City of Farmington Wellhead Protection Plan Amendment

Part I:

Delineation of the Wellhead Protection Area (WHPA), Drinking Water Supply Management Area (DWSMA), and Assessments of Well and DWSMA Vulnerability

Prepared for

March 2016

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Certifications

I hereby certify that this plan, document, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the laws of the state of Minnesota.

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March 15, 2016

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General Information

UNIQUE WELL NUMBER(S) 200932, 201154, 235586, 603051, 626785, 655902, 731123

SIZE OF POPULATION SERVED 21,086 (2010 Census)

COUNTY Dakota

1.0 Introduction

In compliance with the Minnesota Wellhead Protection Rules (MN Rules 4720.5100 through 4720.5590), wellhead protection areas (WHPAs) and Drinking Water Supply Management Areas (DWSMAs) were delineated for the City of Farmington in 2004 (Bonestroo, 2004). Minnesota Rule 4720.5570 states that wellhead protection plans must be reviewed and amended at least every ten years. In addition, the Minnesota Department of Health (MDH) has instituted requirements for inclusion of fracture-flow analysis in the delineation of WHPAs since the last delineation of the City's WHPAs and DWSMAs.

As required by Minnesota Rule 4720.5570, new WHPAs and new DWSMAs have been delineated for the City of Farmington. This report summarizes work completed to update the delineation of the Farmington WHPAs and DWSMAs in compliance with the Minnesota Wellhead Protection Rules and to meet the current MDH requirements. Data elements used in preparation of the report are presented in Table 1.

The City of Farmington currently has 7 municipal water supply wells. Wells 1 and 3 (unique numbers 200932 and 201154, respectively) are open to both the Prairie du Chien Group and Jordan Sandstone aquifers. Wells 4, 5, 6, 7, and 8 (unique numbers 235586, 603051, 626785, 655902, 731123, respectively) are open to only the Jordan Sandstone aquifer. Well locations are shown on Figure 1. Table 2 summarizes construction, use, and vulnerability information for the Farmington water supply wells. Well logs for the City's wells are presented in Appendix A.

2.0 Criteria for Wellhead Protection Area Delineation

The following criteria were used to ensure accurate delineation of the WHPAs.

2.1 Time of Travel

A minimum 10-year groundwater time of travel criterion must be used to delineate a WHPA (MN Rule 4720.5510) so there is sufficient reaction time to respond to potential health impacts in the event of contamination of the aquifer. A groundwater time of travel of ten years was considered in this study. As required by the Wellhead Protection Rules, the one-year groundwater time of travel was also determined for each well addressed in this study.

2.2 Aquifer Transmissivity

For this study, the transmissivity of the Jordan Sandstone aquifer was estimated from an aquifer test conducted at Farmington Well 7 and the transmissivity of the Prairie du Chien Group aquifer was estimated from specific capacity data of nearby wells. Summaries of the aquifer tests are included in Appendix B. See Section 2.5 below for details regarding how these transmissivity values were included in the groundwater model.

The previous Farmington WHPP (Bonestroo, 2004) contains data from a 24-hour pumping test conducted at Farmington Well 7. Wells 5 and 6 were used as observation wells during the test. Analyses by Bonestroo (2004) using the Cooper-Jacob (1946) method for confined aquifers and by Barr for this study using the Hantush-Jacob (1955) method for leaky confined aquifers produced comparable results. The geometric mean transmissivity estimated from the pumping test data was 23,700 ft^2/day (2,200 m^2/day).

The transmissivity of the Prairie du Chien Group was estimated as 1,200 ft^2/day (114 m^2/day) using the TGuess method (Bradbury and Rothschild, 1985) from test pumping data collected from 25 County Well Index (CWI) well records in the vicinity of Farmington.

2.3 Daily Volume of Water Pumped

Pumping data for the City of Farmington for the period 2010 through 2014 are summarized in Table 3. The largest annual withdrawal for 2010-2014 was 801,284,000 gallons in 2012. The projected 2020 average daily demand in the City's Water Supply and Distribution Plan (Bonestroo, 2009) corresponds to a 2020 total annual withdrawal of 1,134,600,000 gallons. The maximum projected 2020 pumping from each well was estimated based on the percentage of the total volume that each well pumped from 2010-2014 and the 2020 projected demand. The pumping rate used in the model for each Farmington well for the WHPA delineation was either the historical maximum for the period 2010-2014 or the maximum projected for 2020, whichever was greater. Table 3 summarizes the pumping rates used in the model for delineation of the WHPAs. Non-revenue water (the difference between the total volume pumped annually by the City's wells and the total amount billed to users) averages approximately 8% (Schorzman, 2015).

2.4 Conceptual Hydrogeologic Model

The regional hydrogeologic conceptual model is presented in Metropolitan Council (2014). Additional geological information is included below, along with discussion of groundwater flow boundaries and flow directions specific to the Farmington area.

2.4.1 Regional Bedrock Geology

A bedrock map derived from the Twin Cities Metropolitan Area geologic map (Mossler, 2013) is shown on Figure 1. Locations of two geologic cross sections through the study area are also shown on Figure 1. Geologic cross section A-A' (Figure 2) is a north to south section that crosses west to east cross section B-B' (Figure 3) at Farmington Well 5.

The hydrostratigraphic units of importance for this study are described in more detail below.

Jordan Sandstone

The Cambrian-aged Jordan Sandstone is typically 85 to 100 feet thick and consists of two interlayered facies of medium- to coarse-grained quartz sandstone and very fine-grained feldspathic sandstone with lenses of siltstone and shale (Mossler, 2013). Groundwater flow in the Jordan Sandstone is primarily intergranular (Palen, 1990). The Jordan Sandstone is the main high-capacity aquifer in much of the Twin Cities metropolitan area and all of Farmington's wells pump water from it.

Prairie du Chien Group

The Ordovician-aged Prairie du Chien Group consists of two formations: the Shakopee Formation, a grayish-orange to yellowish-gray heterolithic unit composed of dolostone, sandy dolostone, and sandstone, and the Oneota Dolomite, a yellowish-gray to pale brown dolostone (Mossler, 2013). The Prairie du Chien Group is present everywhere beneath the City of Farmington. The Prairie du Chien Group is classified as being highly fractured over much of the Twin Cities metropolitan area, especially under shallow bedrock conditions (overlying bedrock thickness < 200 feet, after Runkel et al. (2003)). Groundwater in the Prairie du Chien Group flows through joints, fractures, and bedding planes (Palen, 1990).

St. Peter Sandstone

The Ordovician-age St. Peter Sandstone is divided into two members: the upper Tonti Member is fine- to medium-grained quartzose sandstone that is generally massive- to very thickly bedded, while the lower Pigs Eye Member is an interbedded sandstone, siltstone and shale (Mossler, 2013). The Pigs Eye Member typically has low vertical permeability and, where present, functions as an aquitard over the underlying Prairie du Chien Group (Runkel et. al, 2003). The upper Tonti Member has much greater permeability than the Pigs Eye Member and functions as an aquifer. The St. Peter Sandstone is the uppermost bedrock over much of northern Farmington. It is present at all Farmington wells except Wells 1 and 3.

2.4.2 Flow Boundaries

Groundwater flow boundaries in the vicinity of Farmington include the Vermillion River and its tributaries, which flow through the City towards the Mississippi River to the east.

2.5 Model Description

To accurately delineate the WHPAs, it is necessary to assess how nearby wells, rivers, lakes, and variations in geologic conditions affect groundwater flow directions and velocities in the aquifer. A groundwater model constructed using the finite difference code MODFLOW-NWT (Niswonger, et al., 2011) was used for this study to simulate groundwater flow in the hydrostratigraphic units from the Quaternary aquifer down to the Mt. Simon Sandstone. MODFLOW is public domain software that is available at no cost from the United States Geological Survey. The pre- and post-processor Groundwater Vistas (version 6) (Environmental Simulations, Inc., 2011) was used to create the model data files and evaluate the model results.

2.5.1 Base Model

Since the previous Farmington Wellhead Protection Plan was prepared, the Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0 (Metropolitan Council, 2014) was developed by Barr Engineering for the Metropolitan Council. This regional model includes Farmington and, per discussions at the Pre-Delineation Meeting (MDH, 2015), Metro Model 3 was used as the base model for the new Farmington WHPA delineations.

Major rivers near Farmington (i.e., the Vermillion and Mississippi Rivers) as well as lakes in the area are simulated using the River Package within MODFLOW. Baseflow measurements for rivers and streams in the area were used during calibration of Metro Model 3. Metro Model 3 includes high-capacity wells in the vicinity of Farmington.

Recharge for the groundwater flow model was determined using the SWB recharge model (Westenbroek et al., 2010) for the Twin Cities metropolitan area as described in Metropolitan Council (2012).

Modifications made to Metro Model 3 for the Farmington WHPA delineations are discussed in the following section.

2.5.2 Model Modifications and Updates

The following modifications and updates were made to the base model:

- The pumping rates of the Farmington municipal wells were changed to the model input rates shown in Table 3.
- The model grid was refined from the 500-m square cells of the base model down to 125-m square cells within the Farmington city limits. The grid was further refined to 7.81-m square cells in the immediate vicinity of the Farmington wells.
- Hydraulic conductivity values were updated so that model layer transmissivities in the vicinity of the Farmington wells match aquifer test transmissivities as described below. The values listed below are horizontal hydraulic conductivities (i.e., Kx values); the ratio of horizontal to vertical hydraulic conductivity (i.e., Kx/Kz) in the base Metro Model 3 was preserved when making these changes. See Appendix C for maps of model hydraulic conductivity fields.
    - Prairie du Chien Group. As discussed above in Section 2.2, a transmissivity of 1,200 ft^2/day (114 m^2/day) was estimated for the Prairie du Chien Group. The Layer 3

transmissivities at Wells 1 and 3 in Metro Model 3 are 1,620 and 1,230 ft^2/day (151 and 114 m^2/day), respectively. Since these values were so close to the estimated Prairie du Chien transmissivity, no changes were made to the Layer 3 hydraulic conductivity field. Figure C1 in Appendix C shows the Prairie du Chien horizontal hydraulic conductivity field in the vicinity of Farmington.

- Jordan Sandstone. The transmissivity at Well 7 in Metro Model 3 is 4,240 ft^2/day (394 m^2/day), which is less than the aquifer test value of 23,700 ft^2/day (2,200 m^2/day). In order to match the pumping test transmissivity at Well 7, the Layer 4 hydraulic conductivity field was scaled by a factor of 5.5865 within the Farmington city limits and approximately 7,000 feet (2,100 m) to the south in order to encompass all capture zones. Figure C2 in Appendix C shows the Jordan horizontal hydraulic conductivity field in the vicinity of Farmington.
- St. Peter Sandstone. While no Farmington municipal wells are completed in the St. Peter Sandstone, the Metro Model 3 hydraulic conductivities in this formation seemed too large. Based on data for the St. Peter under shallow bedrock conditions presented by Runkel et al. (2003), all Layer 2 cells representing the St. Peter within Farmington were assigned a Kx value of 25 ft/day (7.62 m/day). A Kx/Kz ratio of 10 was assumed for these cells. Figure C3 in Appendix C shows the St. Peter horizontal hydraulic conductivity field in the vicinity of Farmington.

As discussed at the Pre-Delineation Meeting, no additional recalibration of the model was deemed necessary. Calibration summary plots for the updated model are included in Appendix C (see Figure C4). Full discussion of the Metro Model 3 calibration is presented in Metropolitan Council (2014). MODFLOW files for the updated model are included in Appendix H.

2.6 Groundwater Flow Field

The groundwater flow field used for delineation of the WHPAs was determined by the groundwater flow model; modeled contours for the Prairie du Chien Group and Jordan Sandstone are shown on Figures 4 and 5, respectively.

In general, Figures 4 and 5 show northeasterly to easterly groundwater flow directions consistent with the Prairie du Chien-Jordan groundwater contour map from the Dakota County Geologic Atlas (Palen, 1990). However, local flow directions in the Prairie du Chien Group and the Jordan Sandstone differ in the vicinity of Wells 4-8. Figure 4 shows a southeasterly flow component in the Prairie du Chien Group in this area, while Figure 5 shows northeasterly flow in the Jordan. Flow directions in the Prairie du Chien Group appear to be influenced by the Vermillion River, which passes to the southeast of Wells 4-8. While the Prairie du Chien Group and Jordan Sandstone are sometimes considered a single aquifer (e.g., Palen, 1990), local variations in flow directions between the two units are possible due to the differing nature of groundwater flow in each: flow in the Prairie du Chien Group occurs along fractures, joints, and bedding planes, while flow in the Jordan Sandstone is primarily intergranular. Where unfractured, the thick-bedded, massive dolomite that makes up the lower Oneota Dolomite member of the Prairie du Chien Group may act as a confining unit for the Jordan Sandstone.

3.0 Delineation of the Wellhead Protection Areas

Delineation of the WHPAs for the Farmington wells involved the evaluation of both porous media flow and fracture flow. A porous media capture zone and a fracture flow capture zone were delineated separately for each well and then combined to delineate the composite WHPA.

3.1 Porous Media Flow Evaluation

The groundwater flow model discussed above in Section 2 was used to simulate the groundwater flow field in the vicinity of Farmington. The porous media capture zone for the Farmington well field was delineated using the software program MODPATH (Version 5) with the modeled groundwater flow field. A minimum of 180 particles were tracked from each well. The particles were released from 6 vertical points in each layer along the open interval of each well. These particles were tracked backwards in time for both one and ten years. In plan view, the areas encompassed by the particle traces were then outlined as the one- and ten-year porous media time of travel zones for the well field.

Porosity values used for the porous media flow evaluation were as follows (Norvitch et al., 1974, Schwartz and Zhang, 2003):

- Quaternary Glacial Drift = 0.25
- St. Peter Sandstone = 0.2
- Prairie du Chien Group = 0.056
- Jordan Sandstone = 0.2

3.1.1 Sensitivity Analysis

A sensitivity analysis was performed to test the sensitivity of the model results to varying hydraulic conductivity in the same regions for which modifications were made to the base model (as described in Section 2.5.2 above). The ranges of transmissivities estimated for the various aquifers by the pumping test analyses and specific capacity calculations (Appendix B) were used to assign the upper and lower bounds for the model sensitivity analysis. The ratio of horizontal to vertical hydraulic conductivity in the base Metro Model 3 was preserved for each model sensitivity run.

- Prairie du Chien Group. Transmissivity values from the specific capacity analysis ranged from 340 ft^2/day to 4,800 ft^2/day (32 m^2/day to 443 m^2/day). The low and high bounds of the range are factors of 0.2807 and 3.8860, respectively, of the mean transmissivity. For the sensitivity analysis, scaled K values were used within the Farmington city limits and far enough outside of them to encompass all capture zones by the low and high bound factors.
- Jordan Sandstone. The aquifer test analysis for indicated that the transmissivity ranges from 13,240 ft^2/day to 41,520 ft^2/day (1,230 m^2/day to 3,860 m^2/day). Since the lower bound was still higher than the existing Metro Model 3 transmissivity, the existing K field from Metro Model 3 was used for the sensitivity analysis lower bound. The Metro Model 3 hydraulic conductivity field was scaled over the same area described above by a factor of 9.8017 to match the upper bound for the sensitivity analysis.

The model was most sensitive to changing the Jordan hydraulic conductivity. A summary of the sensitivity analysis results is included in Appendix C (Figure C5).

Multiple particle tracking simulations were conducted to account for uncertainty in the groundwater flow model. In addition to the base model run, particle tracking simulations were conducted for the upper and lower conductivity bounds of each sensitivity run. Particle traces from all simulations were used to delineate the 1-year and 10-year porous media capture zones for each well (Figure 6).

3.2 Fracture Flow Evaluation

As noted in Section 1.0, two of Farmington's wells are open to the Prairie du Chien Group and the remaining five are all completed in the Jordan Sandstone, which is likely hydraulically connected to the Prairie du Chien Group. To address fracture flow in the Prairie du Chien Group, MDH (2011a) guidelines for delineating WHPAs in fractured and solution-weathered bedrock were followed using Delineation Technique Number 3 (wells open to both a porous media aquifer and a fractured or solution-weathered aquifer) for Wells 1 and 3 and Delineation Technique Number 4 (wells open only to a porous media aquifer that is hydraulically connected to a fractured or solution-weathered aquifer) for Wells 4, 5, 6, 7, and 8. A summary of the calculations used in the delineation of fracture flow capture zones is presented in Appendix D.

3.2.1 Fixed Radius Capture Zones and Upgradient Extensions

Wells 1 and 3 are open to both the Prairie du Chien Group and the Jordan Sandstone. Following the MDH guidelines (MDH, 2011a), the total pumping rate for each well was applied to the Prairie du Chien Group and the ratio of the well discharge to the discharge vector was calculated. This ratio was greater than 3,000 for both Wells 1 and 3, so Delineation Technique Number 1 was used for both wells to delineate 1-year and 10-year fixed radius fracture flow capture zones. The 10-year fixed radius capture zones for Wells 1 and 3 overlapped; this overlap was accounted for following the MDH guidelines, except that the intersecting area was calculated using ArcMap™. The fracture flow capture zones are shown on Figure 6.

Although Wells 4, 5, 6, 7, and 8 are only open to the Jordan Sandstone, a porous media aquifer, the porous media modeling suggests that the Jordan Sandstone is hydraulically connected to the fractured and solution-weathered Prairie du Chien Group. The water budget software ZONEBUDGET (Harbaugh, 1990) was used to compute the contribution from model layer 3 (Prairie du Chien Group) to the baseline 10-year porous media capture zone for each well. Flow from model layer 3 to model layer 4 ranged from 14% of the pumping rate for Well 6 to 32% of the pumping rate for Well 4. The MDH guidelines cite a threshold of 10% for determining whether or not recharge from the fractured or solution-weathered aquifer is a significant source of recharge to the porous media aquifer; since the calculated percentages for Wells 4-8 were all above this threshold, it was necessary to delineate fracture flow capture zones for each well.

The ratio of the well discharge to the discharge vector was calculated for Wells 4-8 using the contributions from model layer 3 calculated by ZONEBUDGET as the pumping rates. This ratio was less than 3,000 for Wells 4, 5, 6, 7, and 8, so upgradient extensions were required for the 10-year fracture flow capture zones.

For each well, Delineation Technique Number 1 was used to delineate a 1-year fixed radius capture zone and Delineation Technique Number 2 was used to delineate 5-year fixed radius capture zones with 5-year upgradient extensions. The model layer 3 contributions to the 10-year porous media capture zones were used as the pumping rates, and the flow directions for the upgradient extensions were determined from the baseline model results for the Prairie du Chien Group (Figure 4). Due to the close proximity of Wells 5, 6, and 7, these wells were treated as a single well located at the centroid of a convex polygon with vertices at Wells 5, 6, and 7 and with a total pumping rate equal to the sum of the ZONEBUDGET model layer 3 to model layer 4 flows for Wells 5, 6, and 7.

3.2.2 Overlap from Nearby Wells

A search of the Minnesota Department of Natural Resources' (MnDNR) Permitting and Reporting System (MPARS) was conducted to find any nearby high-capacity wells that may have fixed-radius capture zones that overlap the Farmington well fracture flow capture zones. Twenty-nine active permitted wells completed in the Prairie du Chien and/or Jordan were identified within 4 km of the 10-year porous media capture zones (see Figure D1 in Appendix D for a map). Ten-year fixed radius capture zones were calculated for these wells using the following assumptions:

- Average pumping rate for 2010-2014 calculated from MPARS records
- All pumping applied to the Prairie du Chien Group
- Prairie du Chien porosity = 0.056
- Open interval either 200' or Prairie du Chien open interval recorded on well log, whichever is smaller
- For wells with insufficient construction and/or geologic data, open interval assumed to be 200' since the Prairie du Chien Group is typically greater than 200' thick in this area.

The capture zone for well 242346 intersected the fixed-radius capture zones for both Wells 1 and 3. This overlap was accounted for in the Well 1 and Well 3 capture zones using the methods described in the previous section. A summary of the overlap calculations is included in Appendix D.

3.3 WHPA Delineations

The combined 10-year fracture flow capture zones and composite 10-year porous media capture zones define the WHPAs. There are three distinct WHPAs due to spacing of the City's wells. The Emergency Response Area (ERA) is delineated for each well by the combined 1-year fracture flow capture zones and composite 1-year porous media capture zones. The WHPAs and ERAs are shown on Figure 7.

3.4 Conjunctive Delineation

As discussed below in section 6.0, there are no areas in the DWSMAs in which aquifer vulnerability is classified as high. Therefore, a conjunctive delineation (i.e., inclusion of a surface water catchment area) was not necessary.

4.0 Delineation of the Drinking Water Supply Management Areas

The Farmington DWSMAs encompass the WHPAs with boundaries that correspond to geographically identifiable features (e.g., roads, parcel boundaries, quarter-quarter section lines). Dakota County 2015 parcel data were used to delineate the DWSMAs. The northwestern DWSMA lies entirely within Farmington's city limits, while the southeastern DWSMA extends into Empire, Eureka, and Castle Rock townships. The Farmington DWSMAs are shown on Figure 7. To satisfy Minnesota Rule 4720.5500, Subpart 2, 1:24,000 scale maps of the DWSMAs are included in Appendix E.

5.0 Well Vulnerability Assessment

MDH evaluated the vulnerability of the Farmington municipal wells to contamination from contaminants released at the surface. The evaluation parameters include geology, well construction, pumping rate, and water quality. Farmington Wells 4, 5, 6, 7, and 8 are classified as "vulnerable" and Wells 1 and 3 are classified as "not vulnerable." Copies of the MDH well vulnerability scoring sheets for the Farmington wells are presented in Appendix F.

6.0 Drinking Water Supply Management Area Vulnerability Assessment

The vulnerabilities of the Prairie du Chien Group and Jordan Sandstone aquifers within the DWSMAs associated with the Farmington wells were evaluated in a manner consistent with MDH guidance for assessing aquifer vulnerability (MDH, 1997) using geologic sensitivities based on L scores computed from boring log data and water quality data for the Farmington wells.

The first step in the assessment is to determine the geologic sensitivity rating of the aquifer. The Minnesota Department of Natural Resources (MnDNR) defines geologic sensitivity based on the travel time of water moving vertically from the surface to the aquifer of interest as follows (see MnDNR, 1991):

- Sensitivity = Very High: vertical travel time is hours to months
- Sensitivity = High: vertical travel time is weeks to years
- Sensitivity = Moderate: vertical travel time is years to decades
- Sensitivity = Low: vertical travel time is several decades to a century
- Sensitivity = Very Low: vertical travel time is more than a century

Geologic logs listed in the CWI for wells in the vicinity of the DWSMAs were reviewed and "L scores" based on the thickness of low permeability units at each well location were assigned to each well. (See MnDNR (1991) for a discussion of how to determine L scores). L score calculations were primarily performed for wells completed in the Prairie du Chien Group, Jordan Sandstone, or both, though wells completed in shallower units (e.g., St. Peter Sandstone, Quaternary glacial drift) with low geologic sensitivity were also included. Well logs lacking detail in the Quaternary stratigraphy were excluded from the L score calculations. A map of WHPA geologic sensitivity and the L scores used to develop it is included in Appendix G.

