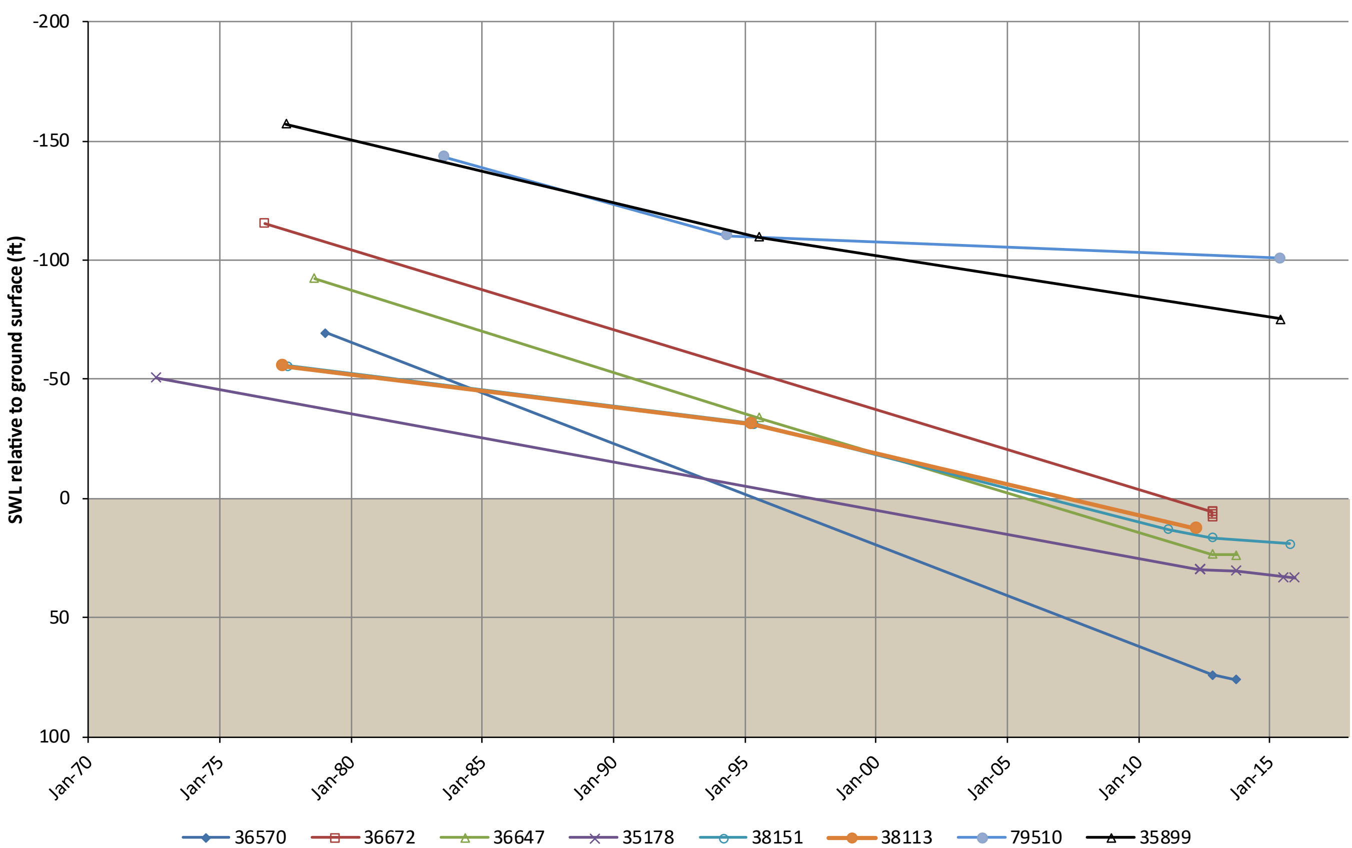

Figure 5. Water-level declines in eight Sidney-area FHHC wells show the trend in this area. Six of these wells are no longer flowing. (Wells are identified by their GWIC ID).

near Terry, Montana where the aquifer has declined at a rate of 1 ft/yr (LaFave, 1999). Water levels in the Sidney area wells inventoried had declined at a rate of over 3 ft/yr in the same time period.

METHODS

The MBMG Groundwater Information Center (GWIC), DNRC water rights, and USGS databases were queried to identify flowing wells in Richland County. Approximately 150 FHHC aquifer wells were reported to have flowed when originally constructed. The inventory initially focused on these wells, but was expanded to include wells without records in the databases. RCCD assisted the MBMG with identifying the current well owners to obtain access to the wells. Well owners and others interested in participating in the project were contacted for background information and permission to inventory their wells. Landowners helped to confirm the location, well depth, and other pertinent information about wells inventoried. Well locations were determined using GPS or Google Earth maps for each well site.

Static water levels, shut-in pressures, and flow rates at wells under artesian conditions were compared to those recorded when the wells were constructed. Field water-quality parameters including specific conductance (SC), pH, temperature, and chloride concentration (test strips) were measured and compiled. The physical condition of the wellhead was evaluated by noting the diameter and condition of the surface casing, the presence of valves to control production, and any winterization of the wellheads to prevent freezing if shut in. The well history was discussed with the owner and summarized. Fifteen wells inventoried in 1995 were revisited in 2015 to provide insight into the history of water-level fluctuations. Poor well head condition and plumbing modifications prevented SWL measurement at some locations.

RESULTS

Initial Well Search

The inventory focused on potential flowing wells identified through queries of the MBMG, DNRC, and USGS databases. The initial FHHC well list included wells coded with one of the four GWIC aquifer codes, 211FHHC, 211FXHL, 211COLG, and 211HLCK (appendix B). Not all FHHC wells recorded in GWIC have been coded with the proper aquifer code, and this initial search revealed less than 50 wells. An expanded search identified 181 wells completed in the FHHC aquifer, with 169 listing the date drilled. Most of the FHHC wells in Richland County were drilled in the 1970s and 1980s (fig. 6), and not all of the records have been preserved in the digital databases.

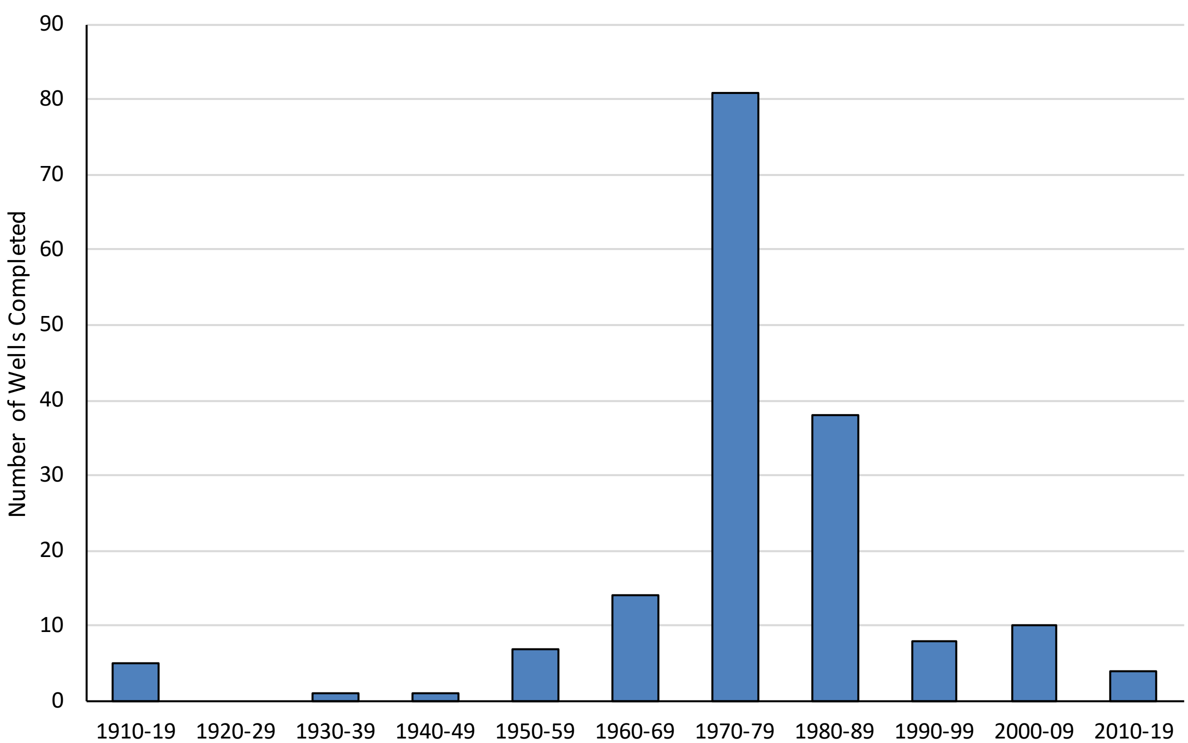

Figure 6. The number of wells constructed in the FHHC aquifer in Richland County by decade (MBMG Groundwater Information Center Database; mbmggwic.mtech.edu).

This inventory focused on FHHC wells that flowed when originally constructed. Wells were selected based on depth, casing diameter, aquifer, shut-in pressure, and reported flowing conditions. Many of the wells were not specified as flowing in the databases, but careful inspection of original drilling logs helped to identify wells that flowed when originally constructed. Well owners identified through cadastral searches and with the help of RCCD were contacted and asked to participate in the inventory. The search for additional well sites continued as new information was compiled during the inventory and wells not in the initial list were identified as potential inventory sites.

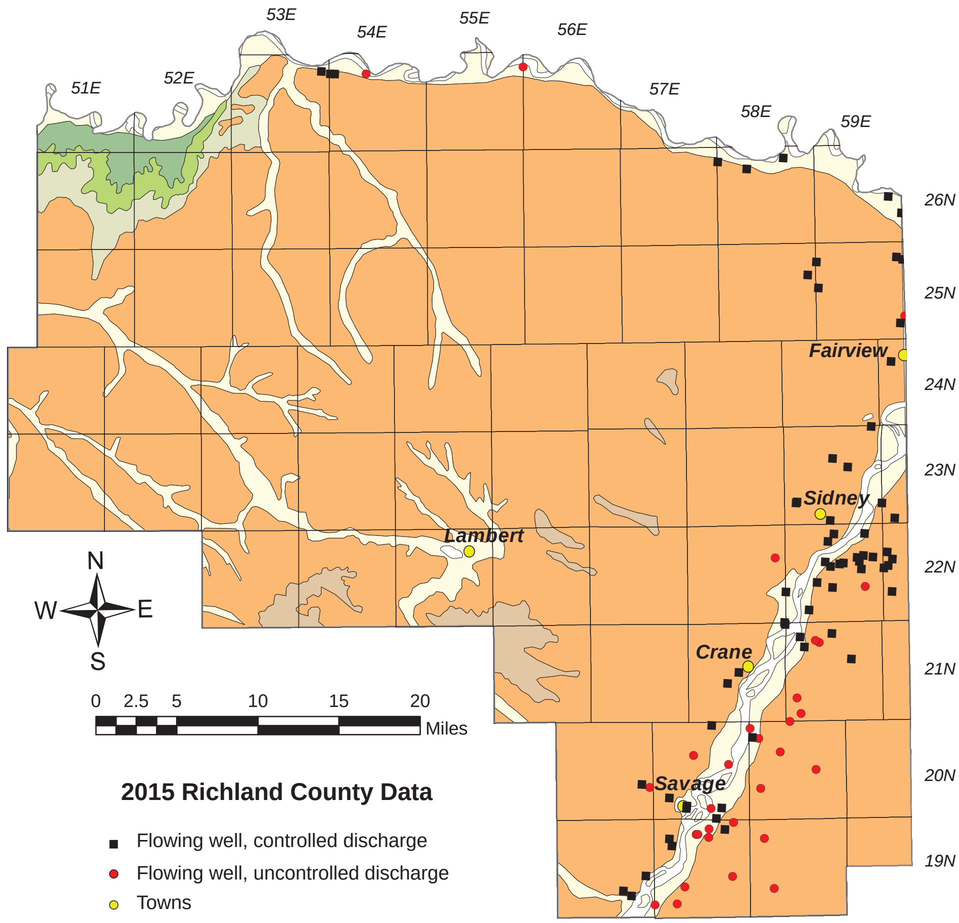

Figure 7. Locations of wells inventoried and well head condition assessed.

FHHC Aquifer Flowing Well Inventory

Preliminary database searches identified approximately 150 Richland County wells that flowed when completed. Well sites were visited and inventory data were recorded, compiled, and stored in GWIC. Attempts were made to contact well owners for all of the potentially flowing wells listed in table 1. Once owners were contacted and permission was obtained, MBMG personnel visited the well. A total of 102 wells were inventoried. The results of the inventories are summarized in table 1 and the locations mapped in figure 7.

Our requests to inventory private wells were generally successful. Permission to inventory 38 wells was not obtained during this project. Only eight well owners refused access to their wells, while other wells were not visited because we were unable to contact the well owner; the listed well was not a flowing FHHC aquifer well; or the well had been abandoned. An additional 16 wells have been recently identified as potentially flowing wells that were not found during the initial work.

Table 1. FHHC well water quality summary statistics.

	Total Depth (ft)	System Discharge (gpm)	Water Temp (°C)	Field SC (µS/cm)	Field pH	Chloride (mg/L)
Minimum	448	0.8	7	1,450	7.9	33
Maximum	1,505	45	23	2,870	9.0	185
Average	1,160	9	15	1,910	8.5	87
Median	1,228	8	15	1,850	8.5	81
Number of Samples	88	96	97	97	97	57

Flowing conditions in this area generally indicate production from the FHHC aquifer, although there are some flowing wells completed in the Fort Union Formation. Several of the water-quality parameters can be used to help determine if a well is indeed producing water from this aquifer. Relatively high water temperature (average = 15.3ºC), pH values around 8 or greater, measurable chloride concentrations (average = 87 mg/L), and moderately high SC values (range 1,400 to 3,000 µS/cm) all suggest a FHHC aquifer source (table 1). Water-quality parameters were collected as part of the well inventory and are listed in appendix B.

This inventory identified 31 wells that have uncontrolled flows (table 2). Many of these are candidates for rehabilitation to reduce water. When discharges from flowing wells are not controlled, a variety of problems can occur. These include water-level declines, accelerated erosion at the well head, and the spread of artificial wetlands downslope of the well site. Examples of problems encountered at the wells inventoried are shown in figures 8–14.

The wellhead repairs or modifications needed to correct the problems were not specified as part of this inventory. In most cases, potential fixes require the wellhead to be winterized and flow control valves installed. This can be accomplished by completing the wellhead in an insulated pit, a heated shed, or buried with valves installed below the frost line.

Updated Water-Level Decline Map

Hydrographs of selected wells demonstrate head declines (appendix A). Rate data from these wells were used to update head decline map (fig. 15). Many wells show significant head declines since they were drilled, with some levels dropping more than 100 ft. The largest decreases in water levels are along the Montana–North Dakota state line near Sidney and Fairview. This area in, or adjacent to, the Yellowstone River Valley contains a high density of FHHC aquifer wells. Coincidentally, most of the FHHC aquifer industrial wells constructed for oil development are also in this area.

Figure 8. Leaking valves and plumbing creating erosion and a wetland at the well head.

Table 2. List of wells visted during the 2015 Richland County FHHC inventory.

