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January 13, 2010

Mr. Steve Robertson
Drinking Water Protection Section
Minnesota Department of Health
625 Robert Street N.
P.O. Box 64975
St. Paul, MN 55164-0975

Re: Amendment to City of Rosemount Part 1 Wellhead Protection Plan

Dear Mr. Robertson:

As you know, the City of Rosemount, Minnesota constructed new municipal water supply Well 12 (unique number 706804) in 2004, Well 14 (722623) in 2005, and Well 15 (753663) in 2008 (see Attachment A for well records). The City's Wellhead Protection Area (WHPA) and Drinking Water Supply Management Area (DWSMA) were delineated in 2002 (Barr, 2002). Also, since the last delineation of the City's WHPA and DWSMA the MDH has instituted additional requirements for inclusion of fracture flow analysis. On behalf of the city of Rosemount, this letter is intended to amend Part 1 of the Rosemount Wellhead Protection Plan and to fulfill the requirements of Minnesota Rule 4720.5570.

This amendment summarizes work completed to update the WHPA and DWSMA for the City of Rosemount. This work includes the addition of Wells 12, 14, and 15 to the groundwater flow model, updating projected pumping rates for all wells, and the delineation of updated fracture flow and porous media capture zones for all wells. Based on these updates, a new WHPA and DWSMA were delineated. Well and aquifer vulnerabilities were also reassessed and updated.

Wellhead Protection Area Delineation

Delineation of the WHPA for the Rosemount wells involved the evaluation of both porous-media and fracture flow. First, the capture zones for each well were delineated based on porous-media flow and then the capture zones were also delineated according to the procedures described in the MDH guidance for WHPA delineations in fractured and solution-weathered bedrock (MDH, 2005).

Fracture flow capture zones were deemed necessary because pumping test results from Wells 7, 8, and 9 (Barr, 2002), along with groundwater modeling, show that leakage occurs from the Prairie du Chien Group to the Jordan Sandstone. Since a hydraulic connection exists between the Jordan Sandstone Aquifer and the Prairie du Chien Group Aquifer in the Rosemount area, and the Prairie du Chien Group is considered a fractured aquifer in the Twin Cities Area, fracture flow delineations are necessary.

Data Elements

The major data elements used in preparing this amendment are consistent with those in Rosemount's original Part 1 Wellhead Protection Plan from 2002 (Barr, 2002). The following highlights data elements identified in the Scoping Decision Notice Number 1 (MDH, 2009) that have changed or were not considered in the previous plan.

Precipitation

The average monthly and annual precipitation for the last five years are shown in Table 1. Recharge for the groundwater flow model was determined using the SWB recharge model of the Rosemount Area developed by Barr Engineering (Barr, 2009).

Geology

All of the Rosemount municipal wells are open to the Jordan Sandstone aquifer. The bedrock geology of the Rosemount Area is shown on Figure 1. Three new geologic cross-sections are shown on Figures 2, 3 and 4. The hydrologic conceptual model is presented Barr (2002) and Barr (2009). Aquifer transmissivity as determined from calibration of the groundwater flow model was used for updating the WHPA. The transmissivity of the Jordan Sandstone closely matches that determined from pumping tests using Rosemount Wells 7, 8, and 9 (Barr, 2002), Well 14 (MDH, 2006), and Well RR1 (Delta, 1991). Well records from the county well index were reviewed during construction of the groundwater flow model and for the assessment of aquifer vulnerability.

Soils

Maps of soils, along with information on each soils hydrologic group (A, B, C, D) from the Natural Resources Conservation Service (NRCS) and Soil Survey Geographic Database (SSURGO) were used in the SWB recharge model to help define recharge rates used in the groundwater flow model. Surficial geology from Meyer (2007) was used for assessing aquifer vulnerability.

Land Use

Land cover data from the USGS (2003) was used in the SWB recharge model. Parcels were used in delineating the DWSMA. A listing of parcels is included in Attachment B on the enclosed CD.

Public Utility Services

The projected daily volume of water pumped by Rosemount's municipal wells used for WHPA delineations was calculated based on historical pumping records. First, a projected water use for 2014 was estimated based on the City's Comprehensive Water System Plan (WSB, 2007). Second, total annual volume pumped by the City's wells was determined for the period 2004 through 2008 from the City's Minnesota Department of Natural Resources (MDNR) Water Use Reports.

Once the total annual volume was determined for the period 2004 through 2008, the projected pumping of each well for the year 2014 was determined. First, the annual percentage of the total volume pumped by each of the wells during each of the last five years was determined and averaged (Table 2). Projected annual pumping for the year 2014 from each of the City's wells was determined by distributing the projected 2014 total annual volume amongst the wells using the average annual percentage for each well (Table 2). Table 2 summarizes the historical and projected distribution of the annual withdrawal among Rosemount's municipal wells. Unaccounted for water is typically around 10% of total usage (WSB, 2007).

Surface Water Quantity

Baseflow measurements for the Vermillion River from EOR (2007) and Metropolitan Council (2009) were used during calibration of the groundwater flow model. For details about the different baseflow reaches in the model and how they were used during model calibration see Barr (2009).

Groundwater Quantity

High capacity wells with water use permit records maintained by the Minnesota Department of Natural Resources (DNR) through the State Water Use Data System (SWUDS) were included in groundwater flow model. Pumping rates for these wells were based on average reported water use from 2003-2007. A list of high capacity wells included in the model is presented in Attachment E. There are currently no known conflicts related to well interference or groundwater withdrawal effects on surface water.

Surface Water and Groundwater Quality

Surface water and groundwater quality data is collected regularly and submitted to the appropriate public agency (e.g. MDH, MPCA). No additional, unreported, data is known.

Criteria for Wellhead Protection Area Delineation

Time of Travel

A 10-year time of travel was used to delineate the new WHPA for the City of Rosemount.

Flow Boundaries

Major groundwater flow boundaries in the area consist of the Minnesota River to the northwest, the Mississippi River to the northeast, and the Vermillion River to the south. For groundwater flow modeling, the boundaries consisted of the Minnesota and Mississippi Rivers, a constant head boundary south of the Vermillion River, and a specified flux boundary to the west. The constant head and specified flux boundary values were determined from the Metro Model 2 (Metropolitan Council, 2009). Major rivers and lakes within the model domain, including the Vermillion River, are simulated using the River Package within MODFLOW.

Daily Volume

The projected daily pumping rate for each well was determined for year 2014 as described above and shown in Table 2. For each well the higher of the projected 2014 pumping or the maximum pumping observed during the period 2004 through 2008 was used as the pumping rate for the WHPA delineation.