The second step in the assessment is to refine the geologic sensitivity using water quality data from the water supply wells. In their source water assessment program, MDH uses a classification scheme that rates the vulnerability of groundwater to surface contamination based on sampling data for a list of parameters that indicate man-made impacts or similarity to rainwater (MDH, 2011b) and gives some indication of relative groundwater residence time in the subsurface. There are five main categories lettered A to E in descending order of vulnerability, ranging from Category A which indicates that groundwater has been recharged rapidly from precipitation to Category E which indicates old, saline groundwater with a very long residence time in the subsurface. The MDH collected water quality samples from Farmington Wells 1, 3, 5, 7, and 8 in July 2015. All samples were analyzed for tritium, and the samples from Wells 5 and 7 were also analyzed for bromide, chloride, nitrate, sulfate, and ammonia. Table 4 summarizes the water quality data. As shown on Table 4, the water from Well 5 was classified as Category B4 ("Post-1953 Impacted Non-Pathogen") and the water from Well 7 was classified as Category B2 ("Mineral Fertilizer Impacted").

Tritium (^3H), a radioactive isotope of hydrogen, has been used extensively to date groundwater. Tritium activities peaked during atmospheric hydrogen bomb testing of the 1950s and 1960s, and values of ^3H in precipitation reached a maximum of approximately 10,000 T.U. (tritium units) in 1963 (Mazor, 2004). Natural production of ^3H in the upper atmosphere introduces approximately 5 T.U. to precipitation each year (Mazor, 2004). Because ^3H has a relatively short half-life of 12.43 years, radioactive decay since the bomb peak has reduced tritium activities to near background levels and ^3H is used mostly for relative age dating today. Groundwater that has little or no detectible ^3H is stated to be "vintage" or pre-bomb. Groundwater with detectable values of ^3H is stated to be "young" or post-bomb. The presence of tritium at concentrations above 1 tritium unit indicates the presence of a significant fraction of post-1954 (i.e., recently infiltrated) water in the groundwater sample. As shown on Table 4, tritium was detected at Wells 5, 7, and 8 but not at Wells 1 and 3.

When water quality data does not indicate the presence of tritium or other constituents that are consistent with contamination from the surface the aquifer vulnerability classification and the geologic sensitivity rating can be the same. The WHPA for Well 4 had low geologic sensitivity, and in the absence of tritium data, this section of the DWSMA was assigned low vulnerability. The WHPA for Wells 5-8 contained high geologic sensitivity around Wells 5 and 6, moderate geologic sensitivity around Well 7, and low geologic sensitivity around Well 8. Tritium has been detected at Wells 5, 7, and 8, and the additional water quality analysis for Wells 5 and 7 indicated some human impacts to the groundwater. The presence of tritium in groundwater samples from a well suggests that the water traveled vertically from the ground surface to the aquifer in less than about 50 years, which corresponds to a minimum vulnerability rating of moderate. Moderate vulnerability was assigned to a subset of the northwestern DWSMA that includes Wells 5-8; the remainder of the northwestern DWSMA was assigned low vulnerability based on high L scores. The area of high geologic sensitivity was not mapped to high vulnerability because the depth from the surface to the top of the Jordan averages 380 feet for Wells 5-8.

Most of the WHPA for Wells 1 and 3 had moderate geologic sensitivity and tritium was not detected at either well, so the entire southeastern DWSMA was assigned moderate vulnerability. The lack of tritium detections did not support mapping the regions of high and very high geologic sensitivity to high vulnerability, and the presence of fractured carbonate bedrock did not support mapping the regions of low geologic sensitivity to low vulnerability.

Figure 8 shows the final aquifer vulnerability map for the uppermost aquifer supplying water to municipal wells in each of the Farmington DWSMAs.

It is recommended that the City work with the MDH to conduct tritium sampling at least every ten years in order to have current data available when updating the aquifer vulnerability assessment as part of the required decennial wellhead protection plan amendments.

7.0 Supporting Data Files

The groundwater model files and GIS files are included in Appendix H. (Appendix H can be found in the "Part1" folder on the CD.)

The groundwater model can be reviewed using MODFLOW-NWT (Niswonger et al., 2011). MODPATH files can be reviewed using MODPATH Version 5.

All coordinates in the modeling files are based on UTM NAD 83 Zone 15 N datum. Elevations are in meters above mean sea level (m MSL). Time units are days. Length units are meters.

The GIS files have been named according to the MDH conventions. Shapefiles are in UTM NAD83 Zone 15 N datum.

8.0 References

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Tables

Table 1

Assessment of Data Elements
Farmington WHPP Amendment

Data Element	Present and Future Implications				Data Source
	Use of the Well s	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	
Precipitation	M	L	M	M	Minnesota Climatology Working Group
Geology					
Maps and geologic descriptions	M	H	H	H	MGS, CWI
Subsurface data	M	H	H	H	MGS, MDH, CWI
Borehole geophysics	M	M	M	M	MGS
Surface geophysics	L	L	L	L	Not Available
Maps and soil descriptions	L	M	M	M	MGS, NRCS
Eroding lands					
Water Resources					
Watershed units	L	L	L	L	DNR
List of public waters	L	L	L	L	DNR
Shoreland classifications					
Wetlands map					
Floodplain map					
Land Use					
Parcel boundaries map	L	H	L	L	Metropolitan Council, Dakota County
Political boundaries map	L	L	L	L	MNGEO
PLS map	L	L	L	L	DNR
Land use map and inventory					
Comprehensive land use map					
Zoning map					
Public Utility Services					
Transportation routes and corridors	L	M	L	L	MNDOT
Storm/sanitary sewers and PWS system map	L	L	L	L	City of Farmington
Oil and gas pipelines map					

Definitions Used for Assessing Data Elements:

High (H) - the data element has a direct impact
Moderate (M) - the data element has an indirect or marginal impact
Low (L) - the data element has little if any impact
Shaded - the data element was not required by MDH for preparing the WHP plan

CWI – Minnesota County Well Index
DNR – Minnesota Department of Natural Resources
MNGEO - Minnesota Geospatial Information Office
MDH – Minnesota Department of Health
MNDOT – Minnesota Department of Transportation
MPCA – Minnesota Pollution Control Agency
NRCS – Natural Resources Conservation Service
SSURGO – Soil Survey Geographic Database
USGS – United States Geological Survey

Table 1

Assessment of Data Elements (Continued)

Data Element	Present and Future Implications				Data Source
	Use of the Well s	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	
Public drainage systems map/lis	L	L	L	L	City of Farmington
Records of well construction, maintenance, and use	H	H	L	L	City of Farmington, CWI, MDH files
Surface Water Quantity					
Stream flow data	L	L	L	L	DNR
Ordinary high water mark data	L	L	L	L	DNR
Permitted withdrawals	L	L	L	L	DNR
Protected levels/flows	L	L	L	L	DNR
Water use conflicts	L	L	L	L	DNR
Groundwater Quantity					
Permitted withdrawals	H	H	H	H	DNR
Groundwater use conflicts	L	L	L	L	DNR
Water levels	H	H	H	H	CWI, MDH
Surface Water Quality					
Stream and lake water quality management classification					
Monitoring data summary	L	L	L	L	MPCA, MDH
Groundwater Quality					
Monitoring data	H	H	H	H	MDH
Isotopic data	H	H	H	H	MDH
Tracer studies	L	L	L	L	Not Available
Contamination site data	L	L	M	M	MPCA, MDH
Property audit data from contamination sites					
MPCA and MDA spills/release reports	L	L	L	L	MDH, MPCA

Definitions Used for Assessing Data Elements:

High (H) - the data element has a direct impact
Moderate (M) - the data element has an indirect or marginal impact
Low (L) - the data element has little if any impact
Shaded - the data element was not required by MDH for preparing the WHP plan

CWI – Minnesota County Well Index
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MDH – Minnesota Department of Health
MNDOT – Minnesota Department of Transportation
MPCA – Minnesota Pollution Control Agency
NRCS – Natural Resources Conservation Service
SSURGO – Soil Survey Geographic Database
USGS – United States Geological Survey

Table 2

Water Supply Well Information
Farmington WHPP Amendment

Local Well ID	Unique Number	Use/ Status[1]	Casing Diameter (in.)	Casing Depth (ft.)	Well Depth (ft.)	Year Constructed	Aquifer	Well Vulnerability
1	200932	P	16	197	402	1938	Prairie du Chien - Jordan	Not Vulnerable
3	201154	P	20 x 12	132	424	1959	Prairie du Chien - Jordan	Not Vulnerable
4	235586	P	24 x 16	392	477	1973	Jordan	Vulnerable
5	603051	P	30 x 24	417	512	1999	Jordan	Vulnerable
6	626785	P	30 x 24	386	485	2002	Jordan	Vulnerable
7	655902	P	30 x 24	408	501	2002	Jordan	Vulnerable
8	731123	P	30 x 24	368	460	2006	Jordan	Vulnerable

[1] P= Primary

Table 3

Annual and Projected Pumping Rates for Farmington Wells
Farmington WHPP Amendment

		Total Annual Withdrawal (gal/yr)				
Unique Number	Well Name	2010	2011	2012	2013	2014
200932	1	100,351,000	78,598,000	112,119,000	68,160,000	59,749,000
201154	3	54,897,000	88,435,000	75,427,000	91,569,000	66,312,000
235586	4	90,373,000	110,996,000	126,743,000	110,967,000	125,109,000
603051	5	111,628,100	55,604,000	125,838,000	110,894,000	117,582,000
626785	6	86,855,100	137,340,000	146,761,000	138,134,000	127,457,000
655902	7	126,672,000	81,466,000	108,551,000	91,611,000	94,134,000
731123	8	109,746,000	156,328,000	105,845,000	106,322,000	93,263,000
	Totals	680,522,200	708,767,000	801,284,000	717,657,000	683,606,000

Source: City water use records

		Percentage of Annual Withdrawal					
Unique Number	Well Name	2010	2011	2012	2013	2014	Average Annual % of Withdrawal
200932	1	14.7%	11.1%	14.0%	9.5%	8.7%	11.6%
201154	3	8.1%	12.5%	9.4%	12.8%	9.7%	10.5%
235586	4	13.3%	15.7%	15.8%	15.5%	18.3%	15.7%
603051	5	16.4%	7.8%	15.7%	15.5%	17.2%	14.5%
626785	6	12.8%	19.4%	18.3%	19.2%	18.6%	17.7%
655902	7	18.6%	11.5%	13.5%	12.8%	13.8%	14.0%
731123	8	16.1%	22.1%	13.2%	14.8%	13.6%	16.0%

		Projected Water Use (2020)			Maximum Total Pumping for Model Input[3]		
Unique Number	Well Name	Total[1] (gal/yr)	% of Total Projected Water Use Well[2]	Projected Well Pumpage Based on % (gal/yr)	gal/yr	gal/day	m^3/day
200932	1		11.6%	131,613,600	131,613,600	360,585	1,365
201154	3		10.5%	119,133,000	119,133,000	326,392	1,236
235586	4		15.7%	178,132,200	178,132,200	488,033	1,848
603051	5		14.5%	164,517,000	164,517,000	450,732	1,706
626785	6		17.7%	200,824,200	200,824,200	550,203	2,083
655902	7		14.0%	158,844,000	158,844,000	435,189	1,647
731123	8		16.0%	181,536,000	181,536,000	497,359	1,883
	Totals	1,134,600,000		1,134,600,000	1,134,600,000	3,108,493	11,768

Appropriation 1,000,000,000

[1] 2020 projected average daily demand from Farmington Water Supply and Distribution Plan (Bonestroo, 2009)

[2] Percentages for all wells are based the average annual % of annual withdrawal for the period 2010 through 2014

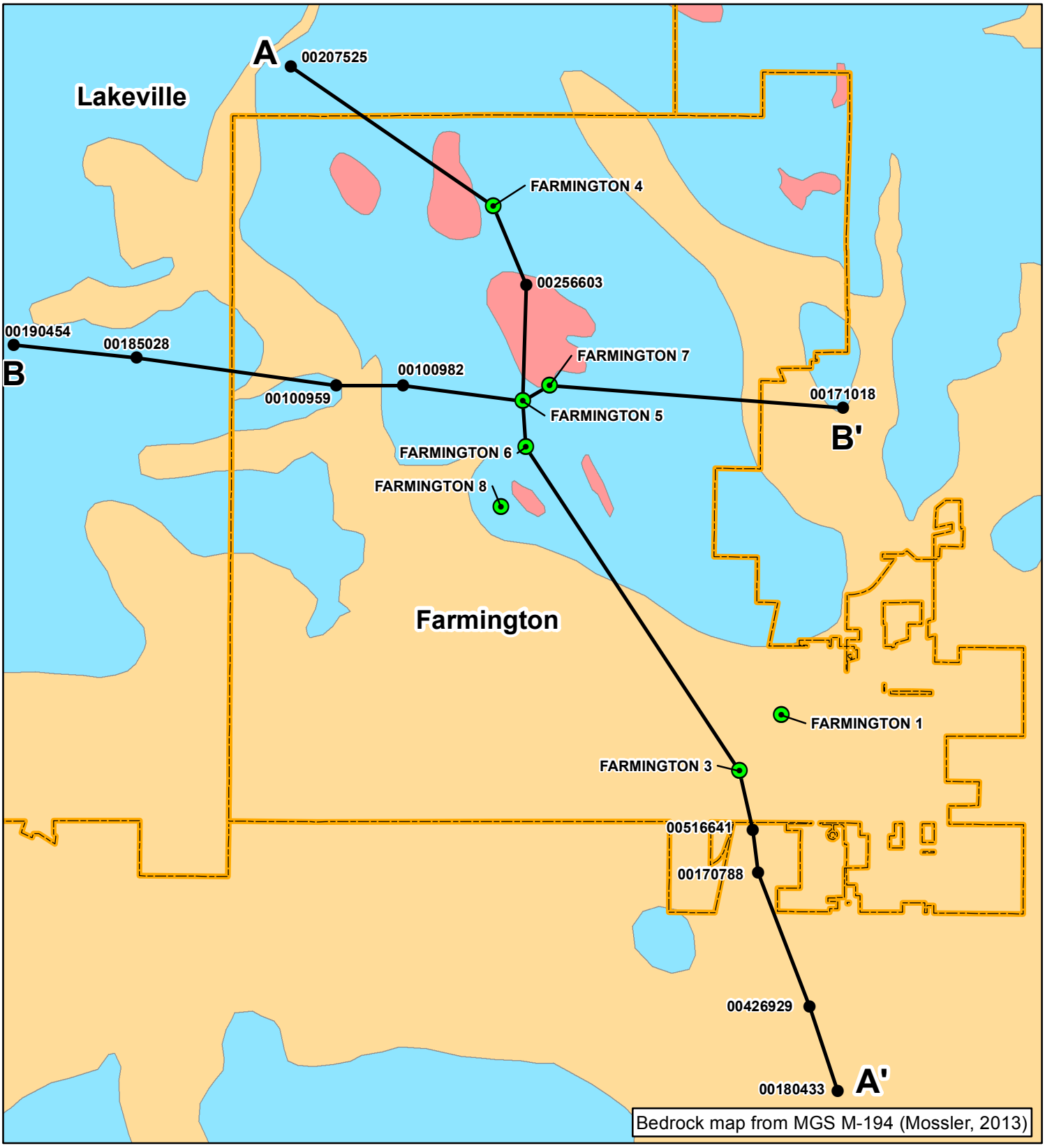
Table 4

2015 Farmington Water Quality Data
Farmington WHPP Amendment

Well	Aquifer	Br (mg/L)	Cl (mg/L)	Cl/Br	NO_3 (mg/L)	SO_4 (mg/L)	NH_3 (mg/L)	^3H (NTU)	MDH Classification
1	Prairie du Chien - Jordan	-	-	-	-	-	-	< 0.8	-
3	Prairie du Chien - Jordan	-	-	-	-	-	-	< 0.8	-
5	Jordan	0.0283	16.4	579.5	< 0.05	28.2	< 0.05	1.6	B4, Post-1953 Impacted Non-Pathogen
7	Jordan	0.0406	30.0	738.9	0.88	41.2	< 0.05	4.8	B2, Mineral Fertilizer Impacted
8	Jordan	-	-	-	-	-	-	1.6*	-

* A duplicate sample from Well 8 returned a non-detect for tritium.

Figures



Barr Footer: ArcGIS 10.3, 2015-06-16 10:52 File: I:\Projects\23\19\1278\Maps\Reports\Figure 01 - Bedrock Subcrop.mxd User: akj

Farmington Municipal Well
Cross Section Well
Cross Section Trace
Municipal Boundary

Metro Bedrock Geology

- Platteville Formation and Glenwood Formation
- St. Peter Sandstone
- Prairie du Chien Group
- Jordan Sandstone

N

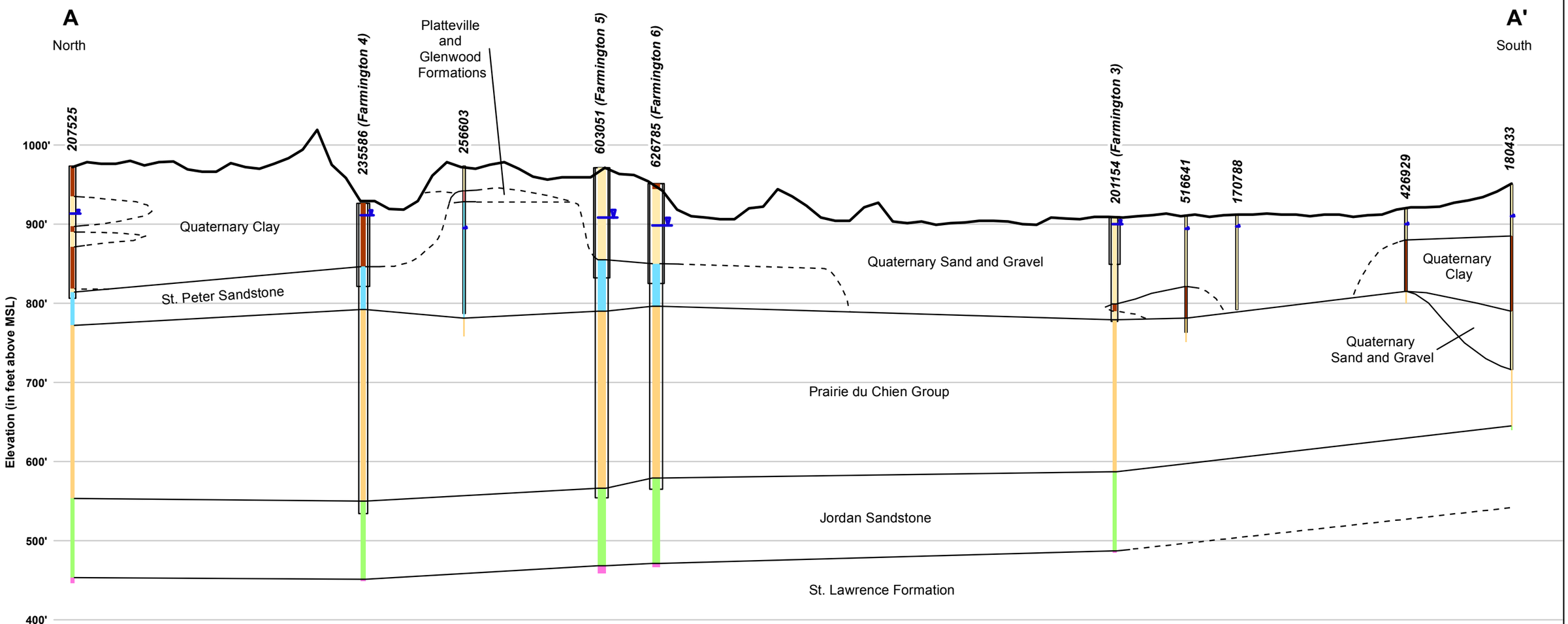
Feet

4,000 0 4,000

BARR

Figure 1

BEDROCK SUBCROP
Farmington WHPP Amendment
City of Farmington, MN



Stratigraphy

- Quaternary Sand and Gravel
- Quaternary Clay
- Platteville and Glenwood Formations
- St. Peter Sandstone
- Prairie du Chien Group
- Jordan Sandstone
- St. Lawrence Formation

- Static Water Level
- Surface Elevation Line
- Well Casing

BARR

Figure 2

CROSS SECTION A-A'
Farmington WHPP Amendment
City of Farmington, MN

Barr Footer: ArcGIS 10.3, 2015-06-16 10:44 File: I:\Projects\23\19\1278\Maps\Reports\Figure 02 - Cross Section A-A.mxd User: akj

B West

B' East

190454 | 185028 | 100959 | 100982 | 603051 (Farmington 5) | 655902 (Farmington 7) | 171018

Elevation (in feet above MSL)

1100'
1000'
900'
800'
700'
600'
500'
400'

Quaternary Clay
Quaternary Sand and Gravel
St. Peter Sandstone
Prairie du Chien Group
Jordan Sandstone
St. Lawrence Formation

?

