CITY OF INVER GROVE HEIGHTS WELLHEAD PROTECTION PLAN PART I

JULY 16, 2015

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CITY OF INVER GROVE HEIGHTS

WELLHEAD PROTECTION PLAN – PART 1

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WELLHEAD PROTECTION AREA AND DRINKING WATER SUPPLY MANAGEMENT AREA DELINEATION AND VULNERABILITY ASSESSMENTS

I hereby certify that this plan, specification, 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.

Print Name: MARK JANOVEC

Signature: _____

Date: JULY 16, 2015 License # 45625

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EXECUTIVE SUMMARY

This report documents the delineation of the wellhead protection area (WHPA) and drinking water supply management area (DWSMA) and the vulnerability assessments for the wells and DWSMA for the City of Inver Grove Heights drinking water supply wells (Table 1). The plan covers the wells listed in Table 1. Well logs are presented in Appendix A. The delineation was performed in accordance with rules (Minnesota Rules 4720.5100 to 4720.5590) for preparing and implementing wellhead protection measures for public water supply wells. The rules are administered by MDH, and the results described in this report were prepared by Stantec.

The City of Inver Grove Heights currently obtains its drinking water supply from six active wells completed in the Jordan sandstone aquifer and one active well completed in the Mt. Simon sandstone aquifer. A computer groundwater modeling platform was utilized for this project to simulate flow through these aquifers. The porous-flow portion of the wellhead protection areas (WHPAs) was delineated using a modified version of the Metropolitan Councils Metro Model 2, originally built in 2009. This model is a steady state MODFLOW model built using Groundwater Vistas. The model was updated to reflect current pumping and geological conditions in and near the area around the Inver Grove Heights well field. The model was used to delineate one-year and ten-year capture zones for Inver Grove Heights's wells (Figure 1).

A fracture flow analysis was then undertaken using current MDH methodology to predict the area of the Prairie du Chien aquifer that overlies the Jordan aquifer that is capable of rapidly transmitting water to the City's wells. This fracture flow delineation was created by utilizing MDH guidance developed for fracture flow settings. The calculated area is shown in Figure 2.

The drinking water supply management area (DWSMA) was determined for the composite groundwater delineations by using property parcels and roadways as boundaries. Figure 3 shows the boundaries of both the WHPA and the DWSMA.

The amount of geologic protection documented in well logs from the water supply wells and regional information, along with water quality information was used to determine well vulnerability. Two of Inver Grove Heights's currently active wells (Wells 3 and 5) are considered vulnerable to contamination, based on the MDH worksheet scoring process. Tritium was detected in Wells 3 and 5 above 1.0 tritium units. While tritium is not harmful for human consumption, its presence indicates that some portion of the water supply these wells infiltrated from the land surface within the past 60 years. Inver Grove Heights's wells appear to meet the construction standards of the State Well Code, however, and the wells themselves are not considered a likely avenue for contamination to reach the aquifer from which they pump.

The DWSMA has varying levels of geologic sensitivity to contamination infiltrating at or near the land surface to the Prairie du Chien and Jordan aquifers. The geologic sensitivity generally ranges from "low" in areas where a thick layer of geologic protection is present, to "moderate" when geologic protection is present but is generally less than 10 feet in continuous thickness. Due to the mixed geologic sensitivity levels and the presence of tritium in at least two of the City's wells, an overall vulnerability level of "moderate" was assigned to the DWSMA. Vulnerability is displayed in Figure 4. Aquifer vulnerability will be used to define the scope of activities required to complete the amendment to Part 2 of the Wellhead Protection Plan.

CHAPTER ONE
DATA ELEMENTS and ASSESSMENT (4720.5200)

PART 1. REQUIRED DATA ELEMENTS

This section contains required data elements that were outlined in the Scoping Decision Notice provided to Inver Grove Heights by the MDH. Appendix D contains a table assessing the data elements required for this plan. Below is a summary of each data element.

A. Physical Environment Data Elements

1. **Precipitation** – The follow tables shows the gridded precipitation data (in inches) as tabulated by the Minnesota Climatology Working Group over the past five years for the Inver Grove Heights area:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
2010	0.68	1.05	0.70	2.63	3.19	6.92	4.84	5.68	6.03	1.81	2.35	3.37	39.25
2011	0.96	1.63	2.33	3.17	4.08	4.28	5.45	3.48	0.59	0.68	0.43	0.91	27.99
2012	0.72	1.88	2.05	3.66	7.94	4.71	4.24	1.91	0.61	1.35	0.77	1.82	31.66
2013	0.93	1.44	2.18	5.10	6.58	6.10	2.84	2.71	1.67	3.12	0.60	1.63	34.90
2014	1.38	1.77	1.01	6.46	5.11	12.40	3.30	4.20	1.65	2.05	0.94	1.09	41.36
Avg	0.93	1.55	1.65	4.20	5.38	6.88	4.12	3.60	2.11	1.80	1.02	1.76	35.03

The precipitation data from the past five years shows an average annual precipitation of 35.03 inches. This is somewhat higher than the published 1981-2010 normals for the same area, which shows an average of 32.36 inches per year.

Precipitation values are generally accounted for in the Twin Cities Metro Model and the model report documents how infiltration rates were established for the model (Metropolitan Council, 2009). While the past five years do show a higher-than-average precipitation amount, bedrock aquifer recharge is a process that occurs over several decades or centuries, so short term changes should not have a significant impact on the modeled results. For the purposes of this modeling effort, the published model infiltration rates have remained unchanged.

2. **Geology** – In the vicinity of the Inver Grove Heights well field, the uppermost bedrock unit varies between the St. Peter sandstone and the Prairie du Chien dolomite. To the north of Inver Grove Heights, upper bedrock units include Platteville Limestone and the Decorah Shale, while to the south of Inver Grove Heights, an east-west trending buried bedrock valley has removed the bedrock down to the Tunnel City (aka Franconia) formation. Depth to bedrock can vary significantly in northern Dakota County, but average depths in the vicinity of the Inver Grove Heights well field range between 100 feet and 200 feet. Bedrock geology and depth-to-bedrock maps can be referenced in the Dakota County Geologic Atlas (Minnesota Geologic Survey, 1990).

   Surficial geology in the area around the Inver Grove Heights well field is comprised chiefly of Superior Lobe till deposits underlain in places by outwash deposits and layers of Old Gray till. A surficial geology map can also be referenced in the Dakota County Geologic Atlas (Minnesota Geologic Survey, 1990).

   As part of this study a series of three geologic cross-sections have been developed using

locally available well data from County Well Index. Figure 4 shows the layout of these cross-sections, while Figure 5, 6, and 7 show the geology observed in these wells, with an interpretation of the geologic layers between each well.

3. **Soils** – Due to the depth of the aquifers serving the Inver Grove Heights wells, mapped soils from the County soil survey are believed to have little impact on the mapped delineations and vulnerability assessments produced by this report. In general, the upper ten feet of soils in the Inver Grove Heights area has been highly disturbed over the past century during development of residential neighborhoods and roadways.

   The impact of soils on the amount of infiltration reaching the water table is addressed to some degree in the Metro Model report (Metropolitan Council, 2009). No changes were made to the model to refine infiltration values in the Inver Grove Heights area.

B. Land Use Data Elements

1. **Land use** – Land use was generally not considered for the Part 1 wellhead protection activities. Land use will be covered in greater detail in the Part 2 plan, where the role of land use on water quality will be closely reviewed.

2. **Public utility services** – The only public utilities that play a direct role in the Part 1 Wellhead Protection Plan are the municipal water supply wells in Inver Grove Heights and other nearby public water supply wells for surrounding communities that utilize the Prairie du Chien aquifer, Jordan aquifer, and Mt. Simon aquifer (South St. Paul, West St. Paul, etc.). Table 2 shows the modeled rates of the wells operated by Inver Grove Heights. Most high capacity wells in the DNR SWUDs database were already included in the MODFLOW model. However, nearby high capacity wells which exceed 10 million gallons per year have been modified (or added) to the model to reflect current conditions. Table 3 shows the modeled rates of municipal wells from surrounding communities that were either added or modified from the existing Metropolitan Council model. Well usage is also addressed in Part 2 of this chapter.

C. Water Quantity Data Elements

1. **Surface water quantity** – The Minnesota River and Mississippi River are the major discharge features located within the domain of the models developed for this project. Numerous smaller discharge features have been added to the model domain and are explained in greater detail in the Metropolitan Council's technical report for the Metropolitan Model (October 2009).

2. **Groundwater quantity** - Review of groundwater appropriations permits in the State Water Use Data System (SWUDS) database was performed to identify high capacity wells in the area that might affect delineation of the wellhead protection area. Most high capacity wells as of 2009 were included in the Metropolitan Council's model. Local exceptions include three high-capacity wells operated by Gerten's Nurseries, which have been added to the model as part of this amendment. Other high capacity wells within Inver Grove Heights and nearby communities were updated in the model for the purposes of this delineation effort and are listed in Table 3. The City of Inver Grove Heights wells were modeled at the rate outlined in the wellhead protection rules, based on historical or projected within with 5 years of the current date. Modeled Inver Grove Heights well rates are shown in Table 2.

D. Water Quality Data Elements

1. **Surface water quality** – Major surface water features in the area, such as the Minnesota River and Mississippi River, which are in direct hydraulic connection with the Prairie du Chien and Jordan aquifers, serve as flow boundaries within select layers of the Metropolitan Model. In general, nitrates contamination within these aquifers is a source for concern in portions of Dakota County, where high nitrates surface water infiltrates to impact groundwater quality. However, at present, nitrates levels in the Inver Grove Heights wells do not exceed the threshold of 10mg/L and generally range between non-detection levels and 2.5 mg/L at maximum. Surface water quality will be addressed in greater detail in the updated Part 2 plan.

2. **Groundwater quality** – Results of routine monitoring of the Inver Grove Heights wells are contained within the files of the Minnesota Department of Health. Historical monitoring has shown that the water quality within the Jordan aquifer and Mt. Simon aquifer in Inver Grove Heights is generally of excellent quality. Nitrates contamination, which is a source of concern in parts of Washington County, does not appear to currently pose a problem in Inver Grove Heights. Nitrates levels in Inver Grove Heights' wells remain well below the health risk limit threshold of 10mg/L.

   Sampling of tritium has taken place at Inver Grove Heights Wells No. 3, 5, and 7. Tritium is an isotope of hydrogen that was released into the atmosphere during the above-ground testing of nuclear weapons in the early 1950s. While harmless, the presence of tritium in aquifers indicates that some portion of the water was in contact with the atmosphere within the past 60 years. A tritium level of 1 tritium unit (TU) or greater is an indication that these aquifers are somewhat vulnerable to contamination. The tritium level of Well 3 was 2.7 TU when sampled in July 2000. The tritium level was 5.17 TU in Well 5 when sampled in May 2008. No tritium was detected in Well 7 when it was sampled in May 2009. This indicates that the Jordan aquifer in this area contains relatively a mixture of younger water, which infiltrated from the land surface greater than 60 years ago, and older water which pre-dates the 1950s. Additional sampling in Wells 4, 8, and 9 in the future could help determine if there is a boundary between younger water and older water entering the Jordan aquifer.

PART 2. ASSESSMENT OF DATA ELEMENTS USED TO DELINEATE THE WELLHEAD PROTECTION AREA

A. Use of the Wells – The wells shown in Table 1 serve as the primary drinking water source for residents of the City of Inver Grove Heights. Pumping from the wells is rotated based on water demand and seasonal usage.

Table 2 shows a comparison of the usage of the City of Inver Grove Heights wells for the past five years versus a projected pumping rate 5 years into the future. The greatest amount of pumping from any of these years is used to represent the pumping rate for that well in the groundwater model. This is done for the purpose of developing a delineation that is conservative and takes into account the potential volume each well may be used in the near future.

Other high capacity wells being included within the model, but not being delineated for the plan, are modeled using an average pumping rate taken from a 5 year period. This is explained in greater detail in the Metropolitan Council's 2009 technical report for the Metropolitan Model. High capacity wells shown in Table 3 were modeled based on an average rate from the years 2007-2011. These pumping volumes modify the volumes originally modeled by the Metropolitan Council. In some cases, the wells in Table 3 are new additions to the model (such as the Gerten's wells), which either weren't yet active when the model was originally constructed or weren't previsouly included in the DNR's database.

B. Wellhead Protection Area Delineation Criteria

1. **Time of travel** – The minimum time-of-travel for porous-flow aquifer delineations is 10-years, which is what was used for the Jordan aquifer. A 1-year-year time-of-travel zone was also delineated using standard techniques and represents the Emergency Response Area.

2. **Hydrologic flow boundaries** – The Minnesota River and Mississippi River represents the major flow boundaries for the Jordan aquifer in the Dakota County area. Hydrologic flow boundaries included in the groundwater model are documented in greater detail in the technical report for the Metropolitan Model (Metropolitan Council, 2009).

3. **Daily volume** – Projected annual pumping volumes for the Inver Grove Heights wells are shown in Table 2. The maximum projected annual pumping volumes were converted to cubic meters per day in order to be applied to the groundwater model.

4. **Groundwater flow field** – The groundwater flow field was calculated by the groundwater flow model. Original model calibration and ambient flow-field simulation results are described in the technical report for the Metropolitan Model (Metropolitan Council, 2009). Model calibration near the river valleys in the model was found to display similar flow direction to contours provided in the Dakota County Geologic Atlas (MGS, 1990), but the gradient of flow was more shallow in the model than observed in well log data. Modifications were made to the model to improve the flow gradient. This is described in greater detail in Chapter Two.

5. **Aquifer transmissivity** – Aquifer transmissivity is the measurement of an aquifer's ability to transmit water. The Jordan aquifer transmissivity was based on a 24-hour aquifer pumping and recovery test conducted on Inver Grove Heights Well No. 9 in September 2008. The results of the test indicated a transmissivity ranging from 4,710 ft^2/day to 6,920 ft^2/day. Using an average thickness of 100 feet for the Jordan aquifer, calculated hydraulic conductivity ranges from 47.1 ft/day to 69.2 ft/day (14.4 m/d to 21.1 m/d).

Modeled hydraulic conductivity for the Jordan aquifer varies throughout the Metropolitan Model. Methodology for selecting different conductivity values is documented within the technical report (Metropolitan Council, 2009). In the area surrounding the municipal wells for Inver Grove Heights, the original model hydraulic conductivity for the Jordan aquifer was established at 8.8 m/day. For the purposes of this modeling effort, the higher calculated conductivity value (21.1 m/day) was selected, since it is based on data directly gathered from the Inver Grove Heights municipal wells and is therefore likely a more reliable measurement of local conditions.

For calculating transmissivity in the Mt. Simon aquifer, the nearest available pumping test was that conducted at Apple Valley Well 14 in June 2001. A representative transmissivity value of 2,460 ft^2/day was calculated from this test, which translates to a hydraulic conductivity of 9.5 ft/day (2.9 m/day) assuming an average aquifer thickness of 260 feet. Specific capacity estimates from Inver Grove Heights Well 6 showed an estimated transmissivity of 3,100 ft/day and a calculated hydraulic conductivity of 11.9 ft/day. While the Well 6 data was of lower quality, it indicates that the calculations from Apple Valley Well 14 are representative of the Mt. Simon aquifer in this area.

For the purposes of the modeling effort, the Mt. Simon conductivity was modified in the Inver Grove Heights area to 2.9 m/day.

C. Quality and Quantity of Water Supplying the Public Water Supply Well - Water in the City of Inver Grove Heights water distribution system is regularly sampled and analyzed for contaminants regulated under the federal Safe Drinking Water Act. Routine monitoring by the Public Water Supply Program at MDH does not indicate contamination that may pose a public health risk. No contaminants of significant concern have been detected in the City's wells.

The Jordan aquifer appears to have sufficient transmissivity and recharge to remain a long-term source of drinking water for the residents of Inver Grove Heights. Any future water supply wells will most likely be completed within the Jordan aquifer. Monitoring of water levels within the aquifer in the region will help establish the long term sustainability of the aquifer as Dakota County continues to develop. Water level data collected in the Inver Grove Heights wells will contribute to the understanding of groundwater sustainability.

