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Christensen Farms Aquifer Test
Swine Finishing Facility; Well Use Impact Evaluation
Hand County, South Dakota
Summary Findings Report

1.0 INTRODUCTION

In February and March 2019, an aquifer test was conducted at two Christensen Farms (CF) swine finishing facilities located in Hand County, South Dakota to address the concern of potentially reducing the artesian flow rates at neighboring wells from the use of the respective production wells at the facilities. The wells and facilities are referred to as G005 and G006. The anticipated maximum daily use from each well is approximately 3,600 to 4,000 gallons which equates to an average flow rate of approximately 2 to 3 gallons per minutes (gpm). The neighboring wells are used for cattle watering purposes. Northwest AqwaTek Solutions (Wadena, Minnesota) was retained by Christensen Farms (Sleepy Eye, Minnesota) to conduct the aquifer test.

The CF and nearby wells are completed in the Dakota Sandstone aquifer at depths ranging from approximately 950 feet to 1,250 feet. The aquifer occurs under flowing artesian conditions in the vicinity of the CF facilities; therefore, the wells flow naturally at the surface at rates of approximately 5 gpm to 20 gpm.

1.1 Design

The monitoring network consisted of four wells; G006 and three cattle water supply wells. Well G005 already had been plumbed into the respective barn and therefore, the pressure probe that was wired to the Grundfos pump in the well maintained a constant pressure head within the respective piping. Consequently, no monitoring was conducted at this well.

Figure 1 provides a geographical distribution of the wells. The respective cattle wells are labelled as Rocky Oakley, Jim Becker, and Fortune 1. It's important to note that the Jeff Bust well shown in Figure 1 was intended to be part of the monitoring network. However, upon contacting Mr. Bust to acquire permission to access his well, he declined our request to include his well for the test. Table 1 provides the location coordinates, elevation, well screen intervals, and respective distances and directions of the wells from the wells.

Each well was equipped with a 5/8-inch x ¾ inch *Badger E-Series* Ultrasonic flow meter attached to an *ORION* cellular fixed radio transmission endpoint antenna. The operating range of the meter is 0.1 gpm to 25.0 gpm. Flow rates were stored at 15-minutes intervals, transmitted electronically every four hours to a cloud-based network and then remotely downloaded to a laptop computer by NWATS personnel.

Wells G006 and Fortune 1 were equipped with an *In-Situ Level Troll 400* absolute pressure transducer to monitor the change in pressure head of the aquifer, compare change in flow rate to change in pressure head, and to calculate the barometric efficiency (i.e., atmospheric pressure effect on the fluctuation of pressure heads and flow rates) of the Dakota sandstone aquifer.

1.2 Implementation

The aquifer test consisted of four monitoring phases: 1) background, 2) pressure head (no flow) response, 3) pumping (flow) response, and 4) recovery. The effect of inversely stressing the aquifer by decreasing the total outflow from it was monitored during Phase 2, whereas the effect of directly stressing the aquifer by increasing the total discharge from it was monitored during Phase 3. The equivalent stress to the aquifer was approximately 2.5 times the maximum anticipated daily use of each production well.

Background monitoring of the pressure heads and flow rates occurred for a period of 8 days from February 10th to February 18th. The pressure response phase which consisted of shutting in and stopping the flow at well G006 occurred over a period of 13 days from February 18th to March 3rd. The pumping phase which consisted of discharging water from well G005 at a continuous rate of approximately 7 gpm occurred for a period 6 days from February 25th to March 3rd. And monitoring for "rebound" (recovery) of flow rates and pressure heads in the neighboring wells following the pumping of G005 occurred from March 3rd to March 22nd for a total of 20 days. Table 2 provides an operational timeline and manual flow rate verification of the wells.

2.0 FINDINGS

The findings from each of the monitoring phases are presented below as bullet items with reference to the subsequent figures. Data plots of the flow rates and hydrostatic pressure heads are provided in Figures 2 thru 5.

2.1 Well G006

- *Background monitoring* – The well was drilled November 2018 and allowed to free flow into a nearby ditch at a rate of approximately 7 gpm upon its completion. The rate was maintained with a gate valve that was installed at the top of the well. The flow remained steady at 7 gpm during background monitoring with minor fluctuations occurring as a result of variations in the barometric pressure (Figure 3).
- *Pressure head monitoring* - Flow from the well stopped upon shutting off the gate valve. The hydrostatic pressure was monitored at the well head at 15-minute intervals and the resultant data reveal a total fluctuation in pressure of approximately 1 psi (2.3 feet of water) and a fluctuating pattern similar to that which occurred at Fortune 1.