Vert. Exag. = 10X

Stratigraphy

- Quaternary Sand and Gravel
- Quaternary Clay
- St. Peter Sandstone
- Prairie du Chien Group
- Jordan Sandstone
- St. Lawrence Formation

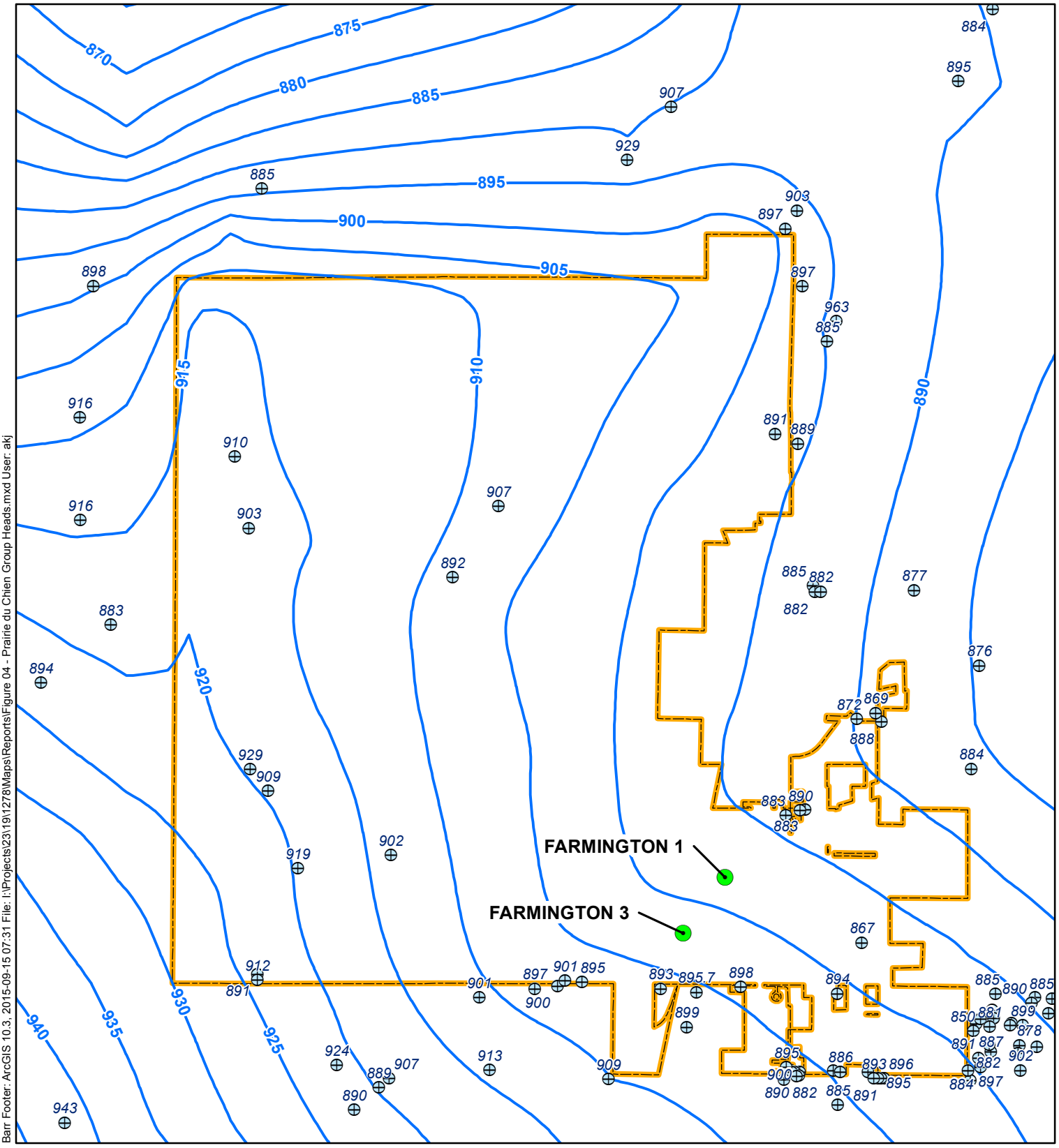
- Ground Surface
- Static Water Level
- Well Casing

BARR

Figure 3

CROSS SECTION B-B'
Farmington WHPP Amendment
City of Farmington, MN

Barr Footer: ArcGIS 10.3, 2015-06-16 09:02 File: I:\Projects\23\19\1278\Maps\Reports\Figure 03 - Cross Section B-B.mxd User: akj



Barr Footer: ArcGIS 10.3, 2015-09-15 07:31 File: I:\Projects\23\19\1278\Maps\Reports\Figure 04 - Prairie du Chien Group Heads.mxd User: akj

Farmington Municipal Well Open to Prairie du Chien Group

CWI OPDC Head Measurement (ft MSL)

Modeled Head (ft MSL)

Farmington City Limits

N

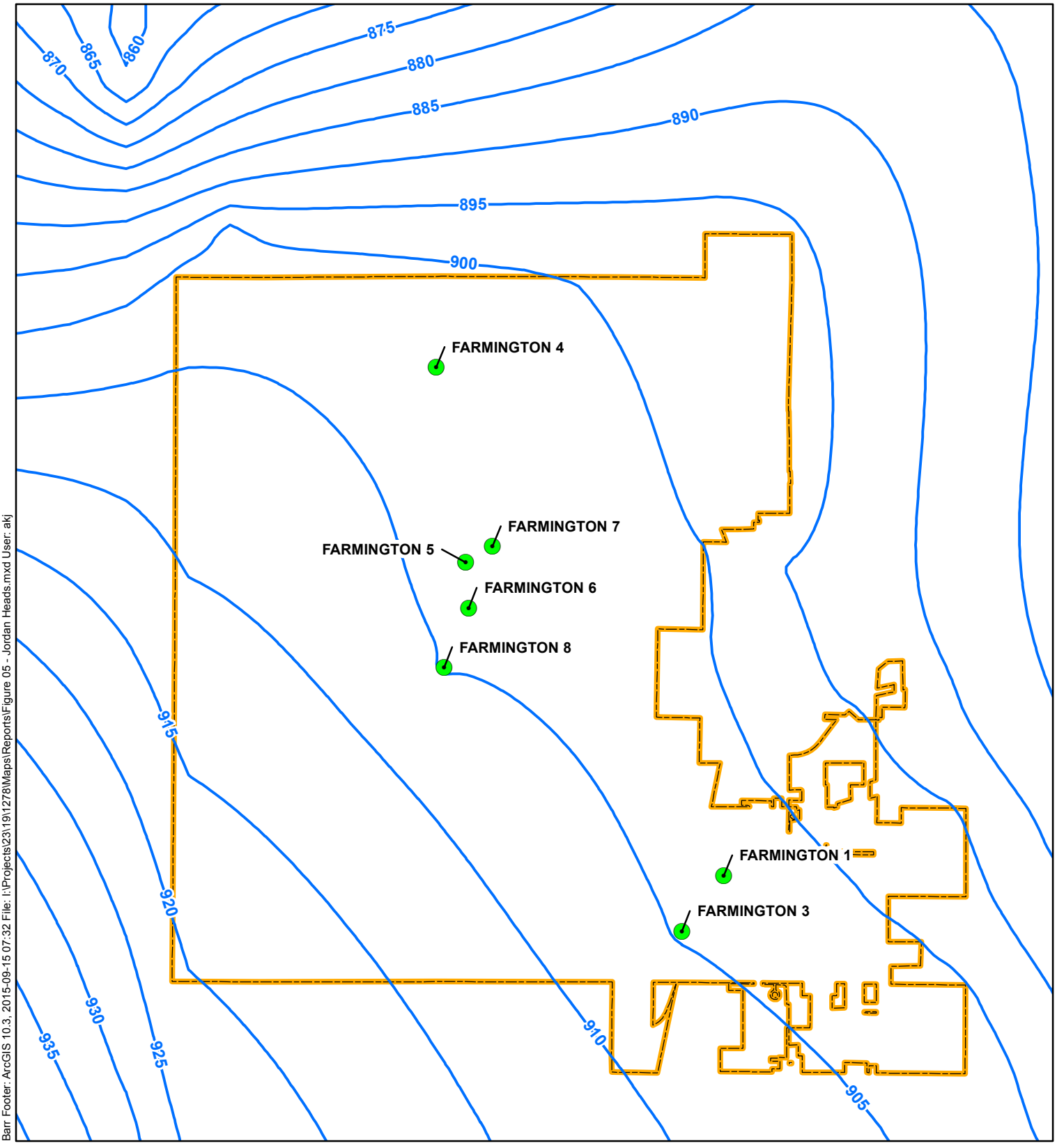
Feet

4,000 0 4,000

BARR

Figure 4

MODELED HEADS IN
PRAIRIE DU CHIEN GROUP
Farmington WHPP Amendment
City of Farmington, MN



Barr Footer: ArcGIS 10.3, 2015-09-15 07:32 File: I:\Projects\23\19\1278\Maps\Reports\Figure 05 - Jordan Heads.mxd User: akj

Farmington Municipal Well Open to Jordan Sandstone

Modeled Head (ft MSL)

Farmington City Limits

N

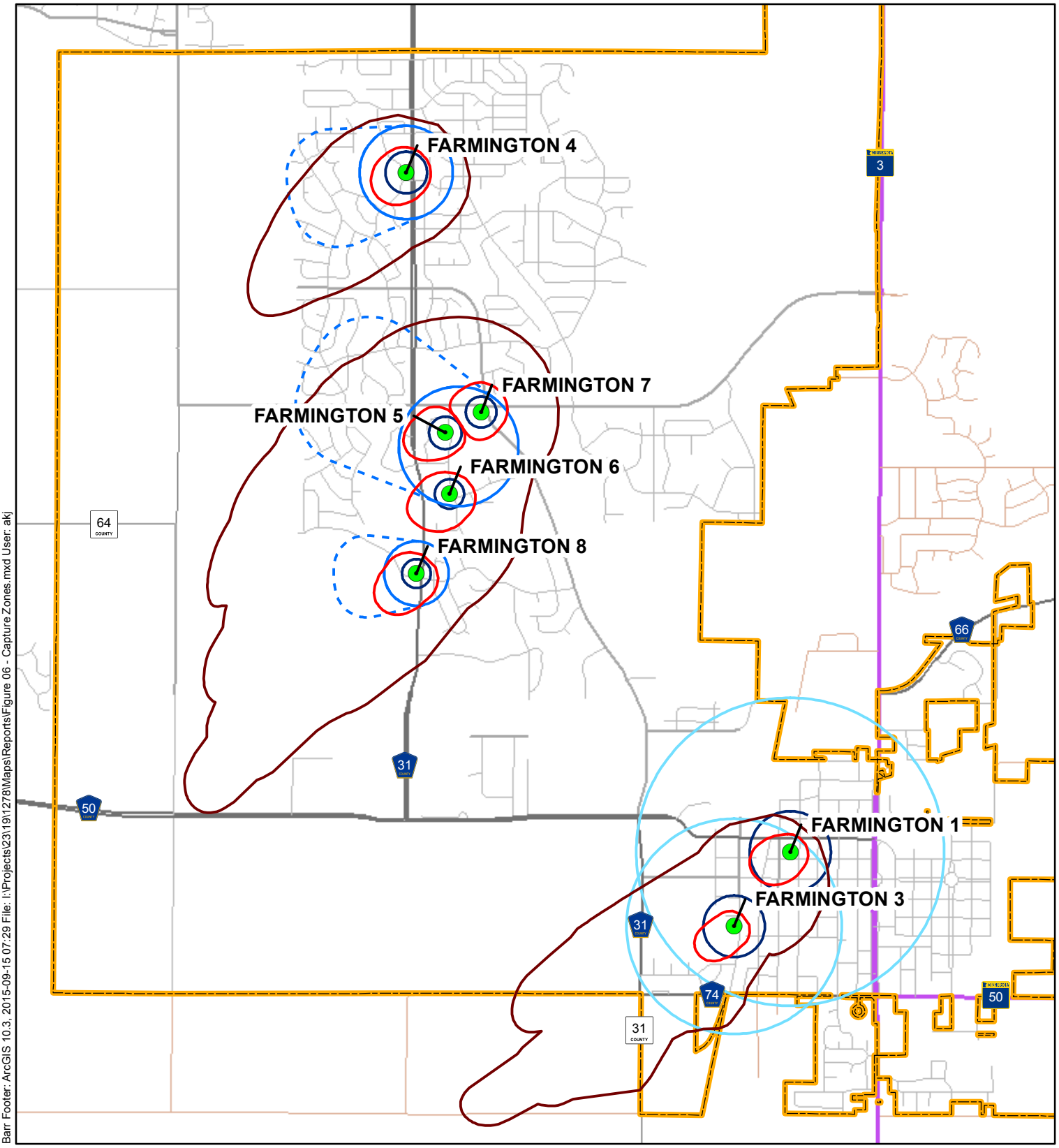
Feet

4,000 0 4,000

BARR

Figure 5

MODELED HEADS IN JORDAN SANDSTONE
Farmington WHPP Amendment
City of Farmington, MN



Farmington Municipal Well

Farmington City Limits

Fracture Flow Capture Zone

1-year Fixed Radius

5-year Fixed Radius

5-year Upgradient Extension

10-year Fixed Radius

Porous Media Capture Zone

1-year

10-year

N

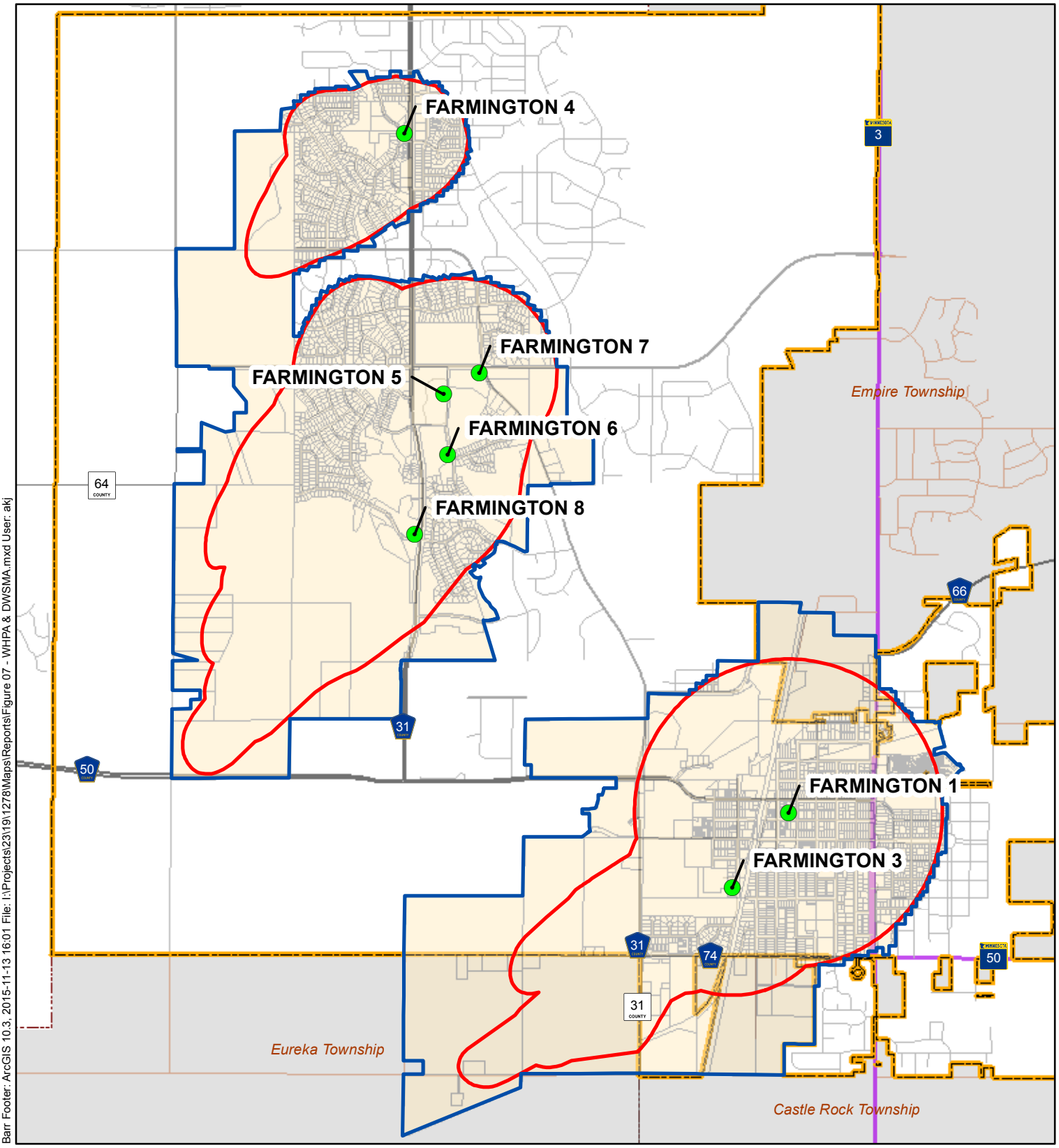
Feet

3,000 0 3,000

BARR

Figure 6

WELL CAPTURE ZONES
Farmington WHPP Amendment
City of Farmington, MN



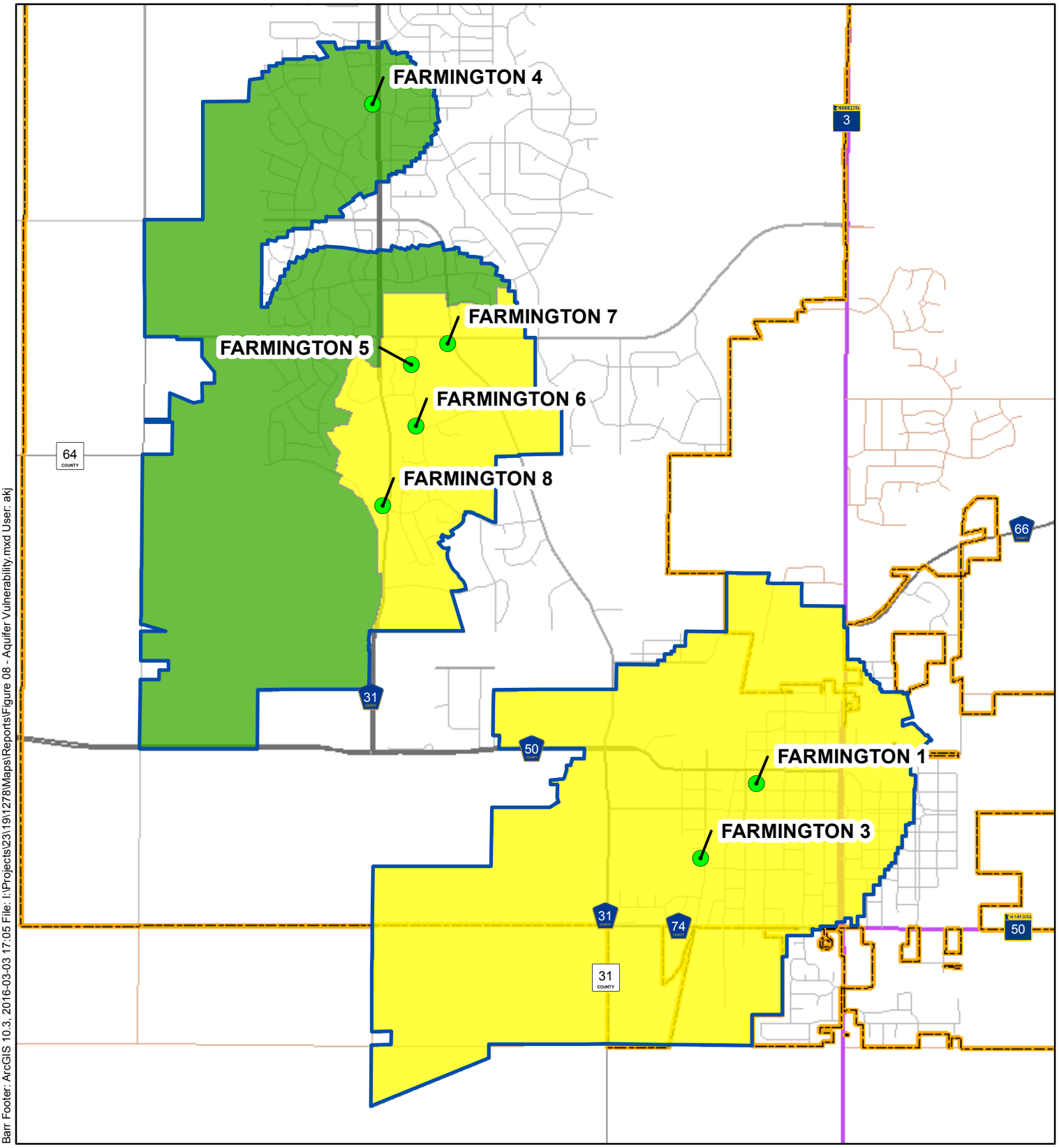
Farmington Municipal Well
DWSMA
WHPA
Parcel
Farmington City Limits
Civil Township

Feet
3,000 0 3,000

BARR

Figure 7

WHPA & DWSMA
Farmington WHPP Amendment
City of Farmington, MN



Farmington Municipal Well

DWSMA

Vulnerability

High

Moderate

Low

Farmington City Limits

N

Feet

3,000 0 3,000

BARR

Figure 8

AQUIFER VULNERABILITY
Farmington WHPP Amendment
City of Farmington, MN

Appendix A

Well Construction Records

Unique No. 00200932

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2003/10/21

Entry Date 1989/12/27

Township Name	Township	Range	Dir	Section	Subsection
	114	19	W	31	ACDBBB

Well Depth		Depth Completed		Date Well Completed
402	ft.	402	ft.	/19/38

Well Name FARMINGTON 1

Drilling Method

Contact's Name FARMINGTON 1

Drilling Fluid

Well Hydrofractured? ☐ Yes ☐ No

From ft. to ft.

FARMINGTON MN 55024

Use Community Supply (municipal)

Casing **Drive Shoe?** ☐ Yes ☐ N

Hole Diameter

Casing Diameter **Weight(lbs/ft)**

16 in. t 197 ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND + GRAVEL			0	50
QUICKSAND			50	96
SANDY CLAY			96	99
GRAVEL + BOULDERS			99	130
BLUE SHALE			130	165
SANDY SHALE			165	173
FINE SAND			173	185
HARDPAN			185	186
GRAY SHALE + LIME			186	195
YELLOW LIME			195	205
BLUE LIME			205	220
BLUE + BROWN LIME			220	318
JORDAN SANDSTONE			318	400
GREEN SHALE			400	402

Screen N

Open Hole From 197 ft. to 402 ft.

Make Type

Static Water Level 11 ft. from Land surface Date /19/38

PUMPING LEVEL (below land surface)

19 ft. after hrs. pumping 230 g.p.m.

Well Head Completion

Pitless adapter mfr Model

Casing Protection ☐ 12 in. above grade

☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☐ Yes ☐ No

Nearest Known Source of Contamination

ft. direction type

Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed Y

Mfr nam

Model HP 25 Volts

Drop Pipe Length ft. Capacity g.p.m

Type T

Any not in use and not sealed well(s) on property? ☐ Yes ☐ No

Was a variance granted from the MDH for this Well? ☐ Yes ☐ No

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 27010

License Business Name

Name of Driller

REMARKS, ELEVATION, SOURCE OF DATA, etc.

FARMINGTON, MN

USGS Quad Farmington Elevation 903

Aquifer: OPCJ Alt Id: 59-072

Report Copy

Unique No. 00200932

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2003/10/21

Entry Date 1989/12/27

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	19	W	31	ACDBBB	402	ft.	402	ft.	/19/38

Well Name FARMINGTON 1 **Lic. Or Reg. No.** 27010 **Name of Driller**

USGS Quad Farmington **Elevation** 903 **Aquifer** OPCJ **Alternative Id** 59-072

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
SAND + GRAVEL			0	50	QFUU	SAND	GRVL	
QFUU = Sand	SAND = Sand		GRVL = Gravel					
QUICKSAND			50	96	QUUU	SAND	SILT	MUDD
QUUU = Unknown deposit type	SAND = Sand		SILT = Silt				MUDD = Mud	
SANDY CLAY			96	99	QUUU	CLAY	SAND	
QUUU = Unknown deposit type	CLAY = Clay		SAND = Sand					
GRAVEL + BOULDERS			99	130	QFUU	GRVL	BLDR	
QFUU = Sand	GRVL = Gravel		BLDR = Boulder					
BLUE SHALE			130	165	QUUG	CLAY		
QUUG = Unknown deposit type	CLAY = Clay							
SANDY SHALE			165	173	QTUU	SHLE	SAND	
QTUU = Till	SHLE = Shale		SAND = Sand					
FINE SAND			173	185	QFUU	SAND		
QFUU = Sand	SAND = Sand							
HARDPAN			185	186	QTUU	CLAY	HDPN	SILT
QTUU = Till	CLAY = Clay		HDPN = Hardpan				SILT = Silt	
GRAY SHALE + LIME			186	195	OPDC	DLMT	SHLE	
OPDC = Prairie Du Chien Group	DLMT = Dolomite		SHLE = Shale					
YELLOW LIME			195	205	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
BLUE LIME			205	220	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
BLUE + BROWN LIME			220	318	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
JORDAN SANDSTONE			318	400	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
GREEN SHALE			400	402	CSTL	SHLE		
CSTL = St.Lawrence	SHLE = Shale							

Unique No. 00201154

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes Chapter 1031

Update Date 2003/10/21

Entry Date 1990/06/29

Township Name	Township	Range	Dir	Section	Subsection
	114	19	W	31	CADCCB

Well Depth		Depth Completed		Date Well Completed
424	ft.	424	ft.	1959/07/31

Well Name FARMINGTON 3

Contact's Name FARMINGTON 3

FARMINGTON MN 55024

Drilling Method

Drilling Fluid

Well Hydrofractured? ☐ Yes ☐ No

From ft. to ft.