D. The Land Uses in the Drinking Water Supply Management Area – Land uses in the DWSMA for the Inver Grove Heights wells is primarily residential and commercial, with some park and industrial land uses as well. Land uses will be discussed in greater detail in the Part 2 Wellhead Protection Plan, which will include the contaminant source inventory for parcels within the DWSMA.

CHAPTER TWO
WELLHEAD PROTECTION AREA AND DRINKING WATER SUPPLY MANAGEMENT AREA DELINEATION (4720.5205)

A. Physical setting and subsurface hydrogeology – The Inver Grove Heights municipal wells draw water from the Jordan aquifer and the Mt. Simon aquifer. A discussion of hydrogeologic conditions across the full model domain is presented in the report *Twin Cities Metropolitan Area Regional Groundwater Flow Model Version 2.00* (Metropolitan Council, 2009).

B. Delineation of the Wellhead Protection Area

1. Porous Flow Delineation Method – Jordan Aquifer

The delineation of the Jordan aquifer capture zone was conducted utilizing the modified Metropolitan Model 2. Original model construction detail, data files, and calibration results are outlined in the Metropolitan Council report (2009). Modifications to the model included:

- Refinement of the model grid was done to reduce model grid size from 500 x 500 meters to 15.6 x 15.6 meters around the Inver Grove Heights municipal wells.
- Updating modeled flow rates for Inver Grove Heights municipal wells to match wellhead protection rule requirements.
- Updating average modeled flow rates for nearby high capacity wells (both municipal and private) to reflect the period from 2007 to 2011. More recent pumping data that 2011 is not currently available from the DNR, so the most recent 5-year period of pumping data was used to calculate an average rate for each well.
- The Jordan Aquifer (layer 4) parameters around the Inver Grove Heights area was adjusted to match local values, as shown in Table 4. Horizontal hydraulic conductivity was adjusted to 21.1 m/day in the Jordan aquifer, based on the aquifer pumping test at the Inver Grove Heights municipal wells. Horizontal hydraulic conductivity was adjusted to 3.84 m/day in the Mt. Simon aquifer, based on the pumping test data from Apple Valley Well 14. A global porosity of 0.20 was chosen to represent the Jordan aquifer and Mt. Simon aquifer across the model domain. A porosity of 0.056 was chosen to represent the overlying Prairie du Chien aquifer.

Calibration of the Metropolitan Model was checked using target wells located in Layer 3 (Prairie du Chien aquifer) and Layer 4 (Jordan aquifer). Comparisons between the original model calibration and the modified model calibration are presented in Appendix B. Calibration was checked on a refined scale which included only the target wells in the area including Inver Grove Heights and neighboring communities. A review of the calibration results indicated that calibration of the Metropolitan Model 2 in the Inver Grove Heights area was displaying a flatter flow gradient in the Prairie du Chien-Jordan aquifer than was observed in water level data in the calibration targets. This calibration issue was noted by the MDH in conversations regarding other wellhead protection delineations near the river valleys in this model.

In order to improve the calibration of the model, the MDH provided assistance with modifying the model in the Inver Grove Heights area to increase recharge in vicinity of the study area. Recharge was increase in the area surrounding a buried bedrock valley that runs in

an east-west orientation, in southern Inver Grove Heights. Recharge was increased in Layer 1 from 8.0 inches/year to 11.5-13.0 inches per year where the bedrock valley was present. Additionally, conductance of the river cells was increased to help drain water, in order to reduce head values at the rivers. The increased recharge and conductance helped to steepen the flow gradient, resulting in a better overall calibration result. A comparison of the calibration results before and after the changes were made is presented in Appendix B. The modeled groundwater contours for the Jordan aquifer are displayed on Figure 1.

Additionally, it was observed that the conductivity of the Prairie du Chien layer was modeled at approximately 3.4 m/d. Pumping test information in the Inver Grove Heights area indicates that actual conductivity in the Prairie du Chien may be somewhat higher (up to 35 m/d). However, these higher conductivity values obtained from aquifer tests are likely reflecting conditions in the Shakopee formation, in the upper half of the Prairie du Chien. For the purposes of calculating recharge to the Jordan, the lower values in the model are likely giving a better representation of the Oneota formation, which lies directly over the top of the Jordan aquifer.

The delineations were created using particle tracking analysis in MODPATH. A circle of particles was established at a radius of 15 meters from each wellhead and tracking backwards (upgradient) with 120 particle lines per well, with four different vertical release points between 0.2 and 0.8 offset. A second run of the model was made with a lower K value in the Jordan (14.3 m/d) to cover the range of potential conductivity values within the aquifer (Model IGH_14B). The composite of the results of Model IGH_14 and IGH_14B were used to determine the capture zones. The path line groupings were then outlined to develop capture zones for 1-year and 10-year time-of-travel delineations. Figure 1 shows the outlined result of the delineation effort. Model files and generated path lines are provided as supplemental data in Appendix E.

2. Fracture Flow Delineation Method – Prairie du Chien Aquifer

Since the Prairie du Chien formation, which overlies the Jordan aquifer, is capable of rapidly transmitting water through its secondary porosity features (fractures and solution cavities) and can transmit water to the underlying Jordan aquifer, an additional delineation effort was required for the Jordan aquifer wells. The Minnesota Department of Health has developed a guidance for delineating the fracture flow component to the delineation of wells in this type of setting, where wells open to a porous-flow aquifer (Jordan) have a fracture flow aquifer (Prairie du Chien) overlying the aquifer being pumped. The methodology is outlined in greater detail in *Guidance for Delineating Wellhead Protection Areas in Fractured and Solution-Weathered Bedrock in Minnesota* (Minnesota Department of Health, December 2011).

While the porous delineation of the Jordan aquifer can account for the full 10-year capture zone of water pumped from the Inver Grove Heights wells, anecdotal evidence from other Twin Cities wells suggest that recharge from the overlying Prairie du Chien aquifer can provide a portion of the pumped volume in each well. As such, completing a fracture-flow delineation for the Prairie du Chien aquifer is required.

The modified MODFLOW model was analyzed to provide an estimation of recharge from the Prairie du Chien aquifer into the Jordan aquifer across the 10-year delineation areas. This was done using a mass-balance calculation in Groundwater Vistas, determine the sum of the cell-by-cell flows within the delineated area. A summary of the results is provided in Table 5. Two modeling runs (IGH_14 and IGH_14B) were used to calculate the water recharging the

Jordan, representing a range of hydraulic conductivity values for the Jordan (between 14.3m/day and 21.1 m/day). This summary shows that the model is calculating roughly 45-60% of the water in these cells being comprised of water recharging from the Prairie du Chien formation. Percentages used for the fracture flow calculations were rounded up to the nearest 5%, resulting in utilized percentages ranging from 50% to 65%.

Using the fracture flow GIS application developed by the MDH, fixed radii calculations were made for each well for the 1-year fracture flow analysis. These calculations takes into account aquifer thickness (based on average thicknesses noted in well logs), aquifer porosity (5%, as noted in MDH guidance documents), and the percentage of pumped volume from each well thought to be supplied by the Prairie du Chien (50-65% of the total pumped volume, in this case). Due to the close proximity of certain wells, groupings were made to simplify the analysis, using a central coordinate point for the group to calculate the fixed radii. Wells 3 and 4 were combined for one grouping. Wells 7, 8, and 9 were combined for a second grouping. Well 5 was calculated as a single well. The results of the 1-year fracture flow analysis are shown on Figure 2 and calculations are displayed in Table 6.

The next step of the process was to delineate a fixed radius 5-year capture zone for the Prairie du Chien aquifer around each municipal well, along with a 5-year upgradient extension and a calculation of overlap between each fracture flow delineation. To complete this effort, the same GIS application developed by the MDH was again utilized to produce these calculated areas. Tables 7A to 7C show the values used to create the five-year fixed radius delineations and five-year extensions for each well. For the analysis, the overlap from the Wells 7, 8, and 9 grouping was calculated with the overlap from the grouping of Wells 3 and 4 (see Table 7A). The results of these calculations (using modified flow volumes) were then used to calculate the overlap from Wells 3 and 4 with Well 5 (see Table 7B). Finally, the resulting calculations (with modified flow volumes) were used to calculate the overlap between Well 5 and the grouping of Wells 7, 8, and 9 (see Table 7C).

The fixed radius delineations and their upgradient extensions produced by the GIS application are shown in Figure 2. These areas were then composited with the porous flow delineation lines from Figure to create the wellhead protection area (WHPA) and Emergency Response Area (ERA) for the Inver Grove Heights aquifer wells as seen in Figure 3.

C. Uncertainties relating to the accuracy of the calculated wellhead protection area boundaries

Using computer models to simulate ground-water flow necessarily involves representing a complicated natural system in a simplified manner. These simplifications are a result of incomplete knowledge or understanding of part of the natural system and the limitations of mathematical models implemented in groundwater modeling computer codes. The necessary simplifications give rise to uncertainty in the model results. A reasonable attempt to account for the most significant causes of model uncertainty was made in the delineation of the WHPA. The technical report for the Metropolitan Model (Metropolitan Council, 2009) outlines some of the model uncertainties that exist within the original MODFLOW model. Wherever possible, locally obtained values of hydraulic conductivity were used to more accurately represent conditions in and around the Inver Grove Heights wells.

The chief area of uncertainty was the portion of water entering the Jordan aquifer porous flow capture zones through the overlying Prairie du Chien aquifer. The MDH guidance for calculating wellhead protection areas in fracture flow and solution-weathered settings is designed to account for a large amount of that uncertainty. The additional areas, added to the delineation around the

wellhead (and extended in the upgradient direction), add a higher degree of confidence that the delineation accounts for areas within both the Prairie du Chien and Jordan aquifers that supply water to the municipal wells over a 10-year period.

Another uncertainty was related to the conductivity of the Jordan aquifer. Two modeling runs were used for the delineation of the well capture zones, with conductivity ranging between 14.3 m/day and 21.1 m/day. By using this range of values, it is believed that the range of likely conductivity values near the well field is accounted for.

D. Delineation of the DWSMA

The Drinking Water Supply Management Area (DWSMA) is shown on Figure 3. This area includes the composite wellhead protection area (WHPA) using both porous-flow and fracture flow capture zones. The DWSMA was delineated using a combination of parcel boundaries, street and road centerlines, and municipal boundaries. Any parcel of land either wholly or partially within one of the delineation areas was included within the DWSMA.

The DWSMA represents the area that will be considered during the creation of the management plan for Part 2. The vulnerability of the DWSMA is discussed in Chapter 3 of this report.

CHAPTER THREE
VULNERABILITY ASSESSMENT

This chapter documents the vulnerability assessments of the wells and drinking water supply management area (DWSMA) for the City of Inver Grove Heights wells listed in Table 1. This assessment was performed in accordance with rules (Minnesota Rule 4720.5210) for preparing and implementing wellhead protection measures for public water supply wells.

The vulnerabilities of the wells were determined by evaluating available information on the 1) geology, 2) well construction, 3) pumping rates, and 3) chemical composition of the well water and comparing these results with the criteria in Minnesota Rule 4720.5550.

The vulnerability of the DWSMA was determined by evaluating available information on 1) the lateral continuity of protective geologic materials overlying the aquifer and 2) the chemical and isotopic composition of well water from the aquifer. DWSMA vulnerability was calculated using a combination of the Dakota County Geologic Atlas, bedrock geology, surface geology, and logged clay thickness in local well data.

A. Well vulnerability assessment - A vulnerability score was calculated for each well based on factors such as well construction, geology at the well site, and chemical data; higher scores correlate to greater perceived vulnerability. A numeric cutoff (of 45 points) is used to identify vulnerable from non-vulnerable wells (MDH, 1997). Vulnerable wells are also identified based on the presence of contamination, such as nitrate-nitrogen in excess of 10 mg/l, or young (post-1953) water, as indicated by the presence of 1 tritium unit or greater in the well water. The completed well vulnerability assessment worksheets are provided in Appendix C.

Wells 4, 6, 7, 8, and 9 were ranked as "non-vulnerable" based on worksheet scores under 45. All of these wells appear to have a low sensitivity to contamination based on geologic data. Chemical and isotopic samples also show relatively low nitrates in these wells, further indicating little influence from surface infiltration. In the case of Well 7, tritium was determined to be below 0.8 TU (tritium units), indicating that water supplying this well is older than 60 years.

Wells 3 and 5 both displayed tritium detected above 1 TU, which automatically scores the well as "vulnerable" regardless of all other factors. The tritium levels in Wells 3 and 5 were measured to be 2.7 TU and 5.17 TU, respectively.

There is nothing that was discovered in the well vulnerability assessment that indicates that the wells themselves are a likely avenue for contamination to reach the aquifer. The wells appear to meet construction standards set fourth in the State Well Code. Well vulnerability in Inver Grove Heights is mostly indicative of overall aquifer vulnerability.

B. Drinking Water Supply Management Area Vulnerability Assessment - The vulnerability of land parcels located within the drinking water supply management area (DWSMA) for Inver Grove Heights was evaluated primarily on the basis of the geologic sensitivity and age dating measurements from the municipal wells.

Geologic sensitivity was analyzed using local geologic data derived from wells within and immediately surrounding the DWSMA. Using a GIS application developed by the MDH, L-Scores and geologic sensitivity ratings were determined for the wells shown on Figure 4. L-scores represent the amount of low-permeability sediment or bedrock found in each well, overlying the aquifer unit of interest. Each L-score unit represents 10 feet of vertical thickness of the low permeability units. In the case of the Inver Grove Heights DWSMA, the sensitivity

calculations were made for the Jordan aquifer only, since the extent of the capture zones for the Jordan aquifer wells fully encompasses the Mt. Simon aquifer capture zone.

Only wells with good location information and reasonably-good geologic data were used for this analysis. In general, shallow monitoring wells were not used since they do not usually penetrate enough geologic layers to give a good indication of aquifer vulnerability. In areas where the basal St. Peter sandstone was present, geologic sensitivity was modified to be "moderate" when there was other no low permeability sediments overlying the bedrock. Drilling and gamma log data across the Twin Cities has shown that the lower portion of the St. Peter sandstone is generally much lower in permeability and acts as a confining layer to the Prairie du Chien. Additionally, some of the well logs were manually reviewed to revised sensitivity ratings, since not all well drillers use a standardized set of geologic terms when creating well logs.

Results of the L-score and geologic sensitivity calculations are displayed in Table 8. These sensitivity ratings are mapped on Figure 4. The majority of the wells in the DWSMA and immediately surrounding the DWSMA were scored to be "low" or "moderate" in geologic sensitivity. Some "high" sensitivity wells were located in or around the DWSMA, but closer analysis of the well log data indicated that in these circumstances the well drillers often did not appear to provide a detailed account of the drift layer. Since nearby "low" and "moderate" vulnerability wells with better geologic data existed, the scatted "high" vulnerability designations were not utilized to assess the final DWSMA vulnerability.

Additionally, geologic cross-sections were developed in an attempt to interpret the geologic layering across the DWSMA. Three separate cross-sections were developed, as laid out in Figure 4, and are presented in Figures 5, 6, and 7. Using the L-Scores, geologic sensitivity ratings, and the geologic cross-sections, there is evidence to support a geologic sensitivity of "low" to "moderate" across the DWSMA.

Finally, age dating samples from the Inver Grove Heights wells was considered to further define aquifer vulnerability. Tritium samples were collected in Wells 3, 5, and 7 between 2000 and 2009. Tritium detections in Wells 3 and 5 indicated that water less than 60 years old is reaching the Jordan aquifer. The absence of tritium in Well 7 suggests that the Jordan aquifer is better-protected in the vicinity of Wells 7, 8, and 9.

Using the tritium data in combination with the geologic sensitivity data, a designation of "moderate" vulnerability best represents the DWSMA for the Jordan aquifer. While areas of "low" vulnerability could possibly be established with further data, there is enough uncertainty and gaps in the well date and age-dating coverage to justify an overall "moderate" vulnerability designation to the entire DWSMA.