- *Pumping phase* – The monitoring interval of the pressure transducers was decreased to one minute, and no decrease in the hydrostatic pressure was observed during the pumping of well G005.
- *Recovery phase* - The gate valve was reopened, and the flow rate reestablished at approximately 7 gpm.

2.2 Fortune 1 Well

- *Background monitoring* – The well has been free flowing from an open pipe in the center of a former cattle watering trough at a rate of several gallons per minute since late fall 2018. No valve controls the flow from the pipe. The flow meter was attached to the end of the pipe and a rate of approximately 4.61 gpm was recorded. The corresponding pressure reading was 1.93 psi (4.4 feet of water). The flow rate fluctuated between 4.65 gpm and 4.85 gpm in direct response to changes in barometric pressure (Figure 4). The barometric efficiency of the aquifer was calculated at 20%.
- *Pressure head monitoring* – The flow rate continued to fluctuate at the same rate and pattern to that which occurred during the background monitoring phase. Therefore, no effect from shutting off the flow at well G006 was observed at the well.
- *Pumping phase* – The flow rate fluctuated between 4.65 gpm and 4.75 gpm, which is approximate 0.1 gpm less than that observed during the previous two monitoring phases. However, the observed decrease in the upper flow rate (4.75 gpm) compared to the respective background and pressure head monitoring rate (4.85 gpm) is a result of a decrease/change in the overall magnitude of the barometric pressure (0.30 psi) during the pumping phase, as compared to the total decrease that occurred during the previous two phases (0.49 psi). In other words, less of a change (decrease) in barometric pressure resulted in less of change (increase) in flow rate. Consequently, no change in the flow rate at the Fortune 1 well occurred as a result of pumping Well G005.
- *Recovery phase* – The flow rate fluctuated between approximately 4.65 gpm and 4.85 gpm in direct response to changes in barometric pressure. Consequently, no change in the flow rate after pumping Well G005 occurred at the Fortune 1 well.

2.3 Becker Well

- *Background monitoring* – The well has been free flowing into a former (unused) cattle watering trough at a rate of approximately 1.35 gpm for the past several years. The rate was maintained with a single lever ball valve that was installed at the end point of ¾ PVC piping that extends underground from the well head and terminates into the center of the trough. The well is approximately 100 feet east of the trough. The valve was not adjusted at the time the flow meter was installed; therefore, the flow rate remained at 1.35 gpm during background monitoring. The data reveal that the flow was steady and not effected by changes in barometric pressure (Figure 5).
- *Pressure head monitoring* – The flow remained steady until around noon on February 19th (Figure 5) when the rate decreased below the operating range of the meter. The exact cause of the decrease is uncertain, but it's believed to be from partial ice buildup in the piping at or near the wellhead due to an extended period of extremely cold

temperatures. The meter recordings continued to fluctuate erratically after that time, perhaps from a malfunction to the electronic sensors in the meter, but the upper end readings reveal that the flow retained a rate of approximately 1.4 gpm and that no upward deflection occurred in the rate due to shutting in G006.

- *Pumping phase* – No change in the flow pattern of the upper end readings is apparent form the data plot indicating that the Becker well was not affected by the pumping of G005.
- *Recovery phase* – A similar pattern continued during the recovery phase from between March 3rd and March 11th. An overall downward deflection occurs in the data after March 11th. The Oakley's stated that approximately 70 head of cattle were transferred to their property at the Fortune 2 well location (see Figure 1) around March 10th and that the usage/consumption from the well increased due to the additional cattle. Also, the pump in the well malfunctioned around March 11th and was replaced March 12th. The Oakley's stated that afterwards, the discharge from the well appeared greater when the float valve activated the pump switch during periods of high consumption. Therefore, the downward deflection observed in the data is likely from the increased pumping of the Fortune 2 well.

2.4 Oakley Well

- *All phases of monitoring* – The well has been free flowing and discharging into a cattle watering area approximately 0.5 miles south of the well location for several years. The flow meter was installed at the end of the discharge line. The flow rate is held constant at the wellhead but is diverted at a few locations along the discharge line for cattle watering and heating purposes. Consequently, the flow rate at the end pipe varies depending on the volume of water that is diverted out of the piping throughout the day.