Groundwater Flow Field

The groundwater flow field used for delineation of the WHPA was determined by the groundwater flow model and is consistent with that shown in Palen (1990).

Porous Media Flow Evaluation

The porous-media flow capture zone for each of the Rosemount wells was delineated using a slightly modified version of a groundwater flow model of the Rosemount area developed by Barr Engineering (Barr, 2009). This groundwater flow model is a TMR of the Metro Model 2 (Metropolitan Council, 2009) that was modified with additional model layers and refined geology and then recalibrated. The

groundwater flow model uses the modeling code MODFLOW-96 (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996).

Updates to Groundwater Flow Model

The groundwater flow model used for this study is described in detail in Barr (2009). Minor changes were incorporated into the groundwater flow model for this study. Pumping rates for the Rosemount wells were adjusted to reflect future pumping projections. Pumping rates for high capacity wells near Rosemount were adjusted and set at the average pumping rate for 2005-2007 based on MDNR Water Use Reports. The model grid was refined in the vicinity of the Rosemount municipal wells to allow for a more accurate delineation of the porous-media flow capture zones. The grid cell size was set at less than 10 x 10 meters around the wells and expands in size to 200 x 200 meters away from the wells.

As agreed upon at the March 11, 2009 pre-delineation meeting, no additional model calibration was conducted. Hydraulic conductivity values from the model correlate well with those determined from pumping tests using Rosemount Wells 7, 8, and 9 (Barr, 2002), Well 14 (MDH, 2006), and Well RR1 (Delta, 1991). The hydraulic conductivity for the Jordan Sandstone determined from the pumping tests ranged from 10.5 m/day to 19.4 m/day. The groundwater flow model uses a hydraulic conductivity ranging from 6.2 m/day to 16.6 m/day for the Jordan Sandstone near Rosemount (Figure 5).

Simulated hydraulic head values correlate well with measured values. The final optimized model had the following characteristics for hydraulic head calibration targets:

- Mean residual = -7.96 ft (-2.43m)
- Residual standard deviation = 19.39 ft (5.91 m)
- 98.7 % of head residuals within 10% of the range in head target values

Simulated hydraulic heads verses measured hydraulic heads are shown on Figure 6.

Particle Tracking

The regional groundwater flow direction for the Jordan Sandstone, as determined from the groundwater flow model, is generally consistent with that shown in the Dakota County Geologic Atlas (Palen, 1990). A large cone of depression is simulated in the Jordan Sandstone and Prairie du Chien Group near the Rosemount wells (Figure 7). The 1-year and 10-year porous-media flow

capture zones for the Rosemount wells were delineated using particle tracking from the groundwater flow model. A total of 1,600 particles were tracked from each well. Particles were released from 20 vertical points along the open section of each well within the Jordan Sandstone (~ 5 ft intervals). Porosity values for the Quaternary sediments, St. Peter Sandstone, Prairie du Chien Group and Jordan Sandstone were 0.25, 0.283, 0.056 and 0.2 respectively (Norvitch at al., 1974, Schwartz and Zhang, 2003). Particles were tracked backwards in time from each well for both one and ten years. When viewed in plan view, the area encompassed by the particle traces were then outlined as the one- and ten-year porous-media capture zones (Figure 8).

Uncertainty Analysis

Model parameter sensitivities and Akaike Information Criterion for alternative models are presented in Barr (2009).

Fracture Flow

The Prairie du Chien Group, which is classified as being highly fractured over much of the Twin Cities, has been shown to be hydraulically connected to the Jordan Sandstone in the Rosemount area (Barr, 2002; Palen, 1990). To address possible fracture flow to the wells, MDH (2005) guidelines for delineating WHPAs in fractured and solution-weathered bedrock were followed using delineation technique number 4. The volume of water in the Jordan Sandstone within the porous media capture zones, with the exception of wells 8 and 15, is less than 90 percent of the total volume of water pumped over the simulated 10 year period. This indicates that leakage is occurring from the Prairie du Chien Group. Leakage from the Prairie du Chien Group to the Jordan Sandstone is also supported by results of the pumping test at wells 7, 8, and 9 which indicate a leaky confining layer (Barr, 2002). Because there is leakage from the Prairie du Chien Group to the Jordan Sandstone, fracture flow should be accounted for in the delineation of the WHPA.

Fixed radius capture zones were also calculated for nearby high capacity wells (unique numbers 186301, 207617, 185278, 207615, and 207618). For these additional high capacity wells the average pumping rates from 2003-2007 were used. Projections of future pumping rates were determined only for the Rosemount municipal wells. The capture zones of these wells did not intersect the capture zones of the Rosemount municipal wells and were, therefore, not considered in the analysis.

The fixed radius fracture flow capture zones for the Rosemount wells were extended up-gradient based on the direction of groundwater flow as determined from the porous media groundwater flow model. Fracture flow capture zones were not extended along fracture orientations as no data are currently available indicating fracture orientations in the Rosemount area. A composite fracture-flow capture-zone was defined by combining the components of the fracture flow analysis for each individual well (Figure 8).

The capture zones for both porous media flow and fracture flow were combined to define the WHPA for the Rosemount Wells (Figure 9). The composite 1-year time of travel zones comprise the emergency response management zones (Figure 9). A summary of calculations used in the delineation of fracture flow capture zones is presented in Attachment F.

DWSMA Delineation

The DWSMA encompasses the entire WHPA as described above and is defined by geographically identifiable features (parcel boundaries and quarter-sections). The DWSMA extends into the cites of Apple Valley and Lakeville as well as Empire Township.

A listing of property parcels within the DWSMA is included in Attachment B on the enclosed CD.

Well Vulnerability Assessment

Well vulnerability scoring sheets from the Minnesota Department of Health are in Attachment C. All wells are classified as being vulnerable to surface contaminants.

DWSMA Vulnerability Assessment

Geologic logs listed in the Minnesota Geological Survey (MGS) County Well Index for wells in the vicinity of the DWSMA along with borehole logs from the UMore Park area in Rosemount (Barr 2009; ProSource Technologies, 2008) were reviewed and “L scores” based on the thickness of confining units above the Jordan Sandstone at each well location were assigned to each well (Attachment D). (See MnDNR (1991) for a discussion of how to determine L scores). L-scores were compared to the surficial geology map from Meyer (2007), the bedrock geology map from Mossler and Tipping (2000), and a map of the extent of till below the water table from Barr (2009, Figure 16). In general, areas where L-scores are less than 1 were assigned an aquifer vulnerability of

high, areas where L-scores are between 1 and 4 were assigned an aquifer vulnerability of moderate, and areas with L-scores greater than 4 were assigned an aquifer vulnerability of low. Well logs did not indicate the presence of a basal St. Peter Sandstone confining unit. Porous media groundwater flow modeling indicated that some 10-year particle tracks extend into the unconsolidated sediments. In areas where L-scores indicate low aquifer vulnerability but particles tracks extended to the unconsolidated sediments the aquifer vulnerability was modified to moderate vulnerability (Attachment D).