Use Community Supply (municipal)

Casing **Drive Shoe?** ☐ Yes ☐ N

Hole Diameter

Casing Diameter		Weight(lbs/ft)
20	in. t 60 ft	
12	in. t 132 ft	

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND + GRAVEL			0	42
FINE SAND			42	80
SAND + GRAVEL			80	110
BLUE CLAY			110	119
FINE SAND WITH BLUE CLA			119	130
SHAKOPEE LIMESTONE			130	322
JORDAN SANDSTONE			322	422
ST. LAWRENCE SHALE			422	424

Screen N

Open Hole From 132 ft. to 424 ft.

Make Type

Static Water Level 9 ft. from Land surface Date 1959/07/31

PUMPING LEVEL (below land surface)

19 ft. after hrs. pumping 750 g.p.m.

Well Head Completion

Pitless adapter mfr Model

Casing Protection ☐ 12 in. above grade

☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☐ Yes ☐ No

Nearest Known Source of Contamination

ft. direction type

Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed Y

Mfr nam

Model HP 75 Volts

Drop Pipe Length ft. Capacity 700 g.p.m

Type T

Any not in use and not sealed well(s) on property? ☐ Yes ☐ No

Was a variance granted from the MDH for this Well? ☐ Yes ☐ No

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 27010

License Business Name

Name of Driller

REMARKS, ELEVATION, SOURCE OF DATA, etc.

M.G.S. NO.964. GAMMA LOGGED 12-1-87.

USGS Quad Farmington Elevation 909

Aquifer: OPCJ Alt Id: 59-072

Report Copy

HE-01205-06 (Rev. 9/96)

Unique No. 00201154

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2003/10/21

Entry Date 1990/06/29

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	19	W	31	CADCCB	424	ft.	424	ft.	1959/07/31

Well Name FARMINGTON 3 **Lic. Or Reg. No.** 27010 **Name of Driller**

USGS Quad Farmington **Elevation** 909 **Aquifer** OPCJ **Alternative Id** 59-072

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
SAND + GRAVEL			0	42	QFUU	SAND	GRVL	
QFUU = Sand	SAND = Sand		GRVL = Gravel					
FINE SAND			42	80	QFUU	SAND		
QFUU = Sand	SAND = Sand							
SAND + GRAVEL			80	110	QFUU	SAND	GRVL	
QFUU = Sand	SAND = Sand		GRVL = Gravel					
BLUE CLAY			110	119	QTUG	CLAY		
QTUG = Till	CLAY = Clay							
FINE SAND WITH BLUE CLAY			119	130	QUUU	SAND	CLAY	
QUUU = Unknown deposit type	SAND = Sand		CLAY = Clay					
SHAKOPEE LIMESTONE			130	322	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
JORDAN SANDSTONE			322	422	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
ST. LAWRENCE SHALE			422	424	CSTL	SHLE	SNDS	
CSTL = St.Lawrence	SHLE = Shale		SNDS = Sandstone					

Unique No. 00235586

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2008/07/16

Entry Date 1989/12/27

Township Name	Township	Range	Dir	Section	Subsection
	114	20	W	14	DAAAAC

Well Depth		Depth Completed		Date Well Completed
477	ft.	477	ft.	1973/00/00

Well Name FARMINGTON 4

Drilling Method Cable Tool

Well Owner's Name FARMINGTON 4

FARMINGTON MN 55024

Drilling Fluid

Well Hydrofractured? ☐ Yes ☐ No

From ft. to ft.

Contact's Name CITY OF FARMINGTON

325 OAK ST

FARMINGTON MN 55024

Use Community Supply (municipal)

Casing **Drive Shoe?** ☐ Yes ☐ N

Hole Diameter

Casing Diameter		Weight(lbs/ft)
24	in. t 105 ft	
16	in. t 392 ft	

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
TOPSOIL	BLACK		0	3
CLAY	YELLO		3	12
BROWN + GREEN CLAY MI			12	40
GREEN CLAY WITH STREA			40	80
ST. PETER SANDSTONE	YELLO	SOFT	80	105
ST. PETER SANDSTONE	YELLO	HARD	105	134
SHAKOPEE LIMEROCK			134	376
JORDAN SANDROCK			376	475
SHALE	GREE		475	477

Screen N

Open Hole From 392 ft. to 477 ft.

Make Type

Static Water Level 15 ft. from Land surface Date 1973/00/00

PUMPING LEVEL (below land surface)

154 ft. after hrs. pumping 1200 g.p.m.

Well Head Completion

Pitless adapter mfr Model

Casing Protection ☐ 12 in. above grade

☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☐ Yes ☐ No

Nearest Known Source of Contamination

ft. direction type

Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed Y

Mfr nam

Model HP 100 Volts

Drop Pipe Length ft. Capacity E+03 g.p.m

Type T

Any not in use and not sealed well(s) on property? ☐ Yes ☐ No

Was a variance granted from the MDH for this Well? ☐ Yes ☐ No

USGS Quad Farmington Elevation 926

Aquifer: CJDN Alt Id: 59-0725

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. MDH

License Business Name

Name of Driller

Report Copy

Unique No. 00235586

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2008/07/16

Entry Date 1989/12/27

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	20	W	14	DAAAAC	477	ft.	477	ft.	1973/00/00

Well Name FARMINGTON 4 **Lic. Or Reg. No.** MDH **Name of Driller**

USGS Quad Farmington **Elevation** 926 **Aquifer** CJDN **Alternative Id** 59-0725

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
TOPSOIL	BLACK		0	3	RUUU	SOIL	ORGD	
RUUU = Recent Deposit	SOIL = Soil				ORGD = Organic Deposits			
CLAY	YELLOW		3	12	QUUB	CLAY		
QUUB = Unknown deposit type	CLAY = Clay							
BROWN + GREEN CLAY MIXED			12	40	QUUU	CLAY		
QUUU = Unknown deposit type	CLAY = Clay							
GREEN CLAY WITH STREAKS OF BRN CL			40	80	QUUU	CLAY		
QUUU = Unknown deposit type	CLAY = Clay							
ST. PETER SANDSTONE	YELLOW	SOFT	80	105	OSTP	SNDS		
OSTP = St.Peter	SNDS = Sandstone							
ST. PETER SANDSTONE	YELLOW	HARD	105	134	OSTP	SNDS		
OSTP = St.Peter	SNDS = Sandstone							
SHAKOPEE LIMEROCK			134	376	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
JORDAN SANDROCK			376	475	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
SHALE	GREEN		475	477	CSTL	SHLE	SLSN	
CSTL = St.Lawrence	SHLE = Shale				SLSN = Siltstone			

Unique No. 00603051

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes Chapter 1031

Update Date 2007/01/12

Entry Date 1999/08/18

Township Name	Township	Range	Dir	Section	Subsection
	114	20	W	24	CBDBBB

Well Depth		Depth Completed		Date Well Completed
512	ft.	512	ft.	1999/07/00

Well Name FARMINGTON 5

Drilling Method Cable Tool

Well Owner's Name FARMINGTON
195TH
FARMINGTON MN 55024

Drilling Fluid
Water

Well Hydrofractured? ☐ Yes ☑ No
From ft. to ft.

Contact's Name FARMINGTON CITY HALL
325 OAK ST
FARMINGTON MN 55024

Use Community Supply (municipal)

Casing **Drive Shoe?** ☑ Yes ☐ N

Hole Diameter
in. t 417 ft
in. t 512 ft

Casing Diameter **Weight(lbs/ft)**
30 in. t 139 ft 118.65
24 in. t 417 ft 94.62

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND & CLAY	BROW	SOFT	0	23
SAND & GRAVEL	BROW	SOFT	23	65
SAND (FINE)	BROW	SOFT	65	116
SANDSTONE	WHITE	HARD	116	135
SHALE, SANDSTONE	TAN	MEDIUM	135	139
SANDSTONE	YELLO	MEDIUM	139	181
LIMESTONE	GRAY	HARD	181	405
SANDSTONE	WHITE	MEDIUM	405	503
SHALEY SANDSTONE	BLUE	MEDIUM	503	512

Screen N

Open Hole From 417 ft. to 512 ft.

Make Type

Static Water Level 63 ft. from Land surface Date 1999/06/18

PUMPING LEVEL (below land surface)
98 ft. after 8 hrs. pumping 1400 g.p.m.

Well Head Completion
Pitless adapter mfr Model
Casing Protection ☑ 12 in. above grade
☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☑ Yes ☐ No

Material	From	To (ft.)	Amount(yds/bags)	
G	0	417	56	Y

Nearest Known Source of Contamination
700 ft. direction W type SDF
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☑ Not Installed Date Installed N
Mfr nam
Model HP Volts
Drop Pipe Length ft. Capacity g.p.m
Type

Any not in use and not sealed well(s) on property? ☐ Yes ☑ No

Was a variance granted from the MDH for this Well? ☐ Yes ☑ No

USGS Quad Farmington Elevation 971
Aquifer: CJDN Alt Id: 59-0725

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 62012
License Business Name
Name of Driller SAMPSON, J.

Report Copy

HE-01205-06 (Rev. 9/96)

Unique No. 00603051

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2007/01/12

Entry Date 1999/08/18

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	20	W	24	CBDBBB	512	ft.	512	ft.	1999/07/00

Well Name FARMINGTON 5 **Lic. Or Reg. No.** 62012 **Name of Driller** SAMPSON, J.

USGS Quad Farmington **Elevation** 971 **Aquifer** CJDN **Alternative Id** 59-0725

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
SAND & CLAY	BROWN	SOFT	0	23	QLUB	SAND	CLAY	
QLUB = Clay & sand	SAND = Sand			CLAY = Clay				
SAND & GRAVEL	BROWN	SOFT	23	65	QHUB	SAND	GRVL	
QHUB = Sand & larger	SAND = Sand			GRVL = Gravel				
SAND (FINE)	BROWN	SOFT	65	116	QFUB	SAND		
QFUB = Sand	SAND = Sand							
SANDSTONE	WHITE	HARD	116	135	OSTP	SNDS		
OSTP = St.Peter	SNDS = Sandstone							
SHALE, SANDSTONE	TAN	MEDIUM	135	139	OSTP	SHLE	SNDS	
OSTP = St.Peter	SHLE = Shale			SNDS = Sandstone				
SANDSTONE	YELLOW	MEDIUM	139	181	OSTP	SNDS		
OSTP = St.Peter	SNDS = Sandstone							
LIMESTONE	GRAY	HARD	181	405	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
SANDSTONE	WHITE	MEDIUM	405	503	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
SHALEY SANDSTONE	BLUE	MEDIUM	503	512	CSTL	SLSN	DLMT	
CSTL = St.Lawrence	SLSN = Siltstone			DLMT = Dolomite				

Unique No. 00626785

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes Chapter 1031

Update Date 2007/01/12

Entry Date 2003/02/17

Township Name	Township	Range	Dir	Section	Subsection
	114	20	W	24	CCDBAB

Well Depth		Depth Completed		Date Well Completed
485	ft.	485	ft.	2002/06/20

Well Name FARMINGTON 6

Drilling Method Cable Tool

Contact's Name CITY OF FARMINGTON/MANN, LEE
325 OAK ST
FARMINGTON MN 55024

Drilling Fluid Bentonite

Well Hydrofractured? ☐ Yes ☐ No
From ft. to ft.

Well Owner's Name FARMINGTON 6
ENGLISH ST
FARMINGTON MN 55024

Use Community Supply (municipal)

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
CLAY	BROW	MEDIUM	0	7
SAND & ROCKS	BROW	MEDIUM	7	101
ST. PETER S.S.	TAN	MEDIUM	101	155
SHAKOPEE	GRAY	V.HARD	155	298
SHAKOPEE	TAN	HARD	298	372
JORDAN	GRAY	M.SOFT	372	383
JORDAN	TAN	SOFT	383	465
JORDAN	GRAY	SOFT	465	480
ST. LAWRENCE	GREE	MEDIUM	480	485

Casing **Drive Shoe?** ☑ Yes ☐ N

Casing Diameter			Weight(lbs/ft)
30	in. t	126 ft	118.65
24	in. t	386 ft	94.65

Hole Diameter

in. t	382	ft
in. t	485	ft

Screen N

Make Type

Open Hole From 382 ft. to 485 ft.

Static Water Level 53 ft. from Land surface Date 2002/03/15

PUMPING LEVEL (below land surface)
86 ft. after 24 hrs. pumping 1850 g.p.m.

Well Head Completion
Pitless adapter mfr Model
Casing Protection ☑ 12 in. above grade
☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☑ Yes ☐ No

Material	From	To (ft.)	Amount(yds/bags)	
G	0	382	42	Y

Nearest Known Source of Contamination
80 ft. direction W type SDF
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Mfr nam GOULDS
Model 14RJMC/4 HP 200 Volts 460
Drop Pipe Length 140 ft. Capacity E+03 g.p.m
Type S

Any not in use and not sealed well(s) on property? ☐ Yes ☑ No

Was a variance granted from the MDH for this Well? ☐ Yes ☑ No

REMARKS, ELEVATION, SOURCE OF DATA, etc.

M.G.S. NO. 4224.

USGS Quad Farmington Elevation 951
Aquifer: CJDN Alt Id: 59-0725

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 71015
License Business Name
Name of Driller SIGAFOOS, R.

Report Copy

HE-01205-06 (Rev. 9/96)

Unique No. 00626785

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2007/01/12

Entry Date 2003/02/17

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	20	W	24	CCDBAB	485	ft.	485	ft.	2002/06/20

Well Name FARMINGTON 6 **Lic. Or Reg. No.** 71015 **Name of Driller** SIGAFOOS, R.

USGS Quad Farmington **Elevation** 951 **Aquifer** CJDN **Alternative Id** 59-0725

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
CLAY	BROWN	MEDIUM	0	7	QCUB	CLAY		
QCUB = Clay	CLAY = Clay							
SAND & ROCKS	BROWN	MEDIUM	7	101	QHUB	SAND	COBL	
QHUB = Sand & larger	SAND = Sand				COBL = Cobble			
ST. PETER S.S.	TAN	MEDIUM	101	155	OSTP	SNDS		
OSTP = St.Peter	SNDS = Sandstone							
SHAKOPEE	GRAY	V.HARD	155	298	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
SHAKOPEE	TAN	HARD	298	372	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
JORDAN	GRAY	M.SOFT	372	383	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
JORDAN	TAN	SOFT	383	465	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
JORDAN	GRAY	SOFT	465	480	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							
ST. LAWRENCE	GREEN	MEDIUM	480	485	CSTL	SLSN	DLMT	
CSTL = St.Lawrence	SLSN = Siltstone				DLMT = Dolomite			

Unique No. 00655902

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes Chapter 1031

Update Date 2011/08/04

Entry Date 2002/10/21

Township Name	Township	Range	Dir	Section	Subsection
	114	20	W	24	CABBDB

Well Depth		Depth Completed		Date Well Completed
501	ft.	501	ft.	2002/09/20

Well Name FARMINGTON 7

Drilling Method Cable Tool

Well Owner's Name FARMINGTON
5225 ORIOLE DR
FARMINGTON MN 55024

Drilling Fluid
Water

Well Hydrofractured? ☐ Yes ☑ No
From ft. to ft.

Contact's Name CITY OF FARMINGTON
325 OAK ST
FARMINGTON MN 55024

Use Community Supply (municipal)

Casing **Drive Shoe?** ☑ Yes ☐ N

Casing Diameter				Weight(lbs/ft)
30	in. t	70	ft	118.76
24	in. t	408	ft	94.71

Hole Diameter

in. t	408	ft
in. t	501	ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND & GRAVEL	BROW	SOFT	0	11
CLAY & GRAVEL	BROW	SOFT	11	28
SANDSTONE-SHALEY	BROW	MEDIUM	28	166
LIMESTONE	GRAY	HARD	166	396
SANDSTONE	TAN	MEDIUM	396	501

Screen N

Open Hole From 401 ft. to 501 ft.

Make Type

Static Water Level 57 ft. from Land surface Date 2002/09/15

PUMPING LEVEL (below land surface)
84 ft. after 10 hrs. pumping 1800 g.p.m.

Well Head Completion
Pitless adapter mfr Model
Casing Protection Y ☑ 12 in. above grade
☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☑ Yes ☐ No

Material	From	To (ft.)	Amount(yds/bags)	
G	0	408	45	Y

Nearest Known Source of Contamination
150 ft. direction SW type BOW
Well disinfected upon completion? ☑ Yes ☐ No

Pump ☑ Not Installed Date Installed N
Mfr nam
Model HP Volts
Drop Pipe Length ft. Capacity g.p.m
Type

Any not in use and not sealed well(s) on property? ☐ Yes ☑ No

Was a variance granted from the MDH for this Well? ☐ Yes ☑ No

USGS Quad Farmington Elevation 971
Aquifer: CJDN Alt Id: 59-0725

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 62012
License Business Name
Name of Driller SAMPSON, J.

Report Copy

Unique No. 00655902

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2011/08/04

Entry Date 2002/10/21

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	20	W	24	CABBDB	501	ft.	501	ft.	2002/09/20

Well Name FARMINGTON 7 **Lic. Or Reg. No.** 62012 **Name of Driller** SAMPSON, J.

USGS Quad Farmington **Elevation** 971 **Aquifer** CJDN **Alternative Id** 59-0725

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
SAND & GRAVEL	BROWN	SOFT	0	11	QHUB	SAND	GRVL	
QHUB = Sand & larger	SAND = Sand				GRVL = Gravel			
CLAY & GRAVEL	BROWN	SOFT	11	28	QPUB	CLAY	GRVL	
QPUB = Pebbly sand/silt/clay	CLAY = Clay				GRVL = Gravel			
SANDSTONE-SHALEY	BROWN	MEDIUM	28	166	OSTP	SNDS	SHLE	
OSTP = St.Peter	SNDS = Sandstone				SHLE = Shale			
LIMESTONE	GRAY	HARD	166	396	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
SANDSTONE	TAN	MEDIUM	396	501	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							

Unique No. 00731123

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING RECORD
Minnesota Statutes Chapter 1031

Update Date 2011/09/19

Entry Date 2006/07/18

Township Name	Township	Range	Dir	Section	Subsection
	114	20	W	25	BBCCCA

Well Depth		Depth Completed		Date Well Completed
460	ft.	460	ft.	2006/06/18

Well Name FARMINGTON 8

Well Owner's Name FARMINGTON 8
15525 200TH W ST
FARMINGTON MN 55024

Contact's Name CITY OF FARMINGTON
325 OAK ST
FARMINGTON MN 55024

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND	BROW	SOFT	0	40
CLAY & STONES	GRAY	MEDIUM	40	50
ST. PETER SANDSTONE	TAN	MEDIUM	50	130
BASAL ST. PETER	GRAY	HARD	130	150
SHAKE MIX	GRAY	HARD	150	185
SHAKOPEE/ONEOTA	GRY/T	V.HARD	185	355
JORDAN SANDSTONE	GRY/T	HARD	355	460

REMARKS, ELEVATION, SOURCE OF DATA, etc.

M.G.S. NO. 4561.

USGS Quad Farmington Elevation 940
Aquifer: CJDN Alt Id: 4561

Report Copy

Drilling Method Cable Tool

Drilling Fluid Additive (+ Bentonite)

Well Hydrofractured? ☐ Yes ☑ No
From ft. to ft.

Use Community Supply (municipal)

Casing **Drive Shoe?** ☑ Yes ☐ N

Casing Diameter				Weight(lbs/ft)
30	in. t	78.5	ft	118.76
24	in. t	368	ft	94.71

Hole Diameter

in. t	368	ft
in. t	460	ft

Screen N

Make Type

Open Hole From 365 ft. to 460 ft.

Static Water Level 28 ft. from Land surface Date 2006/06/06

PUMPING LEVEL (below land surface)
65 ft. after 8 hrs. pumping 1710 g.p.m.

Well Head Completion
Pitless adapter mfr Model
Casing Protection ☑ 12 in. above grade
☐ At-grade(Environmental Wells and Borings ONLY)

Grouting Information Well grouted? ☑ Yes ☐ No

Material	From	To (ft.)	Amount(yds/bags)	
G		367	38	Y

Nearest Known Source of Contamination
500 ft. direction S type SEW
Well disinfected upon completion? ☑ Yes ☐ No

Pump ☐ Not Installed Date Installed
Mfr nam
Model HP Volts
Drop Pipe Length ft. Capacity g.p.m
Type

Any not in use and not sealed well(s) on property? ☐ Yes ☑ No

Was a variance granted from the MDH for this Well? ☐ Yes ☑ No

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 71015
License Business Name
Name of Driller SIGAFOOS, R.

Unique No. 00731123

County Name Dakota

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 1031

Update Date 2011/09/19

Entry Date 2006/07/18

Township Name	Township	Range	Dir	Section	Subsection	Well Depth		Depth Completed		Date Well Completed
	114	20	W	25	BBCCCA	460	ft.	460	ft.	2006/06/18

Well Name FARMINGTON 8 **Lic. Or Reg. No.** 71015 **Name of Driller** SIGAFOOS, R.

USGS Quad Farmington **Elevation** 940 **Aquifer** CJDN **Alternative Id** 4561

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO	STRAT	LITH PRIM	LITH SEC	LITH MINOR
SAND	BROWN	SOFT	0	40	QFUB	SAND		
QFUB = Sand	SAND = Sand							
CLAY & STONES	GRAY	MEDIUM	40	50	QPUG	CLAY	PEBL	
QPUG = Pebbly sand/silt/clay	CLAY = Clay		PEBL = Pebbles					
ST. PETER SANDSTONE	TAN	MEDIUM	50	130	OSTP	SNDS		
OSTP = St.Peter	SNDS = Sandstone							
BASAL ST. PETER	GRAY	HARD	130	150	OSTP	SNDS	SHLE	
OSTP = St.Peter	SNDS = Sandstone		SHLE = Shale					
SHAKE MIX	GRAY	HARD	150	185	OPDC	DACT		
OPDC = Prairie Du Chien Group	DACT = Dacite							
SHAKOPEE/ONEOTA	GRY/TAN	V.HARD	185	355	OPDC	DLMT		
OPDC = Prairie Du Chien Group	DLMT = Dolomite							
JORDAN SANDSTONE	GRY/TAN	HARD	355	460	CJDN	SNDS		
CJDN = Jordan	SNDS = Sandstone							

Appendix B

Aquifer Test Data and Analysis

MINNESOTA MDH DEPARTMENT OF HEALTH
Environmental Health Division
Drinking Water Protection Section
Source Water Protection Unit
P.O. Box 64975
St. Paul, Minnesota 55164-0975

Determination of Aquifer Properties and Aquifer Test Plan (DAP-ATP) Form

Public Water Supply ID:	1190008	PWS Name:	Farmington

Contact Information for Person Completing this Form

Name:	John Greer
Address:	Barr Engineering Company
	4700 West 77th Street, Suite 200
City, State, Zip:	Edina, MN 55435
Phone, Fax, e-mail:	(952) 832-2691

Aquifer Properties Determination Methods

☐ 1) An existing pumping test that meets the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on a well connected to the public water supply system.

☐ 2) An existing pumping test that meets the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on another well in a hydrogeologic setting determined by the department to be equivalent.

☐ 3) A proposed new test to be conducted on a new or existing well connected to the public water supply system and that meets the requirements for larger-sized water systems (wellhead protection rule part 4720.5520). A test plan must be approved before conducting the test.

☐ 4) A proposed new test to be conducted on a new or existing public well connected to the public water supply system and that meets the requirements for smaller-sized water systems (wellhead protection rule part 4720.5530). A test plan must be approved before conducting the test.