  The flow rates vary each day from less than 1 gpm to approximately 5.4 gpm (Figure 5). The magnitude of the variations fluctuates from day to day; however, the peak discharges are fairly consistent with a range of between 5.2 and 5.4 gpm. The pattern of and time length of the peak discharges is consistent throughout all phases of the aquifer test suggesting that neither the stoppage of flow from G006 or the pumping of G005 affected the flow rate of the Oakley well.

3.0 SUMMARY

- An aquifer test was conducting to evaluate the potential of reducing the flow rates of nearby cattle watering wells from the use of two Christensen Farms swine facility production wells.
- The test included four monitoring phases and two aquifer "stress" events. The latter consisted of shutting off the flow at well G006 for a period of 13 days and pumping well G005 at a continuous rate for 6 days. The flow rates at both wells were 7 gpm which is approximately 2.5 times the maximum anticipated daily consumptive use of the production wells.

- The flow rates were monitored at four wells with electronic flow meters, and the artesian pressure heads were measured at two of the four wells using pressure transducers.
- The resultant parameters that were monitored include an increase in flow rate and artesian pressure head during the stoppage of flow at well G006, and a decrease in pressure head and flow at the wells during the pumping of well G005.
- A comparison evaluation of the data collected at each of the wells during all four phases of the aquifer test reveal that neither the stoppage of flow from well G006 or the pumping of well G005 affected the flow rates at any of the neighboring wells.