Model files and shapefiles pertaining to this amendment are included on the enclosed CD. Please contact me at (952) 832-2691 or Andy Brotzler at (651) 322-2025 if you have any questions concerning this WHPA/DWSMA delineation amendment.

I hereby certify that this amendment 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.

John Greer, P.G. (license no 30347)

Enclosures: Attachment A – Well Records, Attachment B – List of Parcels in DWSMA, Attachment C – MDH Well Vulnerability Scoring Sheets, Attachment D – DWSMA Vulnerability, Attachment E – High Capacity Wells in Model, Attachment F – Summary of Fracture Flow Capture Zone Calculations

cc: Andrew Brotzler, City of Rosemount
Nancy Ziegler, WSB & Associates, Inc.

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Table 1
Average Precipitation 2005-2009
Rosemount Agricultural Experiment Station
(COOP ID 217107)

Month	Precipitation (inches)	Year	Precipitation (inches)
Jan	1.02	2005[1]	24.65
Feb	1.01	2006	27.53
Mar	2.00	2007	36.79
Apr	2.91	2008	27.74
May	3.17	2009	29.21
Jun	3.49		
Jul	2.38		
Aug	6.43		
Sep	2.77		
Oct	3.31		
Nov	1.01		
Dec	1.77		

[1] Missing data for January to March, and August

Table 2
Annual and Projected Pumping Rates for Rosemount Wells

		Total Annual Withdrawl (gal/yr)				
Unique Number	Well Name	2004	2005	2006	2007	2008
211999	3	131,200,000	84,900,000	17,200,000	0	0
112212	7	131,600,000	212,800,000	152,900,000	174,700,000	171,698,600
509060	8	172,200,000	168,500,000	169,500,000	83,300,000	87,493,400
554248	9	254,800,000	250,500,000	298,000,000	231,500,000	159,850,300
706804	12	0	0	276,300,000	230,400,000	226,112,100
722623	14	0	0	0	179,900,000	215,847,000
753663	15	--	--	--	--	--
457167	RR1	22,300,000	26,500,000	22,000,000	17,500,000	21,889,000
474335	RR2	20,700,000	18,400,000	8,300,000	20,300,000	27,506,100
	Totals	689,800,000	716,700,000	913,900,000	899,800,000	861,001,400

Source: Rosemount's MDNR Annual Appropriation Reports

		Percentage of Annual Withdrawl					
Unique Number	Well Name	2004	2005	2006	2007	2008	Rosemount Planned Ave. Annual % of Withdrawal
211999	3	19.0%	11.8%	1.9%	0.0%	0.0%	0.0%
112212	7	19.1%	29.7%	16.7%	19.4%	19.9%	15.8%
509060	8	25.0%	23.5%	18.5%	9.3%	10.2%	15.8%
554248	9	36.9%	35.0%	32.6%	25.7%	18.6%	15.8%
706804	12	0.0%	0.0%	30.2%	25.6%	26.3%	15.8%
722623	14	0.0%	0.0%	0.0%	20.0%	25.1%	15.8%
753663	15	0.0%	0.0%	0.0%	0.0%	0.0%	15.8%
457167	RR1	3.2%	3.7%	2.4%	1.9%	2.5%	2.5%
474335	RR2	3.0%	2.6%	0.9%	2.3%	3.2%	2.5%

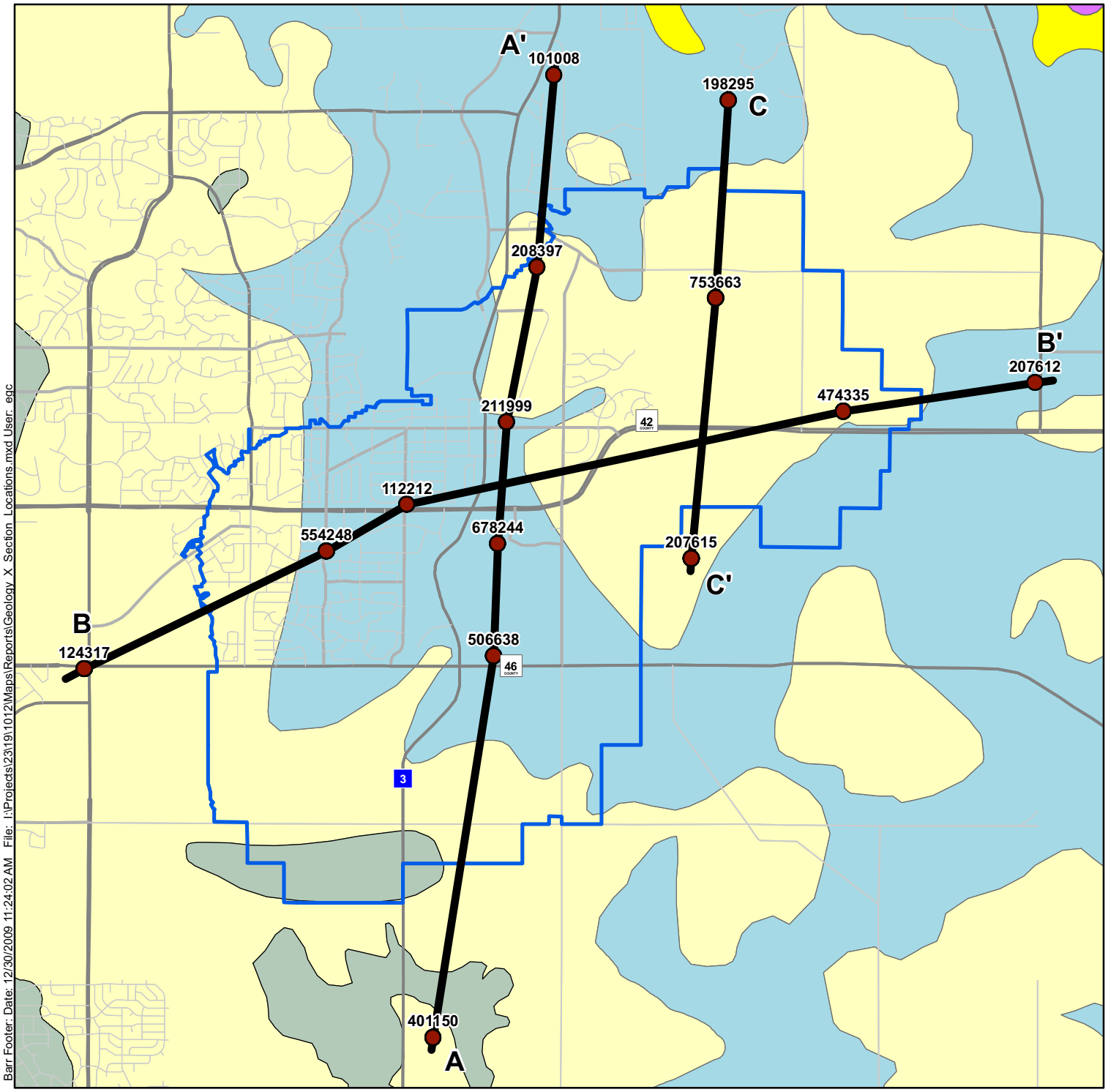
		Projected Water Use (2014)			Maximum Total Pumping for Model Input[4]		
Unique Number	Well Name	Total[1] (gal/yr)	% of Total Projected Water Use Well[2]	Projected Well Pumpage Based on %[3] (gal/yr)	gal/yr	gal/day	m^3/day
211999	3		0.0%	0	0	0	0
112212	7		15.8%	201,253,122	212,800,000	583,014	2,207
509060	8		15.8%	201,253,122	201,253,122	551,378	2,087
554248	9		15.8%	201,253,122	298,000,000	816,438	3,090
706804	12		15.8%	201,253,122	276,300,000	756,986	2,865
722623	14		15.8%	201,253,122	215,847,000	591,362	2,238
753663	15		15.8%	201,253,122	201,253,122	551,378	2,087
457167	RR1		2.5%	31,783,500	31,783,500	87,078	330
474335	RR2		2.5%	31,783,500	31,783,500	87,078	330
	Totals	1,271,340,000		1,006,265,610	1,204,200,122	3,299,178	12,487