GWIC ID	Controlled Flow	Date Visited	Year Drilled	Original SWL (ft)	Original SWL Elevation (ft)	Current SWL (ft)	Current SWL Elevation (ft)	Change in SWL (ft)
2390	yes	9/4/15	1964	-66.9	1990.9	-18.50	1942.5	-48.4
32744	yes	8/23/15	1963	-129.9	2078.9	-67.00	2016	-62.9
32748	yes	9/26/15	1971	-207	2138	-131.7	2062.7	-75.3
32752	yes	7/18/15	1976	-219	2299	0	2227	-72
32758	yes	9/3/15				-147	2015	
32759	yes	9/2/15	1974	-161.4	2074.4	-150.20	2063.2	-11.2
32761	yes	9/25/15	1962	-92.4	2002.4	-104.00	2014	11.6
32764	yes	10/22/15	1971	-92.4	2003.4	-5.00	1916	-87.4
32769	yes	9/25/15	1968	-69.3	1975.3	-7.00	1913	-62.3
32780	yes	9/25/15	1980	-92.4	2013.4	-5.00	1926	-87.4
34259	yes	8/3/15	1974	-73.9	2014.9	-64.7	2005.7	-9.2
34283	yes	7/18/15	1970	-185		-87.8	1997.8	-63
34306	yes	7/20/15	1978	-173	2183	-122	2120	-48
34327	yes	7/20/15	1976		2103	-125	2055	
34332	yes	9/26/15	1971		1948	-129.4	2077.4	-97.0
34337	yes	7/15/15	1974	-143.22	2143.22	0	2046.2	2 9.2
34338	yes	10/12/15	1973			-46.2		-62.2
34339	yes	7/31/15	1979	-92.4	2002.4	-101.6	2011.6	-46.2
34340	yes	7/31/15	1973	-120	2175	-57.8	2112.8	-22
34344	yes	7/31/15	1980	-57.8	2060.8	-11.6	2014.6	
35227	yes	9/4/15	1966	-49.7	1988.7	-27.70	1966.7	
35238	yes	7/6/15	1979	-196.35	2099.35	-83.16	1986.16	-113.19
35242	yes	7/15/15	1974			-76.23	2116.23	
35244	yes	7/6/15	1968	-120.12	2045.12	-57.75	1982.75	-62.37
35246	yes	7/3/15	1985			-69.3	1979.3	
35247	no	7/2/15	1970	-129.36	2070.36	-23.1	1964.1	-106.26
35250	yes	6/17/15	1969	-124.74	2147.74		2023	-124.74
35268	yes	7/15/15	1974	-92.4	2056.4	-23.1	1987.1	-69.3
35725	no	6/22/15	1978	-80.85	2115.85			
35738	no	8/21/15	1972	-92.4	2052.4	-5.00	1965	-87.4
35771	yes	6/21/15	1983	-196.35	2110.35	-78.54	1992.54	-117.81
35773	yes	7/3/15	1971	-194.04	2117.04			
35780	yes	6/3/15	1974	-194.04	2167.04	-91.245	2064.245	-102.795
35852	yes	5/24/15	1980	-226.38	2198.38	-75.075	2047.075	-151.305
35861	yes	6/20/15	1978					
35864	yes	7/30/15	1980				1926	
35866	no	7/16/15	1976	28	1924			
35867	no	7/16/15	1977	-109	2139			
35873	no	6/4/15	1984	-138.6	2165.6	-92.4	2119.4	-46.2
35876	no	6/7/15	1989	-127.05	2119.05	-92.4	2084.4	-34.65
35890	yes	6/22/15	1978	-138.6	2308.6			
35899	yes	6/4/15	1977	-157.08	2182.08	-71.61	2096.61	-85.47
35909	yes	6/5/15	1978	-115.5	2096.5	-31.185	2012.185	-84.315
35912	yes	8/1/15	1974	-120	2217	-11.6	2108.6	-108.4

Table 2—*Continued.*

GWIC ID	Controlled Flow	Date visited	Year Drilled	Original SWL (ft)	Original SWL Elevation (ft)	Current SWL (ft)	Current SWL Elevation (ft)	Change in SWL (ft)
35917	no	7/1/15	1970	-196.35	2287.35	-48.51	2139.51	-147.84
35926	yes	6/21/15	1984	-147.84	2164.84			
35933	yes	6/17/15	1971	-173.25	2139.25	-99.33	2065.33	-73.92
35944	yes	6/5/15	1978	-196.35	2316.35		2120	-196.35
35949	yes	6/19/15	1985	-138.6	2124.6	-85.47	2071.47	-53.13
35952	yes	6/5/15	1979	-184.8	2164.8	-80.85	2060.85	-103.95
35955	yes	7/16/15	1968	148	1844			
36498	yes	6/3/15	1982	-115.5	2200.5	-88.47	2173.473	-27.027
36551	no	5/22/15	1982	-161.7	2116.7	-83.16	2038.16	-78.54
36625	no	8/22/15	1980			-60	2081	
36658	no	5/23/15	1979	-103.95	2194.95			
36762	no	5/22/15	1972		2014			
36789	yes	8/22/15	1980				2040	
37440	yes	10/10/15	1977	-161.7	2141.7	-50.80	2030.8	-110.9
38113	no	10/9/15	1977	-55.4	1997.4	-7.00	1949	-48.4
38146	no	9/28/15	1977	-127	2146	-60.10	2079.1	-66.9
38151	no	10/9/15	1977	-55.4	2044.4	13.00	1976	-68.4
38159	yes	9/7/15	1977	-182.5	2190.5	-99.30	2107.3	-83.2
38161	yes	10/10/15	1977	-53.1	2181.1			
38175	yes	10/9/15	1989	-115.5	2237.5	-78.50	2200.5	-37
38184	no	10/9/15	1980	-138.6	2098.6		1960	-138.6
38712	no	9/7/15	1979	-180	2139	-127.00	2086	-53
38713	no	9/28/15	1980	-180.2	2136.2	-166.30	2122.3	-13.9
38742	yes	10/8/15	1977	-212.5	2167.5	-143.20	2098.2	-69.3
38750	no	10/10/15	1979	-201	2285	-145.50	2229.5	-55.5
39390	no	9/6/15	1983	-34.7	1982.7	-50.80	1998.8	16.1
39400	no	9/6/15	1981	-57.8	2027.8	-50.8	2020.8	-7
39424	yes	9/4/15	1944	-52	2024	-41.6	2013.6	-10.4
79510	no	6/5/15	1983	-143.22	2171.22	-99.33	2127.33	-43.89
129233	no	8/19/15	1992	-110.9	2183.9	-106.3	2179.3	-4.6
132186	no	7/18/15	1970			-6.9	2130.9	
140084	no	6/19/15	1993	-120.12	2087.12	-106.26	2073.26	-13.86
149279	no	8/2/15				-87.8	2025.8	
180092	no	6/17/15	2000	-66.99	2084.99	-41.58	2059.58	-25.41
185519	yes	5/22/15	2000	-103.95	2063.95			
198076	yes	7/19/15	2002	-1.5	1979.5	15.03	1962.97	-16.53
200300	no	10/26/15	2002	129.4	1863.6			
209983	no	6/4/15	2004	-113.19	2025.19	-103.95	2015.95	-9.24
210188	no	7/3/15	2004	-80.85	2008.85			
250070	yes	7/6/15	2009			-78.54	2008.54	
251751	yes	7/6/15	2009			-83.16	2018.16	
255832	yes	10/12/15	2010	-117.8	2045.8	-124.70	2052.7	6.9
256498	yes	9/2/15	2010		1907	-143.2	2050.2	
257069	yes	9/26/15	1963	-34.6	1956.6		1922	-34.6
263081	yes	5/23/15	2011	32	1930			

Figure 9. Erosion from continual flow has exposed more than 10 ft of casing.

Figure 10. A wetland has formed from the overflow from the storage tank. The well head and plumbing needs to be winterized before flow could be shut during freezing conditions. (Well 35890.)

Figure 11. The surface casing (well 34259) has cracks from freezing. The casing and valves are leaking.

Figure 12. This tank has a control valve to shut the water off in the summer, but the valve is opened in the winter to prevent well head freezing (well 35268). The 2-in galvanized pipe casing is leaking around the cement grout.

Figure 13. Leaky valves created a pond around the stock tank at well 35912.

Figure 14. The well pit prevents freezing, but leaky plumbing is problematic. The pit cover is not secure, allowing animals to fall into the pit.

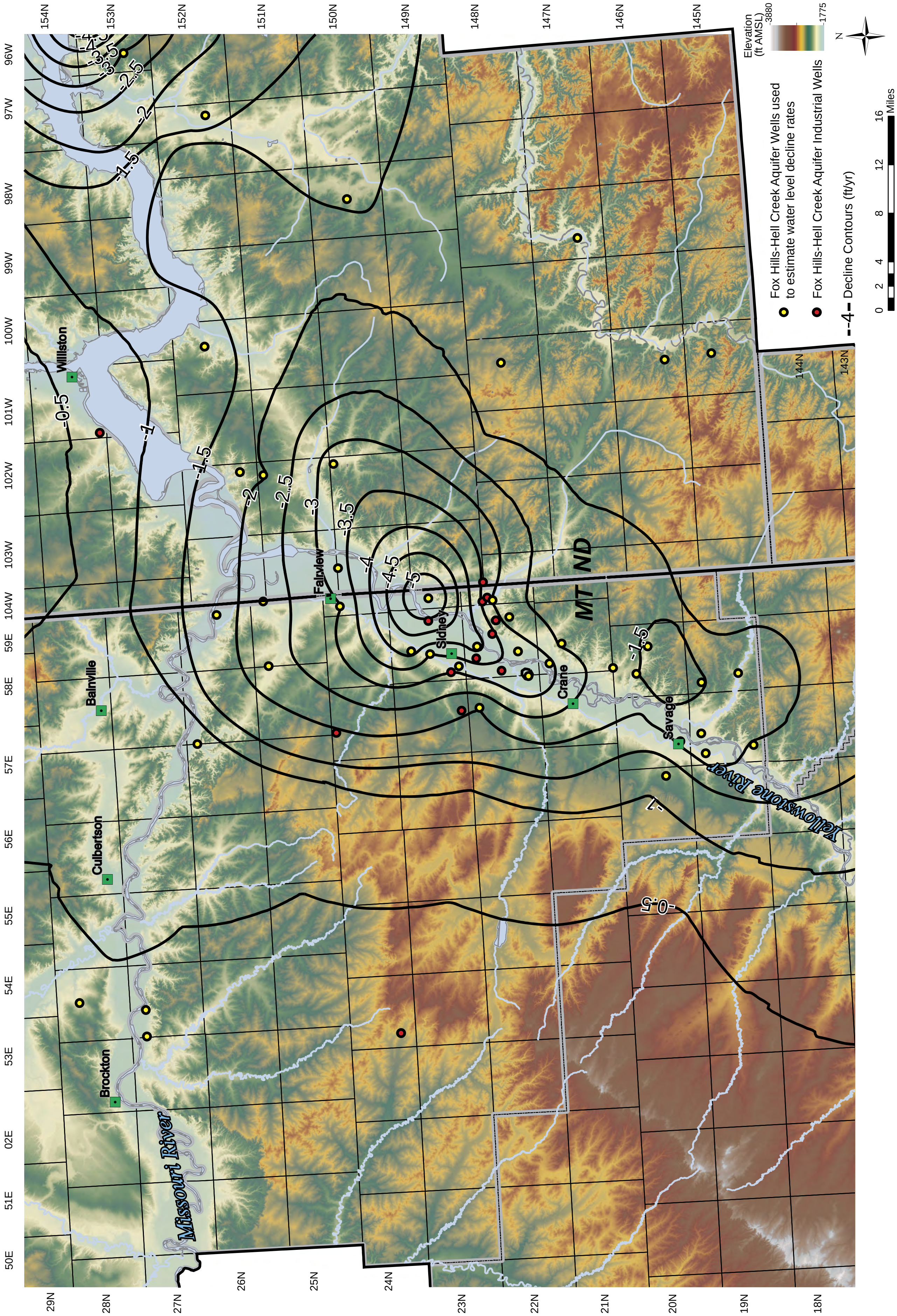

Figure 15. The rate of static water-level decline in feet/year in the FHHC aquifer.

DISCUSSION

This FHHC aquifer well inventory documents water-level declines and well head conditions for 102 wells in Richland County. We inventoried 11 wells not previously listed in the GWIC database. As water levels and artesian flow rates decline, and previously flowing wells cease to flow, a flattening of the water-level decline curve is expected. This trend has been observed in some wells monitored in Montana and North Dakota (fig. 16). However, new wells fitted with submersible pumps produce FHHC aquifer water as artesian flow from the aquifer is decreasing. This additional groundwater withdrawal may prevent a flattening of the water-level decline curve in some areas.

We mapped water-level decline rates for FHHC wells in Richland County and into ND, using rates (ft/yr) to normalize the data given the wide range in the duration of the record (fig. 16). The wells have different completion dates and periods of water-level record. If the water-level decline is nearly linear, as in the case of most of the Sidney area wells, the method works well. But at wells where the rate changes over time, the rate of decline depends highly on the time period sampled (fig. 15). If our only view was the last 10 yr of data from ND well 7877, it would show rising water levels, and not characterize long-term aquifer conditions. The interpolation of water-level decline rates could be improved if the data were limited to those with similar completion dates and water-level record periods, but this would severely reduce the number of wells in the dataset.

Not all of the FHHC wells included in this well survey showed a continuous declining trend. Several wells along the Missouri River have experienced small water-level declines since completion, and have no measurable decreases during the past 5 yr of continuous monitoring. All of these wells were installed with well pits, pressure tanks, and valves systems to use water only when needed (fig. 17). In figure 17, the white PVC pipe with two black-handled valves was plumbed into the system in 2011 to hold a pressure transducer that records hourly pressure readings. Data from the pressure transducers show a decline in aquifer pressure during extended periods of use, but then full recovery during low-use periods.

The head decline observed in the FHHC aquifer can be alleviated by an increase in recharge or a decrease in discharge. Recharge to the aquifer is extremely slow (LaFave, 1999). The recharge areas are small compared to the aquifer extent, and distant from the areas of greatest head decline (fig. 1), making artificial recharge impractical. However, it is possible

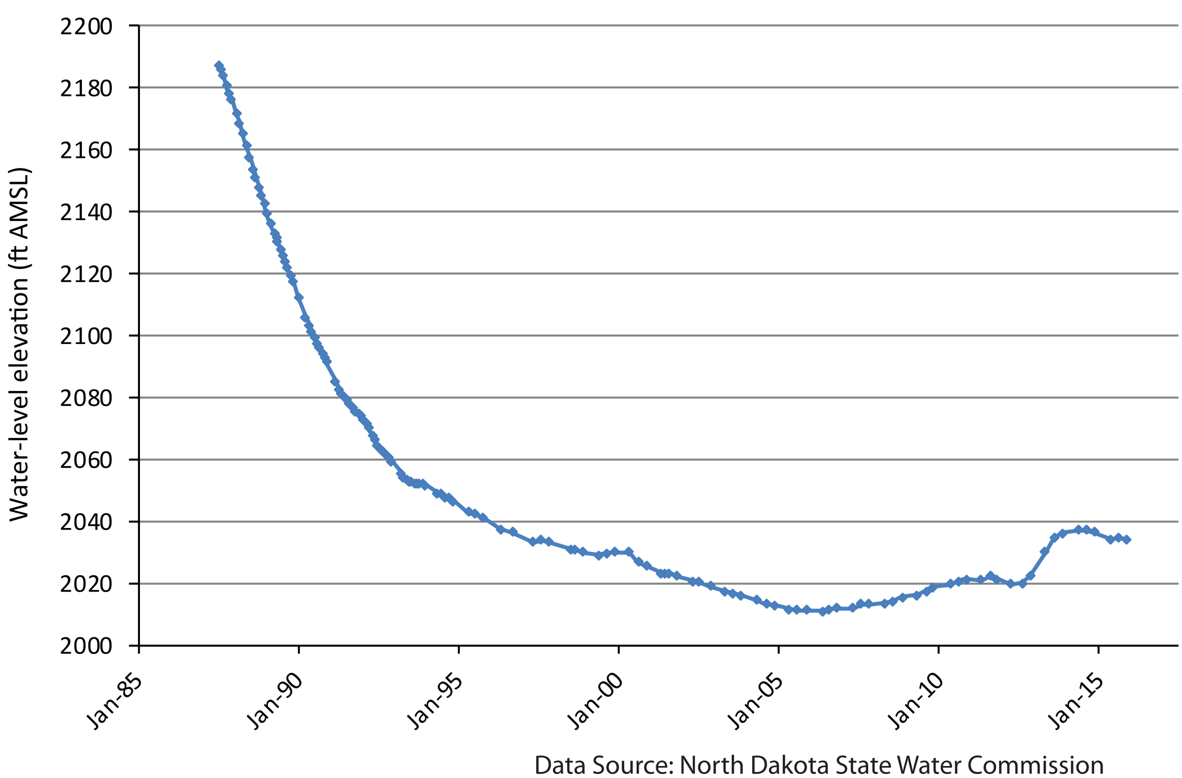

Figure 16. The rate of water-level decline changes with decreasing head in the aquifer.