C. Recommendations – Proper identification of the DWSMA vulnerability is reliant on the data available to help determine infiltration travel times. In order to better define DWSMA vulnerability for future plan updates, the following recommendations may prove useful:

a. Consider testing local wells for age-dating parameters (e.g. tritium). For the City of Inver Grove Heights wells, consider re-testing any wells that have gone 10 or more years without a tritium test. Also, consider testing wells that have not been previously sampled (including Wells 4, 8, and 9).
b. As part of the updated potential contaminant source inventory for the Part 2 plan, track known spills within the DWSMA and identify which spills have impacted the Prairie du Chien and Jordan aquifers. This data will help identify areas where the aquifers appears to be particularly vulnerable to contamination.

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TABLES

Table 1 - Inver Grove Heights Water Suppy Well Information

Well Name	Unique Number	Aquifer	Status	UTM N COORD	UTM E COORD	Model E Coord	Model N Coord	Casing Depth (feet)	Casing Depth (m)	Well Depth (feet)	Well Depth (m)	Year Built	Vulnerability Status*
Well No. 3	207284	Jordan	Primary	496498	4966284	90723	56302	355	108.2	407	124.1	1970	Vulnerable
Well No. 4	207285	Jordan	Primary	496443	4966029	90668	56047	285	86.9	360	109.7	1970	Not Vulnerable
Well No. 5	165640	Jordan	Primary	496443	4965226	90668	55244	358	109.1	452	137.8	1980	Vulnerable
Well No. 6	433259	Mt. Simon	Primary	496413	4965151	90638	55169	802	244.5	1044	318.2	1987	Not Vulnerable
Well No. 7	463527	Jordan	Primary	494980	4965259	89205	55277	420	128.0	514	156.7	1990	Not Vulnerable
Well No. 8	655940	Jordan	Primary	495352	4965434	89577	55452	435	132.6	542	165.2	2004	Not Vulnerable
Well No. 9	759561	Jordan	Primary	494837	4965548	89062	55566	425	129.5	510	155.4	2008	Not Vulnerable

* vulnerability status based on review of well construction, geologic materials encountered during drilling, well use, and water quality.

Table 2 - Inver Grove Heights Water Supply Wells - Historic and Projected Pumping Data

Well Name	Unique Number	Aquifer	Historic Pumping Totals (MG/Y)					Projected 2018 Rate (MG/Y)	Modeled Rate for Plan Update (MG/Y)	Modeled Rate for Plan Update (m^3/d)
			2009	2010	2011	2012	2013			
Well No. 3	207284	Jordan	386.0	215.8	0.0	305.9	355.6	250.0	386.0	4005.8
Well No. 4	207285	Jordan	99.4	111.4	4.7	198.9	306.8	200.0	306.8	3183.9
Well No. 5	165640	Jordan	135.1	237.5	248.0	32.7	52.3	200.0	248.0	2573.7
Well No. 6	433259	Mt. Simon	70.4	81.3	64.6	69.0	116.7	80.0	116.7	1211.1
Well No. 7	463527	Jordan	260.8	137.8	84.0	320.0	78.9	200.0	320.0	3320.9
Well No. 8	655940	Jordan	161.9	97.5	210.5	107.6	0.0	200.0	210.5	2184.5
Well No. 9	759561	Jordan	NA	114.8	393.5	89.2	108.2	200.0	393.5	4083.7
		Total	**1113.6**	**996.1**	**1005.3**	**1123.3**	**1018.5**	**1330.0**	**1981.5**	**20564**

TABLE 3: MODELED HIGH CAPACITY WELLS

Well Name	New Model ID	Unique Number	UTM E	UTM N	Model E	Model N	Aquifer	Upper Model Layer	Lower Model Layer	Recorded Discharge (MG/Y)					Average (MG/Y)	Modeled Average (m^3/d)
										2007	2008	2009	2010	2011		
Atlas of Minnesota 1	205585	205585	488933	4966922	83158	56940	CJDN	4	4	0.4	0.8	0.6	0.1	0.2	0.4	4.4
Atlas of Minnesota 2	205583	205583	488913	4966882	83138	56900	CJDN	4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Blue Cross Blue Shield	151566	151566	484473	4964390	78698	54408	OPDCCJDN	3	4	1.7	2.4	1.4	1.2	1.5	1.6	17.0
Coca Cola Bottling 1	205588	205588	487788	4967022	82013	57040	CJDN	4	4	25.5	22.6	38.6	32.3	10.6	25.9	269.0
Coca Cola Bottling 2	151595	151595	488034	4967076	82259	57094	CJDN	4	4	163.6	151.8	125.6	135.7	137.2	142.8	1481.7
D&D Land LLC	207096	207096	497479	4969417	91704	59435	OPDC	3	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eagan Well No. 1	E1	205596	485718	4964429	79943	54447	CJDN	4	4	176.7	269.3	304.8	459.9	314.5	305.0	3165.6
Eagan Well No. 10	E10	439839	487268	4959687	81493	49705	CJDN	4	4	176.8	121.2	292.4	232.2	171.2	198.8	2062.7
Eagan Well No. 11	E11	433275	485574	4963706	79799	53724	CMTS	9	9	154.3	29.0	6.0	14.1	0.0	40.7	422.2
Eagan Well No. 12	E12	433287	486462	4960473	80687	50491	CJDN	4	4	37.5	53.5	41.7	66.8	68.6	53.6	556.5
Eagan Well No. 13	E13	449230	486444	4959637	80669	49655	CJDN	4	4	8.8	113.9	280.0	96.2	94.0	118.6	1230.6
Eagan Well No. 14	E14	505636	486739	4960320	80964	50338	CJDN	4	4		1.4	16.7	23.5	33.1	14.9	155.0
Eagan Well No. 15	E15	420971	486844	4960502	81069	50520	CJDN	4	4	131.0	3.9	3.7	45.8	4.5	37.8	392.1
Eagan Well No. 16	E16	489215	486000	4965611	80225	55629	CJDN	4	4	487.7	392.0	435.7	248.7	328.0	378.4	3927.2
Eagan Well No. 17	E17	205809	486344	4965692	80569	55710	CJDN	4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eagan Well No. 18	E18	554225	487022	4959781	81247	49799	CJDN	4	4	194.9	193.6	60.9	19.7	153.7	124.6	1292.7
Eagan Well No. 19	E19	559401	486074	4960517	80299	50535	CJDN	4	4	202.6	234.1	156.3	101.0	66.3	152.1	1578.0
Eagan Well No. 2	E2	205595	485709	4964121	79934	54139	CJDN	4	4	114.8	81.1	84.1	67.9	61.8	81.9	850.4
Eagan Well No. 20	E20	626784	486691	4965186	80916	55204	CJDN	4	4	258.8	463.5	265.2	219.3	387.3	318.8	3308.7
Eagan Well No. 21	E21	721699	485565	4963699	79790	53717	CJDNCSTL	4	5	255.4	215.4	334.7	362.8	343.7	302.4	3138.2
Eagan Well No. 3	E3	207258	485597	4963957	79822	53975	CJDN	4	4	47.3	93.6	70.7	83.5	8.5	60.7	630.1
Eagan Well No. 4	E4	235373	485639	4964285	79864	54303	CJDN	4	4	145.2	238.8	362.2	244.7	223.3	242.8	2520.1
Eagan Well No. 5	E5	112234	486884	4959760	81109	49778	CJDN	4	4	357.1	251.0	171.6	229.0	209.0	243.5	2527.4
Eagan Well No. 6	E6	151552	485824	4964669	80049	54687	CJDN	3	4	448.9	363.9	131.3	244.7	351.0	308.0	3195.9
Eagan Well No. 7	E7	151564	485996	4965227	80221	55245	CJDN	4	4	225.3	264.1	313.6	101.9	194.0	219.8	2280.8
Eagan Well No. 8	E8	434046	486105	4964061	80330	54079	CMTS	9	9	37.6	5.8	12.0	38.8	17.8	22.4	232.5
Eagan Well No. 9	E9	434030	486086	4964023	80311	54041	CJDN	4	4	176.7	109.2	103.0	141.4	176.2	141.3	1466.4
Ecolab Inc.	505619	505619	491100	4966520	85325	56538	OPDCCJDN	3	4	3.2	1.8	4.9	0.7	1.3	2.4	24.7
Gerten's Greenhouse*	604676	604676	495995	4968589	90220	58607	OPCJ	3	4	5.3	5.3	5.3	5.3	5.3	5.3	55.0
Gerten's Greenhouse*	699110	699110	495776	4968637	90001	58655	OPCJ	3	4	14.4	16.0	16.0	16.0	16.0	15.7	162.7
Gerten's Greenhouse*	657285	657285	496114	4968631	90339	58649	OPCJ	3	4	52.7	58.3	583.0	58.3	58.3	162.1	1682.4
Ind School District 196	205598	205598	489116	4961365	83341	51383	CJDN	4	4	14.8	14.8	14.8	14.8	14.8	14.8	153.6
Lost Spur Golf Course	205589	205589	486223	4967278	80448	57296	OPDCCJDN	3	4	9.8	9.2	6.6	4.9	3.4	6.8	70.4
Mendakota Country Club 2	509077	509077	489382	4969808	83607	59826	OPDCCJDN	3	4	28.0	25.6	23.3	15.9	21.1	22.8	236.4
Mendakota Country Club 3	238667	238667	489902	4969807	84127	59825	CJDN	4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Skyline Village MHP	208372	208372	498422	4965214	92647	55232	CJDN	4	4	15.6	14.8	14.4	14.0	12.1	14.2	147.2
Somerset Country Club	200848	200848	491132	4972091	85357	62109	OPDCCJDN	3	4	20.7	20.1	17.2	11.4	17.4	17.4	180.2
South Saint Paul Well No. 1	SSP1	200674	496473	4969822	90698	59840	CJDN	4	4	312.0	239.7	370.2	306.8	147.4	275.2	2856.2
South Saint Paul Well No. 3	SSP3	200665	496711	4971463	90936	61481	CJDN	4	4	37.9	203.5	97.7	117.2	234.3	138.1	1433.4
South Saint Paul Well No. 4	SSP4	208347	497224	4968992	91449	59010	OPDCCSTL	3	5	775.2	709.0	735.0	767.5	892.3	775.8	8051.1
South Saint Paul Well No. 8	SSP8	127251	495266	4970470	89491	60488	CJDN	4	4	85.7	20.9	23.8	4.9	8.1	28.7	297.6
Southview County Club 1	236153	236153	494167	4970123	88392	60141	OPDCCJDN	3	4	8.8	8.4	7.8	6.9	9.7	8.3	86.3
Southview County Club 2	200679	200679	494111	4970166	88336	60184	OPCJ	3	4	27.8	21.5	22.3	13.1	14.3	19.8	205.5
St. Thomas Academy	200871	200871	489129	4968330	83354	58348	CJDN	4	4	5.2	4.0	4.8	4.4	3.1	4.3	44.6
West St. Paul No. 1	WSP1	542938	494092	4971868	88317	61886	OPDC	3	3	5.8	6.2	5.6	3.9	5.3	5.4	55.6
Xcel Energy	208388	208388	491902	4960703	86127	50721	CFRNCMTS	6	9	0.1	0.1	0.0	0.0	0.1	0.1	0.6

* Well data not in DNR SWUDS database

TABLE 4A - JORDAN AQUIFER PARAMETERS

PARAMETER	VALUE	SOURCE
Aquifer Material	Sandstone	Well Boring Records
Transmissivity	4,710-6,920 ft^2/day	Well 9 Aquifer Test (2008)
Horizontal Hydraulic Conductivity	47.1-69.2 ft/day	Well 9 Aquifer Test (2008)
Stratigraphic Bottom Elevation (at IGH wells)	127-139m	Well Boring Records
Stratigraphic Top Elevation (at IGH wells)	159-170m	Well Boring Records
Aquifer Thickness	27-34m	Well Boring Records
Aquifer Porosity	0.20	Estimated
Hydraulic Confinement	Confined	Well Boring Records
Groundwater Flow Field	Northeast Towards Mississippi River	Dakota County Geologic Atlas

TABLE 4B – MT. SIMON AQUIFER PARAMETERS

PARAMETER	VALUE	SOURCE
Aquifer Material	Sandstone	Well Boring Records
Transmissivity	2,460 ft^2/day	Apple Valley Well 14 Aquifer Test (2001)
Horizontal Hydraulic Conductivity	9.5 ft/day	Apple Valley Well 14 Aquifer Test (2001)
Stratigraphic Bottom Elevation (at IGH wells)	-53m	Well Boring Records
Stratigraphic Top Elevation (at IGH wells)	26m	Well Boring Records
Aquifer Thickness	79m	Well Boring Records
Aquifer Porosity	0.20	Estimated
Hydraulic Confinement	Confined	Well Boring Records
Groundwater Flow Field	Northeast Towards Mississippi River	Dakota County Geologic Atlas

TABLE 5 - MASS BALANCE SUMMARY FOR GROUNDWATER CAPTURE ZONES

Model IGH_14

Well Capture Zone	Well 3	Well 4	Well 5	Wells 7, 8, 9
Well Discharge from Jordan (m^3/d)	4005.8	3183.9	2573.7	9589.1
Recharge from Prairie du Chien Over Modeled 10-Year Capture Zone (m^3/d)	1854.7	1496.1	1355.4	5688.4
Percentage of Capture Area Recharged by Prairie du Chien	46.3%	47.0%	52.7%	59.3%

Model IGH_14b

Well Capture Zone	Well 3	Well 4	Well 5	Wells 7, 8, 9
Well Discharge from Jordan (m^3/d)	4005.8	3183.9	2573.7	9589.1
Recharge from Prairie du Chien Over Modeled 10-Year Capture Zone (m^3/d)	1849.3	1640.0	1383.3	5781.0
Percentage of Capture Area Recharged by Prairie du Chien	46.2%	51.5%	53.7%	60.3%

Well Capture Zone	Well 3	Well 4	Well 5	Wells 7, 8, 9
Selected Percentage of Capture for Fracture Flow Analysis	50%	55%	55%	65%
Fracture Flow Discharge Rate (m3/day)	2002.9	1751.1	1415.5	6232.9

TABLE 6 - CALCULATION OF FIXED RADII FOR FRACTURE FLOW ASSESSMENT

Wells = 7,8, and 9				
X = 495,056.000, Y = 4,965,414.000				
1 Year Pumping Volume (365 days)				

Pumping Volume (Q):	6232.9 m^3/day	220112.8 ft^3/day	1143.4 gpm	1646558.0 gal/day
Water Producing Zone Thickness (L):	49.7 m	163.1 ft.		
Effective Porosity (n):	0.1			
Original (CFR) Radius:	539.8 m	1771.1 ft.		
Wells = 3 and 4				
X = 496,471.000, Y = 4,966,157.000				
1 Year Pumping Volume (365 days)				

Pumping Volume (Q):	3754.0 m^3/day	132571.3 ft^3/day	688.7 gpm	991701.9 gal/day
Water Producing Zone Thickness (L):	47.9 m	157.2 ft.		
Effective Porosity (n):	0.1			
Original (CFR) Radius:	426.7 m	1400.1 ft.		
Well = 5				
X = 496,443.000, Y = 4,965,226.000				
1 Year Pumping Volume (365 days)				

Pumping Volume (Q):	1415.5 m^3/day	49987.9 ft^3/day	259.7 gpm	373935.5 gal/day
Water Producing Zone Thickness (L):	49.4 m	162.1 ft.		
Effective Porosity (n):	0.1			
Original (CFR) Radius:	258.0 m	846.6 ft.		