[1] Projected 2014 water use presented in City's Water Supply Plan (WSB, 2007)

[2] Percentages are based on City of Rosemount planned usage through 2014.

[3] Estimated per well pumpage based on 2014 estimated water use and average % of annual withdrawal

[4] For each well, the greater of the estimated pumpage based on estimated 2014 water use and actual annual pumpage for 2004 through 2008



Map modifed from Mossler and Tipping (2000)

Bedrock Geology

- PLATTEVILLE-GLENWOOD FRMS.
- ST. PETER SANDSTONE
- PRAIRIE DU CHIEN GROUP
- JORDAN SANDSTONE
- ST.LAWRENCE-FRANCONIA FRMS.
- Wells
- DWSMA
- Geologic Cross Section Alignment

N

Miles
0 0.5 1

Kilometers
0 1 2

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Figure 1

BEDROCK GEOLOGY
WHPP Amendment
City of Rosemount
Dakota County, MN

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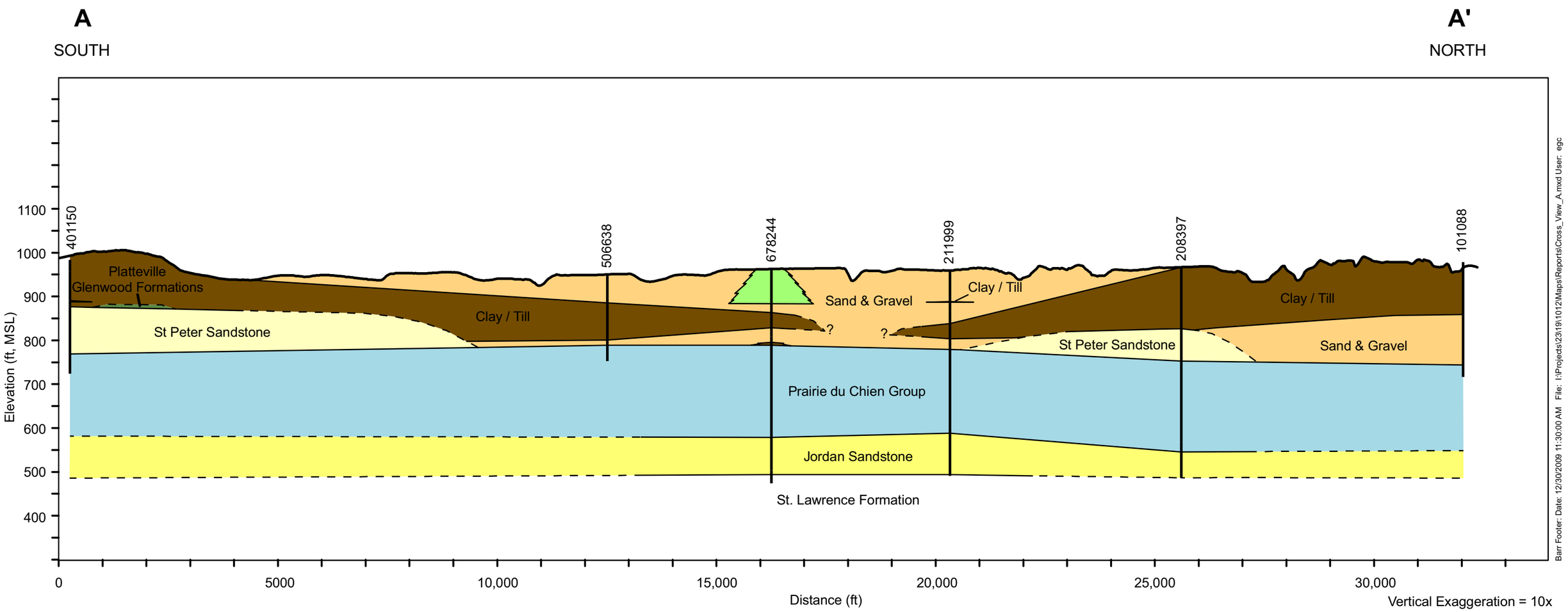

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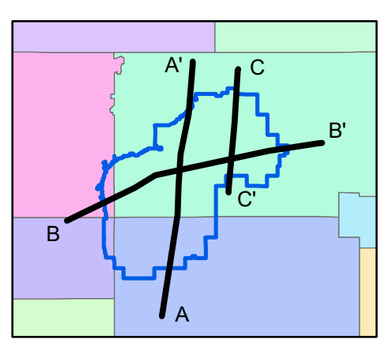
Lithology