Figure 17. Well pit at well 39461 prevents well head freezing.

to reduce aquifer discharge by using flowing wells only when needed and eliminating uncontrolled flow from such wells.

This project has identified 31 flowing wells that with proper winterized controls could reduce the volume of groundwater discharge. Many flowing wells in Montana and North Dakota will cease to flow if the current head trend continues (Honeyman, 2007). The decline in the FHHC aquifer pressure head is a regional problem. Reversing this trend will require extensive decreases in discharge volumes. Reducing the water wasted by continually flowing wells is an important first step.

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North Dakota State Water Commission., 2015, North Dakota State Water Commission & Office of the State Engineer: North Dakota State Water Commission, available at http://www.swc.state.nd.us/info_edu/map_data_resources/ [Accessed 2016].

APPENDIX A

FHHC WELL HYDROGRAPHS

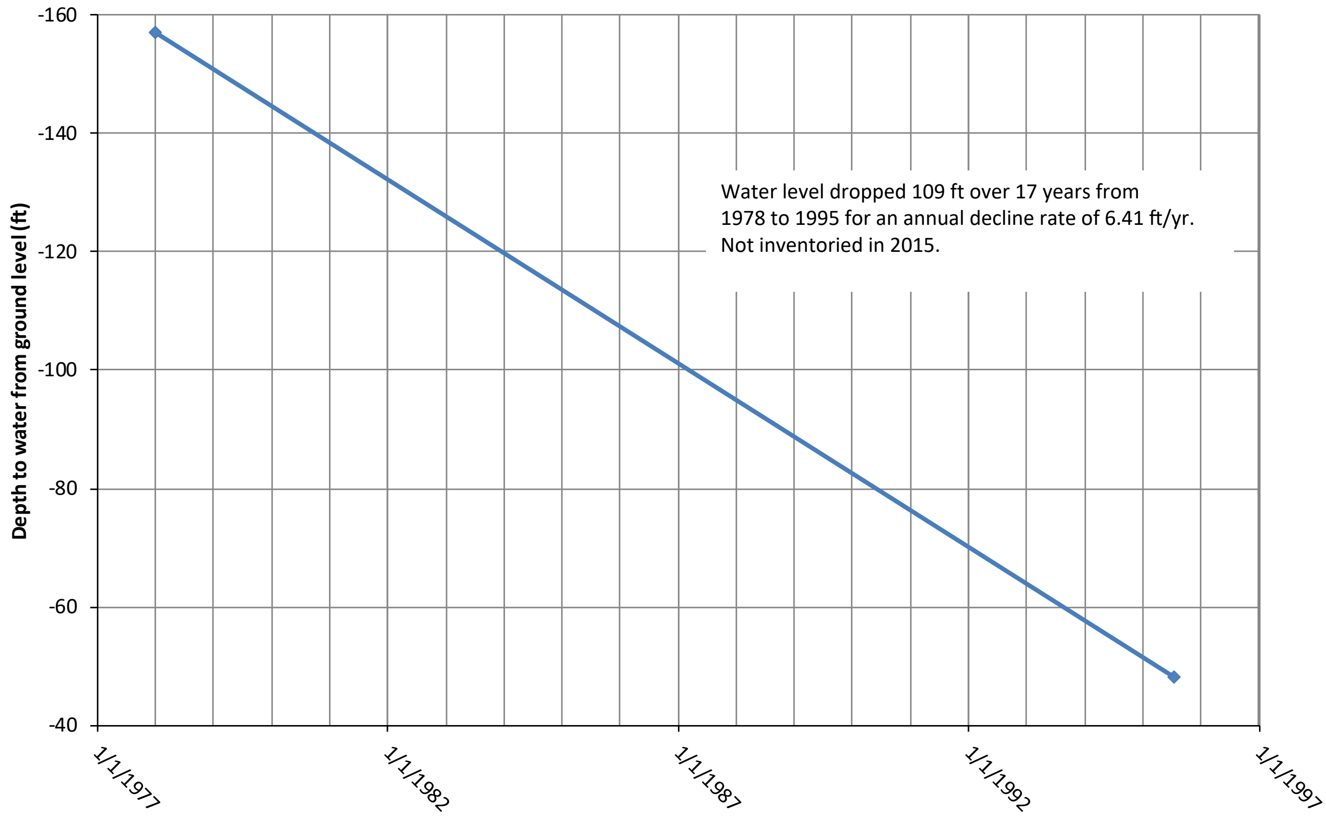

Figure A1. Water-level decline at FHHC well 36785 (Dahl) north of Sidney, MT (T. 23 N., R. 60 E., 19ADBA).

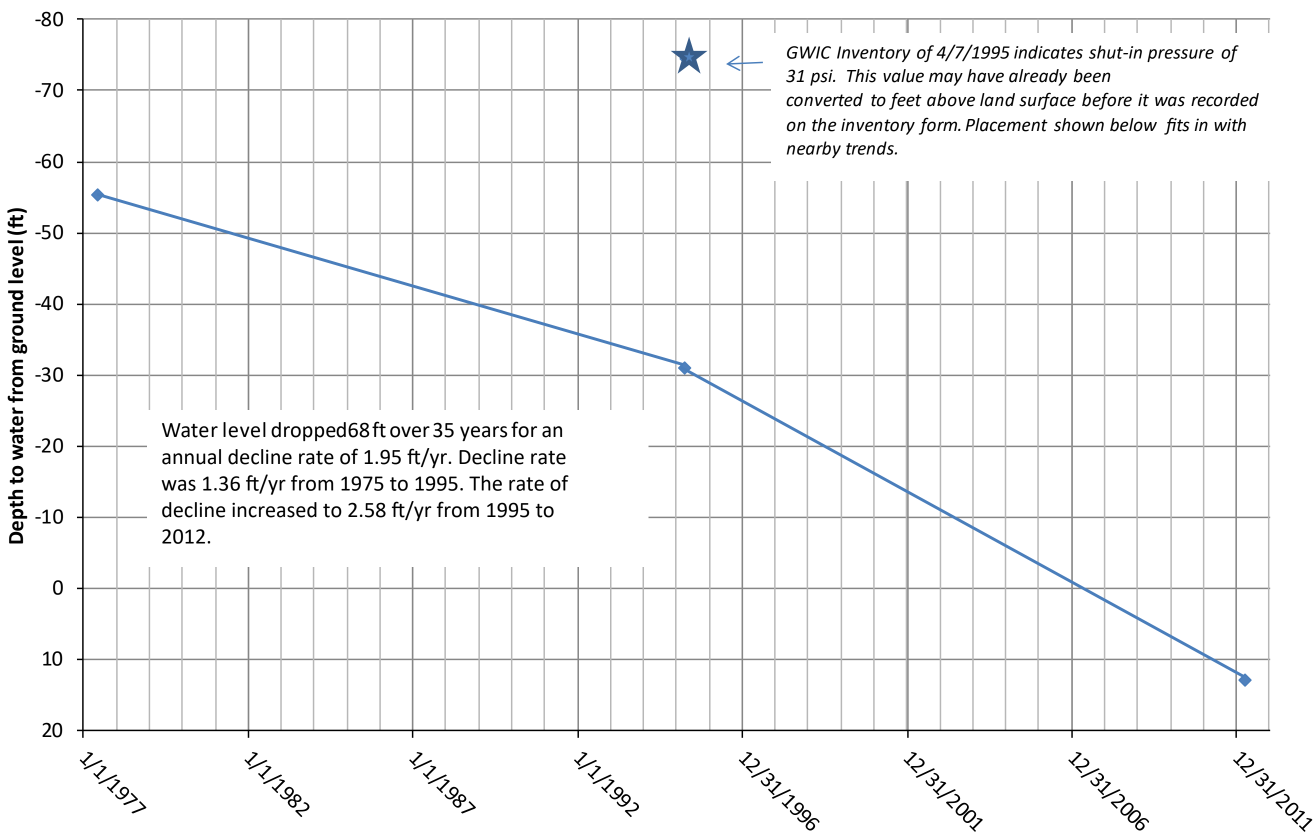

Figure A2. Water-level decline at FHHC well 38113 (Christensen) northwest of Fairview, MT (T. 25 N., R. 58 E., 12CDDD).

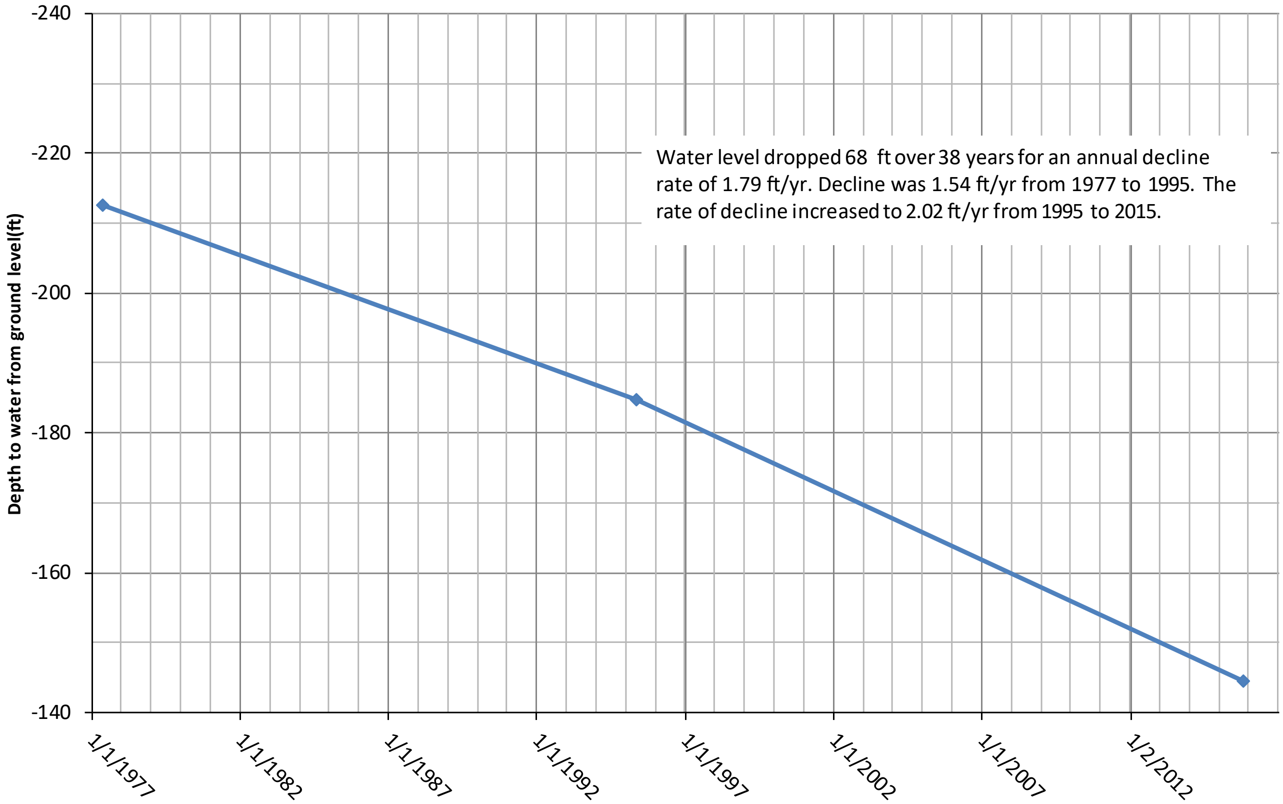

Figure A3. Water-level decline at FHHC well 38742 (Cayko) north of Fairview, MT near the Missouri River (T. 25 N., R. 59 E., 23ABCB).

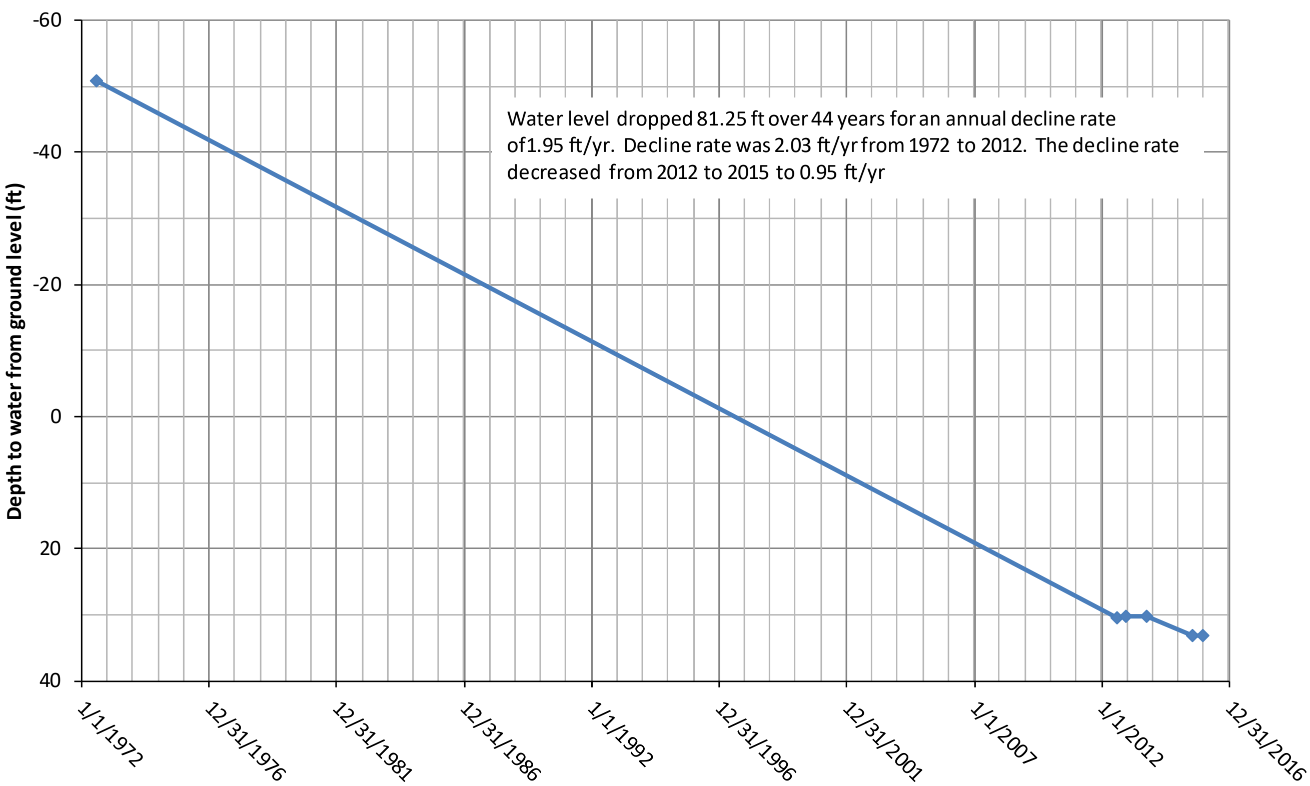

Figure A4. Water-level decline at FHHC well 35178 (Bakken) northwest of Crane, MT (T. 21 N., R. 58 E., 3CBBB).