Figure 2
Fortune 1, Becker, G005 & G006
Flow Rates

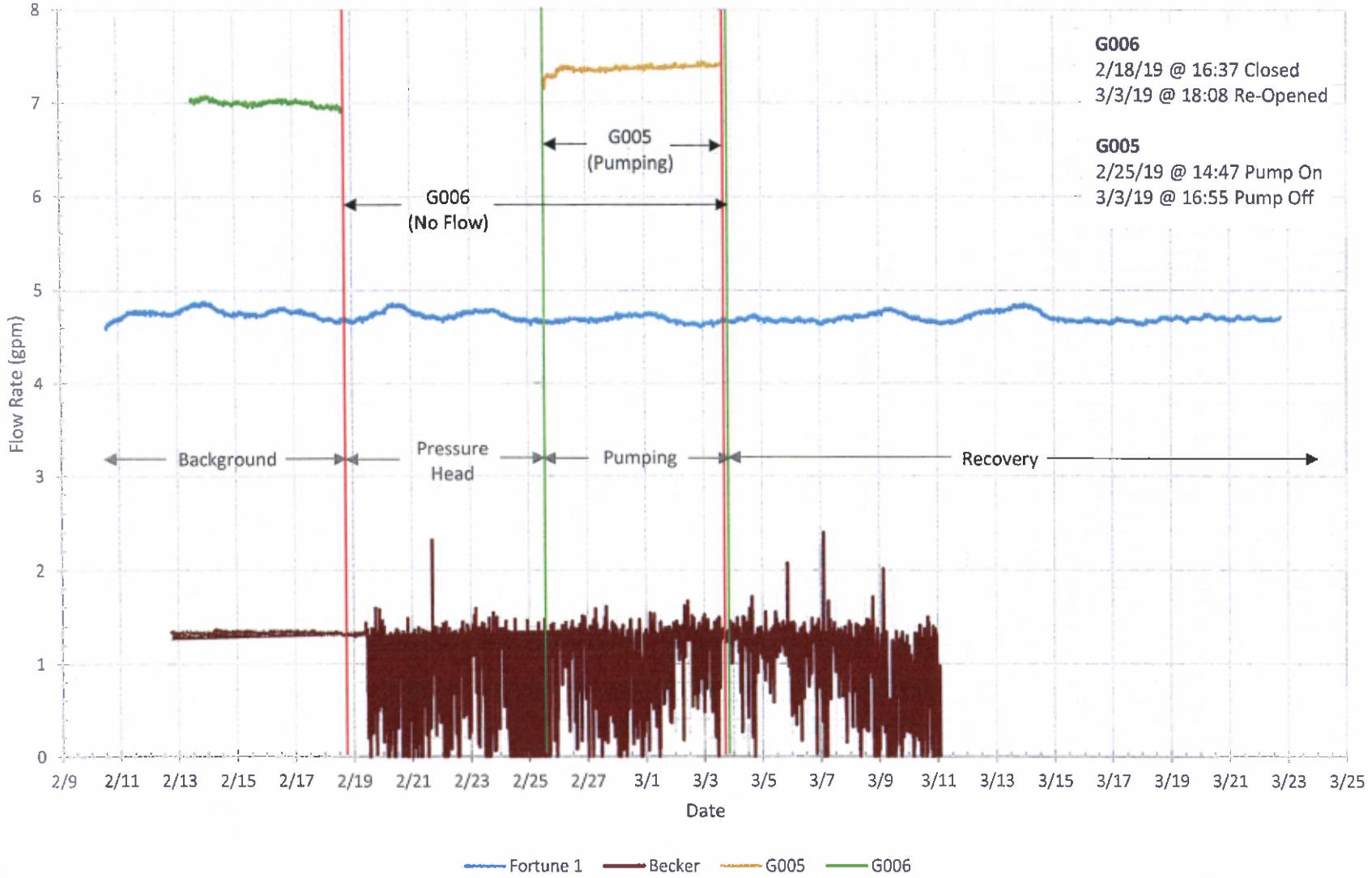


Figure 3
Flow Rates & Pressure Head
G006

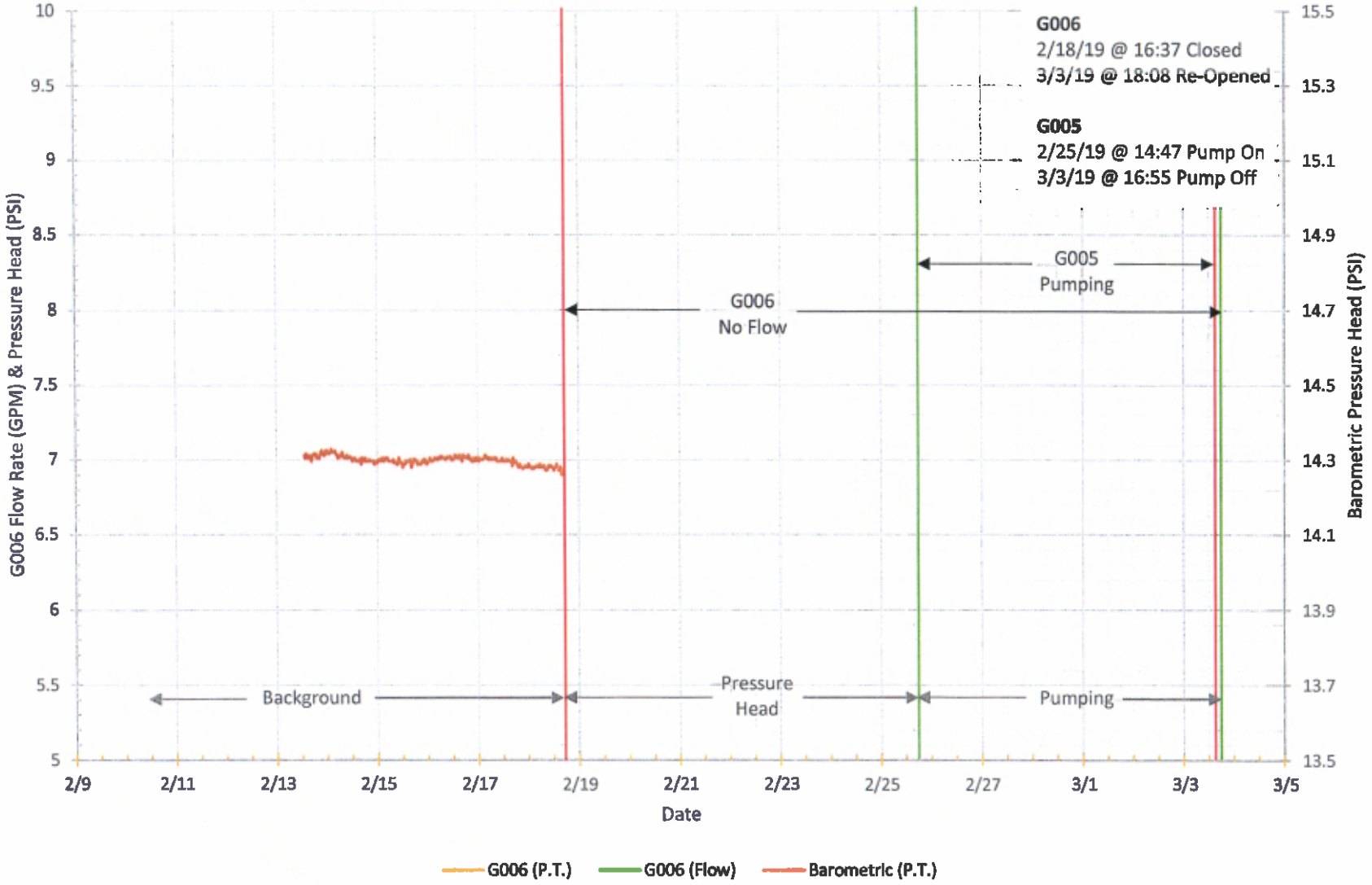


Figure 4
Flow Rates & Pressure Head
Fortune 1

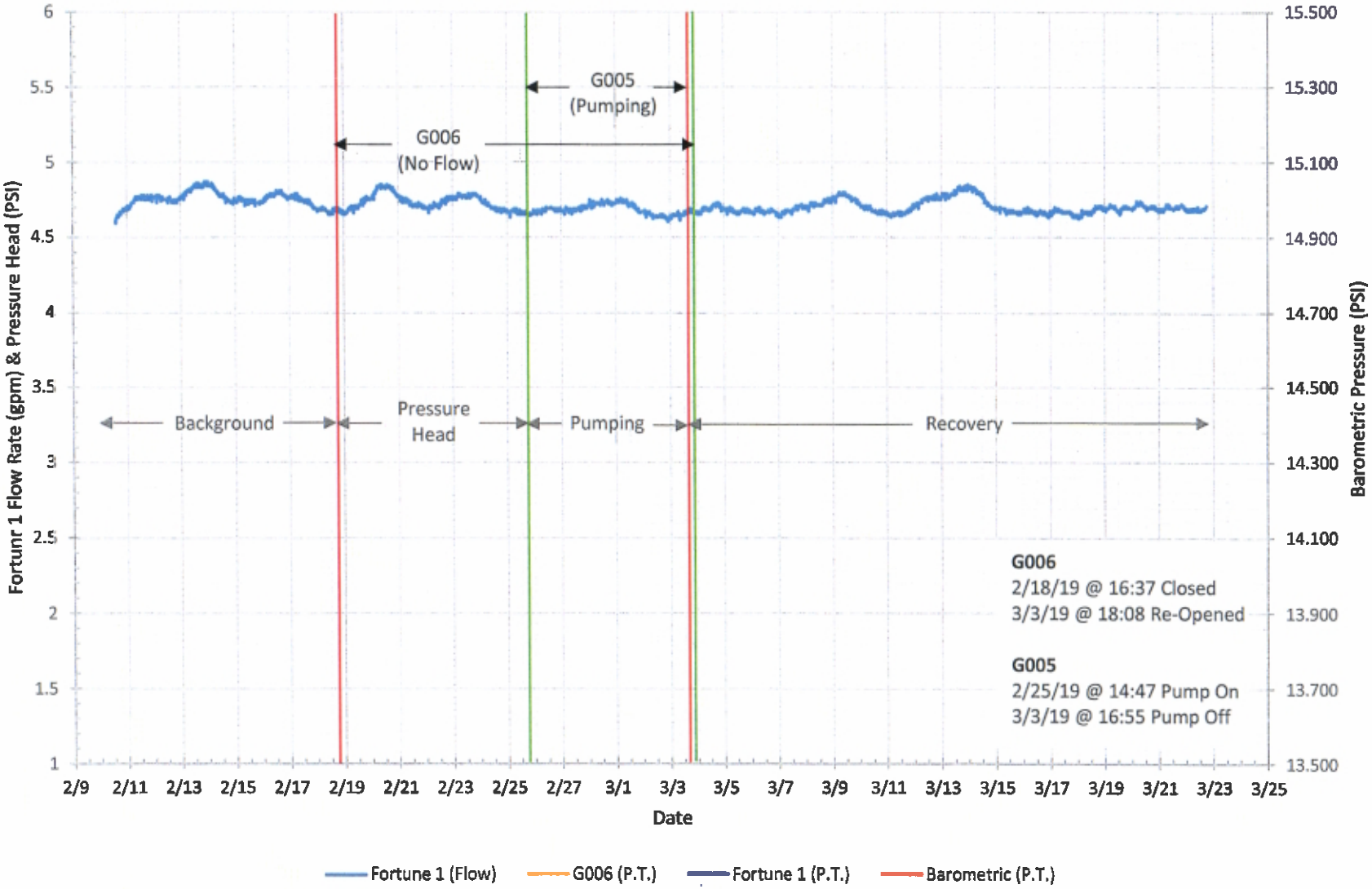