- Sand and Gravel
- Clay / Till
- Clay Mixed with Sand and Gravel
- Platteville - Glenwood Formations
- St Peter Sandstone (OSTP)
- Prairie du Chien Group (OPDC)
- Jordan Sandstone (CJDN)

Cross Section Location Map



Notes

Extent of St. Peter Sandstone and Platteville - Glenwood Formations based on Mossler and Tipping (2000) and Barr (2009)

Dashed lines are inferred

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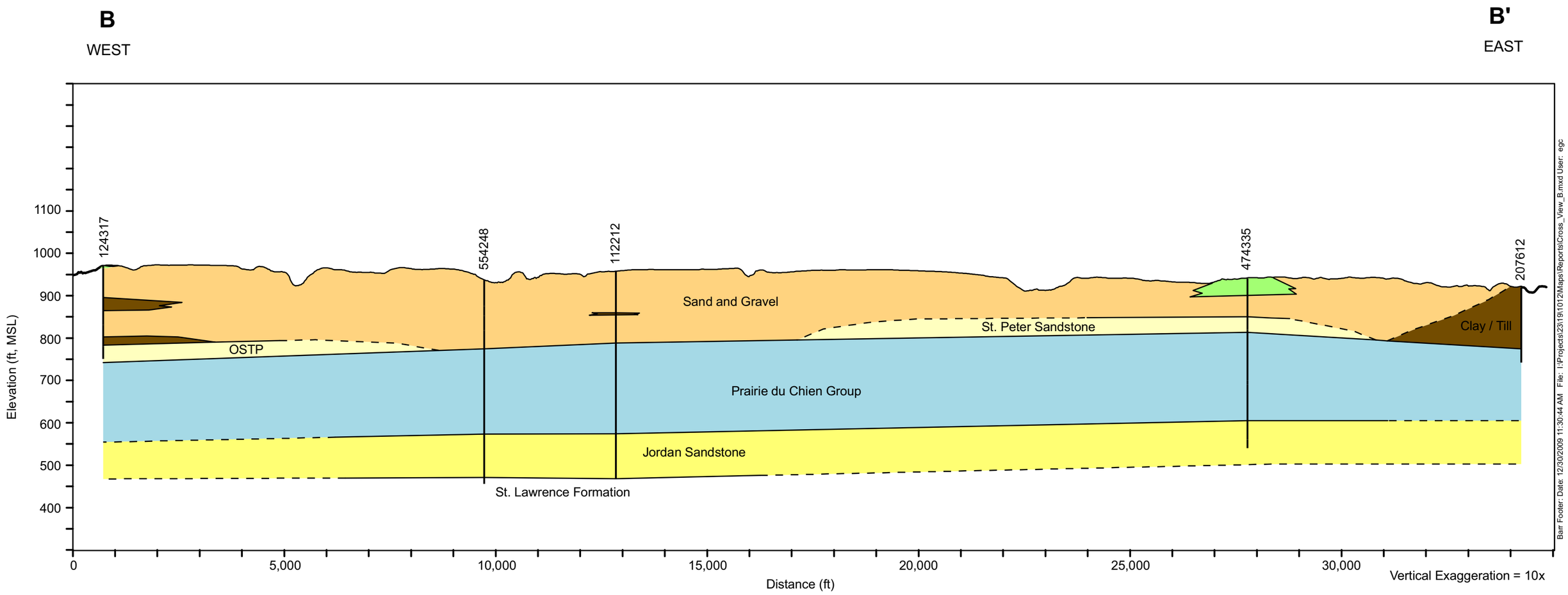
Figure 2

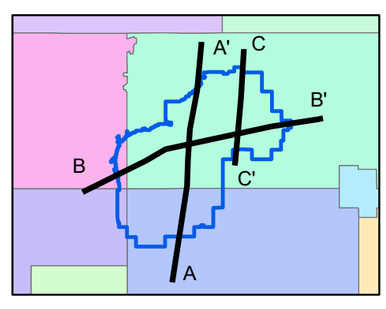
GEOLOGIC CROSS SECTION A-A'
WHPP Amendment
City of Rosemount
Dakota County, MN



Lithology

- Sand / Gravel
- Clay / Till
- Clay with Sand
- St. Peter Sandstone (OSTP)
- Prairie du Chien Group (OPDC)
- Jordan Sandstone (CJDN)

Cross Section Location Map



Notes

Extent of St. Peter Sandstone based on Mossler and Tipping (2000) and Barr (2009)

Dashed lines are inferred

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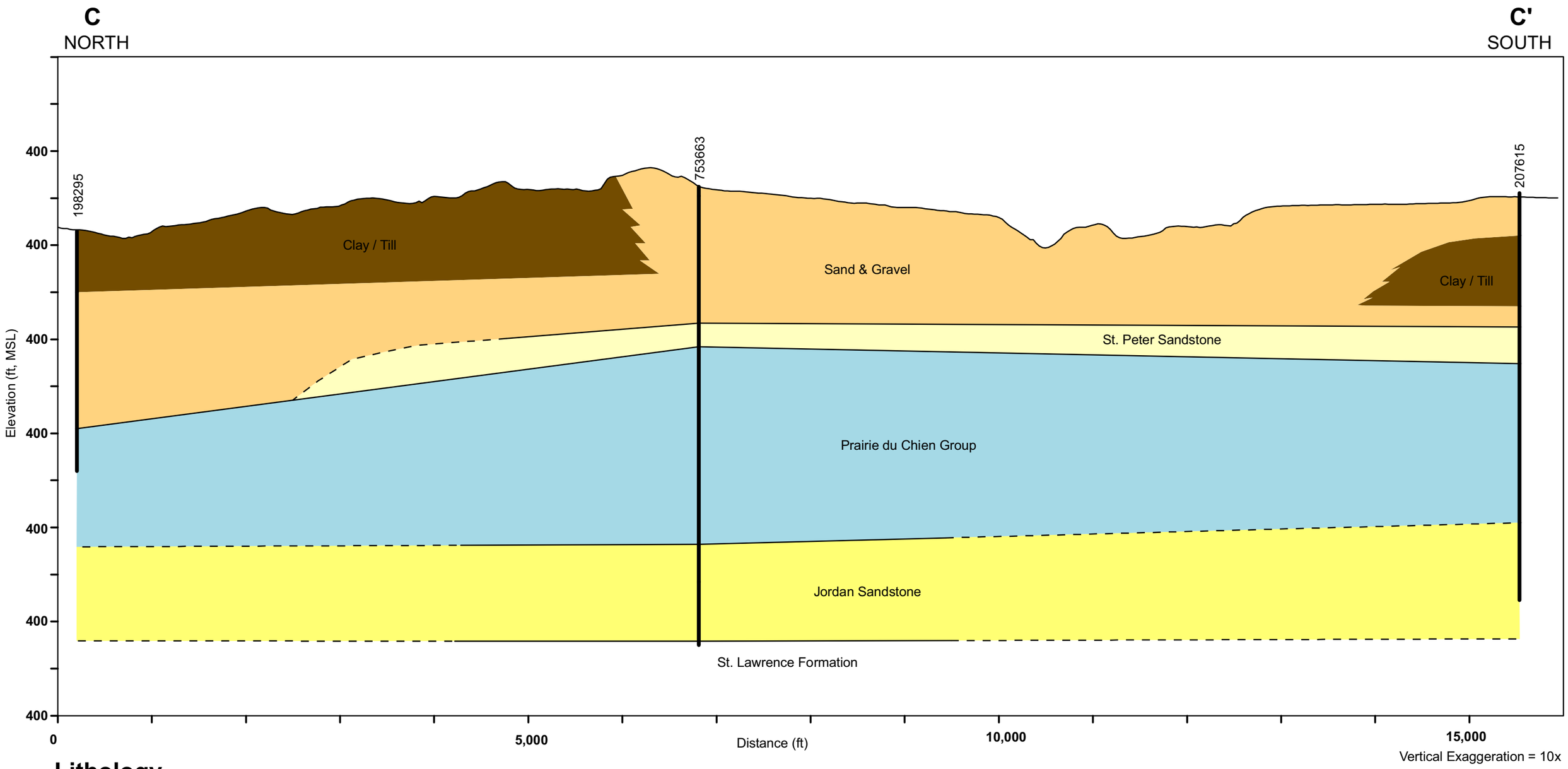
Figure 3