☐ 5) An existing pumping test that does not meet the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on: 1) a public water supply well or 2) another well in a hydrogeologic setting determined by the department to be equivalent.

☑ 6) Existing specific capacity test(s) conducted on the public water supply well(s) or specific capacity tests conducted on other wells in a hydrogeologic setting determined by the department to be equivalent.

☐ 7) An existing published transmissivity value.

- Include all test data and analysis documentation with the estimated transmissivity, ft^2/day, when the aquifer properties determination method is; 1, 2, 5, 6, or 7, listed above.
- ** Attach detailed aquifer test plan for methods 3 or 4.

Submitted by: John C Greer	Prof. License: 30347	Date: 7/6/2015

To request this document in another format, please call our Section Receptionist (651/201-4700) or Division TTY (651/201-5797).

Rationale for: 1) Aquifer Properties Determination or 2) Proposed New Test

Briefly describe the rationale for: 1) selected method to determine aquifer properties from existing data, or 2) a new aquifer test to be conducted on the pumped well referenced below. Include unique well numbers of all wells that were (or will be) monitored during data collection. How does the existing or proposed test deviate from the ideal. (e.g. rate, duration, no. of obwells, interfering wells, etc.) Attach documentation as necessary.

Aquifer Name:	Prairie du Chien Group	☑ Confined	☐ Unconfined	☐ Fractured Rock

Farmington wells 1 (Unique Number 200932) and 3 (Unique Number 201154) are open to both the Prairie du Chien Group dolostone and Jordan Sandstone aquifers. CWI pumping data for 25 wells completed in the OPDC in the Farmington vicinity were analyzed using the TGuess method (see attached) to estimate the transmissivity of the Prairie du Chien Group. The geometric mean transmissivity obtained from this analysis is 114 m**2/day (1200 ft**2/day). This transmissivity will be used as the base case transmissivity in the groundwater model.

The transmissivity range obtained from the analysis is 32 m**2/day to 443 m**2/day (340 ft**2/day to 4800 ft**2/day). This range will be used in the sensitivity analysis.

Proposed New Test Information Summary

Pumped Well Name (Unique Number):	see attached	**Test Duration (Hours):**	
Location: X, Y (meters) UTM-Z15N or Lat-Lon (decimal degrees) datum: NAD83		**Pump Type:**	
		Discharge Rate:	
Number of Observation Wells:		**Flow Rate Measuring Device Type:**	

- A map showing the location of the pumping well and observation well(s) must be included.

List the unique number of each public water supply well to which this DAP-ATP Form applies

200932					
201154					

Reviewed by:	**Approved:** (•) Yes ( ) No	**Approval Date:** 3/15/16

Prairie du Chien Group

Worksheet for Estimating Transmissivity and Hydraulic Conductivity from Specific Capacity Test Data

Explanation and notes attached.

Maximum iterations	100
Error tolerance (as drawdown)	0.001 feet

	Field Data							*Estimated Parameters*			*Calculated Results*									*Diagnostics*					
		Depth to Water				Screened Interval														*Solution Integrity*			*Sensitivity of T:*		
Location	Well Diam.	Initial	Final	Test Duration	Mean Pumping Rate	Depth to Top	Depth to Bottom	Storage Coeff. (S)	Well loss Coeff. (C)	Aquifer Thickness (b)	Measured Drawdown (s_m)	Saturated Screen Length (L)	Well loss (s_w)	Partial Penetration Parameter (s_p)	Specific Capacity	Transmissivity (T)	T (ft^2/day)	Conductivity (K)	K (m/day)	Calculated Drawdown	Error as Drawdown	Well Bore Storage Test	to S at ± 1 factor of 10	to s_w at 10% of s_m	to b at ± 25%
	inches	feet	feet	hours	gpm	feet	feet	-	sec^2/ft^5	feet	feet	feet	feet	-	gpm/ft	sq ft/sec		ft/day		feet			sq ft/sec	sq ft/sec	sq ft/sec
00460123	4	20	30	24	10	142.0	160.0	0.001	0	201.0	10.00	18.0	0.0E+00	47.97	1.00	2.0E-02	1.8E+03	8.7	2.7	10.00	0.00%	pass	4.1E-04	2.3E-03	1.0E-02
00460130	4	14	25	24	10	125.0	150.0	0.001	0	201.0	11.00	25.0	0.0E+00	34.46	0.91	1.4E-02	1.2E+03	6.1	1.8	11.00	0.00%	pass	3.8E-04	1.6E-03	6.9E-03
00502136	4	35	40	24	10	96.0	115.0	0.001	0	201.0	5.00	19.0	0.0E+00	45.45	2.00	3.9E-02	3.4E+03	16.8	5.1	5.00	0.01%	pass	8.2E-04	4.4E-03	2.0E-02
00435175	4	15	60	20	20	89.0	110.0	0.001	0	201.0	45.00	21.0	0.0E+00	41.11	0.44	7.9E-03	6.8E+02	3.4	1.0	45.00	0.00%	pass	1.8E-04	8.8E-04	4.0E-03
00460154	4	25	35	12	10	140.0	160.0	0.001	0	201.0	10.00	20.0	0.0E+00	43.18	1.00	1.8E-02	1.6E+03	8.0	2.4	10.00	0.00%	pass	4.1E-04	2.1E-03	9.4E-03
00460163	4	10	15	12	10	116.0	140.0	0.001	0	201.0	5.00	24.0	0.0E+00	35.92	2.00	3.2E-02	2.8E+03	13.8	4.2	5.00	0.01%	pass	8.3E-04	3.6E-03	1.6E-02
00475939	4	22	34	12	20	107.0	131.0	0.001	0	201.0	12.00	24.0	0.0E+00	35.92	1.67	2.7E-02	2.3E+03	11.5	3.5	12.00	0.00%	pass	6.9E-04	3.0E-03	1.3E-02
00460162	4	35	42	6	10	95.0	120.0	0.001	0	201.0	7.00	25.0	0.0E+00	34.46	1.43	2.2E-02	1.9E+03	9.4	2.9	7.00	0.00%	pass	5.9E-04	2.5E-03	1.1E-02
00462149	6	18	78	4	300	163.0	300.0	0.001	0	201.0	60.00	137.0	0.0E+00	2.30	5.00	1.8E-02	1.6E+03	7.9	2.4	60.00	0.00%	pass	2.1E-03	2.1E-03	7.6E-03
00475908	4	30	38	4	10	147.0	160.0	0.001	0	201.0	8.00	13.0	0.0E+00	66.19	1.25	3.3E-02	2.9E+03	14.3	4.4	8.00	0.00%	pass	5.1E-04	3.7E-03	1.8E-02
00475912	4	30	38	4	10	91.0	120.0	0.001	0	201.0	8.00	29.0	0.0E+00	29.57	1.25	1.7E-02	1.5E+03	7.2	2.2	8.00	0.00%	pass	5.2E-04	1.9E-03	8.3E-03
00435217	4	20	60	2	20	124.0	140.0	0.001	0	201.0	40.00	16.0	0.0E+00	53.92	0.50	1.1E-02	9.5E+02	4.7	1.4	40.00	0.00%	pass	2.1E-04	1.2E-03	5.8E-03
00435224	12	40	100	2	1000	109.0	250.0	0.001	0	201.0	60.00	141.0	0.0E+00	1.78	16.67	5.5E-02	4.8E+03	23.7	7.2	60.00	0.00%	pass	7.2E-03	6.5E-03	2.1E-02
00457146	4	15	60	2	20	75.0	104.0	0.001	0	201.0	45.00	29.0	0.0E+00	29.57	0.44	5.8E-03	5.1E+02	2.5	0.8	45.00	0.00%	pass	1.8E-04	6.6E-04	2.9E-03
00457156	6	30	140	2	150	140.0	300.0	0.001	0	201.0	110.00	150.0	0.0E+00	1.21	1.36	3.9E-03	3.4E+02	1.7	0.5	110.00	0.00%	pass	5.9E-04	4.7E-04	1.7E-03
00457200	4	20	40	2	50	120.0	140.0	0.001	0	201.0	20.00	20.0	0.0E+00	43.18	2.50	4.6E-02	4.0E+03	19.7	6.0	20.00	0.00%	pass	1.0E-03	5.1E-03	2.3E-02
00466803	4	20	60	2	20	120.0	150.0	0.001	0	201.0	40.00	30.0	0.0E+00	28.54	0.50	6.4E-03	5.5E+02	2.8	0.8	40.00	0.00%	pass	2.1E-04	7.2E-04	3.2E-03
00466805	8	20	60	2	20	105.0	140.0	0.001	0	201.0	40.00	35.0	0.0E+00	20.93	0.50	4.9E-03	4.2E+02	2.1	0.6	40.00	0.00%	pass	2.1E-04	5.8E-04	2.4E-03
00498426	4	20	60	2	20	142.0	160.0	0.001	0	201.0	40.00	18.0	0.0E+00	47.97	0.50	9.9E-03	8.5E+02	4.2	1.3	40.00	0.00%	pass	2.1E-04	1.1E-03	5.2E-03
00506623	4	40	90	2	20	127.0	160.0	0.001	0	201.0	50.00	33.0	0.0E+00	25.80	0.40	4.7E-03	4.1E+02	2.0	0.6	50.00	0.00%	pass	1.7E-04	5.3E-04	2.4E-03
00518799	4	15	60	2	20	126.0	140.0	0.001	0	201.0	45.00	14.0	0.0E+00	61.52	0.44	1.1E-02	9.4E+02	4.7	1.4	45.00	0.00%	pass	1.8E-04	1.2E-03	5.9E-03
00525481	4	15	35	2	20	98.0	140.0	0.001	0	201.0	20.00	42.0	0.0E+00	19.79	1.00	9.8E-03	8.4E+02	4.2	1.3	20.00	0.00%	pass	4.2E-04	1.1E-03	4.8E-03
00547276	4	80	95	2	12	200.0	240.0	0.001	0	201.0	15.00	40.0	0.0E+00	20.91	0.80	8.1E-03	7.0E+02	3.5	1.1	15.00	0.00%	pass	3.3E-04	9.2E-04	4.0E-03
00573846	4	15	29	2	18	95.0	120.0	0.001	0	201.0	14.00	25.0	0.0E+00	34.46	1.29	1.9E-02	1.7E+03	8.3	2.5	14.00	0.00%	pass	5.3E-04	2.2E-03	9.7E-03
00585128	4	40	60	2	20	147.0	180.0	0.001	0	201.0	20.00	33.0	0.0E+00	25.80	1.00	1.2E-02	1.0E+03	5.1	1.6	20.00	0.00%	pass	4.1E-04	1.3E-03	5.9E-03
																Max	4.8E+03	2.4E+01	7.2E+00						
																Min	3.4E+02	1.7E+00	5.1E-01						
																Geomean	1.2E+03	6.1E+00	1.9E+00						

References:

Bradbury, K.B., and E.R. Rothschild, 1985. A computerized technique for estimating the hydraulic conductivity of aquifer from specific capacity data: Ground Water vol. 23, No. 2, pp. 240-246.

ASTM International, 2004. Standard Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well, Standard D 5472-93, in Annual Book of ASTM Standards, Vol. 04.08 pp. 1279-1282.

MINNESOTA MDH DEPARTMENT OF HEALTH
Environmental Health Division
Drinking Water Protection Section
Source Water Protection Unit
P.O. Box 64975
St. Paul, Minnesota 55164-0975

Determination of Aquifer Properties and Aquifer Test Plan (DAP-ATP) Form

Public Water Supply ID:	1190008	PWS Name:	Farmington

Contact Information for Person Completing this Form

Name:	John Greer
Address:	Barr Engineering Company
	4700 West 77th Street, Suite 200
City, State, Zip:	Edina, MN 55435
Phone, Fax, e-mail:	(952) 832-2691

Aquifer Properties Determination Methods

☐ 1) An existing pumping test that meets the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on a well connected to the public water supply system.

☐ 2) An existing pumping test that meets the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on another well in a hydrogeologic setting determined by the department to be equivalent.

☐ 3) A proposed new test to be conducted on a new or existing well connected to the public water supply system and that meets the requirements for larger-sized water systems (wellhead protection rule part 4720.5520). A test plan must be approved before conducting the test.

☐ 4) A proposed new test to be conducted on a new or existing public well connected to the public water supply system and that meets the requirements for smaller-sized water systems (wellhead protection rule part 4720.5530). A test plan must be approved before conducting the test.

☑ 5) An existing pumping test that does not meet the requirements of wellhead protection rule part 4720.5520 and that was previously conducted on: 1) a public water supply well or 2) another well in a hydrogeologic setting determined by the department to be equivalent.

☐ 6) Existing specific capacity test(s) conducted on the public water supply well(s) or specific capacity tests conducted on other wells in a hydrogeologic setting determined by the department to be equivalent.

☐ 7) An existing published transmissivity value.

- Include all test data and analysis documentation with the estimated transmissivity, ft^2/day, when the aquifer properties determination method is; 1, 2, 5, 6, or 7, listed above.

▪▪ Attach detailed aquifer test plan for methods 3 or 4.

Submitted by: John C Greer	Prof. License: 30347	Date: 7/6/2015

To request this document in another format, please call our Section Receptionist (651/201-4700) or Division TTY (651/201-5797).

Rationale for: 1) Aquifer Properties Determination or 2) Proposed New Test

Briefly describe the rationale for: 1) selected method to determine aquifer properties from existing data, **or** 2) a new aquifer test to be conducted on the pumped well referenced below. Include unique well numbers of all wells that were (or will be) monitored during data collection. How does the existing or proposed test deviate from the ideal. (e.g. rate, duration, no. of obwells, interfering wells, etc.) Attach documentation as necessary.

Aquifer Name:	Jordan Sandstone	☑ Confined	☐ Unconfined	☐ Fractured Rock

The previous Farmington Part I WHPP (Bonestroo, 2004) includes limited information regarding a 24-hour pumping test conducted at Farmington Well 7 (Unique Number 655902), completed in the Jordan Sandstone aquifer. Wells 5 (Unique Number 603051) and 6 (Unique Number 626785) were used as observation wells. The test date is unknown, and the report contains few specifics about the test other than a pumping rate (1,600 gpm) and tables of measured drawdowns at Wells 5, 6, and 7.

The pumping test data were analyzed in the previous WHPP using the Cooper-Jacob method for confined aquifers. Barr conducted a second analysis of the data from Wells 5 and 6 using AQTESOLV. The Hantush-Jacob solution for leaky confined aquifers provided the best fit to the data. Transmissivity estimates for the two methods were comparable (see the attached summary table).

The geometric mean transmissivity obtained from this analysis is 2200 m**2/day (23700 ft**2/day). This transmissivity will be used as the base case transmissivity in the groundwater model.

The transmissivity range obtained from the analysis is 1230 m**2/day to 3860 m**2/day (13240 ft**2/day to 41520 ft**2/day). This range will be used in the sensitivity analysis.

Coordinates for the wells are as follows:

Well	UTM_x	UTM_y
655902	486456	4945915
603051	486212	4945773
626785	486240	4945356

Proposed New Test Information Summary

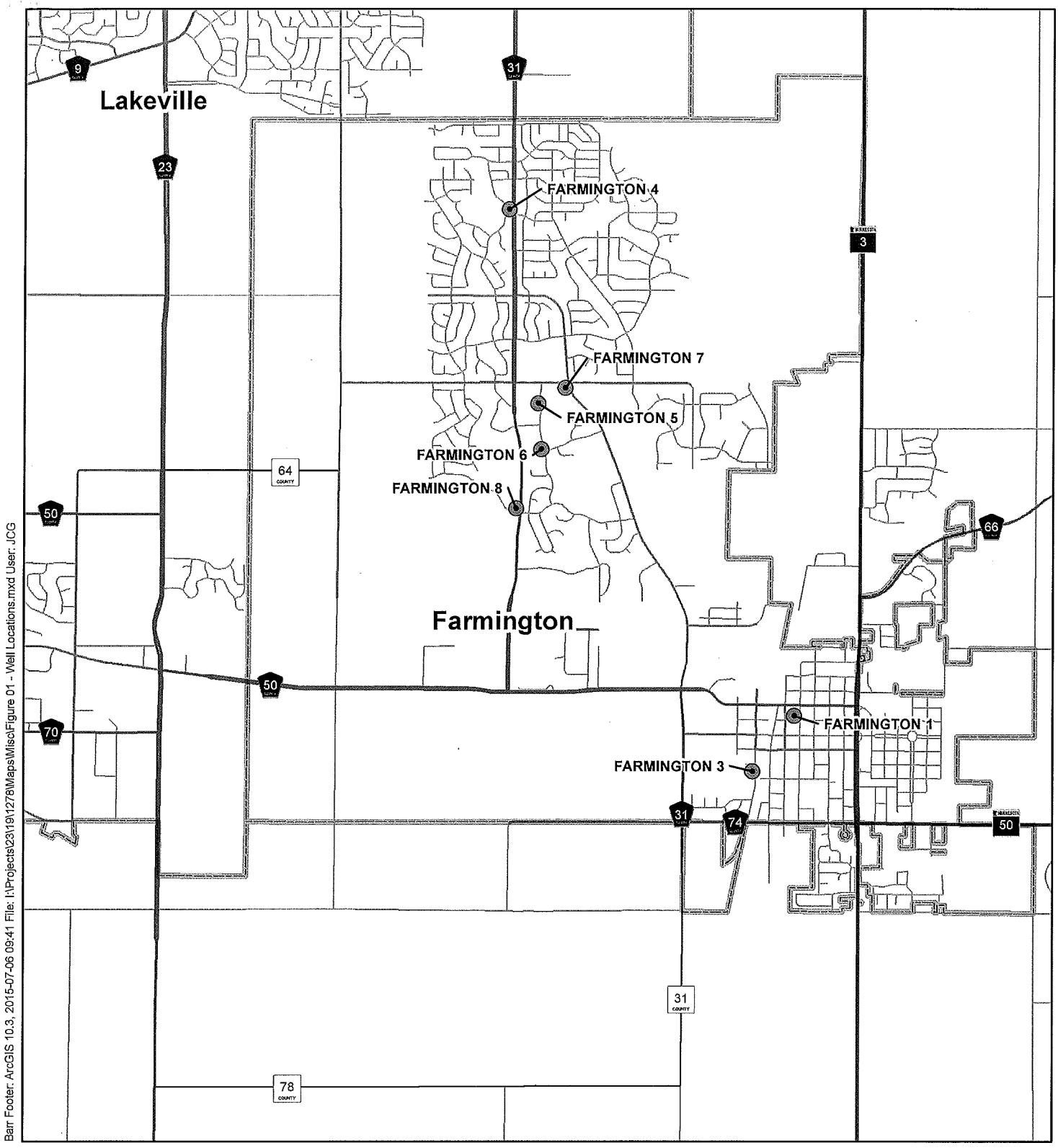
Pumped Well Name (Unique Number):	Well 7 (655902)	**Test Duration (Hours):**	24
Location: X, Y (meters) UTM-Z15N or Lat-Lon (decimal degrees) datum: NAD83	see above	**Pump Type:**	unknown
		Discharge Rate:	1600 gpm
Number of Observation Wells:	2	**Flow Rate Measuring Device Type:**	unknown

- A map showing the location of the pumping well and observation well(s) must be included.

List the unique number of each public water supply well to which this DAP-ATP Form applies

200932	731123				
201154					
235586					
603051					
626785					
655902					

Reviewed by:	**Approved:** ◉ Yes ○ No	**Approval Date:** 3/14/16



Barr Footer: ArcGIS 10.3, 2015-07-06 09:41 File: I:\Projects\23\19\12781Maps\Misc\Figure 01 - Well Locations.mxd User: JCG

Farmington Municipal Well

Municipal Boundary

N

Feet

4,000 0 4,000

BARR

Figure 1

WELL LOCATIONS
Farmington WHPP Amendment
City of Farmington, MN

Farmington Aquifer Test Analysis Summary

Bonestroo Cooper-Jacob Analysis

	Transmissivity (gpd/ft)		Transmissivity (ft^2/day)		Transmissivity (m^2/day)	
Well	Pumping	Recovery	Pumping	Recovery	Pumping	Recovery
5	146159	115410	19540	15429	1815	1433
6	265660	214416	35516	28665	3300	2663
7	310588	187733	41522	25098	3858	2332

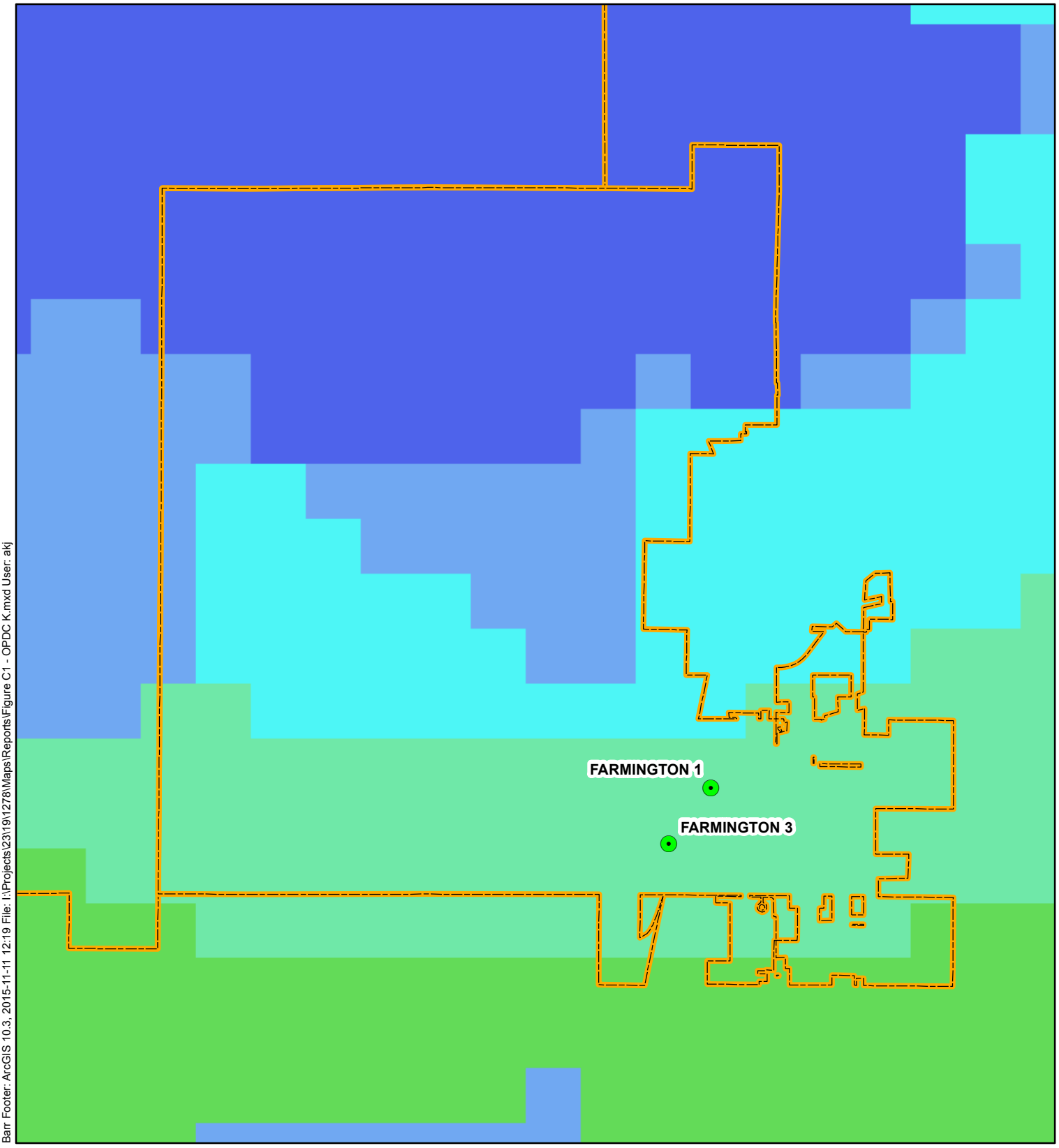
Barr Hantush-Jacob Analysis

	Transmissivity (gpd/ft)		Transmissivity (ft^2/day)		Transmissivity (m^2/day)	
Well	Pumping	Recovery	Pumping	Recovery	Pumping	Recovery
5	--	--	18700	13240	1737	1230
6	--	--	34630	20420	3217	1897