TABLE 7A - CALCULATION OF OVERLAP AREAS AND UPGRADIENT EXTENSION

Wells = 7, 8, and 9				
X = 495,056.000, Y = 4,965,414.000				
5 Year Pumping Volume (1825 days)				
Pumping Volume (Q):	6,232.90 m^3/day	220,112.78 ft^3/day	1,143.44 gpm	1,646,557.98 gal/day
Water Producing Zone Thickness (L):	49.7 m	163.058 ft		
Effective Porosity (n):	0.05			
Original (CFR) Radius:	1,207.09 m	3,960.26 ft		
New Radius:	1,251.44 m	4,105.79 ft		
New Pumping Volume (Q): *	6,699.41 m^3/day	236,587.44 ft^3/day	1,229.03 gpm	1,769,796.98 gal/day
Wells = 3 and 4				
X = 496,471.000, Y = 4,966,157.000				
5 Year Pumping Volume (1825 days)				
Pumping Volume (Q):	3,754.00 m3/day	132,571.26 ft^3/day	688.682 gpm	991,701.88 gal/day
Water Producing Zone Thickness (L):	47.9 m	157.152 ft		
Effective Porosity (n):	0.05			
Original (CFR) Radius:	954.225 m	3,130.66 ft		
New Radius:	989.291 m	3,245.71 ft		
New Pumping Volume (Q): *	4,034.97 m3/day	142,493.74 ft^3/day	740.227 gpm	1,065,927.24 gal/day
OVERLAP SUMMARY INFORMATION				
Original (CFR) Area for Well# :	4,577,481.89 m^2	49,271,557.33 ft^2		
New (CFR) Area for Well# :	4,920,090.12 m^2	52,959,358.02 ft^2		
Original (CFR) Area for Well# :	2,860,563.67 m^2	30,790,821.33 ft^2		
New (CFR) Area for Well# :	3,074,666.68 m^2	33,095,404.72 ft^2		
Overlap Area to Well# :	342,608.23 m^2	3,687,800.69 ft^2		
Overlap Area to Well# :	214,103.01 m^2	2,304,583.38 ft^2		
Total Overlap Area:	556,711.24 m^2	5,992,384.07 ft^2		
* = New Pumping Volumes (Q) if needed for additional overlap computations with another well.				
UP-GRADIENT EXTENSION (UGE)				
(area beyond the New Areas of both Wells)				
(area beyond the New Areas of both Wells)				
Bearing from Well# = 240° from North +/- 10°.				
Bearing from Well# = 240° from North +/- 10°.				
Up-Gradient Extension Area:	6,132,153.95 m^2	66,005,891.94 ft^2		

TABLE 7B - CALCULATION OF OVERLAP AREAS AND UPGRADIENT EXTENSION

Wells = 3 and 4				
X = 496,471.000, Y = 4,966,157.000				
5 Year Pumping Volume (1825 days)				
Pumping Volume (Q):	4035.0 m^3/day	142494.7 ft^3/day	740.2 gpm	1065934.2 gal/day
Water Producing Zone Thickness (L):	47.9 m	157.2 ft		
Effective Porosity (n):	0.05			
Original (CFR) Radius:	989.3 m	3245.7 ft		
New Radius:	1050.1 m	3445.3 ft		
New Pumping Volume (Q): *	4546.5 m^3/day	160556.5 ft^3/day	834.1 gpm	1201046.3 gal/day
Well = 5				
X = 496,443.000, Y = 4,965,226.000				
5 Year Pumping Volume (1825 days)				
Pumping Volume (Q):	1415.5 m3/day	49987.9 ft^3/day	259.7 gpm	373935.5 gal/day
Water Producing Zone Thickness (L):	49.4 m	162.1 ft		
Effective Porosity (n):	0.05			
Original (CFR) Radius:	577.0 m	1893.0 ft		
New Radius:	612.5 m	2009.4 ft		
New Pumping Volume (Q): *	1594.9 m3/day	56324.1 ft^3/day	292.6 gpm	421333.6 gal/day
OVERLAP SUMMARY INFORMATION				
Original (CFR) Area for Well# :	3074686.8 m^2	33095621.8 ft^2		
New (CFR) Area for Well# :	3464417.4 m^2	37290642.8 ft^2		
Original (CFR) Area for Well# :	1045865.4 m^2	11257590.4 ft^2		
New (CFR) Area for Well# :	1178433.6 m^2	12684541.4 ft^2		
Overlap Area to Well# :	389730.6 m^2	4195021.0 ft^2		
Overlap Area to Well# :	132568.2 m^2	1426950.9 ft^2		
Total Overlap Area:	522298.8 m^2	5621972.0 ft^2		
* = New Pumping Volumes (Q) if needed for additional overlap computations with another well.				
UP-GRADIENT EXTENSION (UGE)				
(area beyond the New Areas of both Wells)				
(area beyond the New Areas of both Wells)				
Bearing from Well# = 240° from North +/- 10°.				
Bearing from Well# = 240° from North +/- 10°.				
Up-Gradient Extension Area:	3807345.2 m^2	40981883.0 ft^2		
Up-Gradient Intersection Area:	728993.8 m^2	7846816.1 ft^2		

TABLE 7C - CALCULATION OF OVERLAP AREAS AND UPGRADIENT EXTENSION

Wells = 7, 8, and 9				
X = 495,056.000, Y = 4,965,414.000				
5 Year Pumping Volume (1825 days)				
Pumping Volume (Q):	6699.0 m^3/day	236572.9 ft^3/day	1229.0 gpm	1769688.6 gal/day
Water Producing Zone Thickness (L):	49.7 m	163.1 ft		
Effective Porosity (n):	0.05			
Original (CFR) Radius:	1251.4 m	4105.7 ft		
New Radius:	1287.6 m	4224.4 ft		
New Pumping Volume (Q): *	7092.0 m^3/day	250452.0 ft^3/day	1301.1 gpm	1873511.3 gal/day
Well = 5				
X = 496,443.000, Y = 4,965,226.000				
5 Year Pumping Volume (1825 days)				
Pumping Volume (Q):	1595.0 m3/day	56326.9 ft^3/day	292.6 gpm	421354.4 gal/day
Water Producing Zone Thickness (L):	49.4 m	162.1 ft		
Effective Porosity (n):	0.05			
Original (CFR) Radius:	612.5 m	2009.4 ft		
New Radius:	630.2 m	2067.5 ft		
New Pumping Volume (Q): *	1688.6 m3/day	59631.4 ft^3/day	309.8 gpm	446074.1 gal/day
OVERLAP SUMMARY INFORMATION				
Original (CFR) Area for Well# :	4919788.7 m^2	52956113.9 ft^2		
New (CFR) Area for Well# :	5208419.1 m^2	56062902.5 ft^2		
Original (CFR) Area for Well# :	1178491.9 m^2	12685169.0 ft^2		
New (CFR) Area for Well# :	1247630.8 m^2	13429372.7 ft^2		
Overlap Area to Well# :	288630.4 m^2	3106788.6 ft^2		
Overlap Area to Well# :	69138.9 m^2	744203.7 ft^2		
Total Overlap Area:	357769.2 m^2	3850992.3 ft^2		
* = New Pumping Volumes (Q) if needed for additional overlap computations with another well.				
UP-GRADIENT EXTENSION (UGE)				
(area beyond the New Areas of both Wells)				
(area beyond the New Areas of both Wells)				
Bearing from Well# = 240° from North +/- 10°.				
Bearing from Well# = 240° from North +/- 10°.				
Up-Gradient Extension Area:	6782261.3 m^2	73003581.9 ft^2		

TABLE 8 - GEOLOGIC SENSITIVITY CALCULATIONS FOR NEARBY WELLS

UNIQUE NUMBER	WELL NAME	WELL ELEVATION (FT)	WELL USE	DEPTH DRILLED (FT)	DEPTH TO BEDROCK (FT)	FIRST BEDROCK UNIT	AQUIFER	UTM E COORDINATE	UTM N COORDINATE	L SCORE	GEOLOGIC SENSITIVITY	BASAL ST. PETER PRESENT?
101043	BRENT WEBSTER	910	DO	252	200	OSTP	OPDC	493703	4966014	0	M	Yes
101055	MICHAEL ROWE	820	DO	310	200	OSTP	OPDC	496997	4966614	0	M	Yes
104132	HUGO BLACKFELDNER	905	DO	260	240	OPDC	OPDC	492217	4966526	5	L	No
104188	RICHARD CARLSON	910	DO	275			QBAA	493821	4963912	11	L	NA
104284	JIM KAWSKI	797	DO	175			QWTA	493502	4961951	0	H	NA
104312	JIM MCFARLAND	820	DO	155			QUUU	493498	4964108	2	L	NA
104322	RON REINARDY	900	DO	245	74	OSTP	OPDC	495834	4966395	3	L	Yes
107303	DUANE HINKLEY	845	DO	178			QUUU	493672	4963914	4	L	NA
110568	SHAD	918	DO	258	244	OPDC	OPDC	494884	4967470	6	L	No
112201	SOUTH ST. PAUL 9	820	MU	381	115	OPDC	MTPL	496769	4967948	0	H	No
112277	MAURICE JOHNSON	950	DO	325	225	OPDC	OPDC	494800	4964876	5	L	No
124323	JOHN BANATARRI	980	DO	255			QBAA	492958	4965754	16	L	NA
124342	JAMES GULLICKSON	950	DO	141			QBUA	494723	4966769	2	L	NA
124349	EDGAR GELLE	929	DO	300	266	OPDC	OPDC	492397	4966354	20	L	No
127186	B B LERNER	936	DO	272	242	OPDC	OPDC	494426	4964408	14	L	No
127187	DON RECHTZIGEL	913	DO	276	214	OPDC	OPDC	493807	4964524	0	H	No
127188	LEROY MOTZ	903	DO	291	281	OPDC	OPDC	492095	4964946	27	L	No
127189	RON WARREN	933	DO	271	259	OPDC	OPDC	492354	4966539	1	L	No
127190	MARTIN MOODY	805	DO	361	312	CSTL	CSTL	493565	4961757	30	L	No
127193	STEVE SCHMAICHAL	870	DO	378	314	CJDN	CJDN	492947	4961934	0	H	No
127195	J. BROWN	905	DO	360			QWTA	493607	4962593	0	H	NA
127196	RICHARD ELBERT	870	DO	295			QBUA	492420	4963493	5	L	NA
127591	PAUL BRUST	920	DO	302			QBAA	492398	4966108	5	L	NA
129164	ARENDS, HANK	912	DO	239			QBAA	493969	4963673	10	L	NA
129181	DAVID P. FITCH	900	DO	280	268	OPDC	OPDC	493534	4962597	6	L	No
129251	OTTOMAR BOHRER	900	DO	260	220	OPDC	OPDC	493433	4966010	4	L	No
136461	DONALD FISCHER	964	DO	295	230	OSTP	MTPL	493979	4965908	10	L	Yes
136504	ROBERT A. HARRIS	910	DO	212			QBAA	493848	4963738	17	L	NA
136512	WILLIAM LENGSFELD JR.	953	DO	262	220	OPDC	OPDC	495348	4963284	17	L	No
141811	CLOVER LEAF MOTEL	911	PN	261	195	OSTP	OPDC	493441	4964577	8	L	Yes
145723	JOE ADRIAN	883	DO	270			QWTA	492851	4961809	0	H	NA
145737	GORDY LEACH	899	DO	170			QBUA	493999	4962465	8	L	NA
145901	GLASSING, FRED	955	DO	320	240	OSTP	OPDC	494773	4965539	0	M	Yes
146831	DON GOERS	920	DO	303	270	OPDC	OPDC	494002	4963890	14	L	No
146863	JOHN ZEIEN	883	DO	360	330	OPDC	OPCJ	491748	4962863	25	L	No
151717	RICHARD NEARS	915	DO	309	230	OSTP	OPDC	494836	4967331	6	L	Yes
155587	JIM SEIDL	925	DO	222	208	OPDC	OPDC	494597	4963623	19	L	No
159483	STEVE CAPAHN	910	DO	237			QBAA	493604	4962647	15	L	NA
159489	DOUG SCHAAFS	865	DO	175			QBAA	491846	4965551	8	L	NA
163418	CHARLES A. BOHRER	805	DO	159			QBAA	493638	4961716	5	L	NA
165640	INVER GROVE HEIGHTS 5	895	PC	452	178	OPDC	CJDN	496452	4965244	5	L	No
170804	FRED W. GLASSING JR.	965	DO	335	250	OSTP	OPDC	494644	4965432	2	L	Yes
170805	OLSON	840	DO	232			QWTA	493185	4962286	0	H	NA
171835	ROGER ANDERSON	870	DO	249			QBUA	493790	4963651	3	L	NA
174664	BILL COLE	915	DO	315	274	OPDC	OPDC	491390	4966344	26	L	No
182815	TIMOTHY WAKEFIELD	905	DO	292	275	OPDC	OPDC	491967	4965301	22	L	No
182969	JOE VETTER	878	DO	308	263	OPDC	OPDC	491871	4965351	0	H	No

TABLE 8 - GEOLOGIC SENSITIVITY CALCULATIONS FOR NEARBY WELLS

UNIQUE NUMBER	WELL NAME	WELL ELEVATION (FT)	WELL USE	DEPTH DRILLED (FT)	DEPTH TO BEDROCK (FT)	FIRST BEDROCK UNIT	AQUIFER	UTM E COORDINATE	UTM N COORDINATE	L SCORE	GEOLOGIC SENSITIVITY	BASAL ST. PETER PRESENT?
185277	STEVE WATRUD	911	DO	243			QWTA	493861	4963953	0	H	NA
185937	SHELDAN CARLSON	921	DO	217			QWTA	491864	4965955	0	H	NA
185980	AMELSE	971	DO	300	272	OPDC	OPDC	494607	4966140	0	H	No
185984	RON SHORT	915	DO	233			QWTA	494442	4961898	0	H	NA
186041	HAROLD MASON	963	DO	276	252	OPDC	OPDC	495757	4962647	24	L	No
186042	ANDERSON, SANNY	872	DO	247			QWTA	492085	4962741	0	H	NA
186044	RABUSE	905	DO	175			QWTA	491974	4964447	0	H	NA
186307	DUANE STRUMSTADT	885	DO	420	375	CSLF	MTPL	494235	4962414	0	H	No
186313	JEROME PETERS	891	DO	420	380	CSTL	MTPL	494429	4962222	19	L	No
188205	STEVE MELVIN	900	DO	270			QWTA	494403	4961717	0	H	NA
188208	MARTIN STIENINGER	911	DO	276	248	OPDC	OPDC	491773	4965948	22	L	No
190475	DON FORCIER	850	DO	351	301	OPDC	OPDC	493052	4962395	3	L	No
190476	PAUL VICHICH	892	DO	326	302	OPDC	OPDC	491874	4965394	1	L	No
190477	C. ALLEN	810	DO	241	216	OPDC	OPDC	493482	4964091	2	L	No
190478	SHIMMEK	940	DO	366	341	OPDC	OPDC	494002	4963509	7	L	No
190497	LESLIE LANG	882	DO	391	368	CSLF	MTPL	494287	4962369	1	L	No
194090	BUREA LUTHERN CHURCH	862	PP	251			QBAA	492932	4962352	14	L	NA
194091	BEHAN, ROBERT	804	DO	230	220	OPDC	OPDC	493862	4963248	7	L	No
194093	PATRICK DADDARIO	908	DO	280	250	OPDC	OPDC	493867	4964081	19	L	No
194197	PEACE LUTHERAN CHURCH	900	PN	215	185	OSTP	OSTP	493457	4965757	0	M	Yes
194275	PAUL ABOTT	890	DO	260			QWTA	494133	4962199	0	H	NA
194294	BOB POLLOCH	915	DO	307			QBAA	494537	4961869	25	L	NA
198281	BOB MAIER	852	DO	149			QBUA	493716	4963294	7	L	NA
198282	JIM MCNEARNEY	911	DO	278			QWTA	492045	4965345	0	H	NA
198297	FLOYD REDPENNING	939	DO	280	205	OSTP	OPDC	494385	4966158	19	L	Yes
198328	TERRY VANDER WERT	925	DO	280	248	OPDC	OPDC	494444	4966361	23	L	No
198339	KEN IRISH	940	DO	300	270	OPDC	OPDC	493772	4964242	22	L	No
198340	TOME KELLY	906	DO	275			QBAA	493767	4964146	20	L	NA
198345	J. R. HOFFMAN	910	DO	260			QBAA	492246	4965318	6	L	NA
198347	MICHAEL J. KNAPP	851	DO	265	260	OPDC	OPDC	493736	4963243	18	L	No
198350	CRAIG WAGENKNECHT	920	DO	280	230	OSTP	OPDC	493618	4965732	3	L	Yes
207262	SPECTOR MOTOR FREIGHT	896	CO	465	356	OPDC	MTPL	490929	4964280	25	L	No
207279	J. GESSELONEN	930	AB	294	240	OSTP	OPDC	493922	4966189	0	M	Yes
207281	JOHN AVOLES	950	DO	295	260	OPDC	OPDC	494558	4966744	0	H	No
207282	MORRIS SKANE	920	DO	290	245	OPDC	OPDC	495066	4966838	0	H	No
207284	INVER GROVE HEIGHTS 3	855	PC	407	145	OSTP	CJDN	496520	4966285	0	M	Yes
207285	INVER GROVE HEIGHTS 4	807	PC	360	59	OSTP	CJDN	496441	4966018	0	M	Yes
207286		915	DO	260	180	OSTP	MTPL	495685	4966509	0	M	Yes
207287		970	DO	302	240	OSTP	MTPL	494829	4965005	0	M	Yes
207298		900	DO	245			QUUU	492872	4963221	4	L	NA
208345		983	DO	320	200	OSTP	MTPL	494702	4967858	0	M	Yes
208348	KEN SCHULLER	920	DO	265	100	OSTP	MTPL	494931	4967750	9	L	Yes
208355	FLEMING FIELD	823	PS	396	106	OPDC		497800	4967565	0	H	No
208356		950	DO	303	200	OSTP	MTPL	494984	4966622	0	H	Yes
208357		950	DO	303	230	OSTP	MTPL	495027	4966622	0	M	Yes
208358		960	DO	303	220	OSTP	OPDC	494857	4966491	0	M	Yes
208359		950	DO	303	230	OSTP	MTPL	495064	4966598	0	M	Yes