Figure 5
Becker and Rocky
Flow Rates

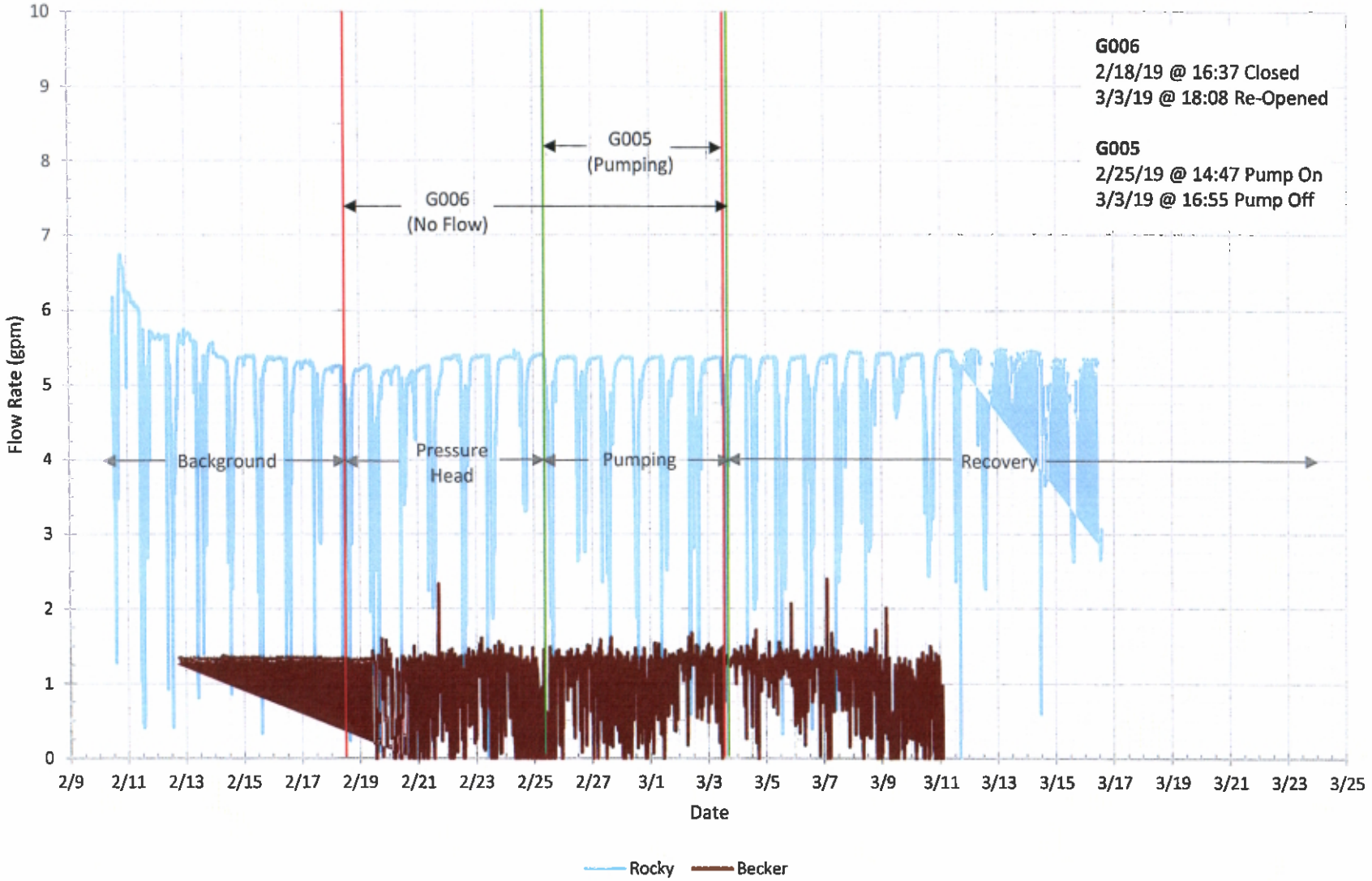


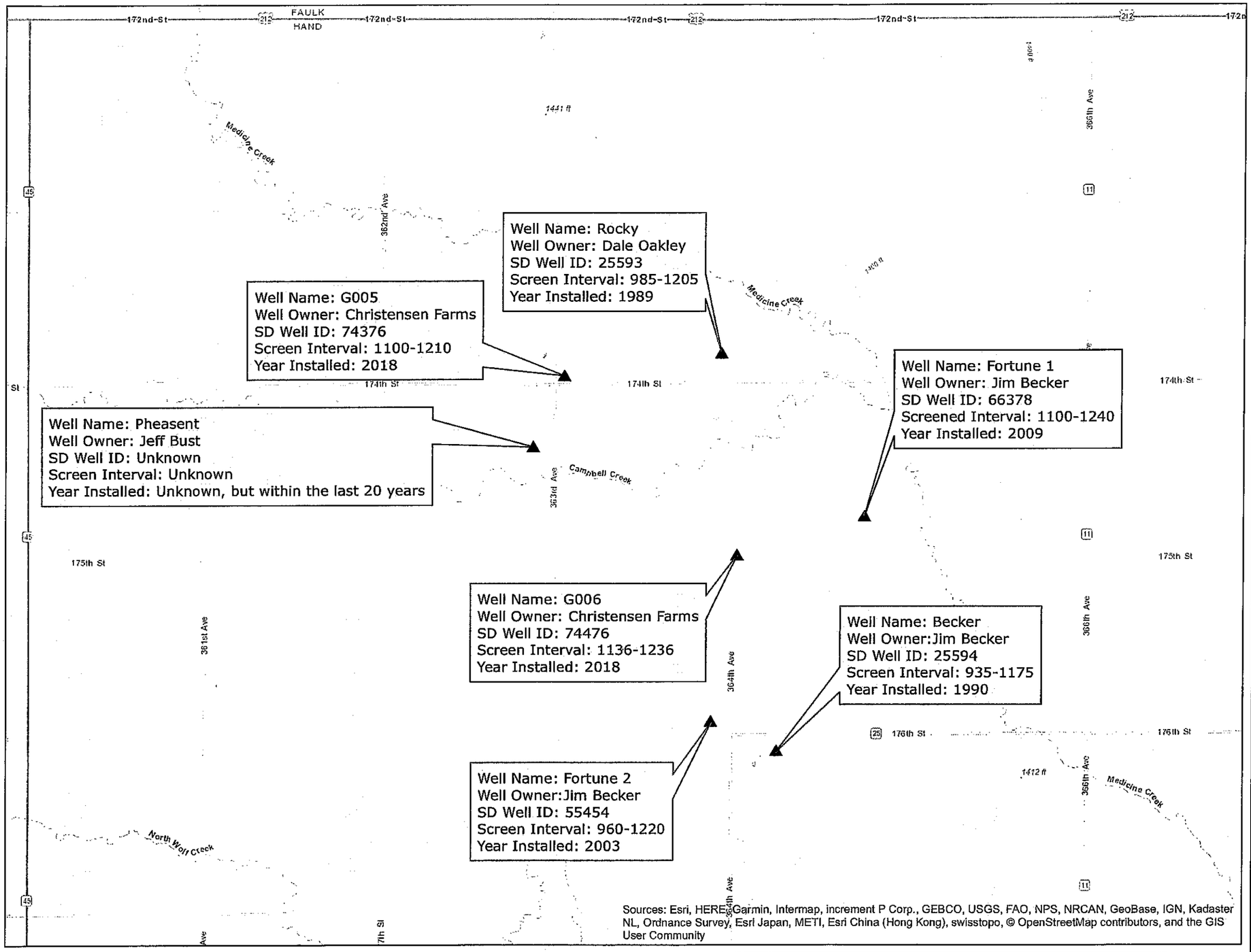
TABLE 1: WELL INFORMATION								
Well Name	**Well Completion #**	**Northing [1]**	**Easting [1]**	**Ground Elevation (ft MSL)**	**Screened Interval (ft BGS)**	**Use**	**Distance (feet) & Direction from Well G005**	**Distance (feet) & Direction from Well G006**
G005	74376	4968309.25	505943.03	1430	1100-1210	Production (Livestock)	0	7,500 NW
Rocky	25593	4968460.50	507229.17	1410	985-1205	Heating and Cattle Well	4,200 E	7,000 N
G006	74476	4966693.51	507417.62	1405	1136-1236	Production (Livestock)	7,500 SE	0
Fortune 1	66378	4966741.13	508826.53	1400	1100-1240	Cattle Well	11,250 SE	4,850 E
Becker	48175	4964806.97	507235.70	1410	935-1175	Former Cattle Well	12,700 SE	6,350 S