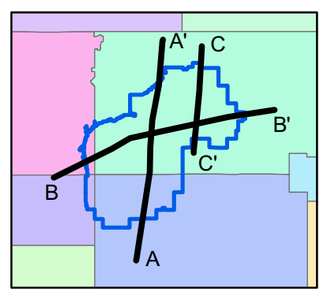
GEOLOGIC CROSS SECTION B-B'
WHPP Amendment
City of Rosemount
Dakota County, MN



Lithology

- Sand / Gravel
- Clay / Till
- St. Peter Sandstone (OSTP)
- Prairie du Chien Group (OPDC)
- Jordan Sandstone (CJDN)

Cross Section Location Map



Notes

Extent of St. Peter Sandstone based on Mossler and Tipping (2000) and Barr (2009)

Dashed lines are inferred

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Figure 4

GEOLOGIC CROSS SECTION C-C'
WHPP Amendment
City of Rosemount
Dakota County, MN

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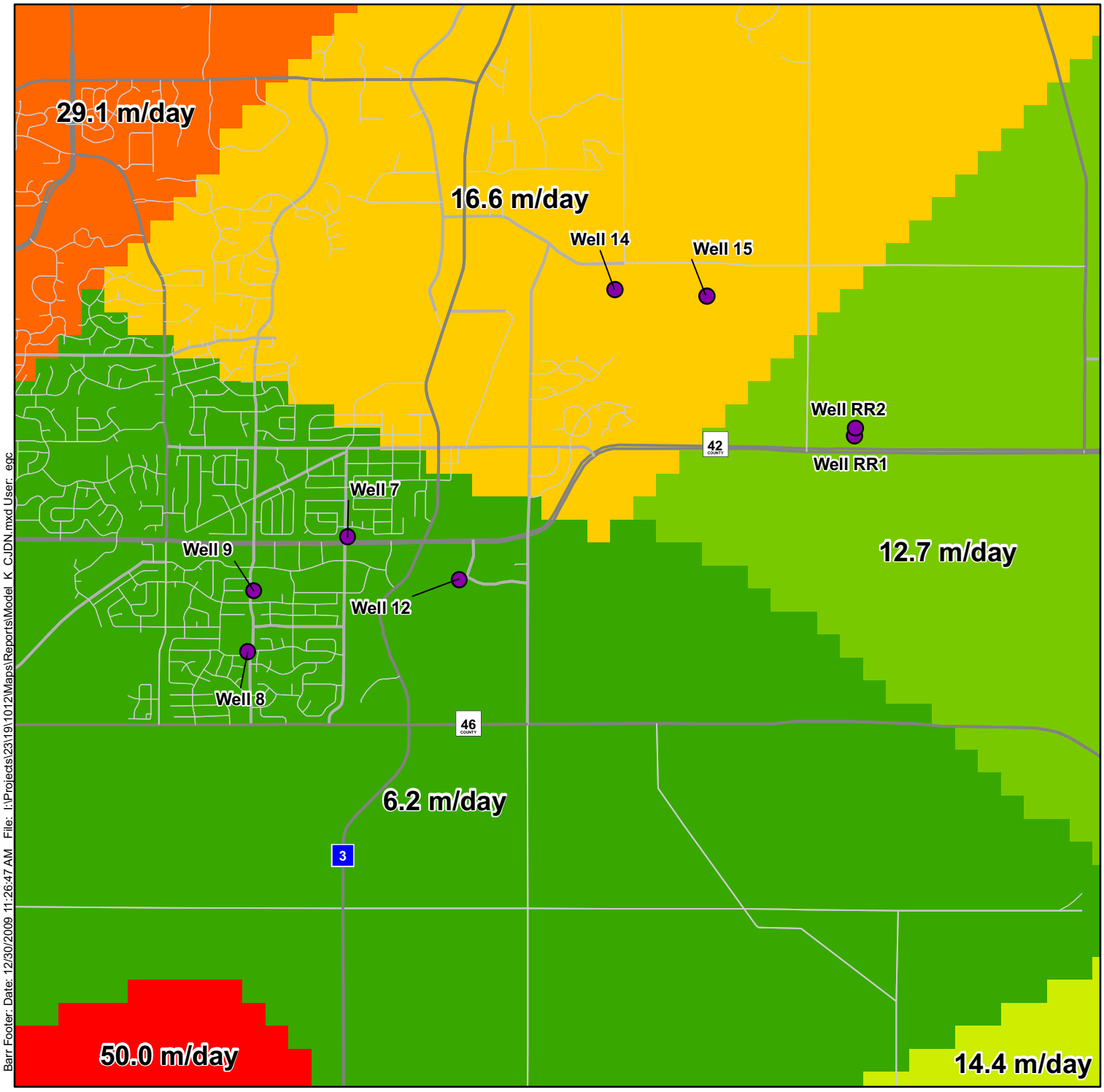

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Model Hydraulic Conductivity (m/day)