	T (ft^2/day)	T (m^2/day)
Geometric Mean	23704	2202
Min	13240	1230
Max	41522	3858

Appendix C

Groundwater Model Details



Barr Footer: ArcGIS 10.3, 2015-11-11 12:19 File: I:\Projects\23\19\1278\Maps\Reports\Figure C1 - OPDC K.mxd User: akj

OPDC Kx (m/day)

- 1.21 - 1.53
- 1.54 - 2.15
- 2.16 - 2.94
- 2.95 - 3.28
- 3.29 - 3.76

Farmington Well Open to OPDC

Municipal Boundary

N

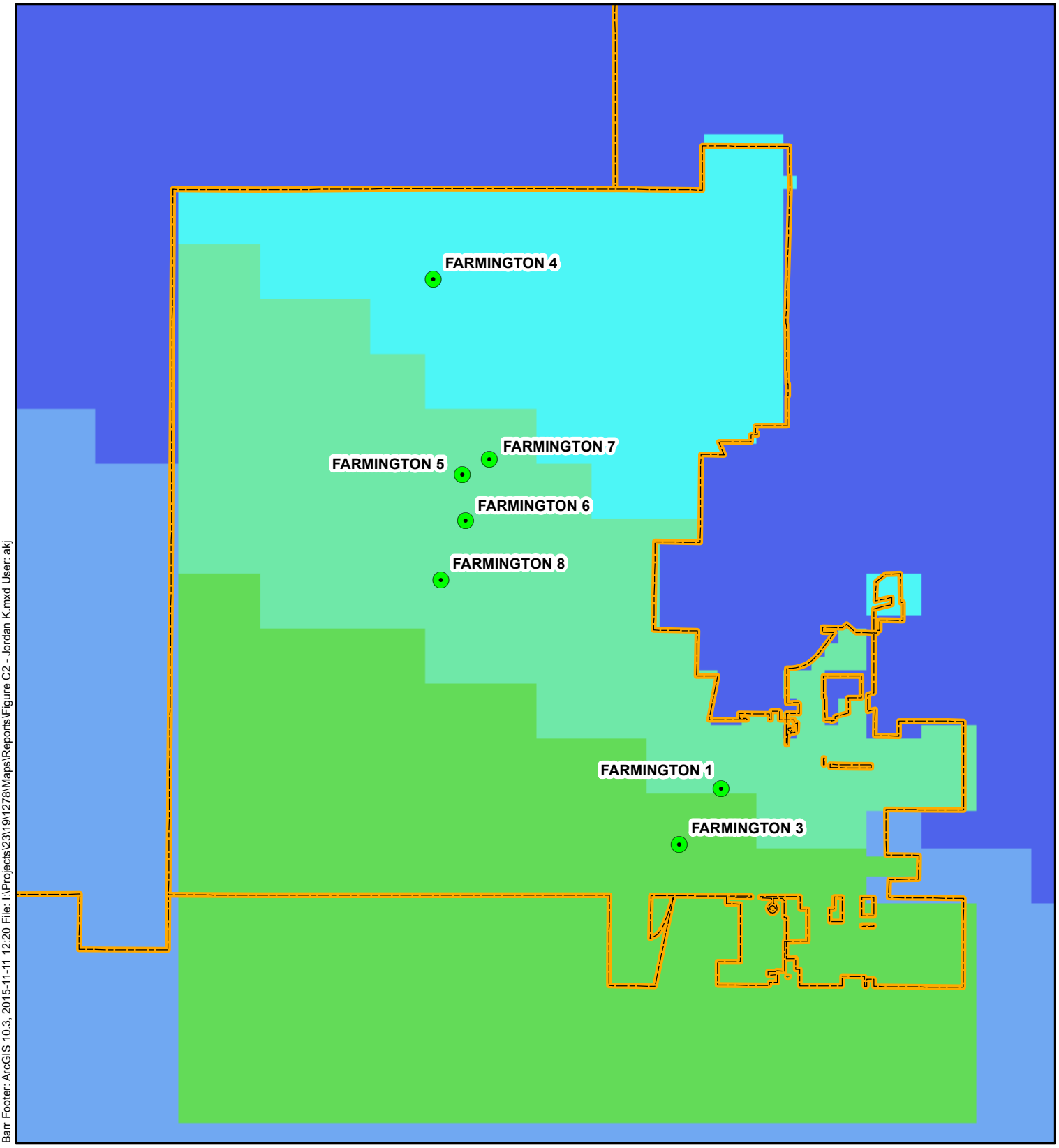
Feet

4,000 0 4,000

BARR

Figure C1

HORIZONTAL HYDRAULIC CONDUCTIVITY PRAIRIE DU CHIEN GROUP
Farmington WHPP Amendment
City of Farmington, MN



Barr Footer: ArcGIS 10.3, 2015-11-11 12:20 File: i:\Projects\23\19\1278\Maps\Reports\Figure C2 - Jordan K.mxd User: akj

CJDN Kx (m/day)

- 10.18 - 12.62
- 12.63 - 14.89
- 14.90 - 67.62
- 67.63 - 72.07
- 72.08 - 81.88

Farmington Well Open to Jordan

Municipal Boundary

N

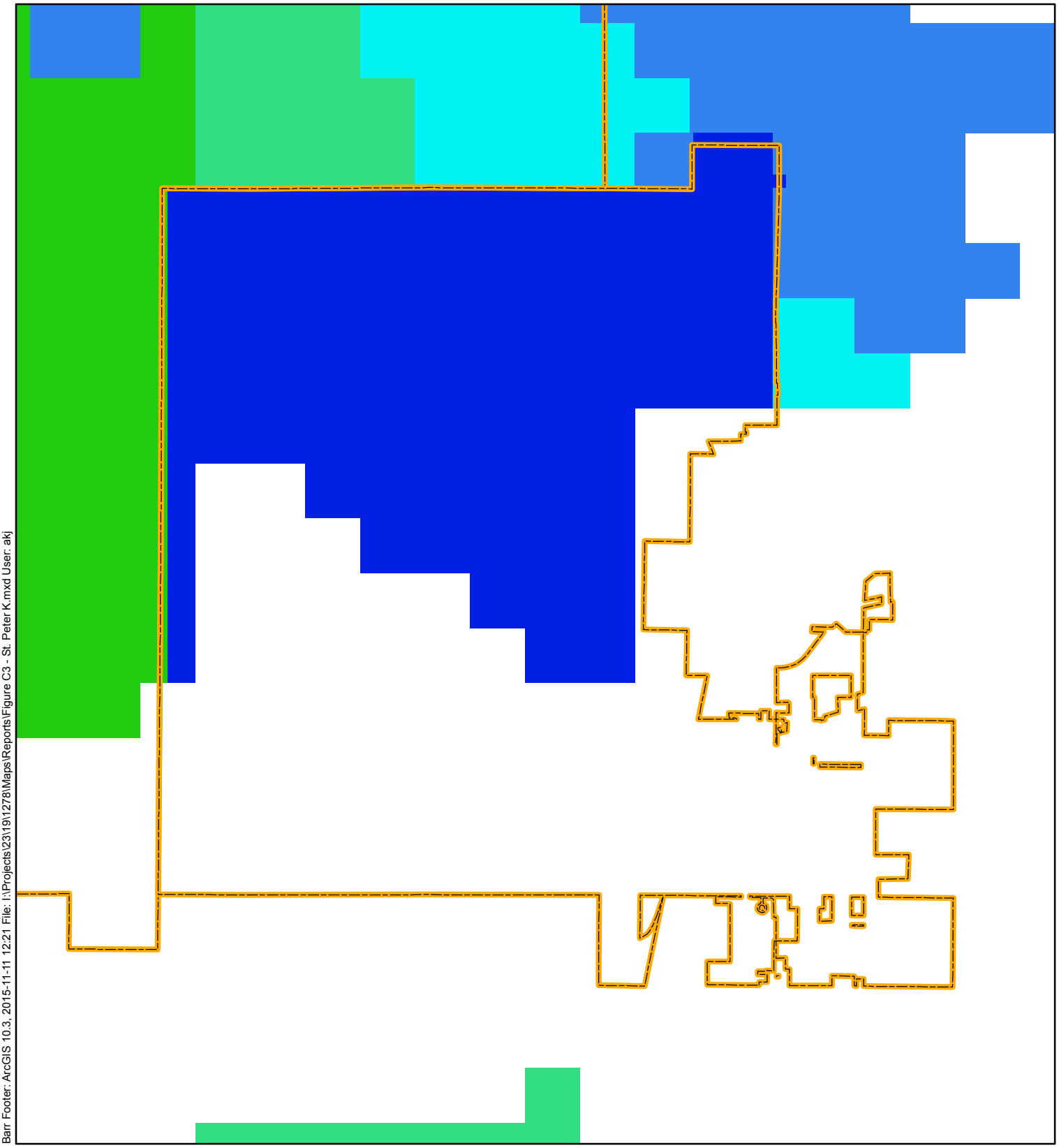
Feet

4,000 0 4,000

BARR

Figure C2

HORIZONTAL
HYDRAULIC CONDUCTIVITY
JORDAN SANDSTONE
Farmington WHPP Amendment
City of Farmington, MN



Barr Footer: ArcGIS 10.3, 2015-11-11 12:21 File: I:\Projects\23\19\1278\Maps\Reports\Figure C3 - St. Peter K.mxd User: akj

Only cells representing St. Peter Sandstone in Layer 2 shown

OSTP Kx (m/day)

- 7.62
- 7.63 - 47.37
- 47.38 - 52.22
- 52.23 - 55.86
- 55.87 - 59.59

Municipal Boundary

N

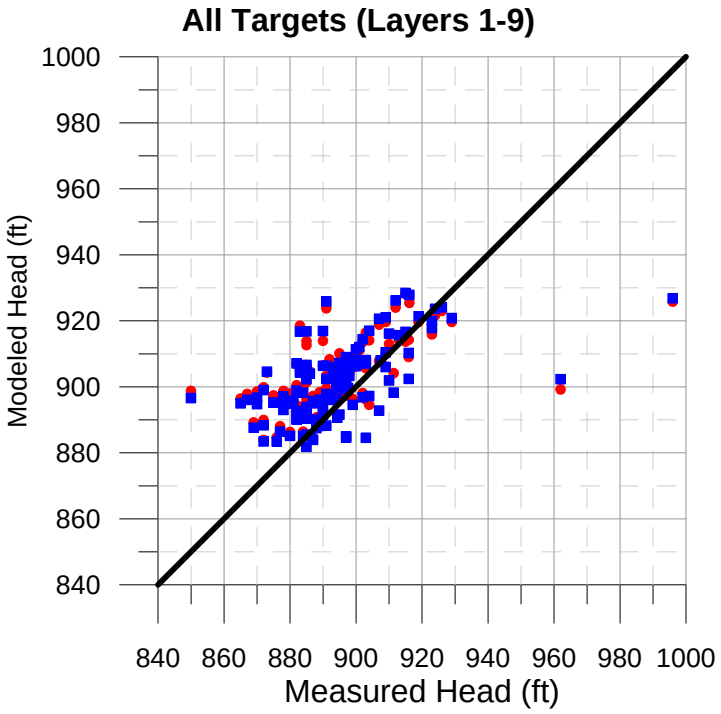
Feet

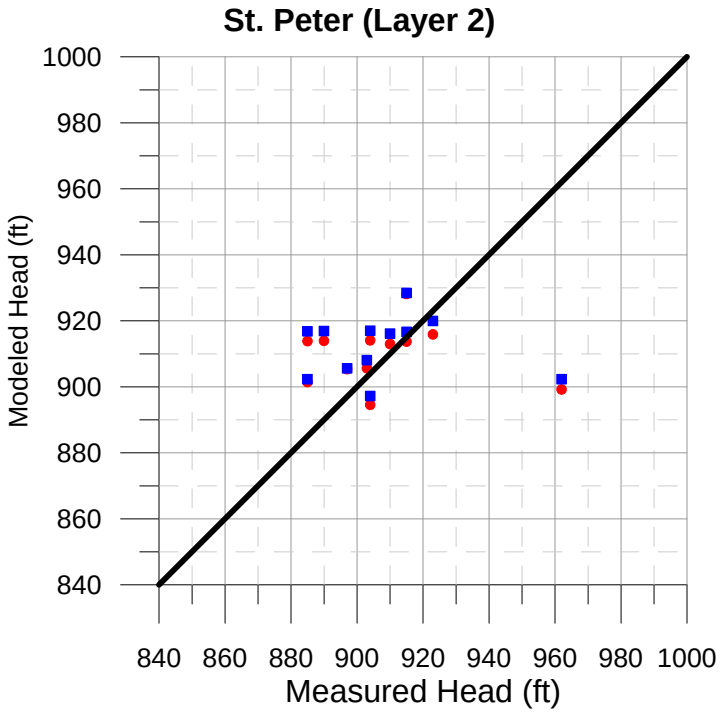
4,000 0 4,000

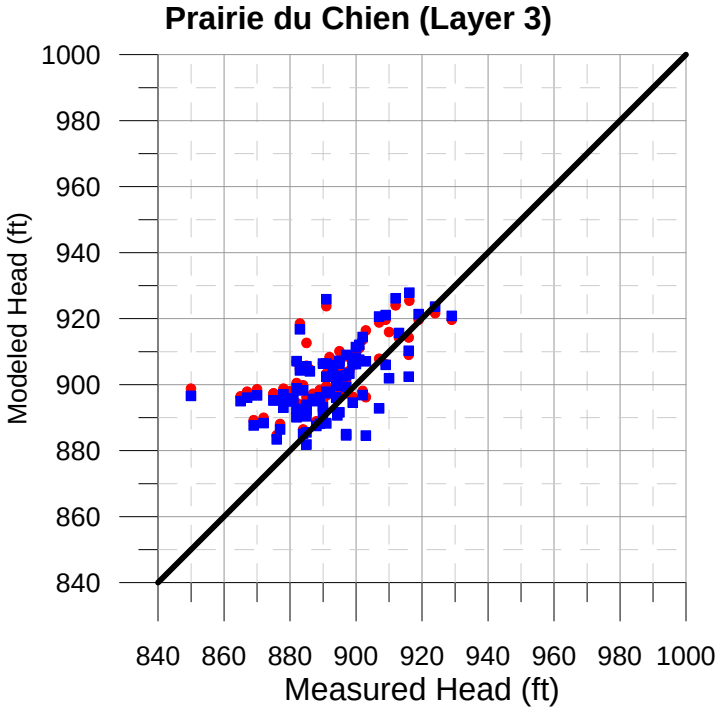
BARR

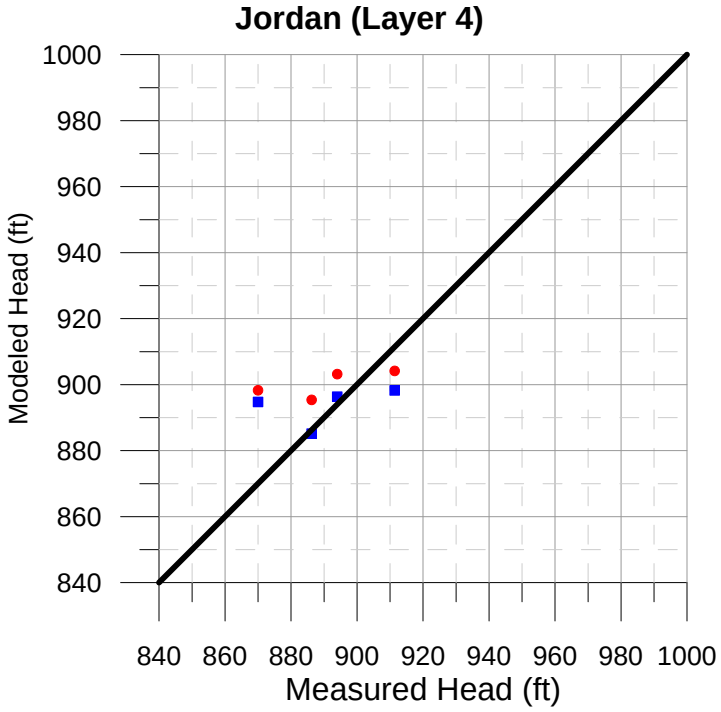
Figure C3

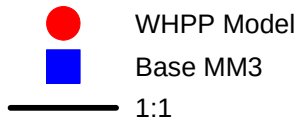
HORIZONTAL
HYDRAULIC CONDUCTIVITY
ST. PETER SANDSTONE
Farmington WHPP Amendment
City of Farmington, MN











Only Metro Model 3 targets within 1 km of Farmington city limits shown.

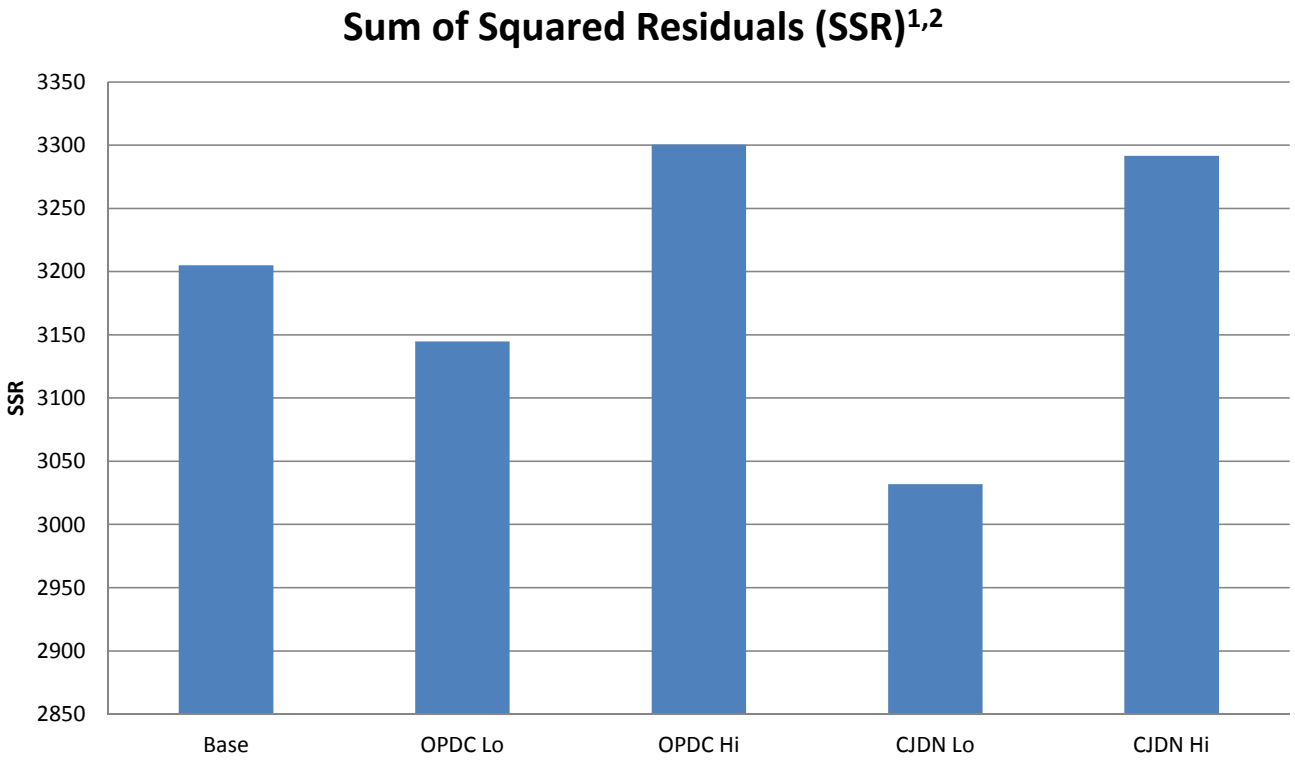
WHPP model has updated K field but uses identical pumping rates to the base Metro Model 3.