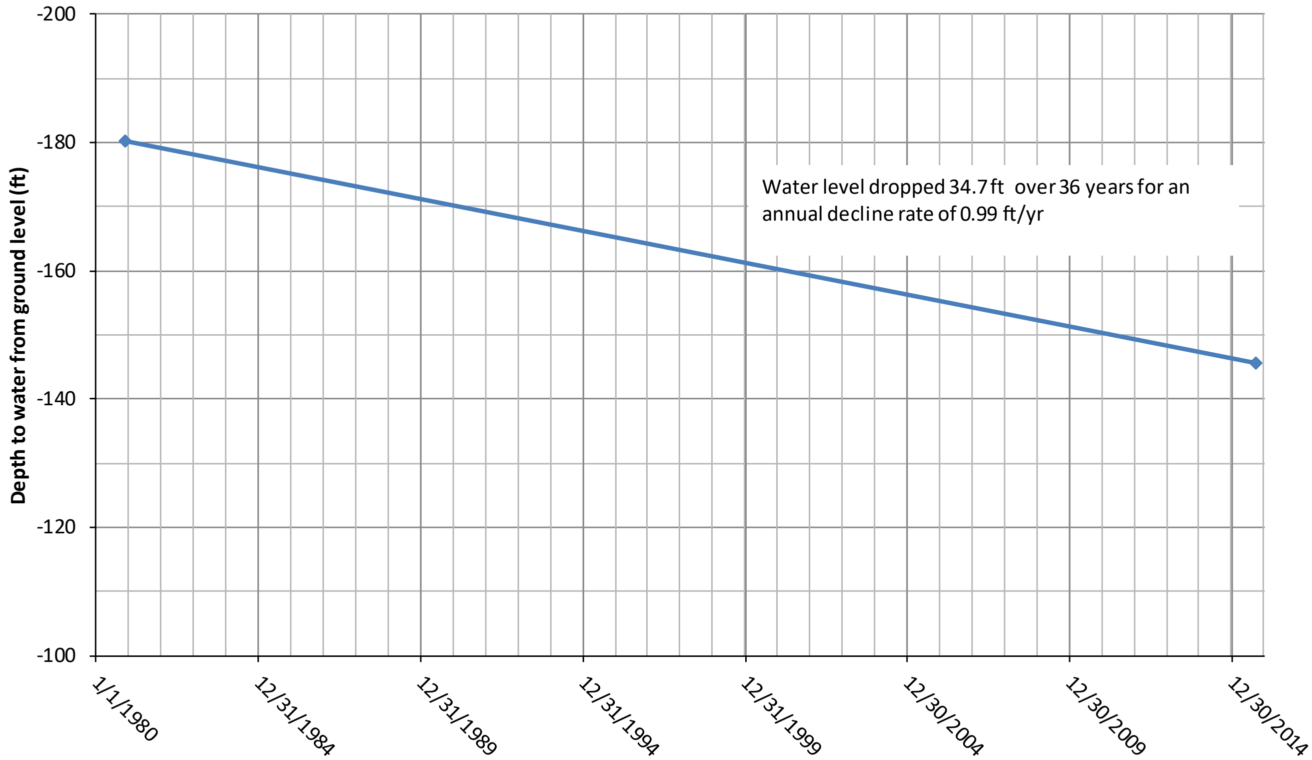

Figure A5. Water-level decline at FHHC well 38713 (Hardy) north of Fairview, MT near the Missouri River (T. 26 N., R. 58 E., 8ACD).

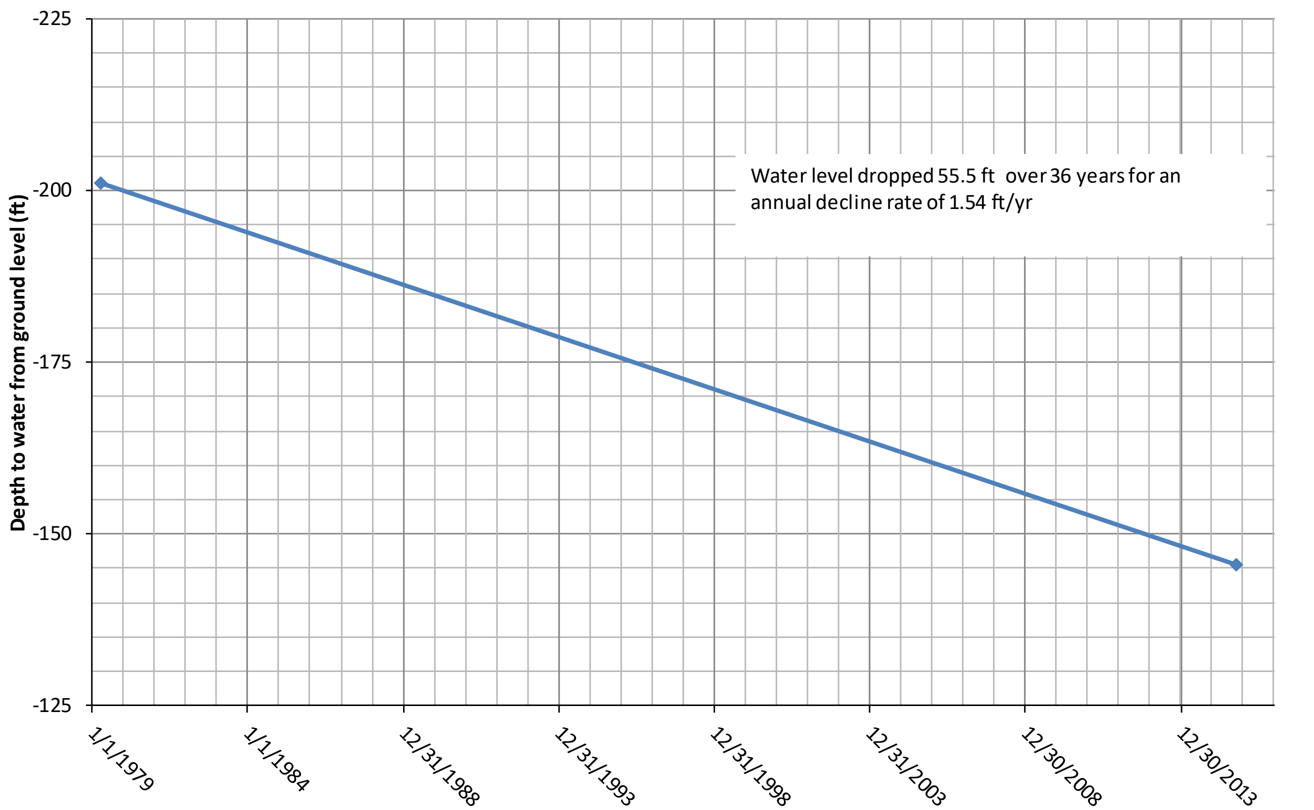

Figure A6. Water-level decline at FHHC well 38750 (Hunter) north of Fairview, MT near the Missouri River (T. 26 N., R. 59 E., 25AADD).

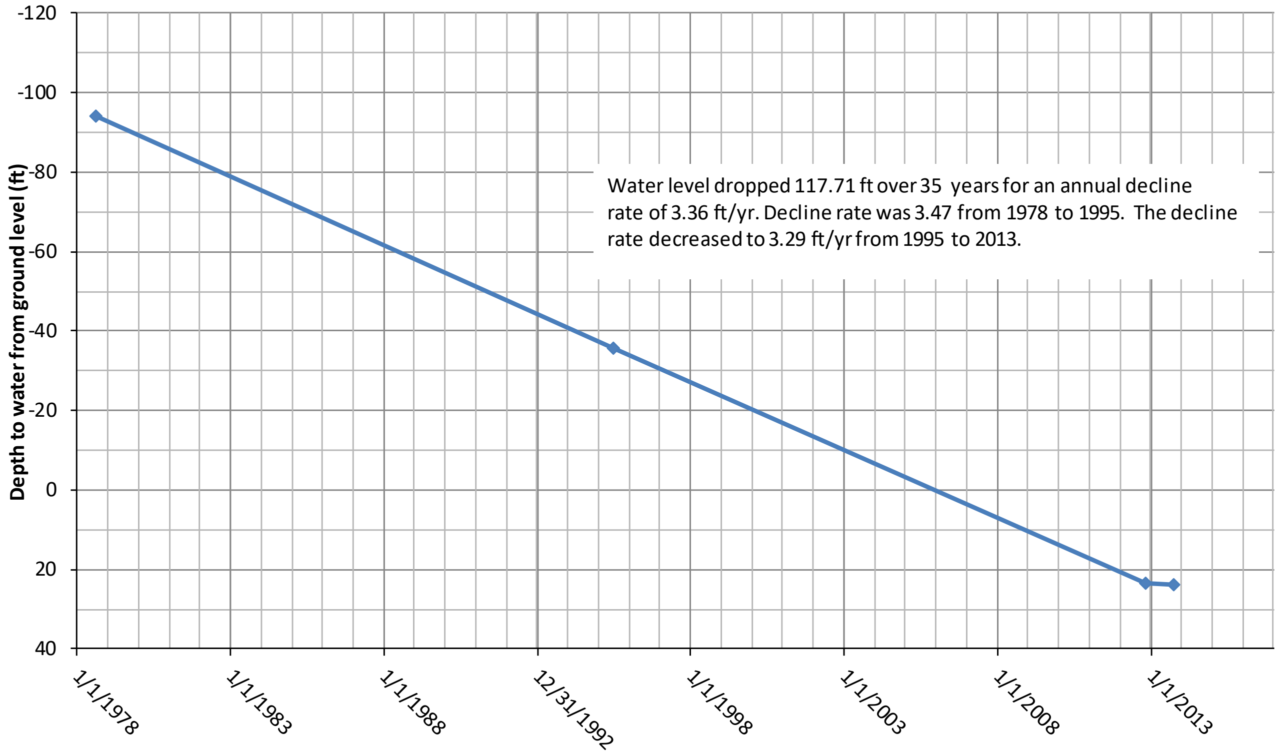

Figure A7. Water-level decline at FHHC well 33647 (Kimble) Sidney, MT (T. 23 N., R. 59 E., 29BBCC).

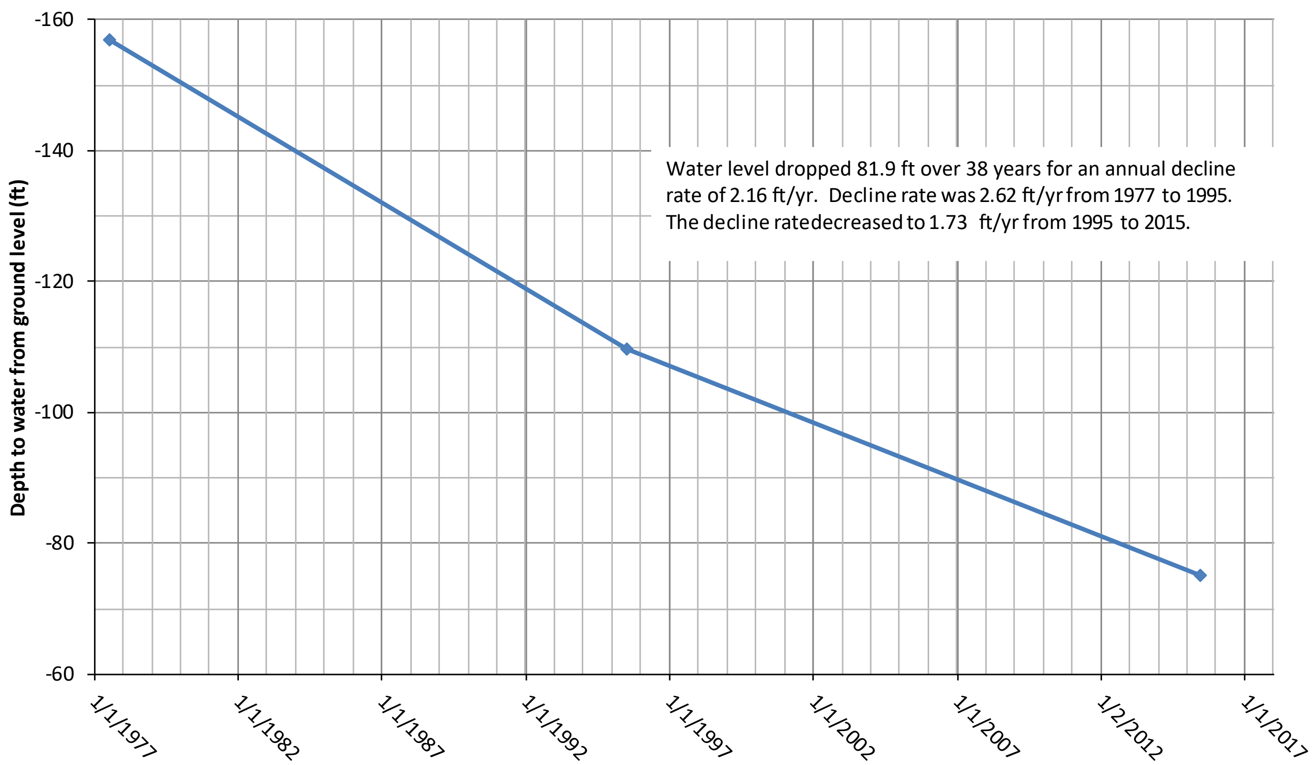

Figure A8. Water-level decline at FHHC well 35899 (Marker) South of Sidney bridge (T. 22 N., R. 59 E., 20DAAD).

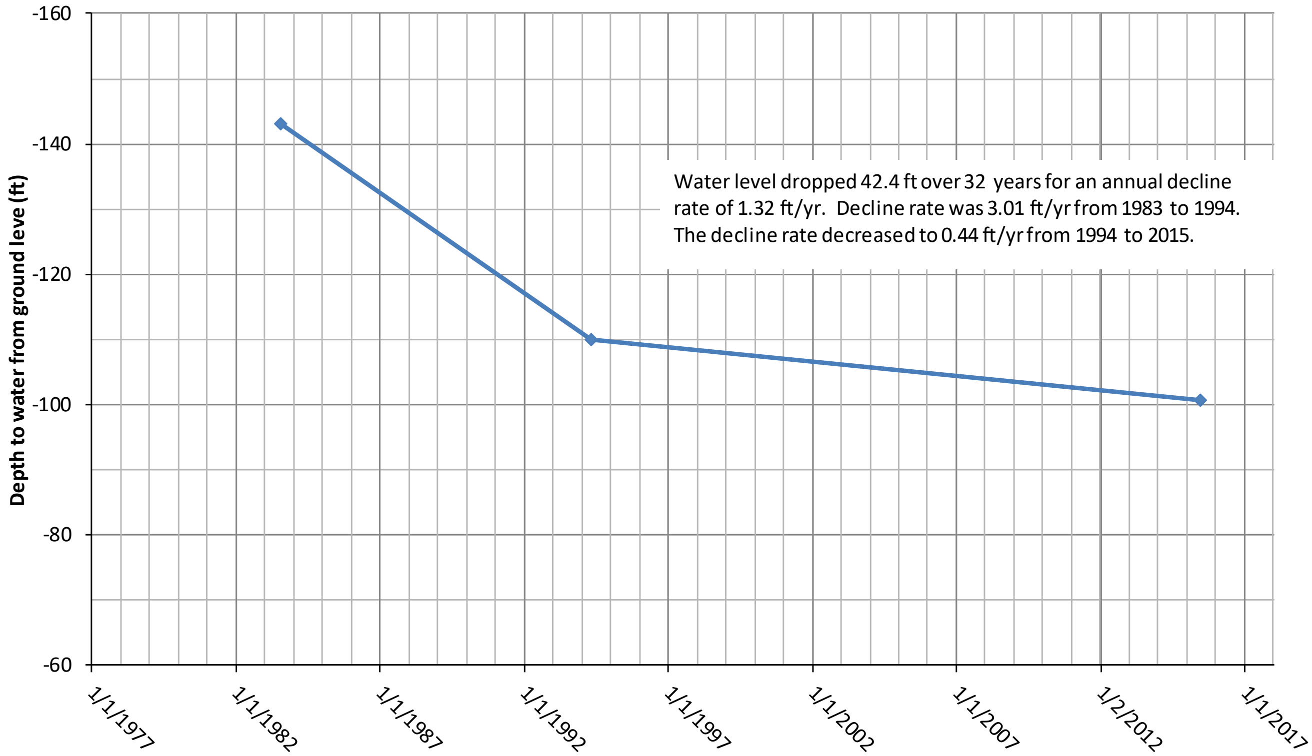

Figure A9. Water-level decline at FHHC well 79510 (Rau School) East of Sidney bridge (T. 22 N., R. 59 E., 16DABC.