TABLE 8 - GEOLOGIC SENSITIVITY CALCULATIONS FOR NEARBY WELLS

UNIQUE NUMBER	WELL NAME	WELL ELEVATION (FT)	WELL USE	DEPTH DRILLED (FT)	DEPTH TO BEDROCK (FT)	FIRST BEDROCK UNIT	AQUIFER	UTM E COORDINATE	UTM N COORDINATE	L SCORE	GEOLOGIC SENSITIVITY	BASAL ST. PETER PRESENT?
208360		940	DO	250	95	OPVL	OSTP	494461	4967529	0	M	Yes
208361		918	DO	290	265	OPDC	OPDC	493332	4966678	0	H	No
208363		960	DO	482	300	OPDC	MTPL	494762	4966649	0	H	No
208364		950	DO	305	270	OSTP	OPDC	494782	4966545	0	M	Yes
208365		950	DO	305	270	OPDC	OPDC	494789	4966496	12	L	No
208367		925	DO	285	250	OPDC	OPDC	492367	4966289	24	L	No
208368		920	DO	300	260	OPDC	OPDC	493656	4965909	0	H	No
208369	JERRY PERRY	815	DO	196	40	OSTP	OPDC	497895	4965682	3	L	Yes
208370	INVER GROVE HEIGHTS 2	914	AB	441	181	OPDC	CJDN	496775	4964494	3	L	No
208375	ROLLAND HUFFMAN	930	DO	286	155	OSTP	OPDC	497461	4964270	8	L	Yes
208377	I.F. SIMLEY JR. HIGH SCH	912	PS	434	260	OPDC	MTPL	496325	4964265	19	L	No
208378		940	DO	275	240	OPDC	OPDC	494700	4964174	0	H	No
208379		830	DO	140			QUUU	493661	4963822	4	L	NA
208380	NICK LAPOINTE	895	DO	350			QUUU	492140	4962480	30	L	NA
208381		891	DO	400	375	CSLF	CSLF	493609	4962771	0	H	No
208384	DALE KLINE	890	DO	192			QUUU	495268	4962660	7	L	NA
225846	INVER GROVE HEIGHTS 1	891	AB	430	169	OPDC	MTPL	497232	4965529	4	L	No
242886	HWY 3 PROJECT WELL NO.3	948	AB	258	158	OSTP	MTPL	495640	4966031	0	M	Yes
242893	HWY. 3 PROJECT WELL NO.6	930	AB	246	154	OSTP	MTPL	495337	4966077	0	M	Yes
242939	HWY. 3 PROJECT WELL A	942	AB	244	150	OSTP	OSTP	495497	4966019	0	M	Yes
242940	HWY. 3 PROJECT WELL B	945	AB	259	157	OSTP	OSTP	495543	4966031	0	M	Yes
401105	ELMER SCHMIDT	908	DO	306	268	OPDC	OPDC	492111	4966336	7	L	No
401865	THIELEN, JAMES	883	DO	360	330	CJDN	CJDN	492212	4962803	7	L	No
402597	TOM + KATHY FAVILLA	896	DO	200			QWTA	493970	4963373	0	H	NA
404813	STEVE AND CINDY WANDERSE	948	DO	320	270	OSTP	OPDC	494146	4966445	11	L	Yes
405088	PHIL NELSON	902	DO	317	290	OPDC	OPDC	492139	4965129	16	L	No
408263	FLANNERY	925	DO	280	264	OPDC	OPDC	492492	4966024	0	M	No
408268	BOB RAUS	888	DO	307			QBAA	494173	4962144	22	L	NA
408269	DON MILLER	921	DO	325	297	OPDC	OPDC	492216	4965184	28	L	No
408289	ROGER + MARSHA MELDE	880	DO	240			QWTA	494155	4961995	0	H	NA
410991	JOSEPH STANDLOF	905	DO	250	195	OSTP	OPDC	493628	4964520	2	L	Yes
412467	DENNY AND PAT CHRIST	960	DO	320	240	OSTP	OPDC	494574	4966225	4	L	Yes
412468	ERIC HOLM	905	DO	320	300	OPDC	OPDC	492144	4965190	15	L	No
412470	GAS PLUS	870	PN	195			QWTA	493317	4966001	0	H	NA
412474	LARRY CERMAK	930	DO	257	231	OPDC	OPDC	495805	4963545	0	H	No
412482	MIKE TAURINSKAS	905	DO	123			QWTA	492159	4966089	0	H	NA
416002		945	DO	320	260	OSTP	MTPL	494411	4966630	8	L	Yes
416015	ANDERSON, DEAN	885	DO	173			QWTA	492238	4965266	0	H	NA
416018	LARRY NELSON	944	DO	300	260	OSTP	OPDC	494155	4966346	13	L	Yes
416023		930	DO	253			QBAA	494372	4966585	5	L	NA
416049	DENNIS NELSON	970	DO	358	325	OPDC	OPDC	494231	4966539	19	L	No
417573	ERIC OLSEN	891	DO	345			QBAA	492171	4963558	8	L	NA
418617	MEL AND MARY SAIGN	917	DO	300	250	OSTP	OPDC	494285	4966263	11	L	Yes
418625	ASSEMBLY OF GOD CHURCH	940	PN	280	220	OSTP	OPDC	494593	4964099	19	L	Yes
418626	AL STANGL	934	DO	260	215	OSTP	MTPL	494450	4966129	12	L	Yes
418641	JOHN RIES	935	DO	320	298	OPDC	OPDC	494351	4966361	21	L	No
418646	PAUL AND DEBBIE SNETTING	900	DO	340	315	OPDC	OPDC	491895	4965433	25	L	No

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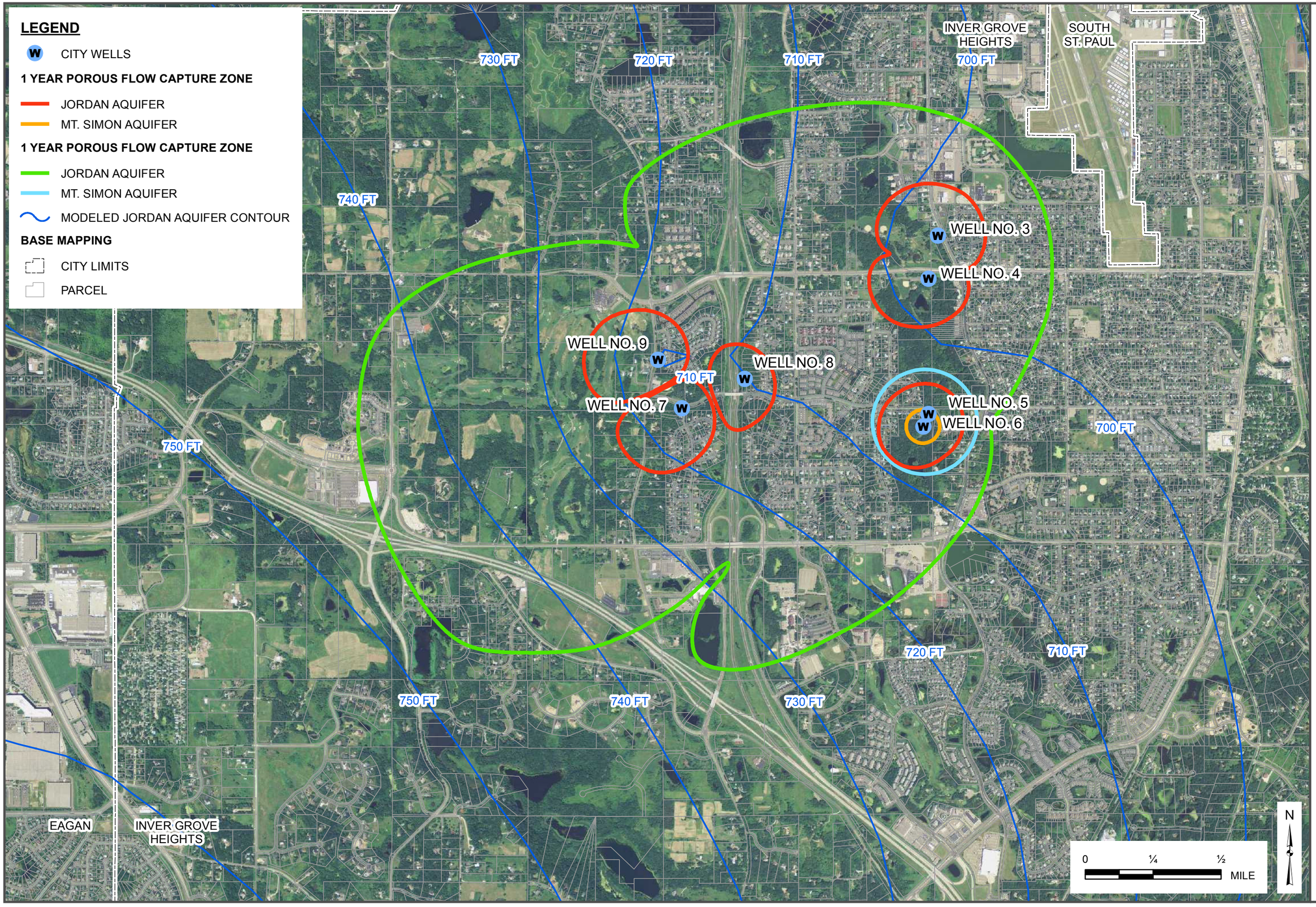
418655	GENE RUTHER	960	DO	320	275	OSTP	MTPL	494180	4966680	26	L	Yes
418660	JOHN SNYDER	938	DO	280	245	OPDC	OPDC	494373	4966673	10	L	No
418661	DUANE E. SPIESS J.R.	930	DO	280	240	OPDC	OPDC	494644	4966388	22	L	No
418663	STEPHENS, MARK	900	DO	280			QBAA	493791	4963731	9	L	NA
418664	MARK STOKBERGER	950	DO	300	250	OSTP	MTPL	494133	4966170	19	L	Yes
418669	DAN WATTS	966	DO	320	260	OSTP	MTPL	494647	4966204	19	L	Yes
418682	JOHN LARSON	882	DO	420	385	CFRN	CFRN	494280	4962135	23	L	No
418688	ROSEMARY PIEKORSKI	980	DO	280	215	OSTP	MTPL	494543	4965152	17	L	Yes
418692	DAVE PARK	925	DO	340	320	OPDC	OPDC	493850	4963592	21	L	No
424909	DON HOLZMER	959	DO	300	255	OSTP	MTPL	494191	4966135	19	L	Yes
425219	FEIDT, ANTHONY & ZANDRA	910	DO	280	255	OPDC	OPDC	493904	4963995	17	L	No
425231	RON HOEFT	912	DO	420	402	CFRN	CFRN	494642	4961955	22	L	No
425263	JACK O'BRIEN	848	DO	300			QBAA	495159	4962160	10	L	NA
425264	STEVE MICHAUD	807	DO	151			QWTA	493664	4963347	0	H	NA
425286	ACONITE CORP.	891	PN	380	345	OPDC	OPDC	491627	4962790	29	L	No
426353	DAVID VANDEVELDE	965	DO	300	290	OPDC	OPDC	494151	4966754	21	L	No
426363	JEFF HAGEN	957	DO	320	305	OPDC	OPDC	494650	4966274	23	L	No
426386	MAURICE BRAUN	890	DO	240	215	OPDC	OPDC	493628	4965872	15	L	No
426923	DONNA AND JIM STOESZ	950	DO	310	280	OPDC	OPDC	494264	4966331	0	H	No
426964	DAVE FRANK	890	DO	227			QWTA	493847	4963463	0	H	NA
426985	JONG CHUI	916	DO	245	224	OPDC	OPDC	495857	4963438	0	H	No
426986	JIM + BONNIE BERQUIST	928	DO	240	215	OPDC	OPDC	495689	4963523	0	H	No
427008		916	DO	220	190	OPDC	OPDC	495898	4963546	0	H	No
427008		916	DO	220	190	OPDC	OPDC	495898	4963546	0	H	No
427024	HANS THOLEY	849	DO	150			QWTA	493963	4963294	0	H	NA
427141	TIM PETERSON	968	DO	335	295	OPDC	OPDC	494126	4966821	0	H	No
428532	PAUL WARD	925	DO	276			QBAA	493918	4963489	9	L	NA
429860	ALFRED WILLENBRING	915	DO	280	242	OPDC	OPDC	493534	4964598	21	L	No
429893	GARY WALLERICH	911	DO	300	270	OPDC	OPDC	493942	4963881	12	L	No
429894	MIKE PLIML	931	DO	300	260	OSTP	OPDC	494531	4966346	15	L	Yes
433259	INVER GROVE HEIGHTS 6	895	PC	1044	167	OPDC	CMSH	496423	4965170	14	L	No
435179	ROBERT MCDERMOTT	960	DO	260	235	OPDC	OPDC	494833	4964807	18	L	No
435181	GARY HORTON	839	DO	297			QBAA	492602	4962046	2	L	NA
435200	RICHARD FURRY	935	DO	290	254	OPDC	OPDC	494147	4966246	15	L	No
435232	KEVIN JONES	901	DO	240			QWTA	494224	4961754	0	H	NA
437852	JOHN MURPHY	810	DO	142			QBUA	493631	4963393	8	L	NA
437855	STEVE RADEMACHER	931	DO	260	210	OPDC	OPDC	494323	4966735	0	H	No
437888	TERRY LAPANTA	925	DO	340	320	OPDC	OPDC	493887	4963649	30	L	No
437896	JIM EVENS	902	DO	236			QBUA	494167	4961738	2	L	NA
437918	MAURY COOK	940	DO	300	292	OPDC	OPDC	494395	4966266	0	H	No
437920	STEVE ERICKSON	965	DO	340	320	OPDC	OPDC	494234	4966617	9	L	No
437925	ALEXANDER CONSTRUCTUION	875	PN	380	330	OPDC	OPCJ	491842	4962782	27	L	No
437941	DALE SUCHSTORFF	870	DO	340			QBAA	494095	4962581	27	L	NA
441863	DICK ANFANG	895		385	365	CFRN	CFRN	494296	4961976	0	H	No
441898	JOANIE GLANCE	860	DO	162			QWTA	493698	4963386	0	H	NA
441920	DAVID + SHARON ROBINSON	912	DO	307	295	OPDC	OPDC	493982	4963798	16	L	No
443613	JOHN TOOMEY	892	DO	231			QBAA	492263	4963366	2	L	NA