- 6.2
- 12.7
- 14.4
- 16.6
- 29.1
- 50.0
- Rosemount Supply Well

N

Miles
0 0.5 1

Kilometers
0 1 2

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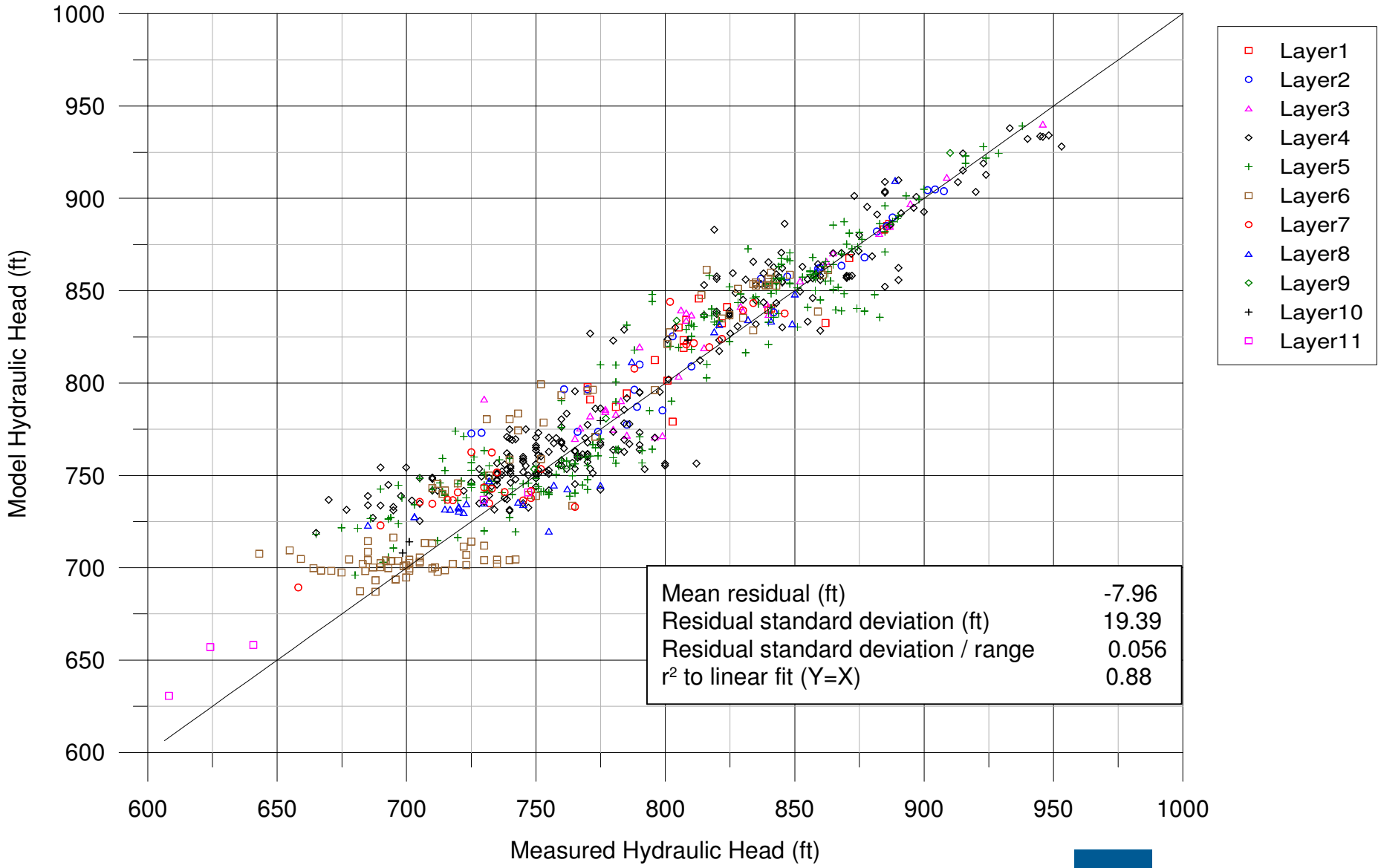
Figure 5

MODEL HYDRAULIC CONDUCTIVITY
JORDAN SANDSTONE
WHPP Amendment
City or Rosemount
Dakota County, MN