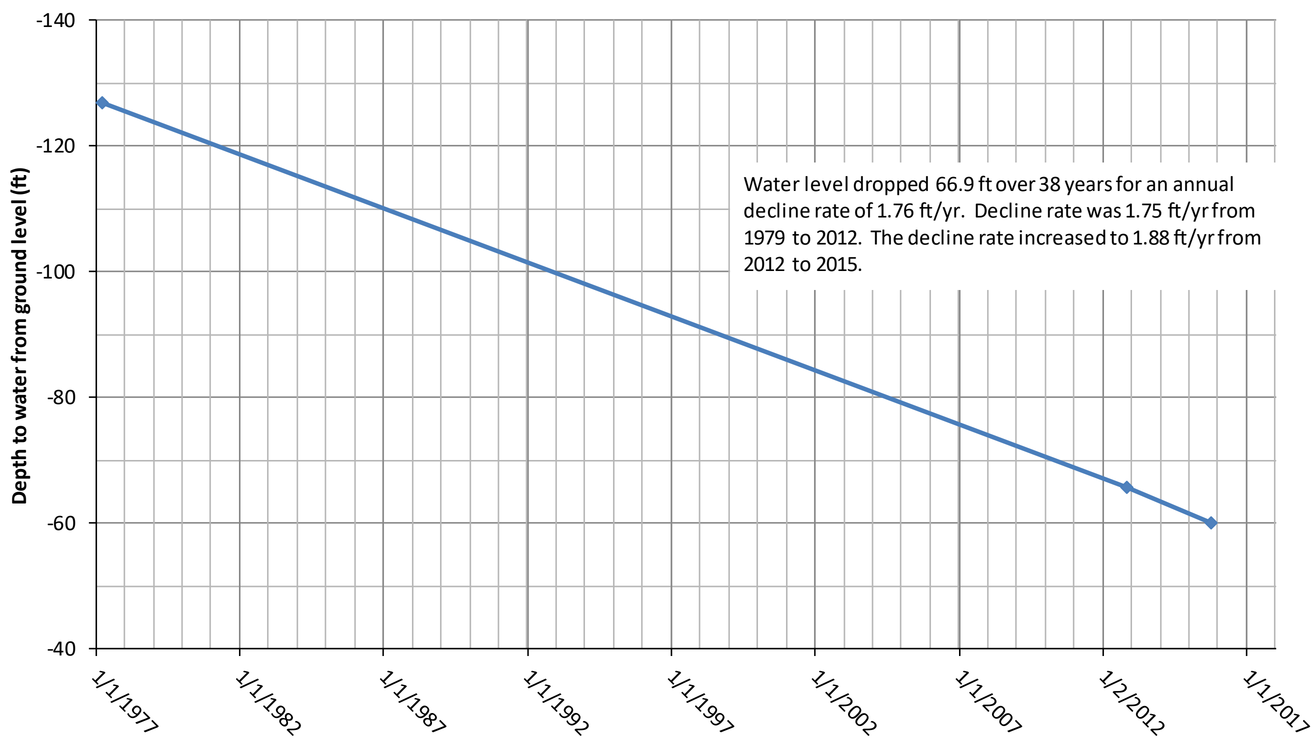

Figure A10. Water-level decline at FHHC well 38146 (Shannon) North of Fairview, MT (T. 25 N., R. 59 E., 1CCCC).

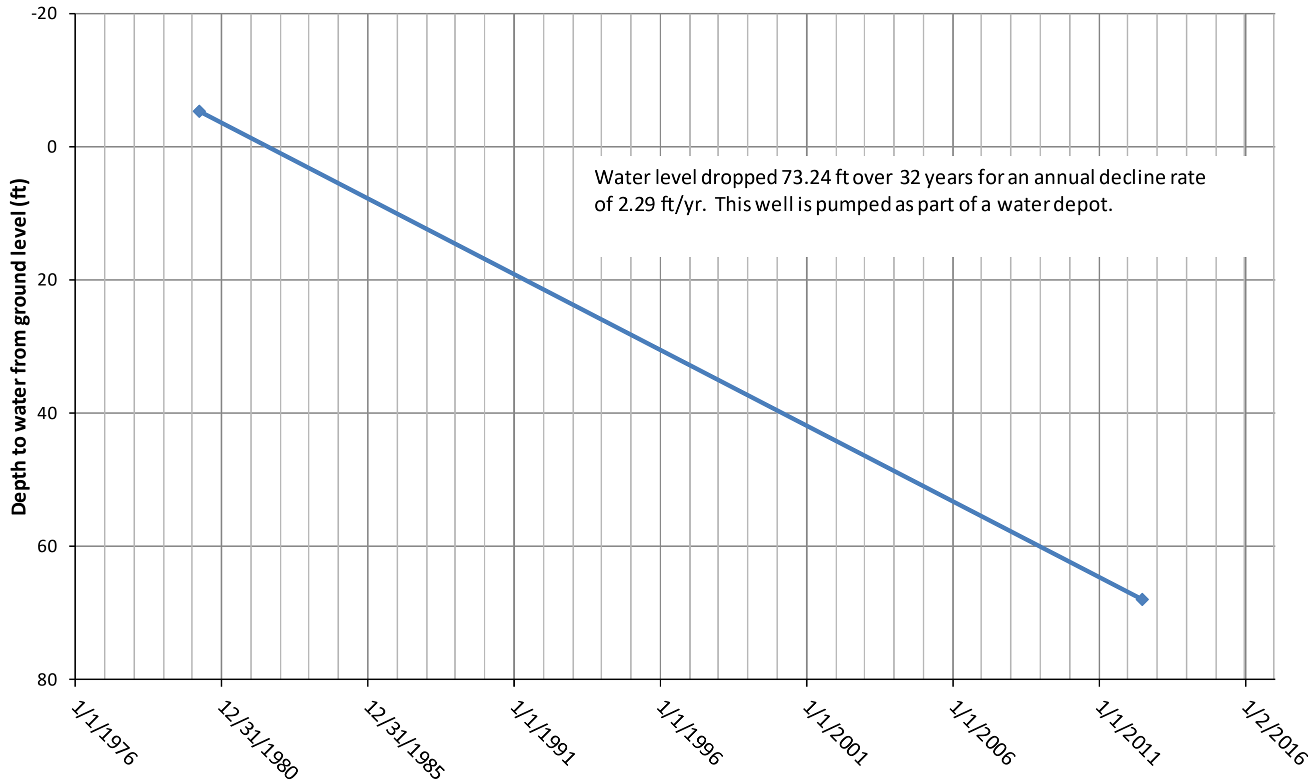

Figure A11. Water-level decline at FHHC well 35864 (Thiel) East of Sidney, MT (T. 22 N., R. 59 E., 14DCAB).

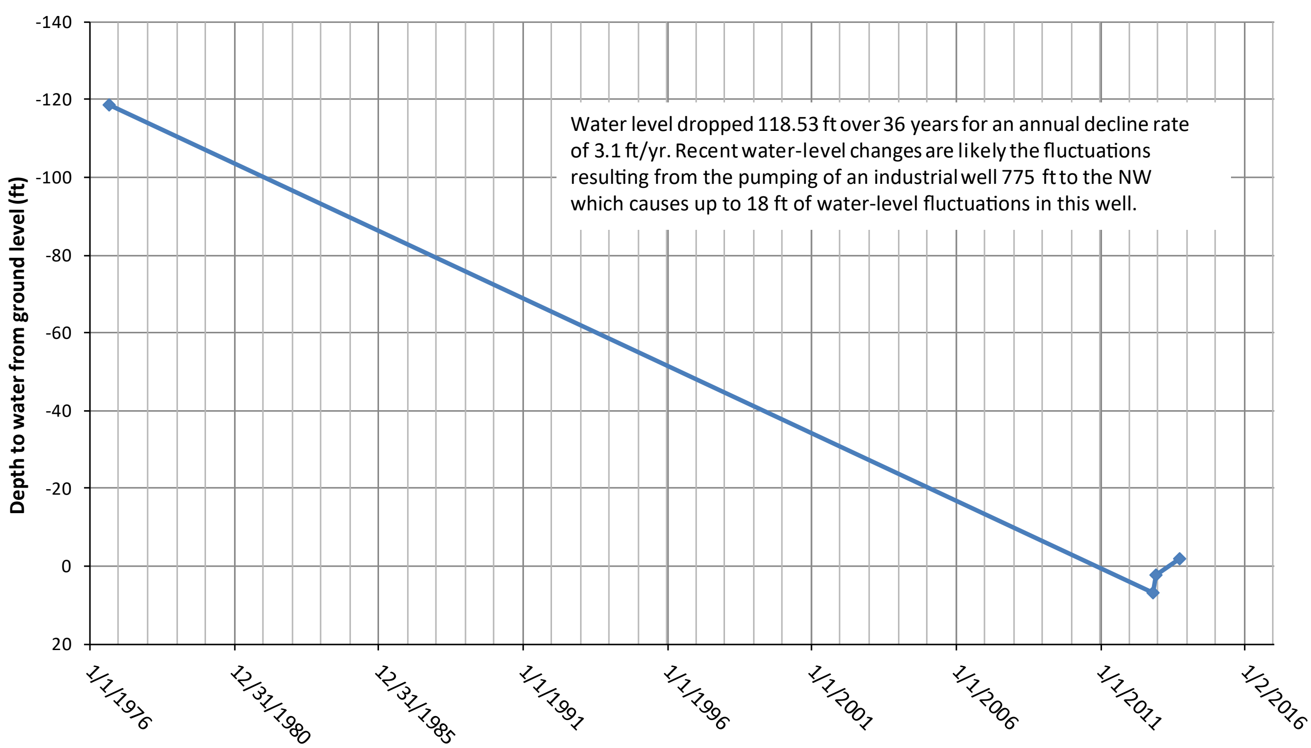

Figure A12. Water-level decline at FHHC well 36672 (Tri County Imp.) Sidney, MT (T. 23 N., R. 59 E., 30DDBC).

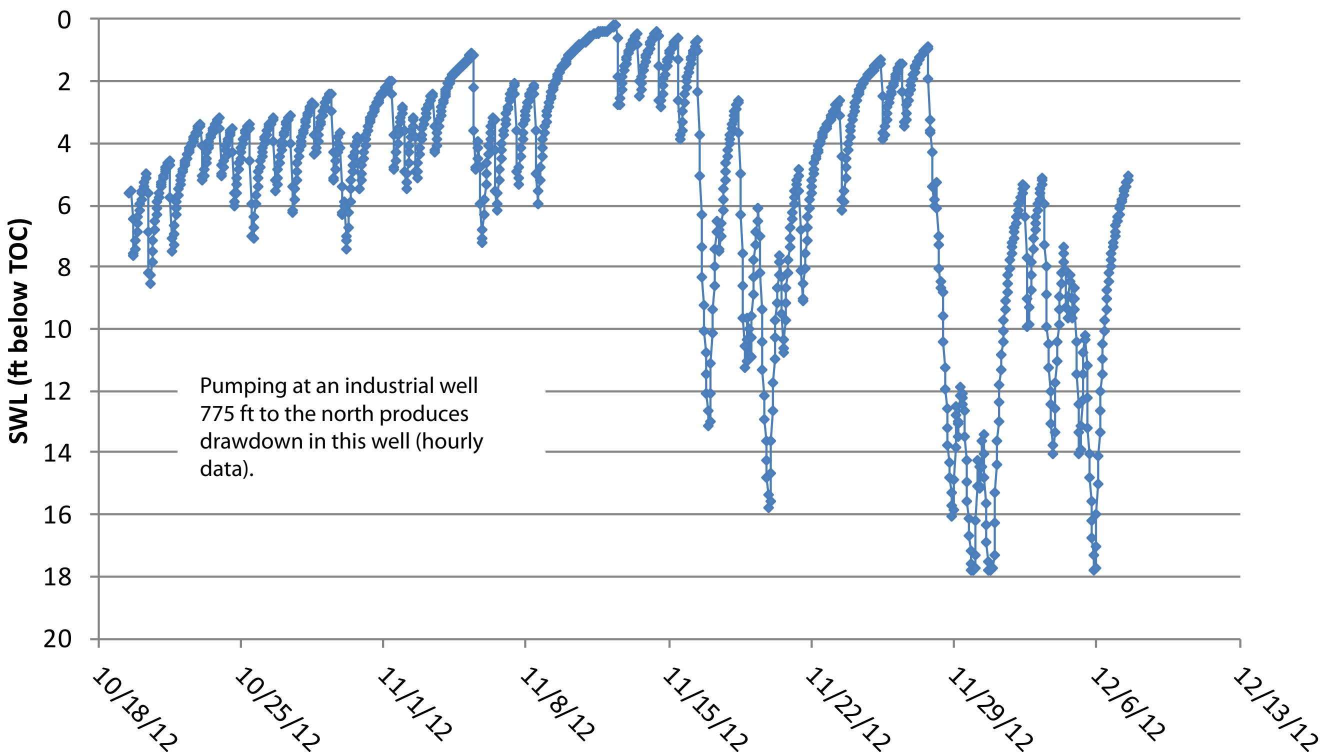

Figure A13. Water-level fluctuations at FHHC well 36672 (Tri County Imp.) Sidney, MT (T. 23 N., R. 59 E., 30DDBC).