TABLE 8 - GEOLOGIC SENSITIVITY CALCULATIONS FOR NEARBY WELLS

UNIQUE NUMBER	WELL NAME	WELL ELEVATION (FT)	WELL USE	DEPTH DRILLED (FT)	DEPTH TO BEDROCK (FT)	FIRST BEDROCK UNIT	AQUIFER	UTM E COORDINATE	UTM N COORDINATE	L SCORE	GEOLOGIC SENSITIVITY	BASAL ST. PETER PRESENT?
443885	MICHEAL MEMAUER	822	DO	162			QBAA	493524	4964245	7	L	NA
443899	GREG SPERL	890	DO	400	376	CSLF	MTPL	494344	4962367	0	H	No
443916	DUANE LINDA RHODES	892	DO	400	370	CSLF	MTPL	494381	4962341	3	L	No
443918	BOB PRUNTY	889	DO	415	383	CFRN	CFRN	494128	4962386	0	H	No
451545	ANDY HANSEN	940	DO	320	290	OPDC	OPDC	494321	4966519	23	L	No
451547	GLORIA LORENTZ	925	DO	240	209	OPDC	OPDC	495838	4963289	15	L	No
451553	BUD JOHNSON	907	DO	220	192	OPDC	OPDC	496041	4963485	15	L	No
451601	DAVE MOLINE	880	DO	420	380	CSLF	MTPL	494145	4962483	24	L	No
451620	DICK BAXTER	933	DO	260	215	OPDC	OPDC	495716	4963367	17	L	No
451625	SPEED ENGINEERING	909	DO	252	230	OPDC	OPDC	493180	4966162	15	L	No
457166	JOE VAN ASSCHE	830	DO	147			QBUA	492772	4964507	11	L	NA
463527	INVER GROVE HEIGHTS 7	955	PC	514	161	OSTP	CJDN	494981	4965274	1	L	Yes
466761	HOKENSON, GARY & CAROL	908	DO	330	305	OPDC	OPDC	493814	4963891	9	L	No
498439	INVERWOOD GOLF COURSE COMFORT STATION	971	PN	280	227	OSTP	OSTP	494307	4965108	4	L	Yes
634293	CHURCH OF CHRIST	965	DO	250	203	OPDC	OPDC	495442	4963193	0	H	No
655940	INVER GROVE HEIGHTS 8	970	PC	542	158	OSTP	OPCJ	495347	4965434	0	M	Yes
709343	MW-001	842	MW	330	142	OSTP	CJDN	496267	4966713	0	M	Yes
759561	INVER GROVE HEIGHTS 9	951	PC	510	172	OSTP	CJDN	494837	4965548	0	M	Yes
767865	CITY OF INVER GROVE HEIGHTS	951	EB	480	220	OPDC	CJDN	495864	4963110	1	L	No

FIGURES



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V:\1938\active\193802191\GIS\Projects\Figure 1 - Porous Flow.mxd

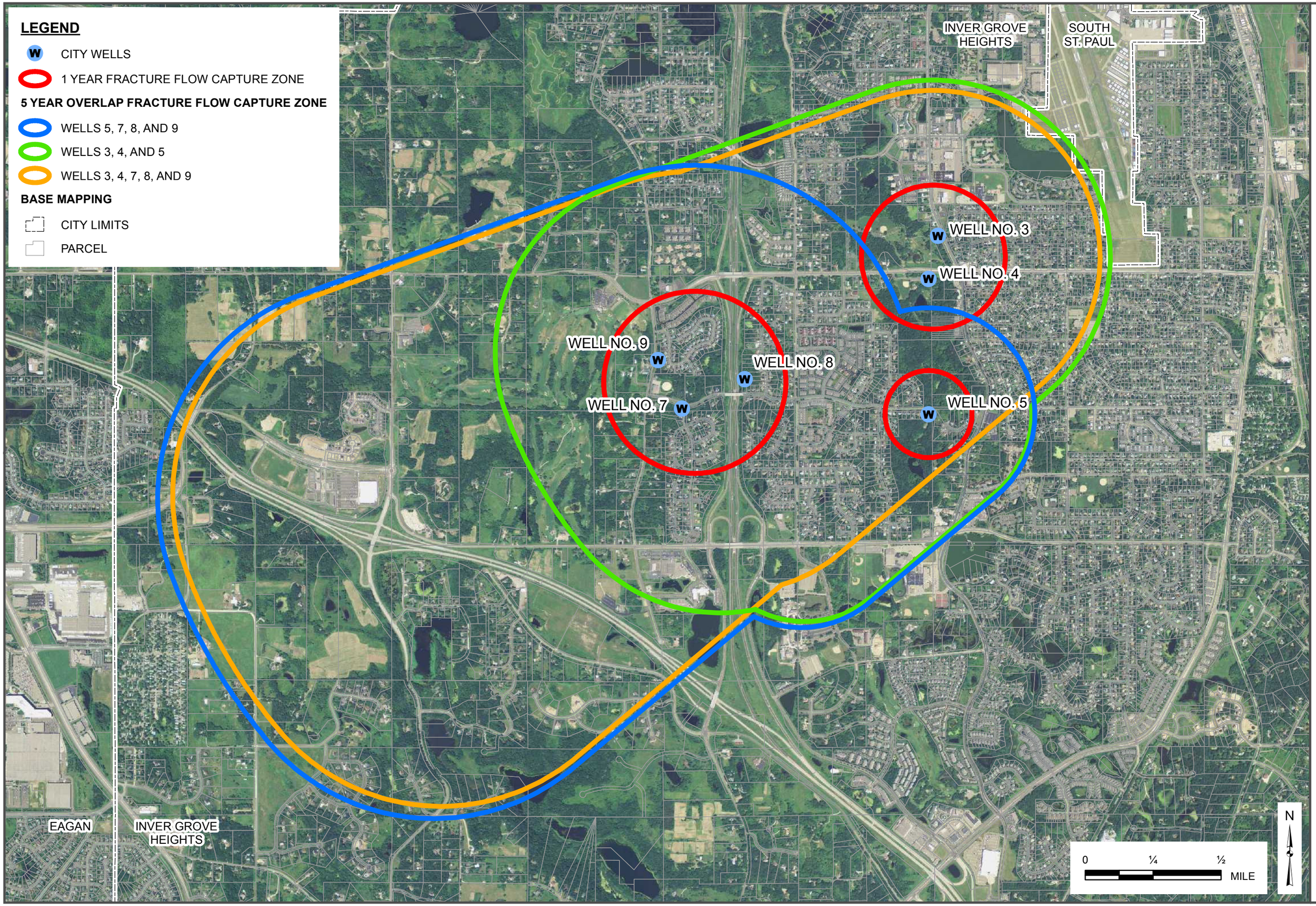
FIGURE 1 - POROUS FLOW MODELED CAPTURE ZONES

INVER GROVE HEIGHTS WELLHEAD PROTECTION PLAN

May 2015

Stantec
Stantec Consulting Services
2335 Highway 36 West
Saint Paul, MN 55113
651.636.4600

Design With Community In Mind



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V:\1938\active\193802191\GIS\Projects\Figure 2 - Fracture Flow.mxd

FIGURE 2 - FRACTURE FLOW CALCULATED CAPTURE ZONES

INVER GROVE HEIGHTS WELLHEAD PROTECTION PLAN

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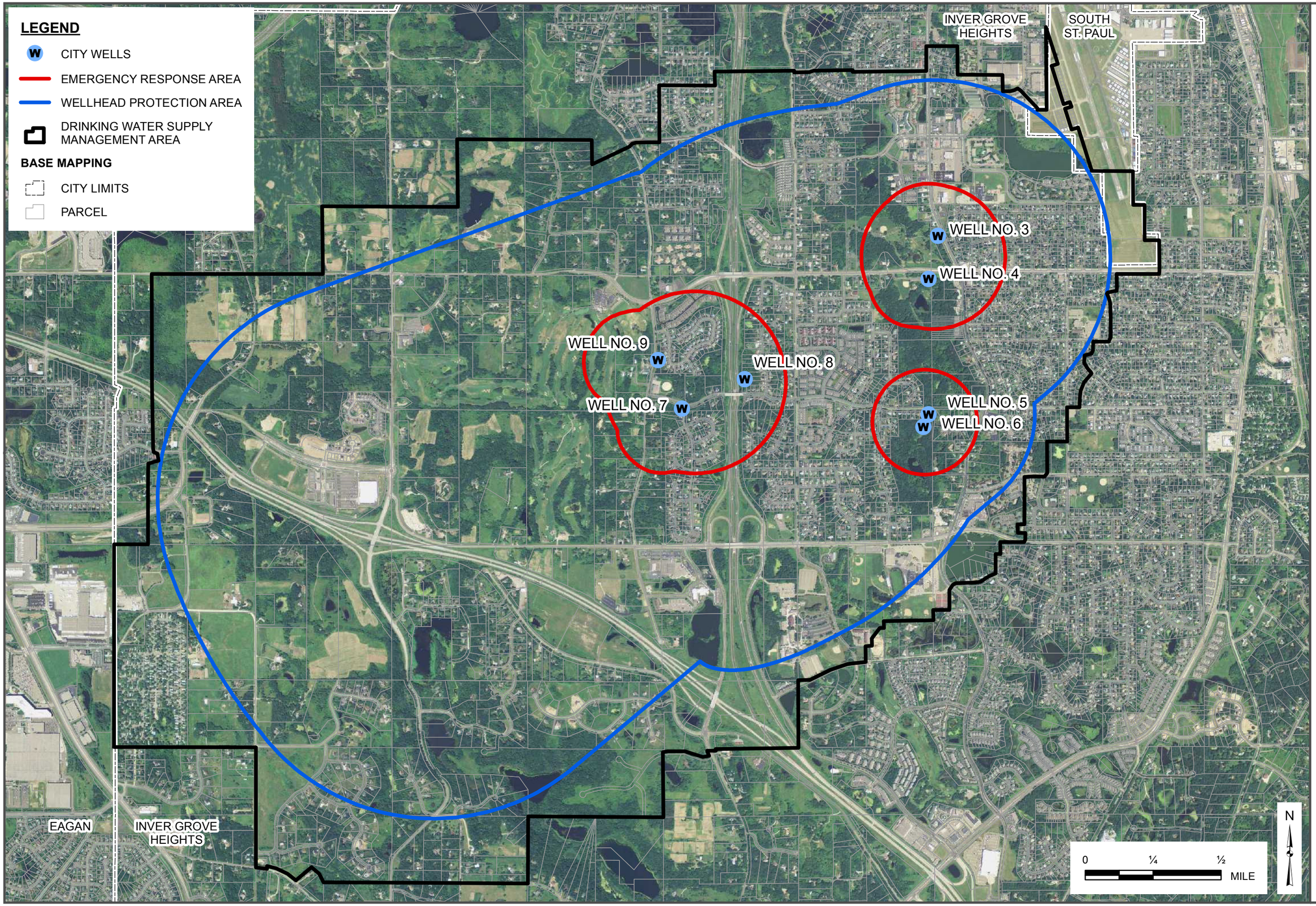

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V:\1938\active\193802191\GIS\Projects\Figure 3 - WHPA and DWSMA.mxd

FIGURE 3 - WHPA AND DWSMA DELINEATION

INVER GROVE HEIGHTS WELLHEAD PROTECTION PLAN

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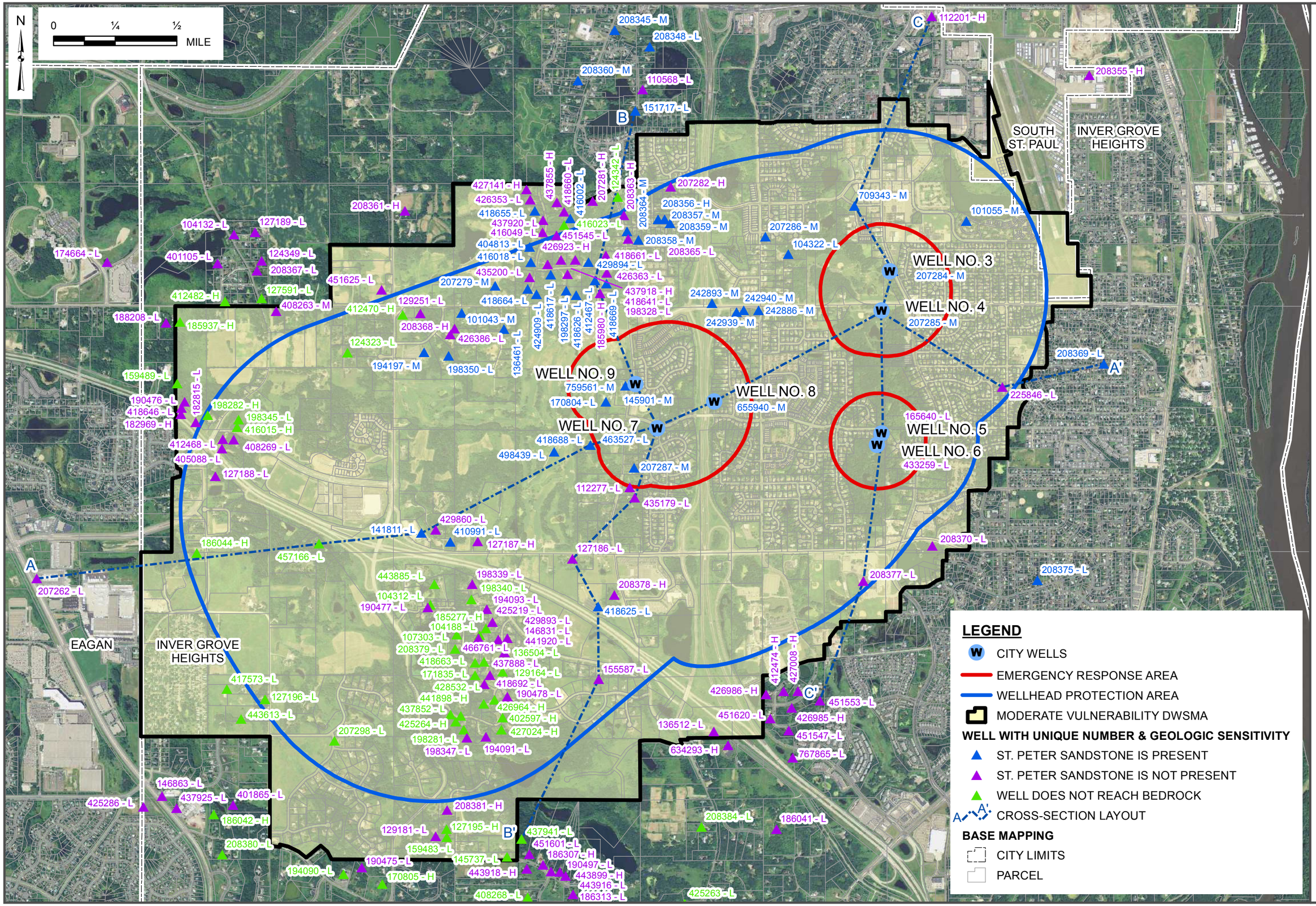

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V:\1938\active\193802191\GIS\Projects\Figure 4 - DWSMA Vulnerability.mxd