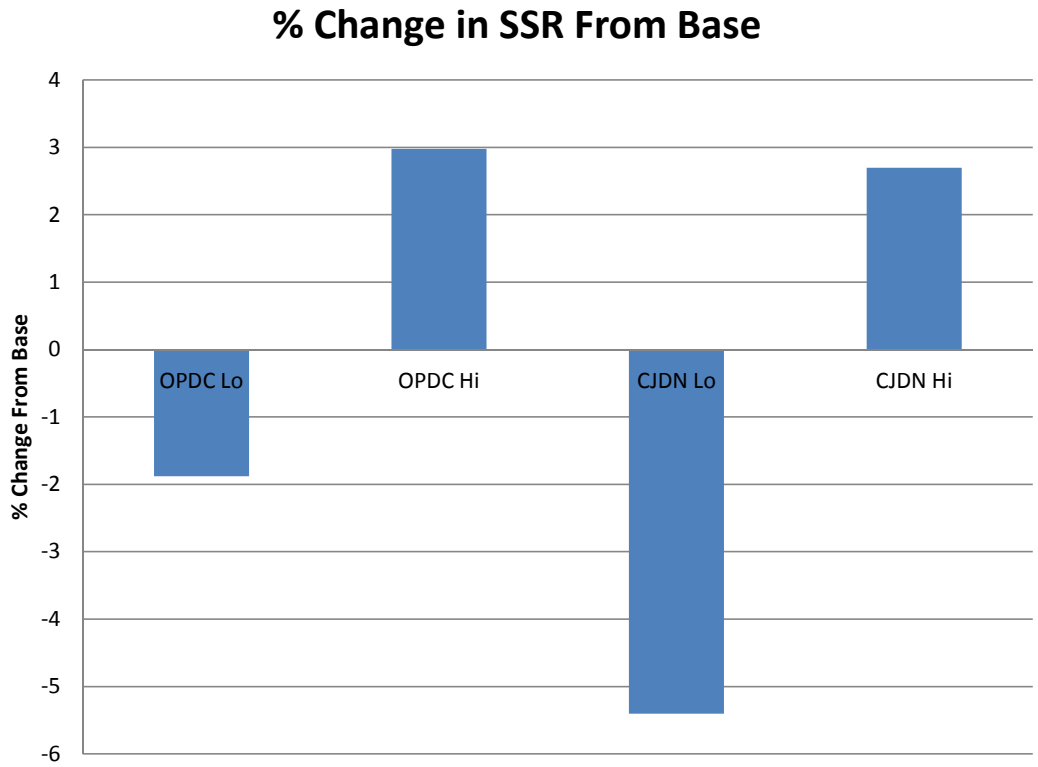
V:\23\19\1278\Targets\Calibration_Comparison.grf

Figure C4

MODEL CALIBRATION
Farmington WHPP Amendment
City of Farmington, MN

Figure C5
Sensitivity Analysis Results
Farmington WHPP Amendment





[1] Residuals calculated for the 126 Metro Model 3 calibration targets within 1 km of Farmington city limits only

[2] Residual = measured head - modeled head

V:\23\19\1278\Targets\Sensitivity Targets\Sensitivity_Analysis.xlsx

Appendix D

Fracture Flow Calculations

Well 1: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

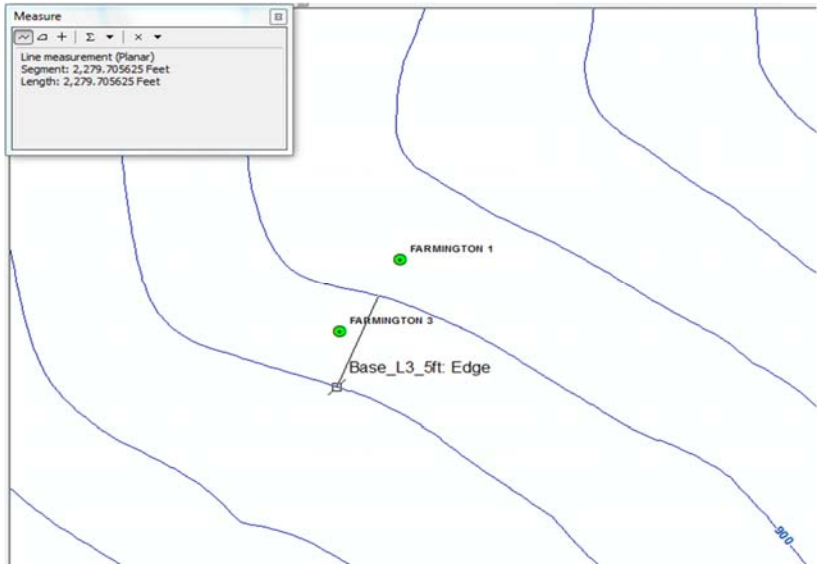
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	1365
Well Discharge, Q (gpm)	250
Aquifer Thickness, H (ft)	121
Aquifer Hydraulic Conductivity K (m/day)	3.01
Hydraulic Gradient, i	0.002193

Calculated Q/Qs (m)

5604



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	1365
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	36.9

Calculated Fixed Radius (m): 277

Volume (m^3): 8,896,875

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 3: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

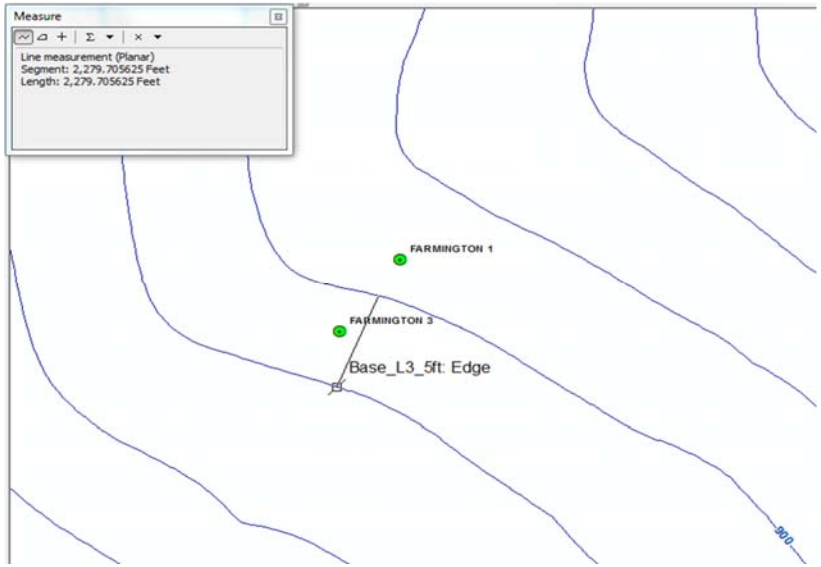
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	1236
Well Discharge, Q (gpm)	227
Aquifer Thickness, H (ft)	190
Aquifer Hydraulic Conductivity K (m/day)	3.07
Hydraulic Gradient, i	0.002193

Calculated Q/Qs (m)

3168



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\min}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	1236
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	57.9

Calculated Fixed Radius (m)

210

Volume (m^3)

8,056,071

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 1: 10-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

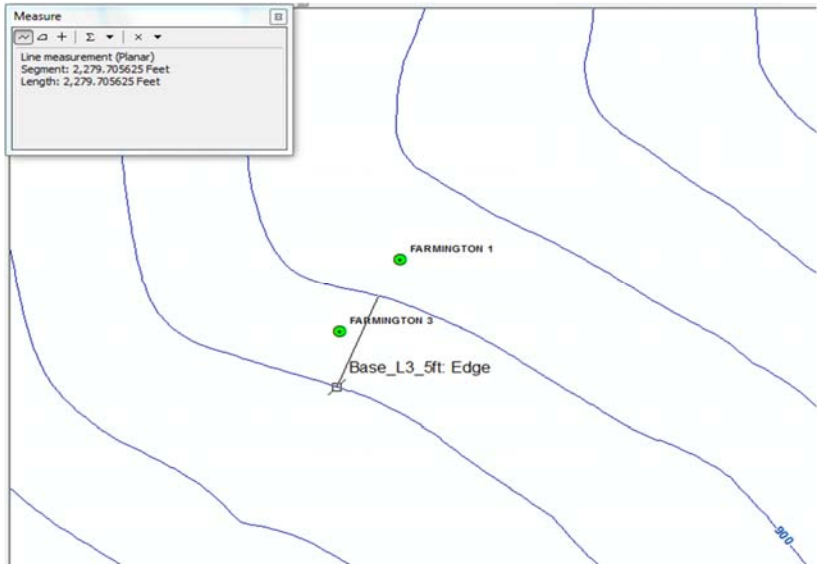
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	1365
Well Discharge, Q (gpm)	250
Aquifer Thickness, H (ft)	121
Aquifer Hydraulic Conductivity K (m/day)	3.01
Hydraulic Gradient, i	0.002193

Calculated Q/Qs (m)

5604



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	1365
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	36.9

Calculated Fixed Radius (m)

876

Volume (m^3)

88,968,750

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 3: 10-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

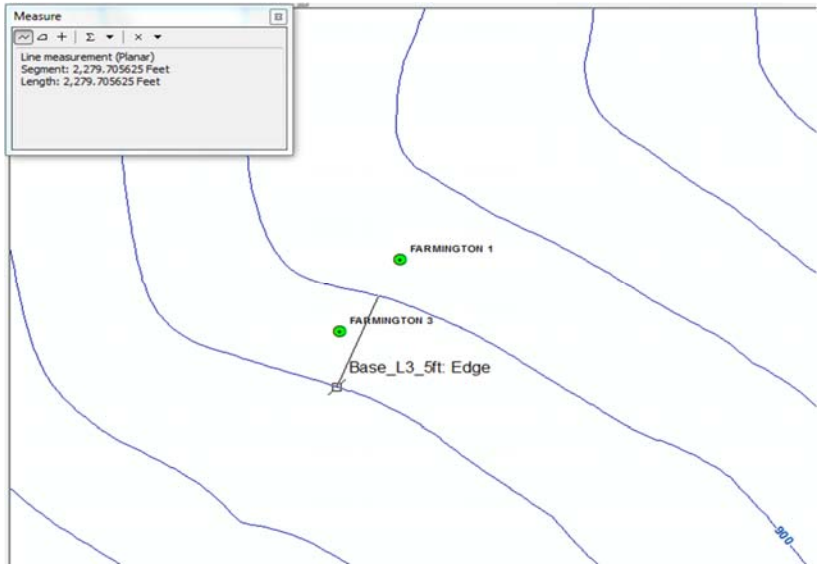
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	1236
Well Discharge, Q (gpm)	227
Aquifer Thickness, H (ft)	190
Aquifer Hydraulic Conductivity K (m/day)	3.07
Hydraulic Gradient, i	0.002193

Calculated Q/Qs (m)

3168



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	1236
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	57.9

Calculated Fixed Radius (m)

665

Volume (m^3)

80,560,714

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 1: 10-Year Overlap

	Overlap With Well…		
	Farmington 3	242346	
Original 10-yr Volume	80,560,714.3	53,540,250.0	m^3
Intersected Area[1]	889,058	953,375	m^2
Open Hole Overlap[2,3]	36.3	36.9	m
Overlap volume	32,272,805.4	35,179,530.1	m^3

[1] Computed with ArcGIS from 10-year fixed radius capture zones

[2] Well 1 open to OPDC from 706 to 585, Well 3 open to OPDC from 777 to 587; 706 - 587 = 119 ft = 36.3 m

[3] Well 1 open to OPDC from 706 to 585, 242346 open to OPDC from 740 to 576; 706 - 585 = 121 ft = 36.9 m

		Apportioned Volume From Well… (m^3)				
Well	Original 10-yr Volume (m^3)	Farmington 3	242346	Adjusted 10-year Volume (m^3)	OPDC Thickness (m)	Revised 10-year Fixed Radius (m)
1	88,968,750.0	16,936,708.7	21,962,674.8	127,868,133.5	36.9	1050.5

Well 3: 10-Year Overlap

	Overlap With Well…		
	Farmington 1	242346	
Original 10-yr Volume	88,968,750.0	53,540,250.0	m^3
Intersected Area[1]	889,058	78,858	m^2
Open Hole Overlap[2,3]	36.3	46.6	m
Overlap volume	32,272,805.4	3,674,773.5	m^3

[1] Computed with ArcGIS from 10-year fixed radius capture zones

[2] Well 1 open to OPDC from 706 to 585, Well 3 open to OPDC from 777 to 587; 706 - 587 = 119 ft = 36.3 m

[3] Well 3 open to OPDC from 777 to 587, 242346 open to OPDC from 740 to 576; 740 - 587 = 153 ft = 46.6 m

		Apportioned Volume From Well… (m^3)				
Well	Original 10-yr Volume (m^3)	Farmington 1	242346	Adjusted 10-year Volume (m^3)	OPDC Thickness (m)	Revised 10-year Fixed Radius (m)
3	80,560,714.3	15,336,096.7	2,207,608.1	98,104,419.1	57.9	734.3

Flow Rates from ZONEBUDGET Calcs (m^3/day)

Well(s)	Pumping Rate	Flow from Layer 3 to Layer 4	Flow from Layer 4 to Layer 3	Net Inflow from Layer 3	% of Pumping Rate
4	1848	592.79	0.0	593	32
5	1706	361.61	0.0	362	21
6	2083	295.32	0.0	295	14
7	1647	323.16	0.0	323	20
8	1883	283.62	0.0	284	15

ZONEBUDGET was used to compute the water balance for the 10-year porous media capture zones in model layer 4

Well 4: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

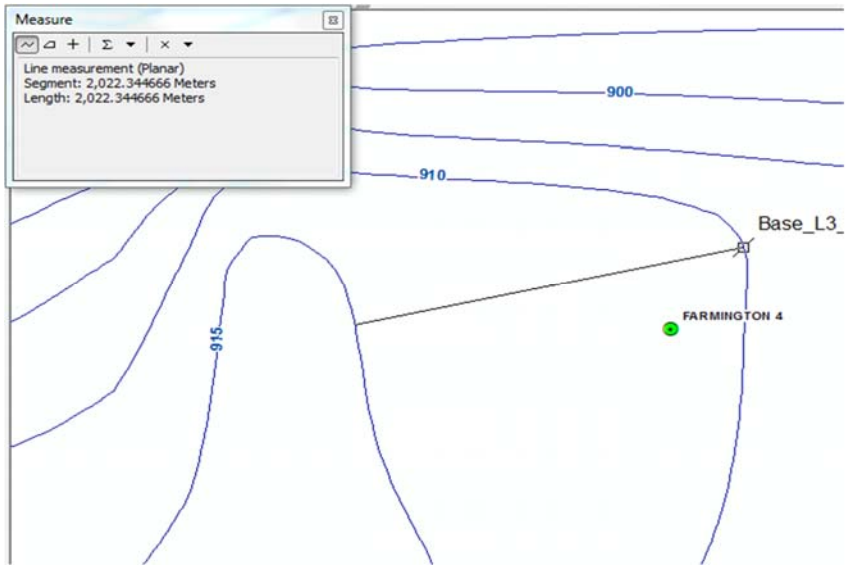
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	593
Well Discharge, Q (gpm)	109
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	1.39
Hydraulic Gradient, i	0.0024728

Calculated Q/Qs (m)

2828



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	593
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

142

Volume (m^3)

3,865,089

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 5: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

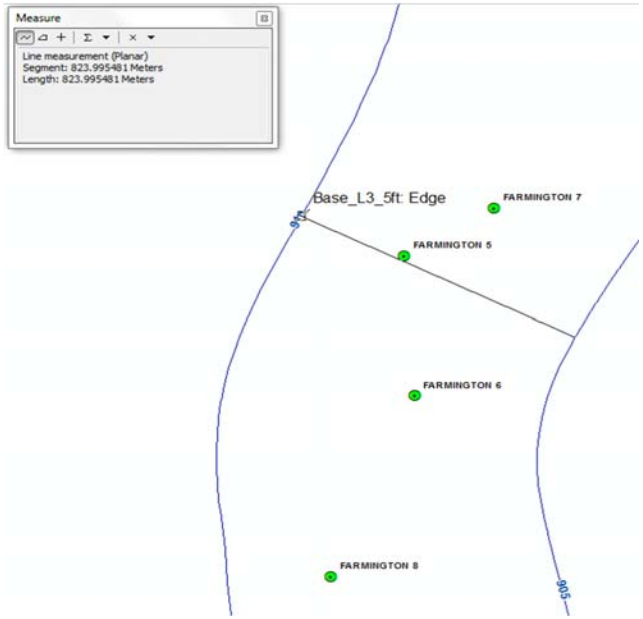
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	362
Well Discharge, Q (gpm)	66
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	1.54
Hydraulic Gradient, i	0.006068

Calculated Q/Qs (m)

635



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\min}{1\,day}\right)\left(\frac{0.0283 m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048 m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	362
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

111

Volume (m^3)

2,359,464

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 6: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

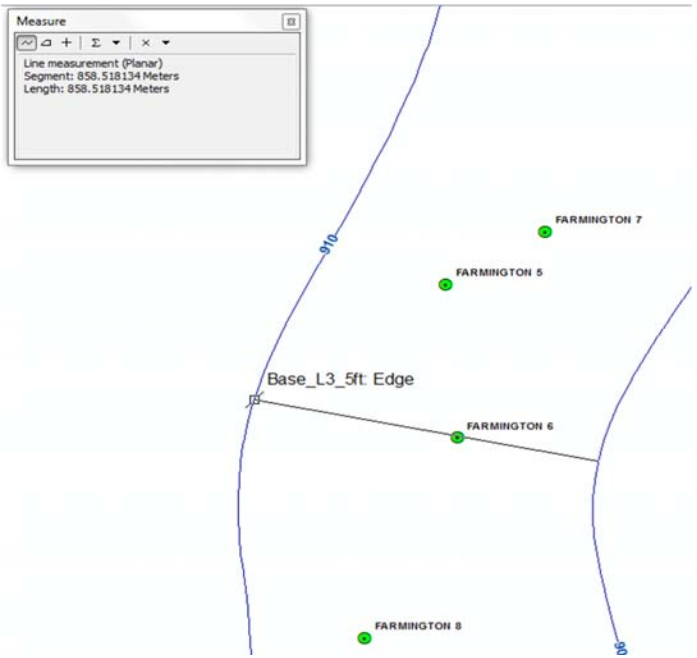
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	295
Well Discharge, Q (gpm)	54
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	1.58
Hydraulic Gradient, i	0.0058207

Calculated Q/Qs (m)

526



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\min}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	295
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

100

Volume (m^3)

1,922,768

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 7: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

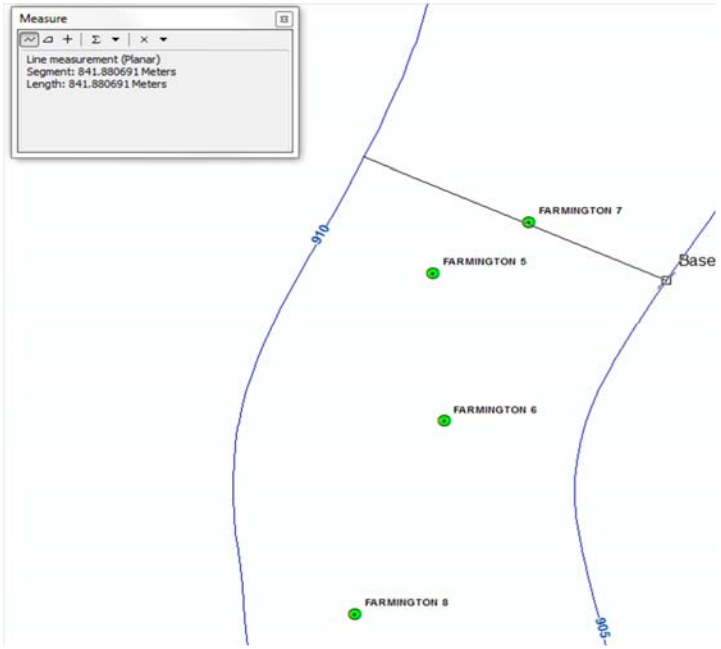
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	323
Well Discharge, Q (gpm)	59
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	1.51
Hydraulic Gradient, i	0.0059382

Calculated Q/Qs (m)

591



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\min}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	323
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

105

Volume (m^3)

2,105,268

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 8: 1-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

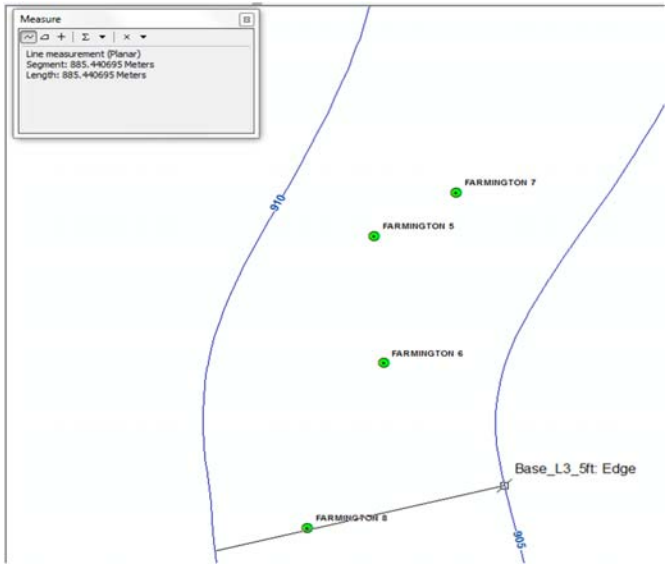
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	284
Well Discharge, Q (gpm)	52
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	2.76
Hydraulic Gradient, i	0.0056497

Calculated Q/Qs (m)

299



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283 m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048 m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	284
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

98

Volume (m^3)

1,851,071

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 4: 5-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

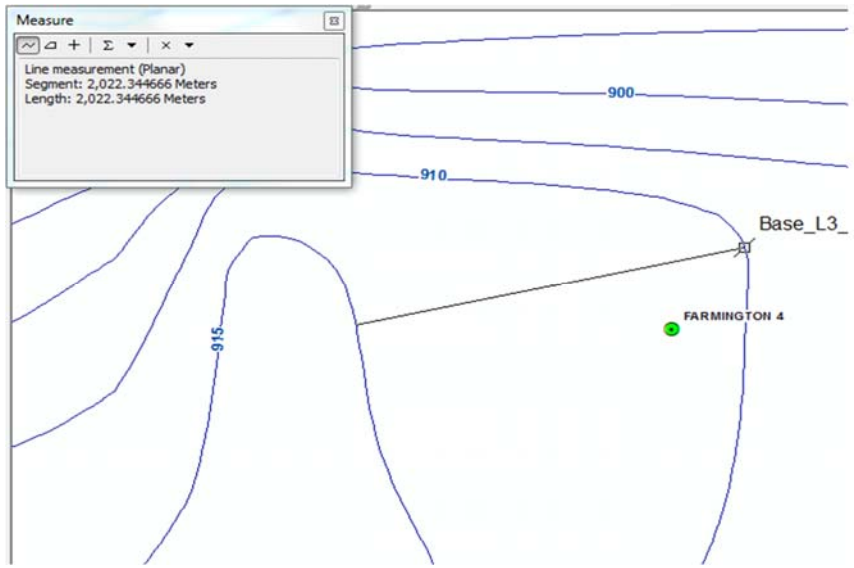
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	593
Well Discharge, Q (gpm)	109
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	1.39
Hydraulic Gradient, i	0.0024728

Calculated Q/Qs (m)

2828



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	593
Pumping Period (years)	5
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)	Volume (m^3)
318	19,325,446

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Wells 5, 6, and 7: 5-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

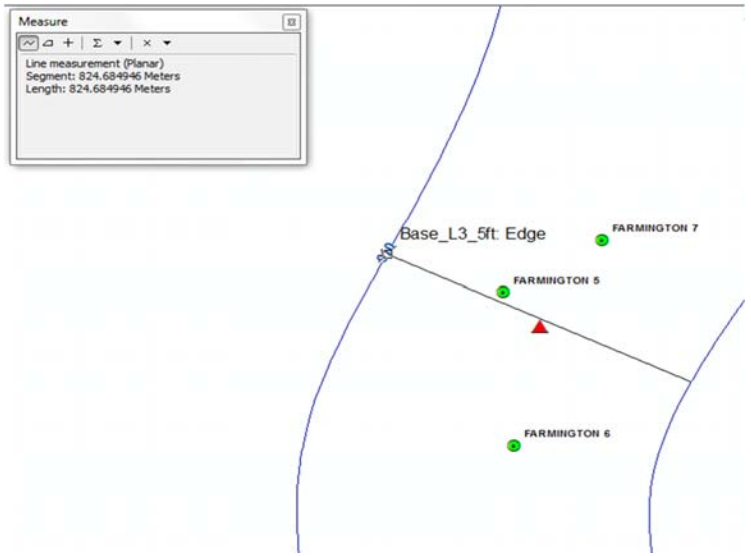
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	980
Well Discharge, Q (gpm)	180
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	1.54
Hydraulic Gradient, i	0.0060606

Calculated Q/Qs (m)

1718



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	980
Pumping Period (years)	5
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

408

Volume (m^3)

31,940,433

$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 8: 5-Year

Calculation for Ratio of Well Discharge to the Discharge Vector (Q/Qs)

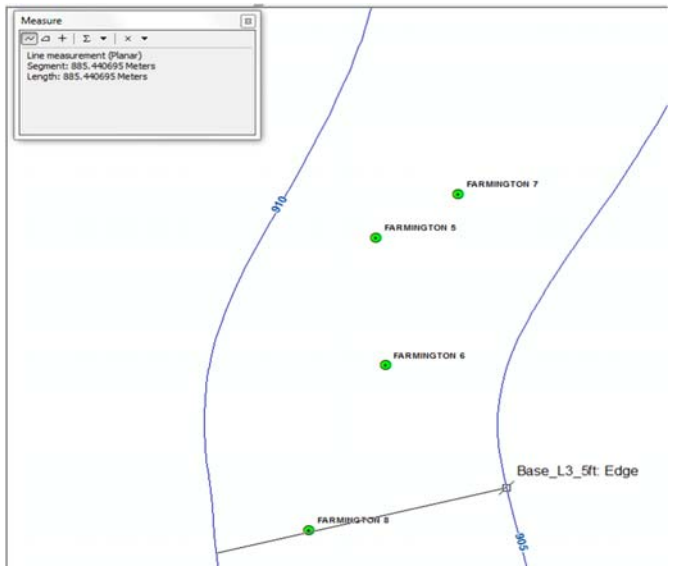
See: Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