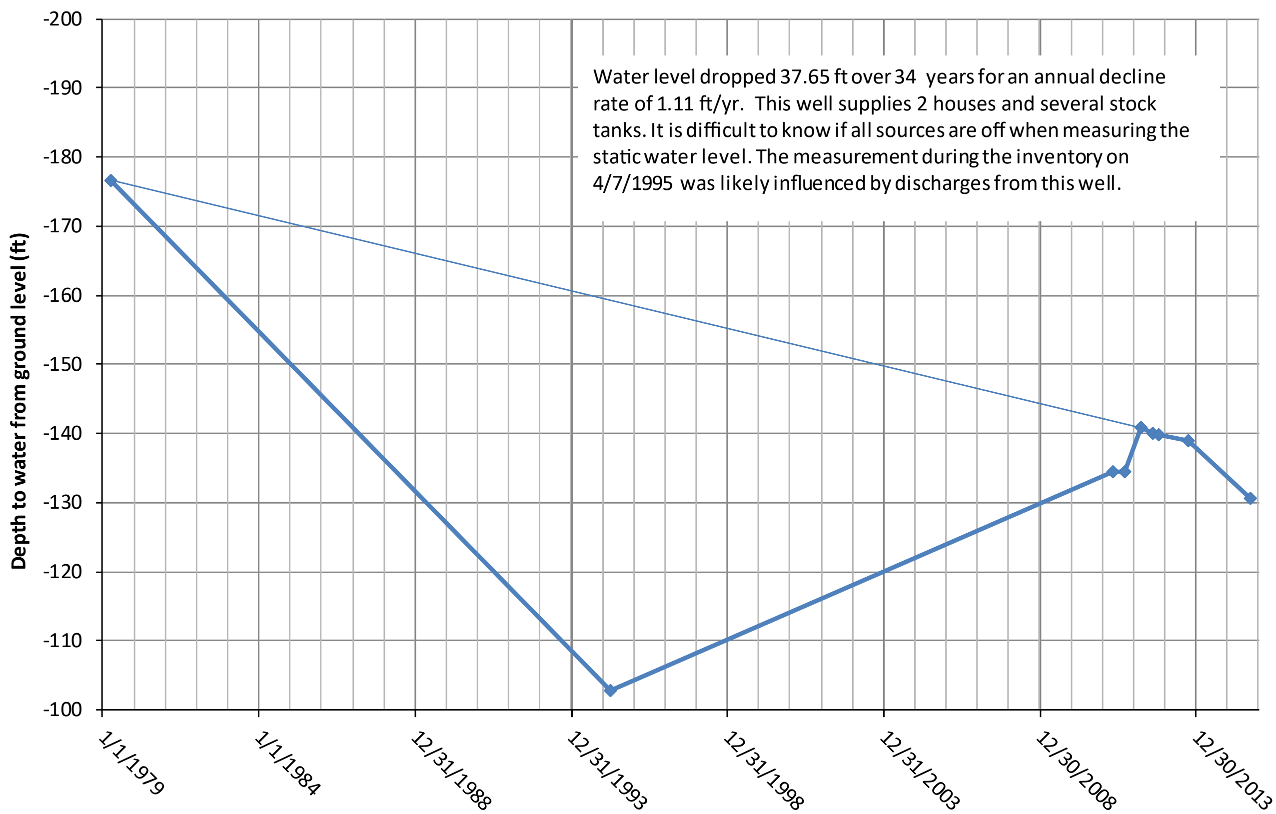

Figure A14. Water-level decline at FHHC well 38712 (Trudell) northwest of Fairview, MT (T. 26 N., R. 58 E., 6CCCC).

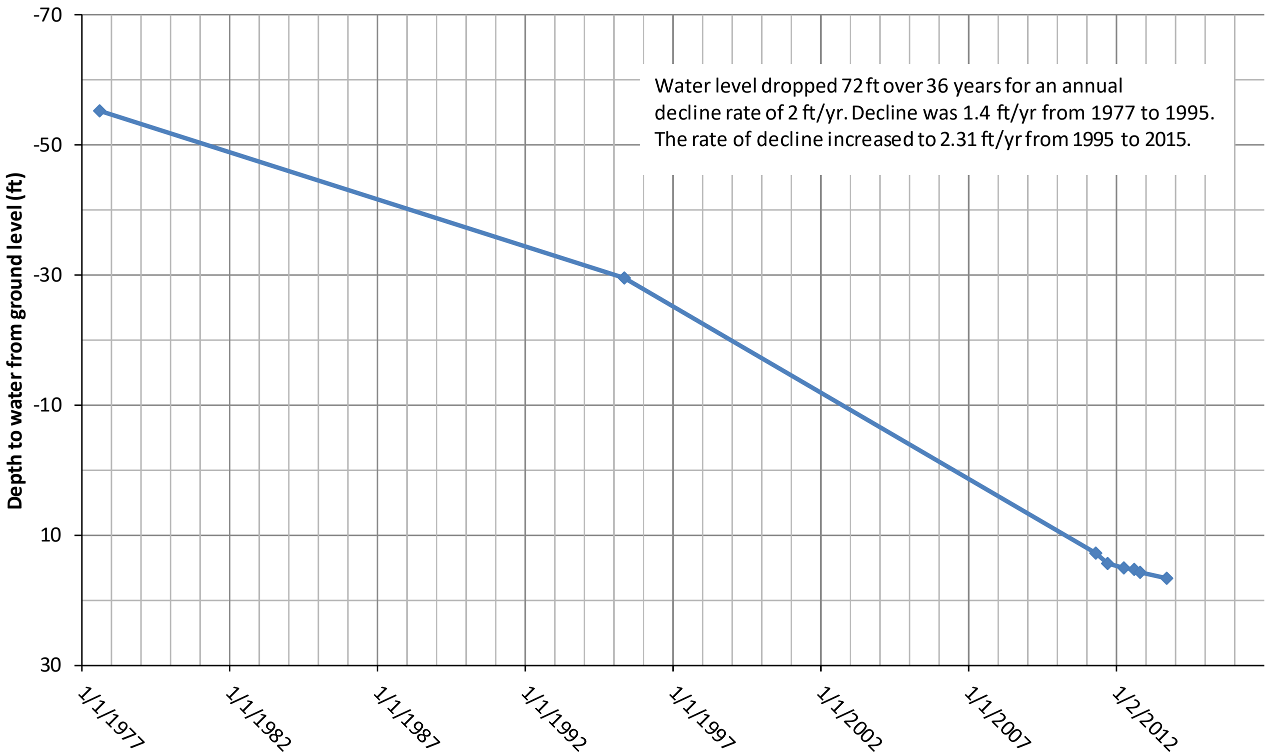

Figure A15. Water-level decline at FHHC well 38151 (Wheeler) northwest of Fairview, MT (T. 25 N., R. 59 E., 7BBCB).

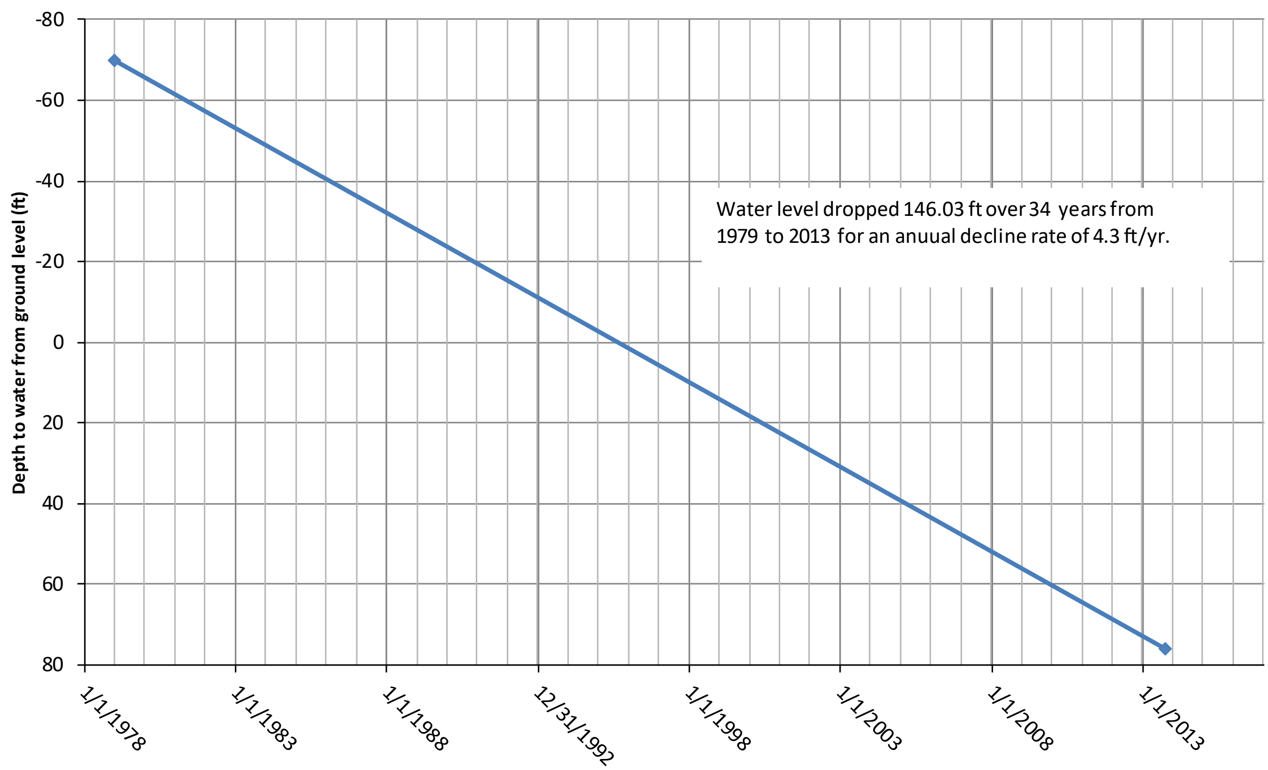

Figure A16. Water-level decline at FHHC well 36570 (Williams) north of Sidney, MT (T. 23 N., R. 59 E., 17ADDA).

APPENDIX B

RICHLAND COUNTY FHHC AQUIFER WELLS

GWIC ID No	Aquifer Code	Site Name	Latitude	Longitude	Twn	Rng	Sec	Q (Sec)	Depth (ft)	Swl (ft)	Yield gpm	Date Drilled	2015 Inventory
218491	211FHHC	GREENWAY DAIRY	47.43788009	-104.3953932	19N	57E	1	ACB	1050	0	72	4/16/2005	no
32738	211COGT	EETZEL HAROLD	47.38	-104.4063	19N	57E	26	ADAA	770	-125	70	3/10/1980	no
149279	211FHHC	CARR ANNIE/BRIAN	47.3797	-104.4238	19N	57E	26	BCAB	800			5/19/1995	yes
279416	211FHHC	REED, DOUG	47.37867174	-104.4154466	19N	57E	26	AC	820	0	80	8/22/2014	yes
32741	211FHHC	RICE GEORGE JR	47.3569	-104.4552	19N	57E	33	DCAD	740		12	2/23/1980	no
209492	211FHHC	JIMISON C.H.	47.36184648	-104.4360868	19N	57E	34	DBAB	727	-113	90	2/21/2004	no
266444	211FHHC	BOLINDER, SHANE	47.360428	-104.431172	19N	57E	34	DA	825		85	6/21/2012	no
701041	211FHHC	D DAVIES	47.3569	-104.4472	19N	57E	34	CC	582		10	1/1/1949	no
32744	211HLCK	OSBORNE FRANK	47.4327	-104.2891	19N	58E	2	DBBB	1029	-129	10	6/26/1963	yes
2390	211HLCK	REDMAN J	47.4325	-104.3111	19N	58E	3	DBBB	474	-66.9	6	6/14/1964	yes
32748	211FHHC	REDMAN JOHN	47.4266	-104.3266	19N	58E	4	DDC	915	-208	35	10/1/1971	yes
257069	211FHHC	REDMAN JOHN R.	47.43033033	-104.3287816	19N	58E	4	DDBD	448	-34.6	5	8/28/1963	yes
32752	211HLCK	TOMBRES INC.	47.4247	-104.3638	19N	58E	7	AADA	875	-219	95	3/20/1976	yes
2391	211FHHC	HERIGSTAD RANCH	47.418	-104.3611	19N	58E	8	CBDB	840	12	35	10/20/1973	no
32758	211HLCK	REDMAN KARNEY	47.42271	-104.318622	19N	58E	10	B	450		4	1/1/1912	yes
32759	211HLCK	HERIGSTAD RANCH CO	47.408269	-104.353747	19N	58E	17	ACB	835	-161	23	5/24/1974	yes
32761	211HLCK	REDMAN KARNEY (2)	47.39189461	-104.2733493	19N	58E	24	BD	871	-92.2	15	1/1/1962	yes
200300	211FHHC	HANSEN ARNOLD	47.38235923	-104.3457609	19N	58E	29	AAAA	860	-129	75	11/15/2002	yes
32762	211HLCK	TOWNLY HARRY	47.366003	-104.38428	19N	58E	31	BBCA	693	-69.3	6	3/7/1964	no(ABD)
32763	211HLCK	BOE H. R.	47.362836	-104.38366	19N	58E	31	BC	525	-23.1	1	6/16/1955	no(ABD)
129233	211FHHC	ROBERTS DAVE C	47.365551	-104.382421	19N	58E	31	BBD	835	-111	72	8/12/1992	yes
32764	211HLCK	REDMAN KARNEY	47.361069	-104.355737	19N	58E	32	BAAA	806	-92.4	20	2/26/1964	yes
32769	211COGT	SULT ROY	47.4241	-104.238	19N	59E	7	AAD	1110	-69.3	15	5/28/1968	yes
32780	211COGT	SMITH CREEK GRAZING	47.374785	-104.2274	19N	59E	29	DBB	1070	-92.4	60	10/11/1980	yes
132186	211COGT	COVERED WAGON RANCH	47.493341	-104.417982	20N	57E	14		1097		15	5/31/1970	yes
34203	211COGT	COVERED WAGON RANCH	47.4736	-104.3997	20N	57E	24	CDBC	1110		30	12/20/1969	no
198076	211FHHC	SEEVE CRAIG	47.47385294	-104.4012505	20N	57E	24	CDBC	1155	-1.5	15	7/20/2002	yes
256498	211FHHC	PUST DOUG	47.52572778	-104.3065778	20N	58E	3	ABD	1200		30	6/16/2010	yes
34259	211COGT	HAGLER LEONARD	47.4897	-104.2861	20N	58E	14	DBCD	1247	-73.9		4/17/1974	yes
700460	211FHHC	COV WAGON RANCH	47.4602	-104.3616	20N	58E	29	CBC	1083		75	8/20/1970	no
34283	211COGT	COVERED WAGON RANCH	47.462543	-104.367655	20N	58E	30	DA	1083		75	8/20/1970	yes
34305	211COGT	DESHAW LAWRENCE	47.449658	-104.354559	20N	58E	32	ADA	1000			3/28/1976	no
34306	211COGT	DESHAW LAWRENCE	47.4516	-104.3427	20N	58E	32	ADAD	1008	-185		8/28/1978	yes
34327	211COGT	LANG LEO	47.453004	-104.338705	20N	58E	33	B	1000	-173	30	4/4/1976	yes
34332	211HLCK	BLM/FRANK OSBOURNE	47.442648	104.302319	20N	58E	34	DDD	620	-80.9	30	0/15/1971	yes
34335	211COGT	ALBERT LEWIS	47.522313	-104.156339	20N	59E	2	ADCA	1550			4/27/1971	no
34336	211COGT	HOCTETTER N. J.	47.522839	-104.181697	20N	59E	3	AC	1320	-57.8	11	5/9/1972	no
700478	211FHHC	HOSTETTER M	47.52	-104.1802	20N	59E	3	DBA	1320	-57.5	2	5/9/1972	no
34337	211COGT	HASTETTER THOMAS	47.527426	-104.204133	20N	59E	4	ABB	1200	-143	17	10/10/1974	yes
34338	211COGT	BALDUCKE BROS.	47.522032	-104.261427	20N	59E	6	BCC	1240		15	12/18/1973	yes
255832	211FHHC	BALDUCKE DAVID	47.861667	-104.393889	20N	59E	6	CCD	1120	-118	40	6/1/2010	yes
34339	211COGT	LELAND JOE	47.514286	-104.244871	20N	59E	7	ABAA	1045	-92.4	30	2/6/1979	yes
34340	211FHHC	LELAND ERNEST & SONS	47.50027	-104.217786	20N	59E	8	DDD	1120	-120	38	11/29/1973	yes
34341	211COGT	CLARK MRS. CHARLES	47.5072	-104.1669	20N	59E	11	BDC	1390	-57.8	8	4/2/1971	no
34344	211COGT	SULT LAND & LIVESTOCK	47.485883	-104.170902	20N	59E	14	CCD	1280	-57.8	30	10/4/1980	yes
34348	211COGT	WICK LLOYD	47.4733	-104.1422	20N	59E	24	CADC	1362	-23.1	32	11/20/1982	no
34351	211COGT	SULT RAY	47.468641	-104.188585	20N	59E	27	BA	1190	-64.7	15	1/8/1971	no
35173	211FHHC	STANE HARLAN L	47.615344	-104.20883	21N	58E	1	AAA	1120	-185	55	1/1/1978	no
35174	211FHHC	NELSON CHARLES	47.614401	-104.226236	21N	58E	1	BB	1090	-69.3	15	5/20/1968	no
210188	211FHHC	RAMBUR HOWARD	47.614739	-104.207553	21N	58E	1	AAAD	1160	-80.9	25	3/12/2004	yes
35178	211FHHC	BAKKEN MELVIN	47.608517	-104.27138	21N	58E	3	CBBB	1325	-50.8	8	8/1/1972	no
251751	211FHHC	RANDY & PATTI SEARER	47.572706	-104.269746	21N	58E	15	CC	1240		30	9/3/2009	yes
250070	211FHHC	PUST,STEVE	47.562925	-104.284918	21N	58E	21	CA	1180		60	5/26/2009	yes
35227	211HLCK	BAXTER JESSE	47.549033	-104.193494	21N	58E	30	DDA	830	-49.7	6	8/10/1966	yes
35228	211FHHC	NOLLMEYER HENRY	47.5294	-104.2847	21N	58E	33	CDDB	990	-220	35	4/14/1976	no
180092	211FHHC	REDMAN JOHN R.	47.605975	-104.146306	21N	59E	4	DAD	1290	-65.8	40	3/11/2000	yes
35238	211COGT	LEO MCGINNIS ESTATE	47.6033	-104.1875	21N	59E	6	DDAA	1222	-196	32	5/4/1979	yes
35242	211FHHC	HASTETTER,JUDITH ET.AL.	47.60016	-104.168091	21N	59E	8	AAA	?	-76.2	6	10/12/1972	yes
35244	211COGT	LEO MCGINNIS ESTATE	47.5947	-104.1827	21N	59E	8	BCD	1270	-120	20	4/16/1968	yes
35246	211FHHC	HASTETTER,JUDITH ET.AL.	47.598235	-104.163094	21N	59E	9	BBD	?	-73.3	16	5/16/1985	yes
35247	211COGT	HASTETTER DR. N J	47.588124	-104.158682	21N	59E	9	CD	1278	-129	15	3/9/1970	yes
35248	211COGT	FRANJEN TOM	47.600377	-104.136613	21N	59E	10	BAAB	1235	-134	30	2/12/1980	no
35249	211COGT	BUXBAUM BROS.	47.5727	-104.0947	21N	59E	13	CDC	1368	-69.3	19	2/14/1970	no
35250	211COGT	FRANZEN ALFORD	47.5819	-104.1188	21N	59E	14	BCA	1330	-125	30	5/1/1969	yes
35251	211COGT	PREVOST RONALD F	47.576299	-104.119922	21N	59E	14	CBD	1400		2	7/7/1982	no
35262	211COGT	HASTETTER N.J.	47.544512	-104.137152	21N	59E	27	CD	1310	-67	13	5/6/1971	no
35268	211COGT	HASTETTER THOMAS	47.533743	-104.190491	21N	59E	31	DA	1302	-92.4	9	7/11/1974	yes
35270	211COGT	HALVORSEN BROS.	47.535	-104.1538	21N	59E	33	DBBB	1300	-34.5	12	10/27/1971	no
35272	211COGT	FRANZEN TOM	47.615755	-104.058974	21N	60E	5	BBB	1258	-92.4	50	5/24/1977	no