FIGURE 4 - DWSMA VULNERABILITY

INVER GROVE HEIGHTS WELLHEAD PROTECTION PLAN

July 2015

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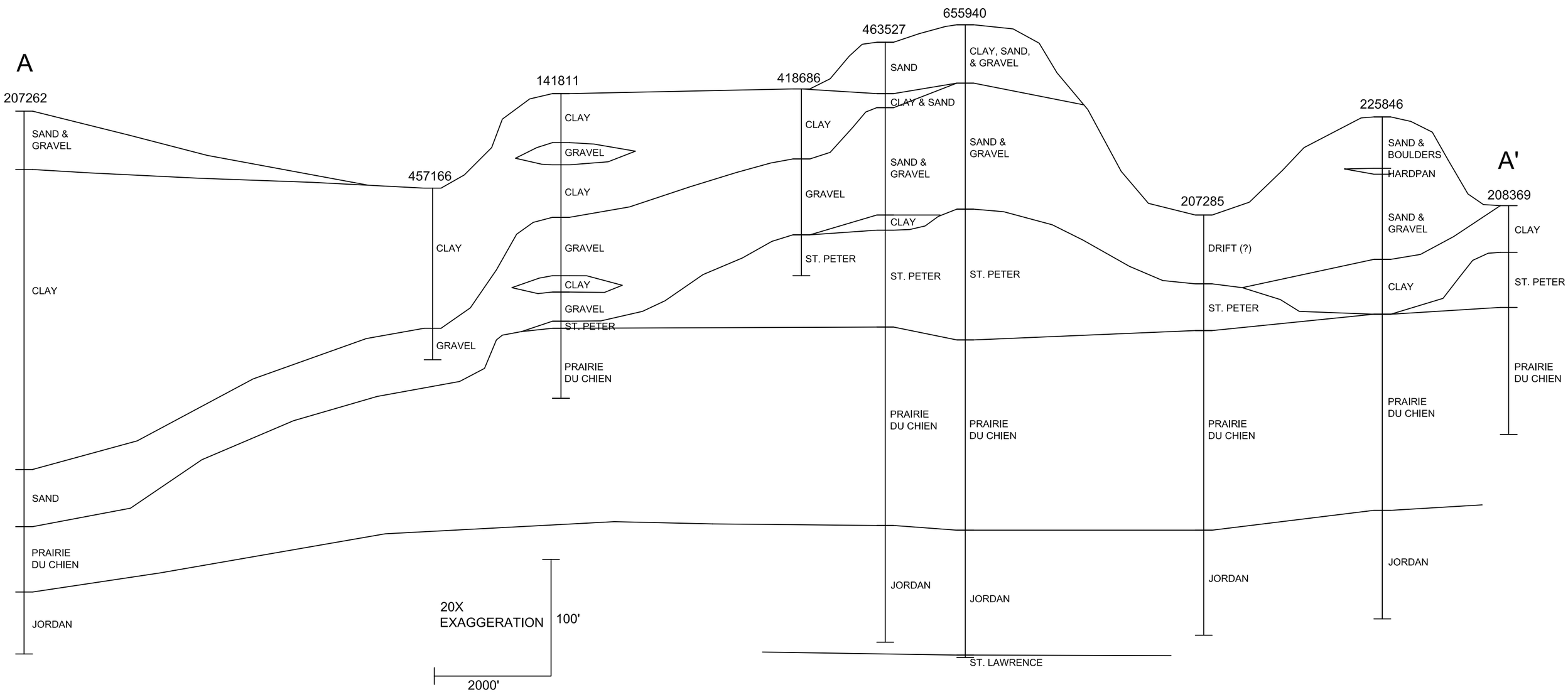
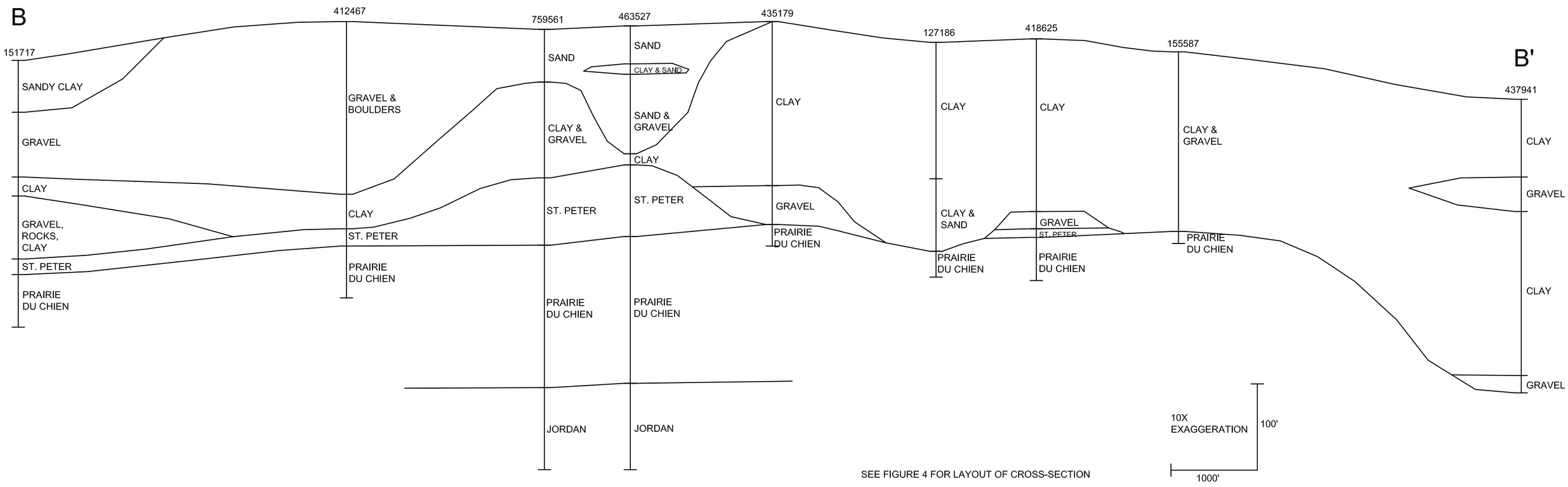
FIGURE 5 - INVER GROVE HEIGHTS GEOLOGIC CROSS-SECTION A-A'



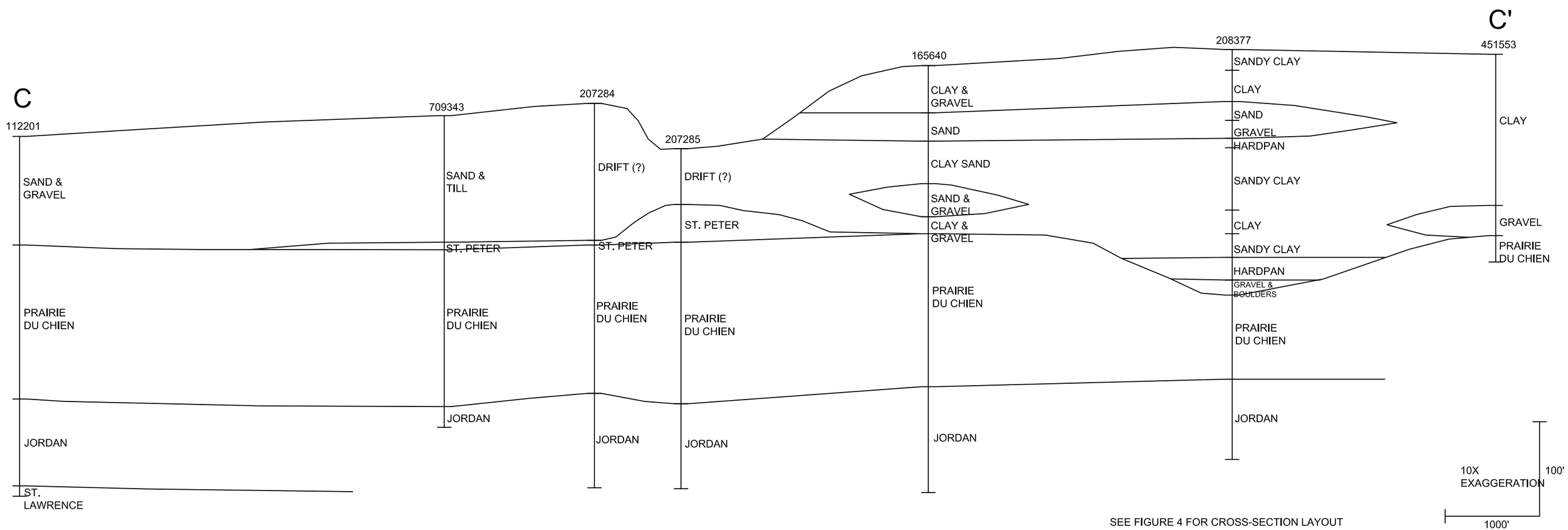
SEE FIGURE 4 FOR LAYOUT OF CROSS-SECTION

FIGURE 6 - INVER GROVE HEIGHTS GEOLOGIC CROSS-SECTION B-B'



SEE FIGURE 4 FOR LAYOUT OF CROSS-SECTION

FIGURE 7 - INVER GROVE HEIGHTS GEOLOGIC CROSS-SECTION C-C'



APPENDIX A

CITY OF INVER GROVE HEIGHTS WELL LOGS

Unique No. 00207284	MINNESOTA DEPARTMENT OF HEALTH	Update Date 2004/12/27
County Name Dakota	**WELL AND BORING RECORD**	Entry Date 1990/10/19
	Minnesota Statutes Chapter 1031	

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	3	CCBCCA

Well Depth	Depth Completed	Date Well Completed
407 ft.	407 ft.	1970/02/27

Well Name INVER GROVE HEIGHTS 3

Drilling Method

Contact's Name INVER GROVE HEIGHTS 3
6857 CAHILL AV
INVER GROVE HEIGHTS MN

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)**
30 in. t 155 ft
24 in. t 355 ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
GLACIAL DRIFT			0	145
ST. PETER SANDSTONE			145	150
SHAKOPEE-ONEOTA DOLO			150	307
JORDAN SANDSTONE			307	407

Screen
Make Type

Open Hole From ft. to ft.

Static Water Level 132 ft. from Land surface Date 1970/02/27

PUMPING LEVEL (below land surface)
155 ft. after hrs. pumping 1600 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
Mfr nam
Model HP 0 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

REMARKS, ELEVATION, SOURCE OF DATA, etc.

CASING: 030 TO 0155;024 TO 0355.

M.G.S. NO.541

WELL 3

USGS Quad Inver Grove Heights Elevation 866
Aquifer: CJDN Alt Id: 80-6052

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 27118
License Business Name
Name of Driller

Report Copy

Unique No. 00207285	MINNESOTA DEPARTMENT OF HEALTH	Update Date 2004/12/27
County Name Dakota	**WELL AND BORING RECORD**	Entry Date 1990/10/19
	Minnesota Statutes Chapter 1031	

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	9	AAAAAC

Well Depth	Depth Completed	Date Well Completed
360 ft.	360 ft.	1970/03/31

Well Name INVER GROVE HEIGHTS 4

Drilling Method

Contact's Name INVER GROVE HEIGHTS 4
2800 70 ST
INVER GROVE HEIGHTS MN

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)
30 in. t	100 ft	
24 in. t	285 ft	

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
GLACIAL DRIFT			0	59
ST. PETER SANDROCK			59	99
SHAKOPEE-ONEOTA DOLO			99	270
JORDAN SANDSTONE			270	360

Screen
Make Type

Open Hole From ft. to ft.

Static Water Level 87 ft. from Land surface Date 1970/03/31

PUMPING LEVEL (below land surface)
226 ft. after hrs. pumping 1800 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
Mfr nam
Model HP 0 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

REMARKS, ELEVATION, SOURCE OF DATA, etc.

MGS 542 CITY WELL NO. 4

CASING: 030 TO 0100;024 TO 0285.

M.G.S. NO.542

USGS Quad Inver Grove Heights Elevation 807
Aquifer: CJDN Alt Id: 80-6052

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 27118
License Business Name
Name of Driller

Report Copy

Unique No. 00165640	MINNESOTA DEPARTMENT OF HEALTH	Update Date 2004/12/27
County Name Dakota	**WELL AND BORING RECORD**	Entry Date 1990/12/02
	Minnesota Statutes Chapter 1031	

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	9	DAAAAB

Well Depth	Depth Completed	Date Well Completed
452 ft.	452 ft.	1980/01/01

Well Name INVER GROVE HEIGHTS 5

Drilling Method

Contact's Name INVER GROVE HEIGHTS 5
8650 COURTHOUSE BL
INVER GROVE HEIGHTS MN

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)**
16 in. t 358 ft
24 in. t 182 ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
CLAY & GRAVEL	RED		0	50
SAND	RED		50	80
CLAYISH SAND	BROW		80	125
SAND & GRAVEL	BROW		125	160
CLAY & GRAVEL	BROW		160	178
LIMEROCK	YELLO		178	340
SANDSTONE	WHITE		340	370
SANDSTONE	YELLO		370	400
SANDSTONE	WHITE		400	410
SANDSTONE	GRAY		410	452

Screen N
Make Type

Open Hole From 358 ft. to 452 ft.

Static Water Level 171 ft. from Land surface Date 1979/12/00

PUMPING LEVEL (below land surface)
315 ft. after hrs. pumping 1500 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
Mfr nam
Model HP 0 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

REMARKS, ELEVATION, SOURCE OF DATA, etc.

CASING: 024 TO 0182;016 TO 0358.

M.G.S. NO.1598

USGS Quad Inver Grove Heights Elevation 882
Aquifer: CJDN Alt Id: 80-6052

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 02015
License Business Name
Name of Driller

Report Copy

Unique No.	00433259	MINNESOTA DEPARTMENT OF HEALTH	Update Date	2004/12/27
County Name	Dakota	**WELL AND BORING RECORD**	Entry Date	1990/03/26
		Minnesota Statutes Chapter 1031		

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	9	DAADBD

Well Depth	Depth Completed	Date Well Completed
1044 ft.	1044 ft.	1987/10/14

Well Name INVER GROVE HEIGHTS 6

Drilling Method

Contact's Name INVER GROVE HEIGHTS 6

INVER GROVE HEIGHTS MN

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)
24	in. t	446	ft
18	in. t	802	ft
30	in. t	170	ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND + GRAVEL	BROW	SOFT	0	167
SHAKOPEE	TAN	HARD	167	332
JORDAN	WHITE	MEDIUM	332	420
JORDAN	WHITE	MEDIUM	420	433
ST. LAWRENCE	GRAY	HARD	433	472
FRANCONIA	GREE	HARD	472	505
IRONTON-GALESVILLE	GREE	MEDIUM	505	635
IRONTON-GALESVILLE	GREE	MEDIUM	635	680
EAU CLAIRE	GREE	HARD	680	690
EAU CLAIRE	GREE	HARD	690	780
MT. SIMON-HINCKLEY	GRAY	MEDIUM	780	980
MT. SIMON-HINCKLEY	GRAY	MEDIUM	980	1040
RED CLASTICS	RED		1040	1044

Screen N

Open Hole From 802 ft. to 1044 ft.

Make Type

Static Water Level 216 ft. from Land surface Date 1987/10/10

PUMPING LEVEL (below land surface)

312 ft. after hrs. pumping 1500 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

Mfr nam

Model HP 0 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

REMARKS, ELEVATION, SOURCE OF DATA, etc.

M.G.S. NO.2793.

USGS Quad Inver Grove Heights Elevation 885

Aquifer: CMSH Alt Id: 80-605

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 62012

License Business Name

Name of Driller CALVIN, M

Report Copy

Unique No. 00463527	MINNESOTA DEPARTMENT OF HEALTH	Update Date 2004/12/27
County Name Dakota	**WELL AND BORING RECORD**	Entry Date 1992/12/04
	Minnesota Statutes Chapter 1031	

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	9	BCCDDA

Well Depth	Depth Completed	Date Well Completed
514 ft.	514 ft.	1990/10/17

Well Name INVER GROVE HEIGHTS 7

Drilling Method Cable Tool

Contact's Name INVER GROVE HEIGHTS 7

INVER GROVE HEIGHTS MN 55077

Drilling Fluid

Well Hydrofractured? ☐ Yes ☐ No

From ft. to ft.

Use Community Supply (municipal)

Casing **Drive Shoe?** ☐ Yes ☐ N

Hole Diameter

0 in. t 120 ft

0 in. t 514 ft

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

30 in. t 120 ft

18 in. t 420 ft

24 in. t 202 ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND	BROW	SOFT	0	44
CLAY AND SAND	BROW	SOFT	44	56
SAND AND GRAVEL	BROW	MEDIUM	56	148
CLAY	BROW	MEDIUM	148	161
SANDSTONE	YELLO	SOFT	161	201
SANDSTONE	YELLO	MEDIUM	201	244
SHAKOPEE	GRAY	HARD	244	414
JORDAN	GRAY	MEDIUM	414	485
JORDAN SHALEY	BLUE	MEDIUM	485	514

Screen N

Open Hole From 420 ft. to 514 ft.