If Q/Qs is less than 3000 m then delineation Technique 2 should be used: Calculated Fixed Radius with An Upgradient Extension

Input variables	
Well Discharge, Q (m^3/day)	284
Well Discharge, Q (gpm)	52
Aquifer Thickness, H (ft)	200
Aquifer Hydraulic Conductivity K (m/day)	2.76
Hydraulic Gradient, i	0.0056497

Calculated Q/Qs (m)

299



Equation listed in Appendix 2 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

$$Q/Qs = \frac{Q\left(\frac{1\,ft^3}{7.48\,gal}\right)\left(\frac{1440\,\text{min}}{1\,day}\right)\left(\frac{0.0283m^3}{1\,ft^3}\right)}{(H)\left(\frac{0.3048m}{1\,ft}\right)(K)(i)}$$

Calculation for Fixed Radius with No Upgradient Extension

See method 1 of Guidance for Delineating Wellhead Protection Area in Fractured and Solution-Weathered Bedrock in Minnesota (MDH, 2005)

Input Variables	
Well Pumping Rate m^3/day	284
Pumping Period (years)	5
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	61.0

Calculated Fixed Radius (m)

220

Volume (m^3)

9,255,357

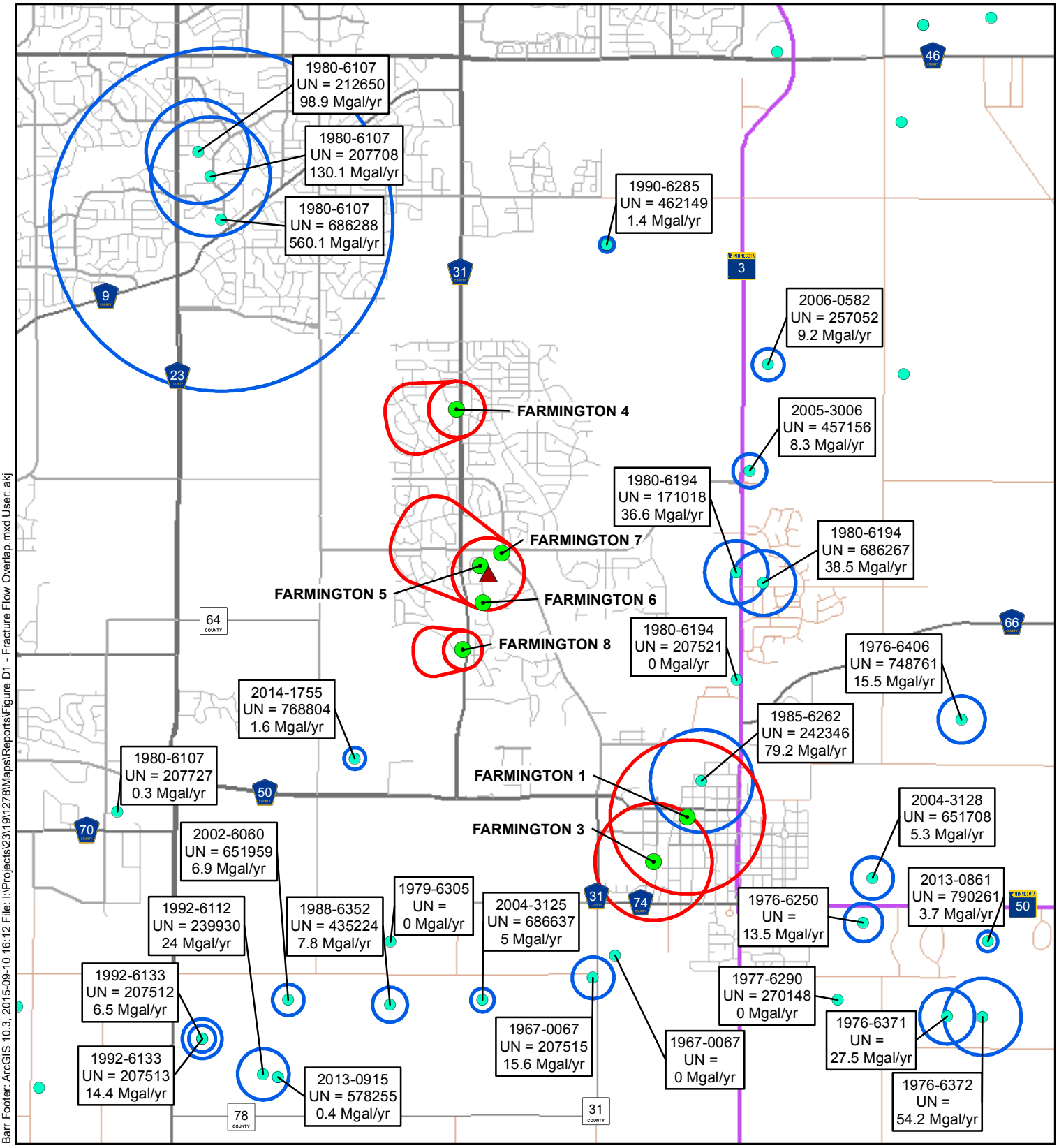
$$R = \sqrt{\frac{Q}{nL\pi}}$$

Where:

Q = Well Discharge (L^3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft



Capture zones shown for Farmington Wells 1 and 3 have not been adjusted for overlap.
Only MPARS wells open to OPDC and/or CJDN shown.
Pumping rates shown are 2010-2014 averages

- MPARS Active WA Permits
- Farmington Municipal Well
- Centroid of Wells 5, 6, and 7
- Farmington 10-year Capture Zone
- MPARS 10-year Capture Zone

Feet
5,000 0 5,000

DRAFT

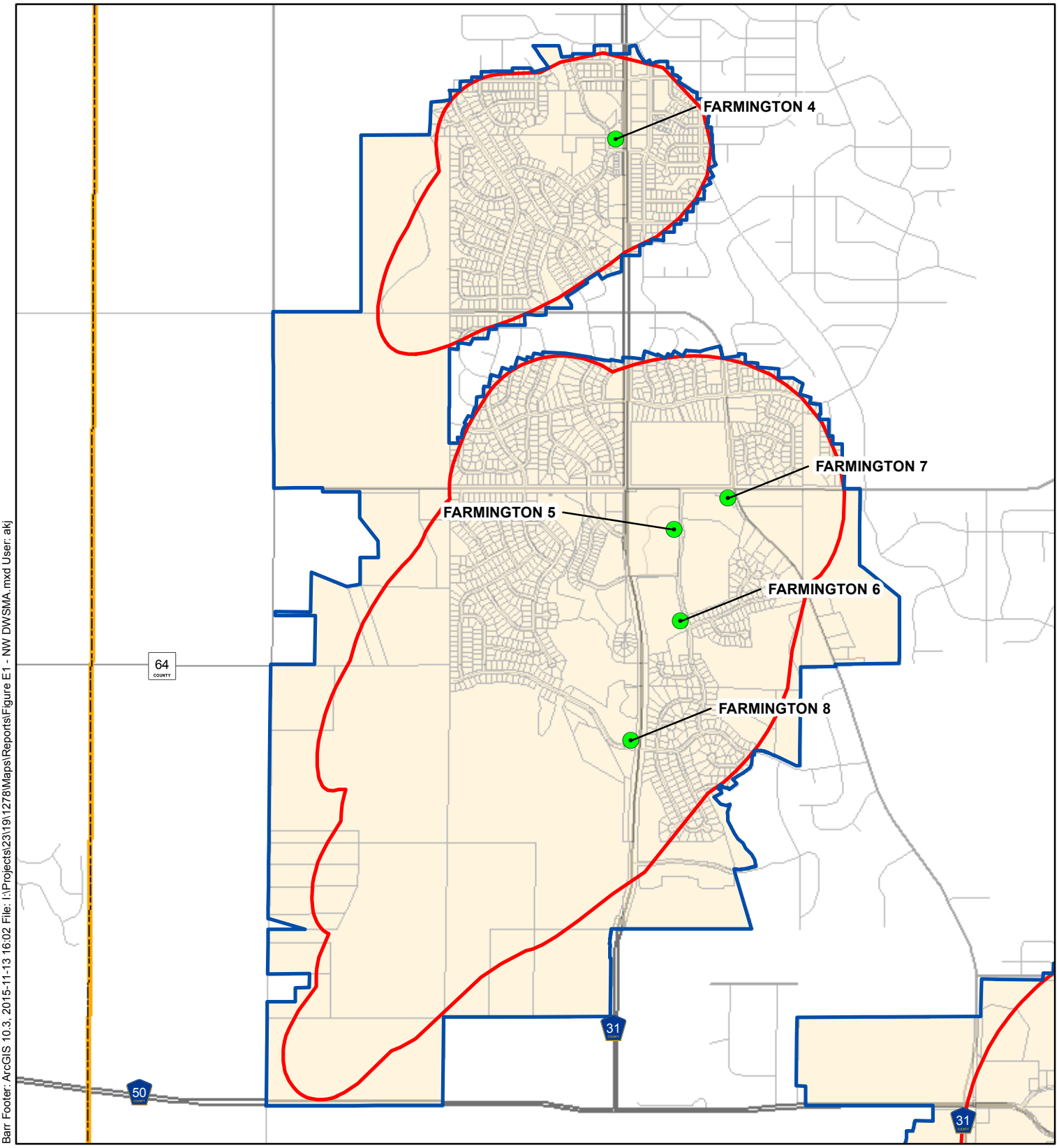
BARR

Figure D1

MPARS FRACTURE FLOW
Farmington WHPP Amendment
City of Farmington, MN

Appendix E

1:24,000 DWSMA Maps



Barr Footer: ArcGIS 10.3, 2015-11-13 16:02 File: I:\Projects\23\19\1278\Maps\Reports\Figure E1 - NW DWSMA.mxd User: akj

Farmington Municipal Well
DWSMA
WHPA
Parcel
Farmington City Limits
Civil Township

N

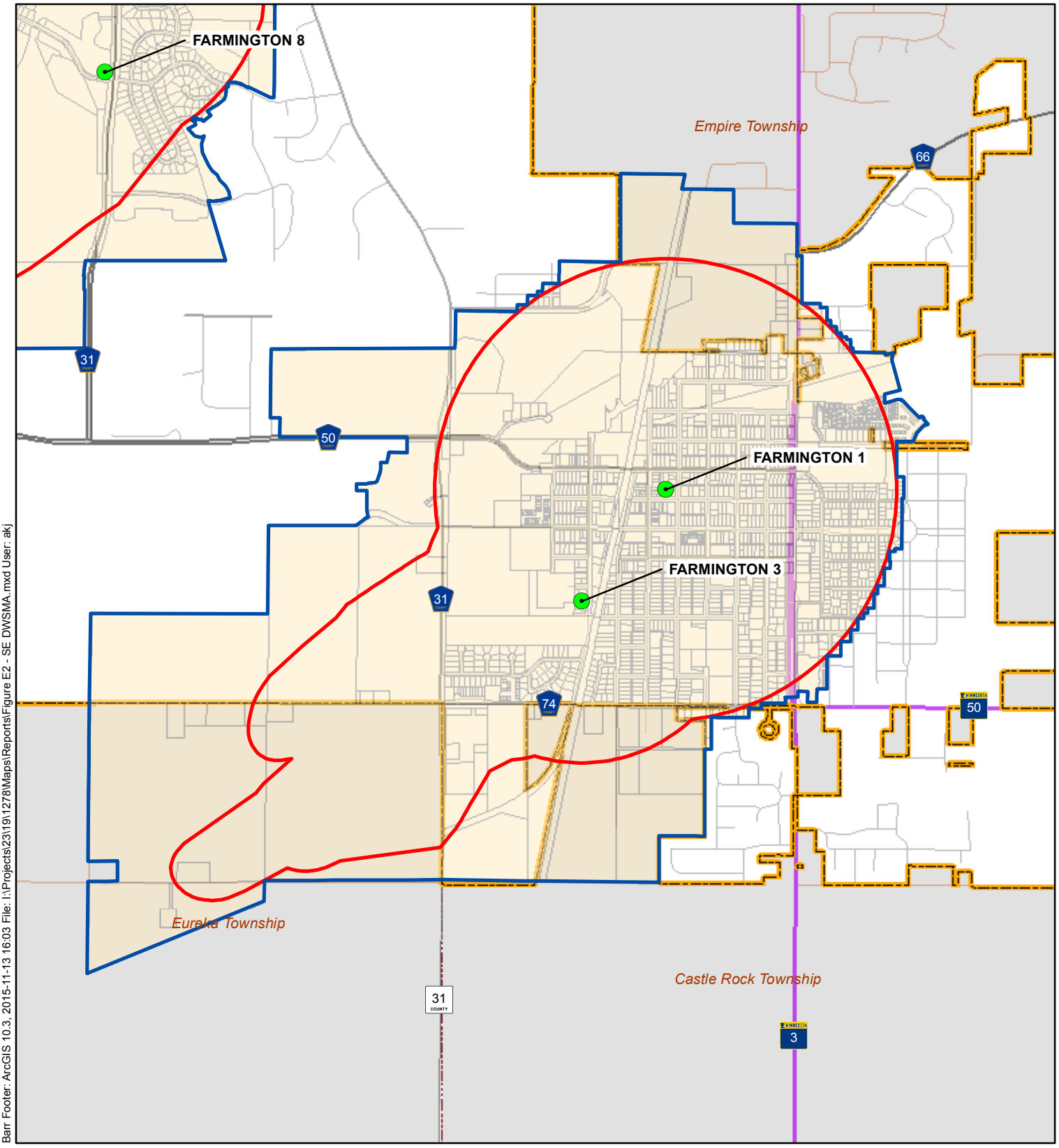
Feet
2,000 0 2,000

DRAFT

BARR

Figure E1

NORTHWEST DWSMA
Farmington WHPP Amendment
City of Farmington, MN



Barr Footer: ArcGIS 10.3, 2015-11-13 16:03 File: I:\Projects\23\19\1278\Maps\Reports\Figure E2 - SE DWSMA.mxd User: akj

Farmington Municipal Well
DWSMA
WHPA
Parcel
Farmington City Limits
Civil Township

N

Feet
2,000 0 2,000

DRAFT

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Figure E2

SOUTHEAST DWSMA
Farmington WHPP Amendment
City of Farmington, MN

Appendix F

MDH Well Vulnerability Assessments

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #1 UNIQUE WELL #: 00200932

COUNTY: Dakota TOWNSHIP NUMBER: 114 RANGE: 19 W SECTION: 31 QUARTERS: ACDB

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Prairie Du Chien-Jordan	
DNR Geologic Sensitivity Rating	:	Very low	0
L Score	:	4	
Geologic Data From	:	Well Record	
Year Constructed	:	1938	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	197	10
Well Depth	:	402	
Casing grouted into borehole?		Unknown	0
Cement grout between casings?		Not applicable	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1000	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4 10/08/1991	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		20
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #3 UNIQUE WELL #: 00201154

COUNTY: Dakota TOWNSHIP NUMBER: 114 RANGE: 19 W SECTION: 31 QUARTERS: CADC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Prairie Du Chien-Jordan	
DNR Geologic Sensitivity Rating	:	Medium	25
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1959	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	132	10
Well Depth	:	424	
Casing grouted into borehole?		No	0
Cement grout between casings?		Not applicable	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1000	10
Pathogen Detected?			NOT VULNERABLE
Surface Water Characteristics?			NOT VULNERABLE
Maximum nitrate detected	:	<.4 09/05/1990	NOT VULNERABLE
Maximum tritium detected	:	<.8 04/03/1998	NOT VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		45
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS

DRIFT STRATIGRAPHY INFERRED FROM WELL #1.
3H sample by YCM.

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #4 UNIQUE WELL #: 00235586

COUNTY: Dakota TOWNSHIP NUMBER: 114 RANGE: 20 W SECTION: 14 QUARTERS: DAAA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Very low	15
L Score	:	7	
Geologic Data From	:	Public Water File	
Year Constructed	:	1973	
Construction Method	:		5
Casing Depth	:	392	5
Well Depth	:	477	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Unknown	5
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1000	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<1 09/05/1990	0
Maximum tritium detected	:	2.9 08/26/2008	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		40
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS
Vulnerable because of tritium levels in nearby well No. 5.

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #5 UNIQUE WELL #: 00603051

COUNTY: Dakota TOWNSHIP NUMBER: 114 RANGE: 20 W SECTION: 24 QUARTERS: CBB

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	0
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1999	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	417	0
Well Depth	:	512	
Casing grouted into borehole?		Yes	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1400	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	.06 07/15/2013	0
Maximum tritium detected	:	2.7 02/01/2001	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		20
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #6 UNIQUE WELL #: 00626785

COUNTY: Dakota TOWNSHIP NUMBER: 114 RANGE: 20 W SECTION: 24 QUARTERS: CBC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	1	
Geologic Data From	:	Well Record	
Year Constructed	:	2002	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	386	5
Well Depth	:	485	
Casing grouted into borehole?		Unknown	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1850	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.05 05/04/2004	0
Maximum tritium detected	:	1.9 06/23/2011	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		45
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #7 UNIQUE WELL #: 00655902

COUNTY: Dakota TOWNSHIP NUMBER: 114 RANGE: 20 W SECTION: 24 QUARTERS: CAB

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	2	
Geologic Data From	:	Well Record	
Year Constructed	:	2002	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	408	0
Well Depth	:	501	
Casing grouted into borehole?		Unknown	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1800	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	1 06/23/2014	10
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		50
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS
Tritium detection of 2.7 in nearby well no. 5.

625 Robert St. N. St. Paul MN 55155
P.O. Box 64975 St. Paul MN 55164 - 0975

MINNESOTA DEPARTMENT OF HEALTH
SECTION OF DRINKING WATER PROTECTION
SWP Vulnerability Rating

PWSID: 1190008 TIER: 2
SYSTEM NAME: Farmington WHP RANK:
WELL NAME: Well #8 UNIQUE WELL #: 00731123

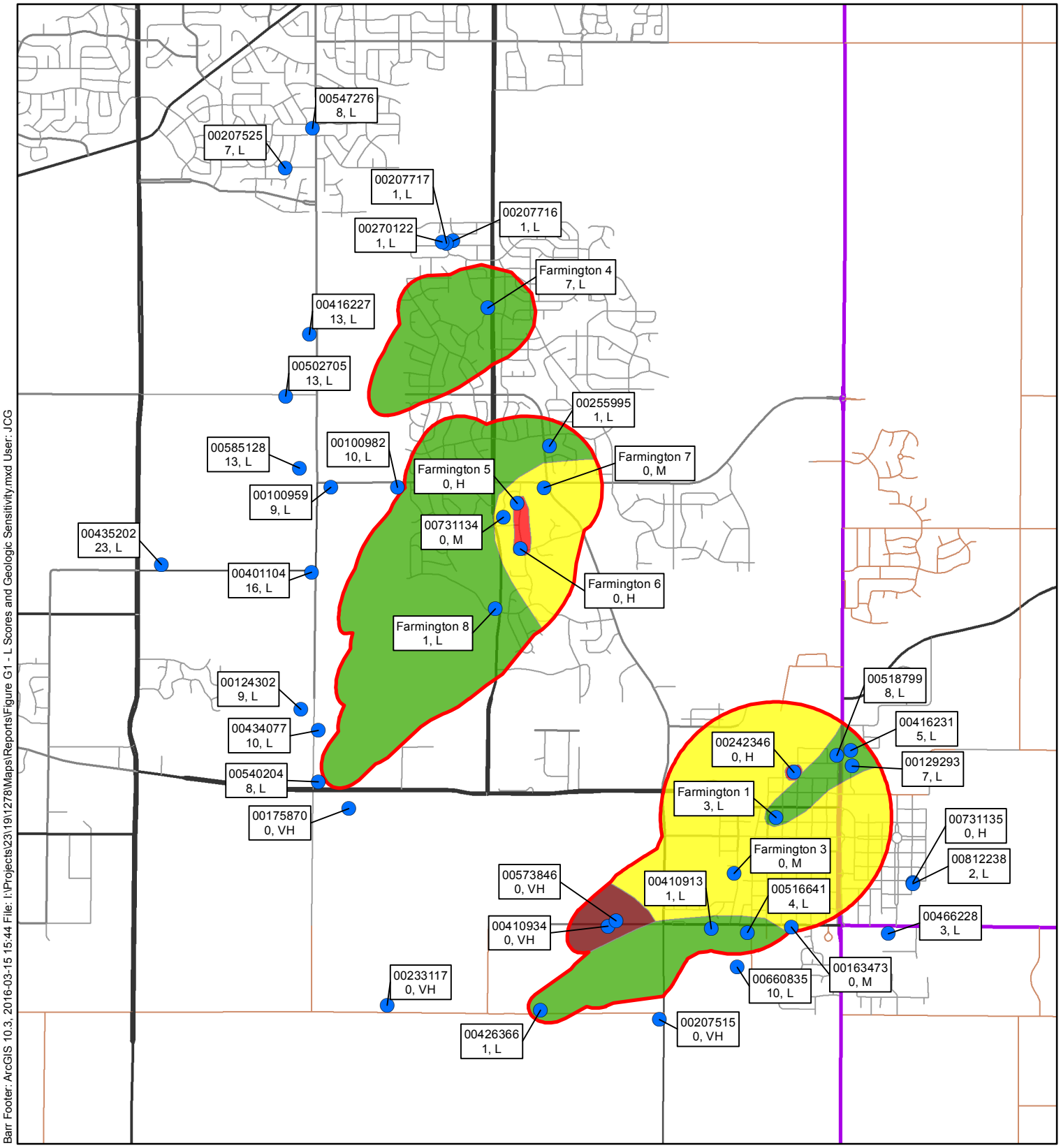
COUNTY: Dakota TOWNSHIP NUMBER: RANGE: SECTION: QUARTERS:

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	2	
Geologic Data From	:	Well Record	
Year Constructed	:	2006	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	368	5
Well Depth	:	460	
Casing grouted into borehole?		No	0
Cement grout between casings?		Yes	0
All casings extend to land surface?		Yes	0
Gravel - packed casings?		No	0
Wood or masonry casing?		No	0
Holes or cracks in casing?		Unknown	0
Isolation distance violations?			0
Pumping Rate	:	1710	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.05 05/01/2008	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		45
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

Appendix G

L-Score and Geologic Sensitivity Maps



Barr Footer: ArcGIS 10.3, 2016-03-15 15:44 File: I:\Projects\23\19\1278\Maps\Reports\Figure G1 - L Scores and Geologic Sensitivity.mxd User: JCG

L Score Well

WHPA

Unique Number/Well Name
L score, Geologic Sensitivity

Geologic Sensitivity

- Very High
- High
- Moderate
- Low

Feet
4,000 0 4,000

BARR

Figure G1

L SCORES AND
GEOLOGIC SENSITIVITY
Farmington WHPP Amendment
City of Farmington, MN

Appendix H

Groundwater Model Files and GIS Shapefiles