GWIC ID No	Aquifer Code	Site Name	Latitude	Longitude	Twn	Rng	Sec	Q (Sec)	Depth (ft)	Swl (ft)	Yield gpm	Date Drilled	2015 Inventory
700546	211FHHC	FRANZEN TOM	47.6122	-104.0558	21N	60E	5	BADC	1258	-92	50	5/24/1977	no
35697	211FHHC	SULBRANANG SEIB	47.632959	-104.452142	22N	57E	30	DC	1270		30	1/1/1976	no
35725	211FHHC	GOSS TED	47.6883	-104.2116	22N	58E	12	ABAA	1267	-80.9	30	12/18/1978	yes
35738	211FHHC	HAFFNER GEORGE	47.6744	-104.2158	22N	58E	12	DCCC	1140	-92.3	15	4/12/1972	yes
35748	211FXHL	AULT EDDIE	47.6516	-104.2286	22N	58E	23	DAAA	1260	-150	43	2/28/1979	no
35771	211FXHL	STEINBEISSER & SONS	47.63	-104.2086	22N	58E	36	AAAB	1134	-196	75	9/6/1983	yes
35773	211FXHL	RAMBUR MATT	47.6166	-104.2077	22N	58E	36	DDDC	1120	-194	30	8/3/1971	yes
700583	211FHHC	RAMBUR MATT	47.6163	-104.2094	22N	58E	36	DDD	1120	-193		8/3/1971	no
35775	211FHHC	LIEN CLARA	47.696316	-104.109992	22N	59E	2	DAA	900		3	1/1/1930	no
140084	211FHHC	BELL LAND & LIVESTOCK	47.69541623	-104.1006477	22N	59E	2	DAA	1275	-120	34	11/29/1993	yes
35780	211FHHC	TENDERLAIN INDUST.	47.694479	-104.139758	22N	59E	3	CB	1220	-194	75	5/9/1974	yes
35806	211COGT	YOUNGKIN NICK	47.68987567	-104.1707401	22N	59E	5	DCD	1220		70	6/1/1980	no
35843	211FHHC	BUXBAUM VICTOR	47.687181	-104.177486	22N	59E	8	BA	1240		30	7/17/1979	no
35852	211FHHC	YOUNGQUIST DEAN	47.688185	-104.15186	22N	59E	9	ABB	1240	-226	80	2/10/1980	yes
35861	211FHHC	HERTZ W H	47.6755	-104.1036	22N	59E	11	DDCB	1410	-69.3	32	8/8/1978	yes
274382	211FHHC	BELL, RAYMOND & TRISH	47.6738	-104.09048	22N	59E	13	BA	1243	-3	7	8/9/2013	yes
35864	211FXHL	THIEL ARNOLD	47.667418	-104.110223	22N	59E	14	DCAB	1410	-50.8	15	4/1/1980	yes
35866	211FXHL	VALLEY VIEW WUA WELL #1	47.66924564	-104.1075079	22N	59E	14	AC	1431	28	32	9/2/1976	yes
35867	211FHHC	VALLEY VIEW WUA WELL #3	47.673	-104.1125	22N	59E	14	BABD	1345	-109	35	9/7/1977	yes
35873	211FHHC	GETTY TRODINGOND TNP	47.67013072	-104.1303184	22N	59E	15	ACB	1191	-138	60	4/3/1984	yes
35876	211FHHC	GULLICKSON MARK & L.	47.66783181	-104.1350396	22N	59E	15	BDCD	1195	-127	26	6/12/1989	yes
35878	211FHHC	PENNZOIL CO.	47.666452	-104.133016	22N	59E	15	CAA	1210			8/26/1980	no
79510	211FHHC	RAU SCHOOL DISTRICT 21	47.6658	-104.1455	22N	59E	16	DABC	1380	-143	18	7/29/1983	yes
209983	211FHHC	BELL RYAN R	47.670177	-104.153456	22N	59E	16	BDA	1300	-114	25	3/29/2004	yes
35890	211FHHC	HI LINE TRUCKING INC	47.6605	-104.195	22N	59E	18	DCCB	1286	-139	50	10/10/1978	yes
35899	211FXHL	MARKER VICTOR	47.6511	-104.1641	22N	59E	20	DAAD	1277	-157	20	6/27/1997	yes
35909	211FHHC	LORENZ WILLMER A.	47.646373	-104.143793	22N	59E	21	DDD	1320	-116	24	2/28/1978	yes
35912	211FHHC	RAU WILLMER	47.647396	-104.102247	22N	59E	23	DD	1233	-120	30	9/14/1974	yes
700628	211FHHC	RAU W	47.6513	-104.0963	22N	59E	24	CBBD	1300			1/1/1976	no(ABD)
35914	211FHHC	RAU BROTHERS	47.63572	-104.085092	22N	59E	25	DBD	1375		20	7/8/1977	no
35917	211FHHC	PETERSEN ANDREW JR	47.6358	-104.163	22N	59E	28	CBCB	1172	-196	30	12/19/1970	yes
35919	211FHHC	SHELL OIL CO.	47.635476	-104.163016	22N	59E	28	CBC	1305	-104		2/26/1981	no
35926	211FHHC	SIMARD FARMS INC	47.642845	-104.206006	22N	59E	30	BBC	1180	-148		11/12/1984	yes
35933	211FHHC	REIDLE THEODORE J.	47.625413	-104.17287	22N	59E	32	AC	1140	-196	22	11/27/1971	yes
35944	211FXHL	SHELL OIL CO	47.679158	-104.076778	22N	60E	7	CBC	1240	-196	60	11/22/1978	yes
35949	211FXHL	EAGLE-P INDUSTRIES	47.67191	-104.063389	22N	60E	18	ABD	1260	-138	25	8/31/1985	yes
35952	211FXHL	WILLIAMS MIKE	47.666931	-104.070812	22N	60E	18	CABA	1240	-185	30	5/9/1979	yes
36498	211COGT	WILLIAMS, NEIL	47.79030833	-104.0921711	23N	59E	1	BAB	1320	-116	30	2/2/1982	yes
146788	211FXHL	TJELDE, PAUL	47.8061	-104.0633	23N	59E	1	DCCB	280	-16.2	0.5	7/25/1992	no
185519	211FHHC	STEINBEISSER, BILL & DAVE	47.762373	-104.141474	23N	59E	10	CCCC	1280	-104	36	10/13/2000	yes
36551	211FHHC	LOWMAN CHARLES H.	47.75479	-104.121401	23N	59E	15	ADDD	1370	-129		4/30/1980	yes
36570	211FXHL	WILLIAMS TERRY	47.755629	-104.164572	23N	59E	17	ADDA	1385	-69.3		1/6/1979	no
263605	211FHHC	WICK, DENNIS AND LINDA	47.74397	-104.09899	23N	59E	23	AADD	1238	-173	50	5/10/1980	no
36625	211FHHC	SCHILLING LESLIE	47.722775	-104.079348	23N	59E	25	DAD	1200		20	12/31/1980	yes
36646	211FXHL	PIGG R HARMON	47.72999	-104.184372	23N	59E	29	BBC	1360	-87.8	20	9/1/1978	no(ABD)
36647	211FXHL	KIMBLE ROGER	47.7294	-104.1838	23N	59E	29	BBCC	1420	-92.4	22	8/4/1978	no
36654	211FXHL	MERCIER W L	47.725406	-104.196381	23N	59E	30		1320		30	7/9/1979	no
36658	211FHHC	BOYCE ROBERT F	47.72632	-104.195039	23N	59E	30	ACC	1285	-104	25	1/22/1979	yes
36659	211FXHL	PEDERSEN CLARENCE	47.72632	-104.186987	23N	59E	30	ADD	1290	-92.4	30	9/9/1978	no
36668	211FXHL	RAMBUR GORDON & IKE	47.7216	-104.1863	23N	59E	30	DADD	1265	-116	60	7/27/1978	no
36672	211FHHC	MCNUTT WALTER	47.72006389	-104.1899139	23N	59E	30	DDBC	1250	-116	30	9/9/1976	no
263081	211FHHC	FRANZ, DON	47.723283	-104.191173	23N	59E	30	DB	1400	32	30	9/22/2011	yes
36762	211HLCK	YELLOWSTONE LIVESTOCK	47.705925	-104.146521	23N	59E	33	DCCA	1200	-116	50	1/8/1972	yes
36785	211FXHL	DAHL DENNIS	47.7422	-104.0588	23N	60E	19	ADBA	1290	-157	20	1/1/1978	no
36789	211FXHL	SHELL OIL CO.	47.708135	-104.060759	23N	60E	31	DAC	1490	0	15	11/1/1980	yes
37251	211FXHL	JAMBOR CLEMENT W	47.858154	-104.589194	24N	56E	7	BCAA	1400			2/11/1976	no
226823	211FHHC	BANNON PIPELINE	47.807833	-104.481714	24N	56E	25	C	1620			6/9/2006	no
37372	211COGT	BIEBER JAMES A	47.82206	-104.08268	24N	59E	24	DD	1370	-153	60	7/19/1977	no
37383	211FXHL	CANDEE GARY AND KAREN	47.8094	-104.1022	24N	59E	26	DADC	1348	-139	42	5/28/1982	no
37440	211FXHL	JOHNSON ROGER	47.8463	-104.0608	24N	60E	18	AACA	1360	-162	50	5/11/1977	yes
38113	211FXHL	CHRISTIANSEN MARIAN	47.9263	-104.185	25N	58E	12	CDDD	1500	-55.4	20	6/4/1977	yes
38146	211FXHL	SHANNON, EDWARD J.	47.9417	-104.05228	25N	59E	1	CCCC	1445	-127	25	3/15/1977	yes
38151	211FXHL	WHEELER VINCENT	47.93792	-104.15912	25N	59E	7	BBCB	1505	-55.4	15	8/9/1977	yes
38159	211FXHL	NILES REX A	47.9391	-104.0427	25N	59E	12	AAAA	1420	-182	30	7/29/1977	yes
38161	211FXHL	VANDERHOOF BROS	47.9169	-104.1536	25N	59E	18	CABC	1488	-53.1	20	2/28/1977	yes
38175	211FXHL	VALLEY VIEW FEED LOT	47.8886	-104.0436	25N	59E	25	CAA	1405	-116	55	1/30/1989	yes
38184	211FXHL	REIDLE DALE	47.8816	-104.0483	25N	59E	36	ABAA	1400	-139	25	4/18/1980	yes
38712	211FXHL	TRUDELL BROTHERS	48.02833	-104.28799	26N	58E	6	CCCC	1335	-180	30	4/10/1979	yes
38713	211FXHL	HARDY BOYD	48.023	-104.2536	26N	58E	8	ADC	1434	-180	30	11/26/1980	yes

GWIC ID No	Aquifer Code	Site Name	Latitude	Longitude	Twn	Rng	Sec	Q (Sec)	Depth (ft)	Swl (ft)	Yield gpm	Date Drilled	2015 Inventory
38742	211FHHC	CAYKO NICKIE N.	47.9958	-104.0611	26N	59E	23	ABCB	1430	-213	30	5/17/1977	yes
38750	211FHHC	HERDT ELMER	47.980048	-104.050884	26N	59E	25	B	1440	-201	32	4/2/1979	yes
38755	211FHHC	FILLER ALVIN F.	47.9763	-104.0522	26N	59E	26	DDA	1442	-220	45	3/26/1977	no
39390	211FHHC	CASTERLINE, MARK	48.11334	-104.814633	27N	53E	12	BAAB	619	-34.7	20	8/23/1983	yes
256584	211FHHC	CASTERLINE MARK	48.112853	-104.816999	27N	53E	12	BAA	600	-27.7	20	6/12/2010	no
139797	211FHHC	SCHMITZ TRUST	48.053855	-104.872358	27N	53E	33	AA	426		15	4/19/1991	no
3355	211FHHC	TURNBULL, NEIL	48.1105	-104.795	27N	54E	7	BADD	684			10/5/1947	no(ABD)
268478	211FHHC	A7 RANCH INC.	48.1107	-104.79672	27N	54E	7	BA	700	-3	15	10/2/2012	yes
39400	211FHHC	FOSS GENE	48.1102	-104.7547	27N	54E	9	BAC	900	-57.8	5	10/7/1981	yes
39420	211HLCK	JOHNSON MARIE	48.0652	-104.5797	27N	55E	26	BDAD	870	-3.2	2	1/1/1958	no
39424	211FHHC	GUSTAFSON	48.1158	-104.5447	27N	56E	6	CCCB			5	1/1/1944	yes