Notes:
1 - UTM Zone 14N Meters

TABLE 2: AQUIFER TEST AND OPERATION INFORMATION

Date	Well	Flow Meter #	Time	Flow Rate (gpm)	Notes
2/8/2019	G005	18653349	NA	NA	Flow meter installed at 2:57 pm
2/25/2019	G005	"	14:49	7.05	**14:47; start of pumping phase of aquifer test**
2/25/2019	G005	"	14:55	7.03	
3/3/2019	G005	"	12:20	7.34	
3/3/2019	G005	**End Point:**	13:48	7.50	
3/3/2019	G005	*#110384608*	16:54	7.40	Total Gals: 64,609.86 gals
3/3/2019	G005	"	16:55	NA	**Pumping Ceased; Total Gallons Pumped: 64,612.29: Avg. rate of 7.37 gpm**
2/10/2019	Rocky	18142983	11:44	6.16	Flow meter installed at approximately 11:42 am
2/13/2019	Rocky	"	13:38	3.93	
2/18/2019	Rocky	**End Point:**	NR	NR	**NR = Not Recorded**
2/25/2019	Rocky	*#110381536*	14:13	1.84	
3/23/2019	Rocky	"	15:30	4.87	Total Gals: 295,811.47 gals
2/10/2019	Fortune 1	18142981	14:05	4.63	2:05
2/13/2019	Fortune 1	"	13:14	4.82	
2/18/2019	Fortune 1	**End Point:**	14:30	4.69	Note: No recording on 2/25 due to access road completely drifted in
2/25/2019	Fortune 1	*#110381518*	NR	NR	**NR = Not Recorded**: access road completely drifted in
3/3/2019	Fortune 1	"	13:30	4.68	Total Gals: 142,872.5 gals; 4.73 gpm average rate
3/7/2019	Fortune 1	"	***Per MTS***		**Note: New reading of 153,333.80; est. time 12:00; flowrate - ~4.27 pgm**
3/22/2019	Fortune 1	"	18:05	4.7	Total Gals: 272,467.66 gals; 4.71 gpm average rate
2/12/2019	Becker	18653350	17:12	1.32	**Flow meter installed at approximately 5:00 pm**
2/13/2019	Becker	"	13:28	1.38	
2/18/2019	Becker	"	14:52	1.34	
2/25/2019	Becker	**End Point:**	13:37	1.44	
3/3/2019	Becker	*#110381734*	12:53	0	Water was trickling out of end of tube; Total gallons reading: 29,691.51
3/3/2019	Becker	"	12:56	1.40	Flow meter displaying + flow rate
3/3/2019	Becker	"	13:00	1.58	Flow rate reading maintained
3/7/2019	Becker	"	***Per MTS***		**Note: New reading of 32,249; est. time 02:00; flowrate - ~0.50 pgm**
3/23/2019	Becker	"	13:23	1.37	Totalizer reading: 44,610.24. Ave flow rate since 3/3: **~ 0.52 gpm;**
3/23/2019	Becker	"			Final Totalizer reading for Becker well: **44,615.86** gallons.
3/23/2019	Becker	"			**Note: Add. 70 head cattle at Fortune 2 by 3/10; New pump install. complete 3/12**

Date	Well	Flow Meter #	Time	Flow Rate (gpm)	Notes
2/13/2019	G006	18142982	12:14	7.04	**Flow meter installed at G006 @ 11:30 am.**
2/18/2019	G006	"	9:39	6.98	
2/18/2019	G006	"	13:33	6.95	
2/18/2019	G006	**End Point:**	15:32	6.92	
2/18/2019	G006	*#110387432*	16:34	6.95	**Shutoff flow @ 16:37; Totalizer Reading: 56,723.16**
2/18/2019	G006	"	16:37	0	**Total Gals: 56,723.16 - 4,339.45 = 52,383.71; Avg flow rate: (7,387 min.) = 7.09 gpm**
3/3/2019	G006	"	18:08	~7	**Reopened shutoff valve - estimated flow rate: approximately 7 gpm**
3/6/2019	G006	"	~ 16:00	0	Well shut in - no longer flowing per well driller/construction personnel



N

0 1,500 3,000 6,000

Feet

1 inch = 3,000 feet

Legend

▲ Well Location

Northwest AqwaTek Solutions
NWATS
123 Jefferson St So.
Wadena MN 56482
nwats.com

Version	Description	Drawn	Date	Checked	Date
1	Original Issue	KLA	Date	KLA	Date

Christensen Farms
Linn Township
Hand County, SD

Figure 1
Map Showing
Well Locations

NWATS Project #: 10601
Date: 3/30/2019

1