Make Type

Static Water Level 209 ft. from Land surface Date 1990/10/22

PUMPING LEVEL (below land surface)

247 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

Material	From	To (ft.)	Amount(yds/bags)	
G	0	120	7	Y
G	0	420	25	Y

Nearest Known Source of Contamination

ft. direction type

Well disinfected upon completion? ☐ Yes ☐ No

Pump ☑ Not Installed Date Installed N

Mfr nam

Model HP 0 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

REMARKS, ELEVATION, SOURCE OF DATA, etc.

M.G.S. NO. 3367.

USGS Quad Inver Grove Heights Elevation 944

Aquifer: CJDN Alt Id: 80-605

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 62012

License Business Name

Name of Driller

Report Copy

Unique No. 00655940	MINNESOTA DEPARTMENT OF HEALTH	Update Date 2006/12/05
County Name Dakota	**WELL AND BORING RECORD**	Entry Date / / 0
	Minnesota Statutes Chapter 1031	

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	9	BDCBAA

Well Depth	Depth Completed	Date Well Completed
542 ft.	542 ft.	2004/05/00

Well Name INVER GROVE HEIGHTS 8

Drilling Method Cable Tool

Well Owner's Name INVER GROVE HEIGHTS
2307 75TH E ST
INVER GROVE HEIGHTS MN 55077

Drilling Fluid Water

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

Contact's Name CITY OF INVER GROVE HEIGHTS
8150 BARBARA AV
INVER GROVE HEIGHTS MN 55077

Use Community Supply (municipal)

Casing **Drive Shoe?** ☑ Yes ☐ N

Hole Diameter
in. t 213 ft
in. t 542 ft

Casing Diameter **Weight(lbs/ft)**
24 in. t 213 ft
30 in. t 168 ft
18 in. t 435 ft

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
CLAY, SAND, GRAVEL	BROW	SOFT	0	50
SAND, GRAVEL, BOULDER	BROW	SOFT	50	125
SAND, GRAVEL	BROW	SOFT	125	158
SANDSTONE	YELLO	SOFT	158	256
SANDSTONE & SHALE	GRAY	MEDIUM	256	270
LIMESTONE	GRAY	HARD	270	433
SANDSTONE	GRAY	MEDIUM	433	490
SANDSTONE & SHALE	GRAY	MEDIUM	490	540
SHALE	GRAY	MEDIUM	540	542

Screen N
Make Type

Open Hole From 213 ft. to 542 ft.

Static Water Level 240 ft. from Land surface Date 2004/05/02

PUMPING LEVEL (below land surface)
273 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	213	16	Y
G		435	29	Y

Nearest Known Source of Contamination
200 ft. direction S 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 Inver Grove Heights Elevation 957
Aquifer: OPCJ Alt Id: 80-6052

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 62012
License Business Name
Name of Driller GALVIN, M.

Report Copy

Unique No.	00759561	MINNESOTA DEPARTMENT OF HEALTH	Update Date	2011/04/08
County Name	Dakota	**WELL AND BORING RECORD**	Entry Date	2008/04/11

Minnesota Statutes Chapter 1031

Township Name	Township	Range	Dir	Section	Subsection
	27	22	W	8	ADAADC

Well Depth	Depth Completed	Date Well Completed
510 ft.	510 ft.	2008/09/30

Well Name INVER GROVE HEIGHTS 9

Drilling Method Cable Tool

Well Owner's Name INVER GROVE HEIGHTS 9
7302 BABCOCK TR
INVER GROVE HEIGHTS MN 55077

Drilling Fluid Bentonite

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

Contact's Name CITY OF INVER GROVE HEIGHTS
8150 BARBARA AV
INVER GROVE HEIGHTS MN 55077

Use Community Supply (municipal)

Casing **Drive Shoe?** ☑ Yes ☐ N

Hole Diameter

in. t	210	ft	
in. t	418	ft	
in. t	507	ft	

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

30	in. t	201	ft	118
24	in. t	216	ft	94
18	in. t	425	ft	70.53

GEOLOGICAL MATERIAL	COLOR	HARDNESS	FROM	TO
SAND	BROW	MEDIUM	0	61
CLAY & GRAVEL	BROW	MEDIUM	61	70
SAND	BROW	MEDIUM	70	72
CLAY & GRAVEL	BROW	MEDIUM	72	172
ST. PETER SANDSTONE	TAN	SFT-MED	172	250
SHAKOPEE DOLOMITE	TAN	V.HARD	250	345
ONEOTA/DOLOMITE	LT. GR	V.HARD	345	415
JORDAN SANDSTTONE	LT. GR	SOFT	415	510

Screen N
Make Type

Open Hole From 418 ft. to 510 ft.

Static Water Level 210 ft. from Land surface Date 2008/09/09

PUMPING LEVEL (below land surface)
273.4 ft. after 9 hrs. pumping 2000 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		201	12	Y
G		418	29.5	Y

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

Pump ☐ Not Installed Date Installed
Mfr nam GOULD
Model 14R5LX HP 150 Volts 480
Drop Pipe Length 300 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

REMARKS, ELEVATION, SOURCE OF DATA, etc.

M.G.S. NO. 4821.

NOTE: GRADE CHANGED UP 6FT AFTER WELL DRILLED. FF-33

ELEVATION: 950 FT MSGS QUAD: D103

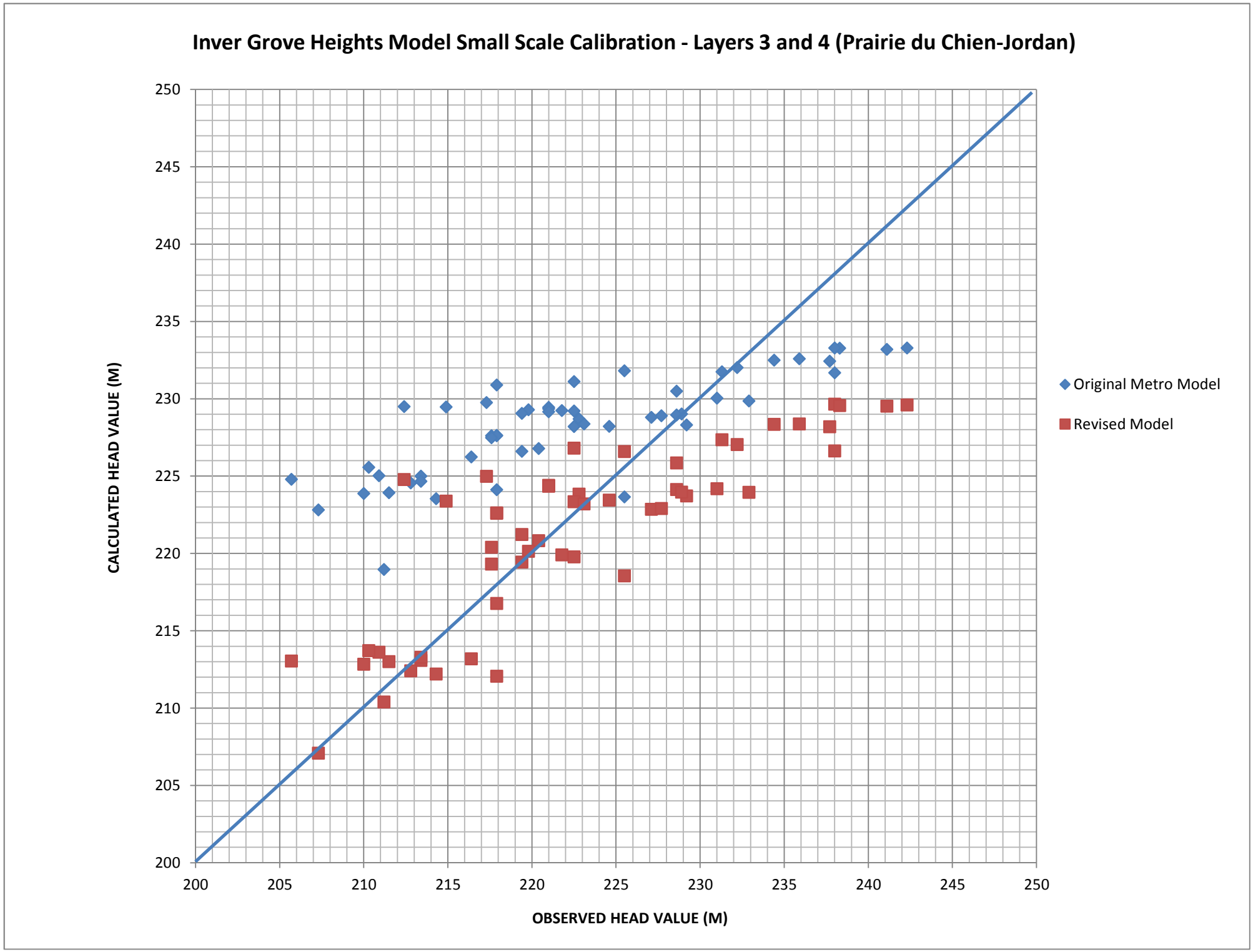
USGS Quad Inver Grove Heights Elevation 951
Aquifer: CJDN Alt Id: 4821

Well CONTRACTOR CERTIFICATION Lic. Or Reg. No. 1431
License Business Name
Name of Driller LEDBETER, L.

Report Copy

APPENDIX B

MODEL CALIBRATION COMPARISONS


Inver Grove Heights Model Small Scale Calibration - Layers 3 and 4 (Prairie du Chien-Jordan)
CALCULATED HEAD VALUE (M)
OBSERVED HEAD VALUE (M)
200
205
210
215
220
225
230
235
240
245
250
Original Metro Model
Revised Model

APPENDIX C

WELL VULNERABILITY ASSESSMENT WORKSHEETS

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: 1190014
SYSTEM NAME: Inver Grove Heights
WELL NAME: Well #3

TIER: 2
WHP RANK:
UNIQUE WELL #: 00207284

COUNTY: Dakota | TOWNSHIP NUMBER: 27 | RANGE: 22 W | SECTION: 3 | QUARTERS: CCBC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Very low	0
L Score	:	4	
Geologic Data From	:	Well Record	
Year Constructed	:	1970	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	355	5
Well Depth	:	407	
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	:	1200	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	2.4 07/13/1990	10
Maximum tritium detected	:	2.7 07/12/2000	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		35
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS
L score is interpreted from the logs of wells 1,2, and 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: 1190014
SYSTEM NAME: Inver Grove Heights
WELL NAME: Well #4

TIER: 2
WHP RANK:
UNIQUE WELL #: 00207285

COUNTY: Dakota | TOWNSHIP NUMBER: 27 | RANGE: 22 W | SECTION: 9 | QUARTERS: AAAA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Very low	0
L Score	:	4	
Geologic Data From	:	Data Inferred From Nearby Wells	
Year Constructed	:	1970	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	285	5
Well Depth	:	360	
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	:	1200	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<1 09/01/1972	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		25
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS
L score is interpreted from wells 1,2, and 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: 1190014 | TIER: 2
SYSTEM NAME: Inver Grove Heights | WHP RANK:
WELL NAME: Well #5 | UNIQUE WELL #: 00165640

COUNTY: Dakota | TOWNSHIP NUMBER: 27 | RANGE: 22 W | SECTION: 9 | QUARTERS: DAAA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Very low	15
L Score	:	5	
Geologic Data From	:	Well Record	
Year Constructed	:	1980	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	358	5
Well Depth	:	452	
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	:	1000	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4 07/13/1990	0
Maximum tritium detected	:	5.17 05/14/2008	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		30
Wellhead Protection Vulnerability Rating	:		VULNERABLE

Vulnerability Overridden :

COMMENTS

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

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

PWSID: 1190014 | TIER: 2
SYSTEM NAME: Inver Grove Heights | WHP RANK:
WELL NAME: Well #6 | UNIQUE WELL #: 00433259

COUNTY: Dakota | TOWNSHIP NUMBER: 27 | RANGE: 22 W | SECTION: 29 | QUARTERS: DAAD

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Mt. Simon-Hinckley	
DNR Geologic Sensitivity Rating	:	Very low	0
L Score	:	14	
Geologic Data From	:	Well Record	
Year Constructed	:	1987	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	802	0
Well Depth	:	1044	
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	:	1200	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4 07/13/1990	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	A	-20
Wellhead Protection Score	:		0
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS

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

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

PWSID: 1190014 | TIER: 2
SYSTEM NAME: Inver Grove Heights | WHP RANK:
WELL NAME: Well #7 | UNIQUE WELL #: 00463527

COUNTY: Dakota | TOWNSHIP NUMBER: 27 | RANGE: 22 W | SECTION: 9 | QUARTERS: BC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	1	
Geologic Data From	:	Well Record	
Year Constructed	:	1990	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	420	0
Well Depth	:	514	
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	:	1300	20
Pathogen Detected?			NOT VULNERABLE
Surface Water Characteristics?			NOT VULNERABLE
Maximum nitrate detected	:	<.05 11/15/1993	NOT VULNERABLE
Maximum tritium detected	:	<.8 05/06/2009	NOT VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		40
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: 1190014
SYSTEM NAME: Inver Grove Heights
WELL NAME: Well #8

TIER: 2
WHP RANK:
UNIQUE WELL #: 00655940

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

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	0
L Score	:	5	
Geologic Data From	:	Well Record	
Year Constructed	:	2004	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	435	0
Well Depth	:	542	
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	:	<.05 05/19/2014	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: 1190014
SYSTEM NAME: Inver Grove Heights
WELL NAME: Well #9

TIER: 2
WHP RANK:
UNIQUE WELL #: 00759561

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

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	2008	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	425	0
Well Depth	:	510	
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?		No	0
Isolation distance violations?			0
Pumping Rate	:	1400	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.05 05/19/2014	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		40
Wellhead Protection Vulnerability Rating	:		NOT VULNERABLE
Vulnerability Overridden	:		

COMMENTS
Nearby well No. 7 (463527) has no tritum and similar construction to this well.

APPENDIX D

ASSESSMENT OF DATA ELEMENTS

Assessment of the Data Elements

This table presents the assessment of these data elements relative to the present and future implications of planning items that are specified in Minnesota Rules, part 4720.5210.

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	L	M	M	M	MN Climatology Office
Geology					
Maps and geologic descriptions	M	H	H	H	MGS
Subsurface data	M	H	H	H	MGS, MDH, CWI
Borehole geophysics	M	H	H	H	MGS
Surface geophysics	L	L	L	L	Not Available
Maps and soil descriptions	L	L	M	M	NRCS
Eroding lands					
Water Resources					
Watershed units	M	H	H	H	DNR, USGS
List of public waters	M	H	H	H	DNR
Shoreland classifications					
Wetlands map					
Floodplain map					
Land Use					
Parcel boundaries map	L	H	L	L	Dakota County, Inver Grove Heights
Political boundaries map	L	H	L	L	Inver Grove Heights, MnGEO
PLS map	L	H	L	M	MnGEO, MDH
Land use map and inventory					
Comprehensive land use map					
Zoning map					
Public Utility Services					
Transportation routes and corridors	L	H	L	L	MnGEO, MnDOT
Storm/sanitary sewers and PWS system map	L	M	M	M	Inver Grove Heights
Oil and gas pipelines map					
Public drainage systems map/list	L	H	M	M	Inver Grove Heights
Records of well construction, maintenance, and use	H	H	H	H	Inver Grove Heights, CWI, MDH Files
Surface Water Quantity					
Stream flow data	L	M	L	L	DNR, USGS
Ordinary high water mark data	L	M	L	L	DNR, USGS

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	
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, Inver Grove Heights
Groundwater use conflicts	M	M	M	M	DNR
Water levels	H	H	H	H	CWI, MDH, Inver Grove Heights

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	
Surface Water Quality					
Stream and lake water quality management classification					
Monitoring data summary	L	L	M	M	SWCD
Groundwater Quality					
Monitoring data	H	H	H	H	MDH
Isotopic data	H	H	H	H	MDH
Tracer studies	H	H	H	H	Not Available
Contamination site data	M	M	M	M	Not Available
Property audit data from contamination sites					
MPCA and MDA spills/release reports	M	M	M	L	MPCA, MDA

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

Acronyms used in this report are listed on page ii, after the "Glossary of Terms."

APPENDIX E

ELECTRONIC DATA FILES

(see attached files on CD-ROM)