APPENDIX C

WATER-QUALITY DATA

Gwic Id	Td	Inv Date	Aquifer	Who	Swl Grnd	Swl Elev	System Discharge	Water Condition	Well Condition	Water Temp (°C)	Field SC	Field pH	Chloride (mg/L)
285388		42219.4375	211FHHC	MARK WOLFRAM			6	CLEAR	NEW	13.4	1816	8.37	41
279416	820	42205.47569	211FHHC	MARK WOLFRAM	-124	2116	10	CLEAR	NEW	13.1	1822	8.68	
149279	800	42218	211FHHC	MARK WOLFRAM	-82.8	2122.8	10	CLEAR	NOT VISIBLE	14.8	1793	8.68	56
285447		42274.51736	211FHHC	MARK WOLFRAM			1.5	CLEAR	FAIR	16	1820	8.8	60
32744	1029	42239.59375	211HLCK	MARK WOLFRAM	-67	2189	2.5	CLEAR	NOT VISIBLE	8.74	1668	8.74	56
2390	474	42251.75	211HLCK	MARK WOLFRAM	-18.5	1978.5	2	CLEAR	FAIR	13.3	1990	8.41	41
257069	448	42273.625	211FHHC	MARK WOLFRAM			2	CLEAR	FAIR	16.3	2350	8.52	
32752	875	42203.63333	211HLCK	MARK WOLFRAM	-149	2115	4	CLEAR	FAIR	14.5	1858	8.64	48
32758	450	42250.75	211HLCK	MARK WOLFRAM			2	CLEAR	NOT VISIBLE	11.4	1760	8.5	
32759	835	42249.58681	211HLCK	MARK WOLFRAM			18	CLEAR	NOT VISIBLE	12.5	1781	8.97	41
32761	871	42272.52083	211HLCK	MARK WOLFRAM	-106	2134	8	CLEAR	F	15.3	1787	8.99	41
200300	860	42303.45486	211FHHC	MARK WOLFRAM			1.1	CLEAR	FAIR	12.3	1840	8.62	48
129233	835	42235.67014	211FHHC	MARK WOLFRAM	-109.3	2128.3	12	CLEAR	FAIR	15.4	1823	8.5	48
32764	806	42299.67292	211HLCK	MARK WOLFRAM	-7	2056	4	CLEAR	FAIR	16.2	1832	8.55	41
32769	1110	42272.6875	211COGT	MARK WOLFRAM	-9	2133	1	CLEAR	FAIR	14.1	1810	8.84	59
32780	1070	42272.59722	211COGT	MARK WOLFRAM	-9	2082	2.5	CLEAR	FAIR	14.2	2210	8.34	40
198076	1155	42204.55208	211FHHC	MARK WOLFRAM	13.03	2106.97		STAGNANT	FAIR				56
256498	1200	42249.61458	211FHHC	MARK WOLFRAM	-85.2	2055.2	12	CLEAR	GOOD	15.3	1782	8.95	77
34259	1247	42219	211COGT	MARK WOLFRAM	-67.7	2009.7	8	CLEAR	POOR	16.8	1921	8.32	63
285359		42200.59792	211FHHC	MARK WOLFRAM	-59.8	2051.8	30	CLEAR	GOOD	16.1	1897	8.51	48
285641		42273.70833	211FHHC	MARK WOLFRAM			2	CLEAR	FAIR	17	2520	8.46	33
34283	1083	42203.55903	211COGT	MARK WOLFRAM	-87.8	2104.8	10	CLEAR	FAIR	15.6	1874	8.63	
132186	1097	42203.52778	211COGT	MARK WOLFRAM	-9.9	2100.9	3	CLEAR	FAIR	13.2	1854	8.57	59
34306	1008	42205.42569	211COGT	MARK WOLFRAM	-122	2102	8	CLEAR	INACCESSIBLE	12.9	1847	8.61	52
34327	1000	42205.39444	211COGT	MARK WOLFRAM	-127	2113	8	CLEAR	FAIR	13.7	1865	8.58	52
285457		42250	211FHHC	MARK WOLFRAM	18.8	1929.2	2.5	CLEAR, SANDY	FAIR	10.3	2420	8.47	35
34332	620	42273.65694	211FHHC	MARK WOLFRAM	-132.4	2104.4	14	CLEAR	FAIR	15.5	1801	8.77	
285408		42274.48611	211FHHC	MARK WOLFRAM	-97.7	2052.7	6	CLEAR	NOT LOCATED	17.2	1821	8.92	48
34337	1200	42200.42361	211COGT	MARK WOLFRAM	-49.2	2076.2	6	CLEAR	FAIR	15.2	1851	8.53	81
34338	1240	42289.52778	211COGT	MARK WOLFRAM			5	CLEAR	FAIR	15	1840	8.61	90
255832	1120	42289.47917	211FHHC	MARK WOLFRAM	-127.7	2100.7	7	CLEAR	GOOD	17.2	1866	8.61	82
34339	1045	42216.37153	211COGT	MARK WOLFRAM	98.6	1856.4	6	CLEAR	FAIR	16.6	1846	8.49	72
34340	1120	42216.41181	211FHHC	MARK WOLFRAM	-60.8	2081.8	15	CLEAR	FAIR	15.1	1897	8.44	81
34344	1280	42216.45833	211COGT	MARK WOLFRAM	9.6	2081.4	3	CLEAR	FAIR	16.4	1863	8.53	81
285660		42273.6875	211FHHC	MARK WOLFRAM			2	CLEAR	FAIR	19.7	1860	8.83	
210188	1160	42188.40972	211FHHC	MARK WOLFRAM			7	CLEAR	UNKNOWN	19.4	1767	8.42	
251751	1240	42191.40625	211FHHC	MARK WOLFRAM	-86.2	2059.2	8	CLEAR	GOOD	18.2	1797	8.54	
250070	1180	42191.47222	211FHHC	MARK WOLFRAM	-80.5	2052.5	10	CLEAR	GOOD	18.3	1840	8.54	81
35227	830	42251.4125	211HLCK	MARK WOLFRAM	-30.7	2023.7	1	CLEAR	FAIR	13.7	2170	8.31	52
180092	1290	42172.77431	211FHHC	MARK WOLFRAM	-43.6	2046.6	8	CLEAR	GOOD	19.4	1804	8.58	
35238	1222	42191.75	211COGT	MARK WOLFRAM	-86.2	2012.2	12	CLEAR	FAIR	19.4	1793	8.43	
35242		42199.34375	211FHHC	MARK WOLFRAM				CLEAR	FAIR	16.8	1792	8.42	90
35244	1270	42191.70139	211COGT	MARK WOLFRAM	-57.1	2040.1	4	CLEAR, SILTY	FAIR	14.6	1803	8.42	
35246		42188.33333	211FHHC	MARK WOLFRAM	-73.3	2033.3	16	CLEAR	FAIR	18	1733	8.42	
35247	1278	42187.60417	211COGT	MARK WOLFRAM	-14.6	2049.6	2	CLEAR	FAIR	17	1755	8.38	

Gwic Id	Td	Inv Date	Aquifer	Who	Swl Grnd	Swl Elev	System Discharge	Water Condition	Well Condition	Water Temp (°C)	Field SC	Field pH	Chloride (mg/L)
35250	1330	42172.72917	211COGT	MARK WOLFRAM			12	CLEAR	FAIR	14.9	1810	8.63	
35268	1302	42200.38889	211COGT	WOLFRAM, CHANDLE	21.1	2008.9	2	CLEAR	FAIR	17.1	1844	8.53	77
35725	1267	42177.64583	211FHHC	MARK WOLFRAM			14	CLEAR	NOT VISIBLE	16.5	1920	8.63	
35738	1140	42237.64028	211FHHC	MARK WOLFRAM			0.8	CLEAR	FAIR	13.8	1951	8.34	81
35771	1134	42176.70833	211FXHL	MARK WOLFRAM	-82.4	1992.4	10	CLEAR	BURIED	18.4	1864	8.67	
35773	1120	42188.45833	211FXHL	MARK WOLFRAM			8	CLEAR	UNKNOWN	18.2	1785	8.42	
140084	1275	42174.73264	211FHHC	MARK WOLFRAM	-109.3	2012.3	15	CLEAR	GOOD	16.3	1903	8.58	
35780	1220	42158.60417	211FHHC	MARK WOLFRAM	-93.3	2004.3	20	OFF YELLOW	FAIR	12.3	2113	8.45	
35852	1240	42148.58333	211FHHC	MARK WOLFRAM	-78.1	1991.1	5	CLEAR	NOT VISIBLE	16.6	1855	8.3	
35861	1410	42175.58333	211FHHC	MARK WOLFRAM			5	CLEAR	FAIR	14.1	1856	8.57	
274382	1243	42160.52431	211FHHC	MARK WOLFRAM	-19.2	2017.2	30	CLEAR	NOT VISIBLE	14	1863	8.43	
35864	1410	42215.4375	211FXHL	MARK WOLFRAM			45	CLEAR	FAIR	22.8	1850	8.4	90
35866	1431	42201.3875	211FXHL	MARK WOLFRAM			18	CLEAR	FAIR	14	1815	8.82	85
35867	1345	42201.39792	211FHHC	MARK WOLFRAM			15	CLEAR	FAIR	21.5	1844	8.48	90
35873	1191	42159	211FHHC	MARK WOLFRAM	-2013.4	2013.4	2	OFF YELLOW	FAIR	14.3	1824	8.38	
35876	1195	42162.72917	211FHHC	MARK WOLFRAM	-95.4	2022.4	20	CLEAR	GOOD	17	1862	8.44	
209983	1300	42160	211FHHC	MARK WOLFRAM	-107	2013	14	CLEAR	FAIR	15.4	1891	8.38	
79510	1380	42160.5	211FHHC	MARK WOLFRAM	-100.8	2010.8	14	CLEAR	GOOD	17	2290	8.22	
35890	1286	42177.53472	211FHHC	MARK WOLFRAM			10	CLEAR	FAIR	19.4	1902	8.66	
35899	1277	42160.46181	211FXHL	MARK WOLFRAM	-75.1	2015.1	10	CLEAR	FAIR	17.6	1944	8.39	
35909	1320	42160	211FHHC	MARK WOLFRAM	-34.2	2034.2	4	CLEAR	NOT VISIBLE	11	1838	8.28	
35912	1233	42217.45139	211FHHC	MARK WOLFRAM	9.6	2004.4	3	CLEAR	FAIR	15.9	1817	8.56	90
35917	1172	42186.71875	211FHHC	MARK WOLFRAM	-51.8	2016.8	10	CLEAR	FAIR	18.9	1735	8.39	
35926	1180	42176	211FHHC	MARK WOLFRAM			1	CLEAR		10.7	1841	8.59	
35933	1140	42172.58333	211FHHC	MARK WOLFRAM	-101.3	2011.3	10	CLEAR	FAIR	14.5	1890	8.57	
35944	1240	42160	211FXHL	MARK WOLFRAM			8	LIGHT ORANGE	FAIR				
285378		42201.43056	211FHHC	MARK WOLFRAM			10	CLEAR	NOT VISIBLE	14.7	1823	8.47	
35949	1260	42174.60417	211FXHL	MARK WOLFRAM	-88.5	2027.5	10	CLEAR	UNKNOWN	12.1	1888	8.6	
35952	1240	42160.6875	211FXHL	MARK WOLFRAM	-83.9	2031.9	12	CLEAR	FAIR	16.7	1910	8.47	
36498	1320	42158.47569	211COGT	MARK WOLFRAM	-91.5	2001.5	8	CLEAR	NOT VISIBLE	12.2	2030	8.33	
185519	1280	42146.51736	211FHHC	MARK WOLFRAM			10	CLEAR	FAIR	18	2051	8.3	
36551	1370	42146.48264	211FHHC	MARK WOLFRAM	-85.2	1999.2	5	CLEAR	BURIED	11.3	2318	8.11	
36625	1200	42238.41667	211FHHC	MARK WOLFRAM	-72.1	2080.1	7	CLEAR	COVERED IN CULVERT	13.3	2097	8.25	110
36646	1360	42146	211FXHL	MARK WOLFRAM					INACTIVE				
36658	1285	42147	211FHHC	MARK WOLFRAM						11.7	1913	8.25	
36762	1200	42146.41667	211HLCK	MARK WOLFRAM			8	CLEAR	FAIR	7.4	1547	8.44	
36789	1490	42238.51181	211FXHL	MARK WOLFRAM			20	CLEAR	FAIR	12.4	1795	8.5	141
37440	1360	42287	211FXHL	MARK WOLFRAM	-53.8	2009.8	7	CLEAR	FAIR	14	2040	8.41	142
38113	1500	42286.65625	211FXHL	MARK WOLFRAM	-10	2060	8	CLEAR	FAIR	15.9	2080	8.38	147
38146	1445	42275.50486	211FXHL	MARK WOLFRAM	-62.1	2015.1	10	CLEAR	GOOD	17.3	2180	8.73	185
38151	1505	42286.59375	211FXHL	MARK WOLFRAM	19.15	2033.85			FAIR				
38159	1420	42254.59792	211FXHL	MARK WOLFRAM	-101.3	2023.3	12	CLEAR	NOT VISIBLE	16	1775	8.71	172
38161	1488	42287.52917	211FXHL	MARK WOLFRAM			6	CLEAR	FAIR	10.7	2016	8.35	147
38175	1405	42286.51181	211FXHL	MARK WOLFRAM	-81	2029	10	CLEAR	GOOD	14.9	2370	8.17	

Gwic Id	Td	Inv Date	Aquifer	Who	Swl Grnd	Swl Elev	System Discharge	Water Condition	Well Condition	Water Temp (°C)	Field SC	Field pH	Chloride (mg/L)
38184	1400	42286.56389	211FXHL	MARK WOLFRAM			10	CLEAR	FAIR	12.5	2105	8.33	142
285661		42275.56319	211FHHC	MARK WOLFRAM	-99	1999	14	CLEAR	NOT VISIBLE	21	2180	8.72	185
38712	1335	42254.47222	211FXHL	MARK WOLFRAM	-121.1	2028.1	15	CLEAR	FAIR	16.9	1770	8.74	165
38713	1434	42275.60417	211FXHL	MARK WOLFRAM	-168.6	2063.6	14	CLEAR	GOOD	18.5	2130	8.73	172
38742	1430	42285.65625	211FHHC	MARK WOLFRAM	-144.5	2024.5	12	CLEAR	GOOD	20.6	2245	8.33	176
38750	1440	42287.59722	211FHHC	MARK WOLFRAM	-148.5	2026.5	15	CLEAR	NOT VISIBLE	17.7	2870	7.94	170
39390	619	42253.75	211FHHC	MARK WOLFRAM	-44.8	1972.8	6	CLEAR	FAIR	13.3	1840	8.86	110
284329	750	42253.70417	211FHHC	MARK WOLFRAM	-33	1963	8	CLEAR	FAIR	14.9	1820	8.86	110
268478	700	42253.60069	211FHHC	MARK WOLFRAM	-39	1974	10	CLEAR	NEW	13.8	1450	8.84	110
39400	900	42253.65625	211FHHC	MARK WOLFRAM	-51.8	1979.8	3	CLEAR	FLOODED, NOT VISIBLE	14.9	1530	8.83	126
39424		42251.55903	211FHHC	MARK WOLFRAM	-43.6	1955.6	2.5	CLEAR	FAIR	10.9	2010	8.35	57
39425		42274.48611	211FHHC	MARK WOLFRAM			6	CLEAR	NOT LOCATED	17.2	1821	8.92	48