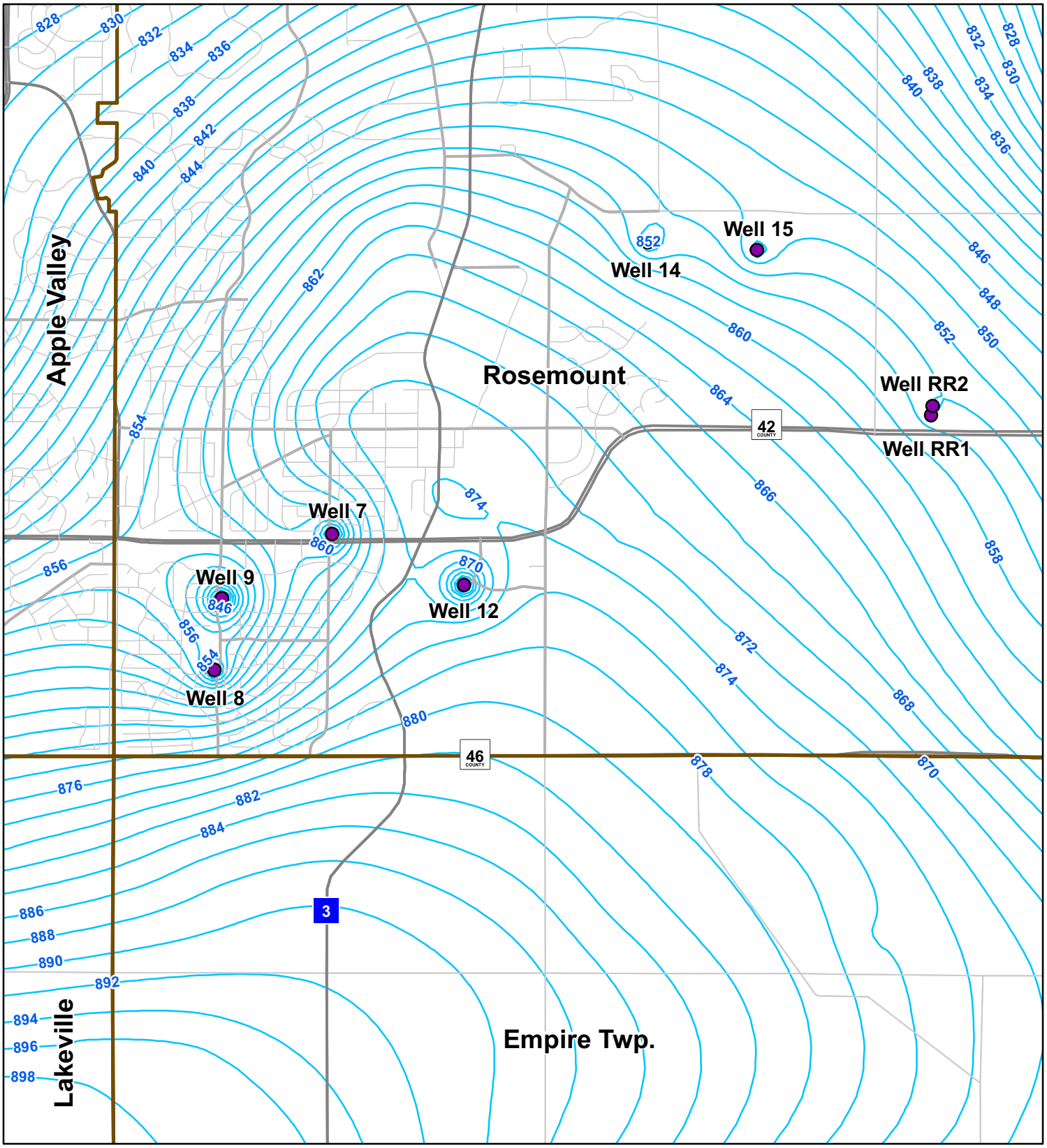


BARR

Figure 6

OBSERVED VS COMPUTED HYDRAULIC HEAD VALUES
WHPP Amendment
City of Rosemount
Dakota County, MN

P:\Mpls\23 MN\19\23191012 Rosemount Pt 1 WHPP Amend 1\WorkFiles\Report\Figures\Head_Residual_Plots_All_Heads.grf



Barr Footer: Date: 12/30/2009 11:25:57 AM File: I:\Projects\23\19\1012\Maps\Reports\CJDN_Contours.mxd User: egc

Rosemount Supply Well

Muncipal Boundaries

Groundwater Contour
Contour Interval = 2 ft

N

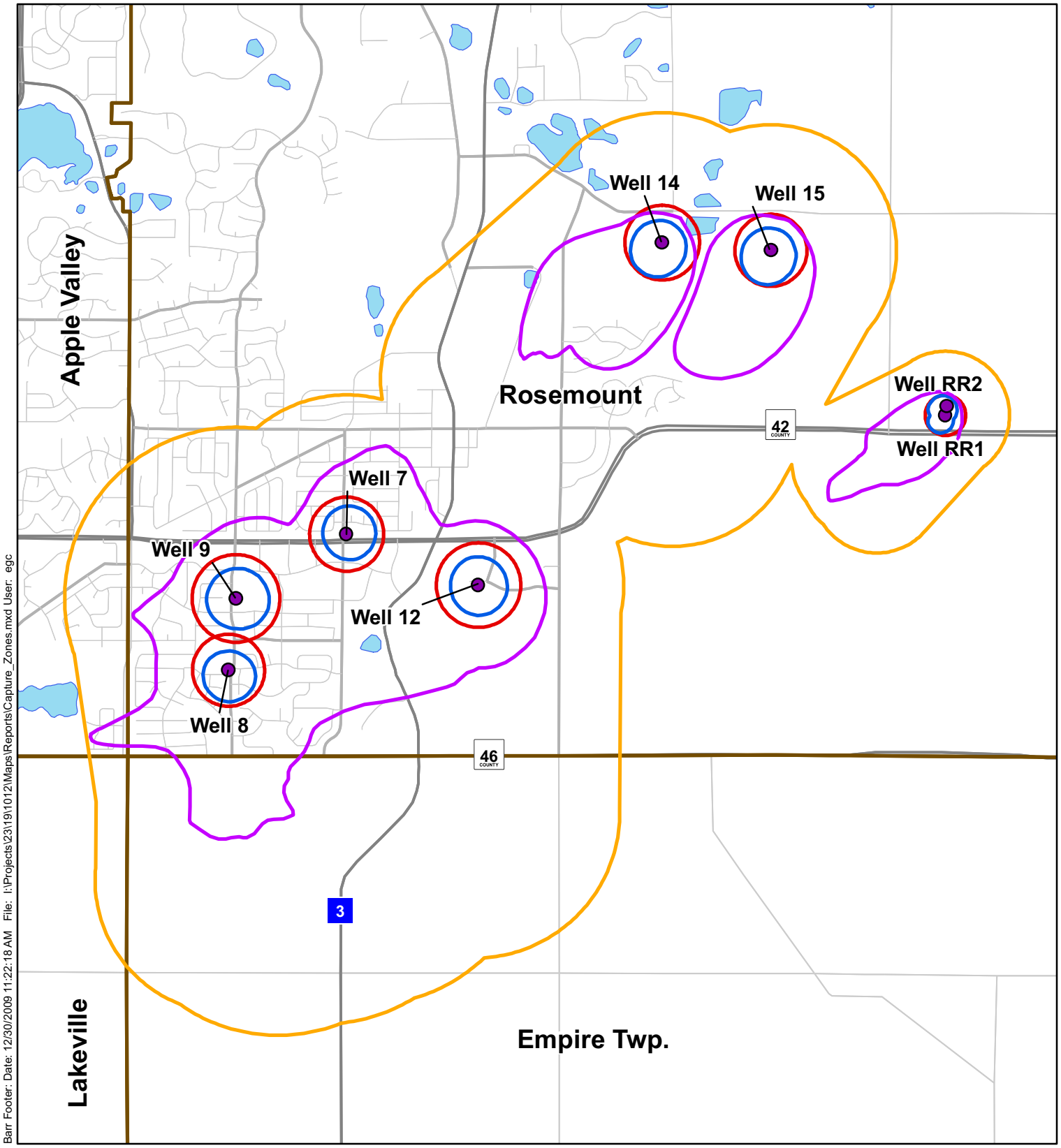
Miles
0 0.5 1

Kilometers
0 1 2

BARR

Figure 7

SIMULATED GROUNDWATER CONTOURS
JORDAN SANDSTONE
WHPP Amendment
City of Rosemount
Dakota County, MN



Barr Footer: Date: 12/30/2009 11:22:18 AM File: I:\Projects\23\19\1012\Maps\Reports\Capture_Zones.mxd User: egc

Rosemount Supply Well
10 Year Fracture Flow Capture Zone
10 Year Porous Media Capture Zone
1 Year Fracture Flow Capture Zone
1 Year Porous Media Capture Zone
Muncipal Boundaries
Water Body

N

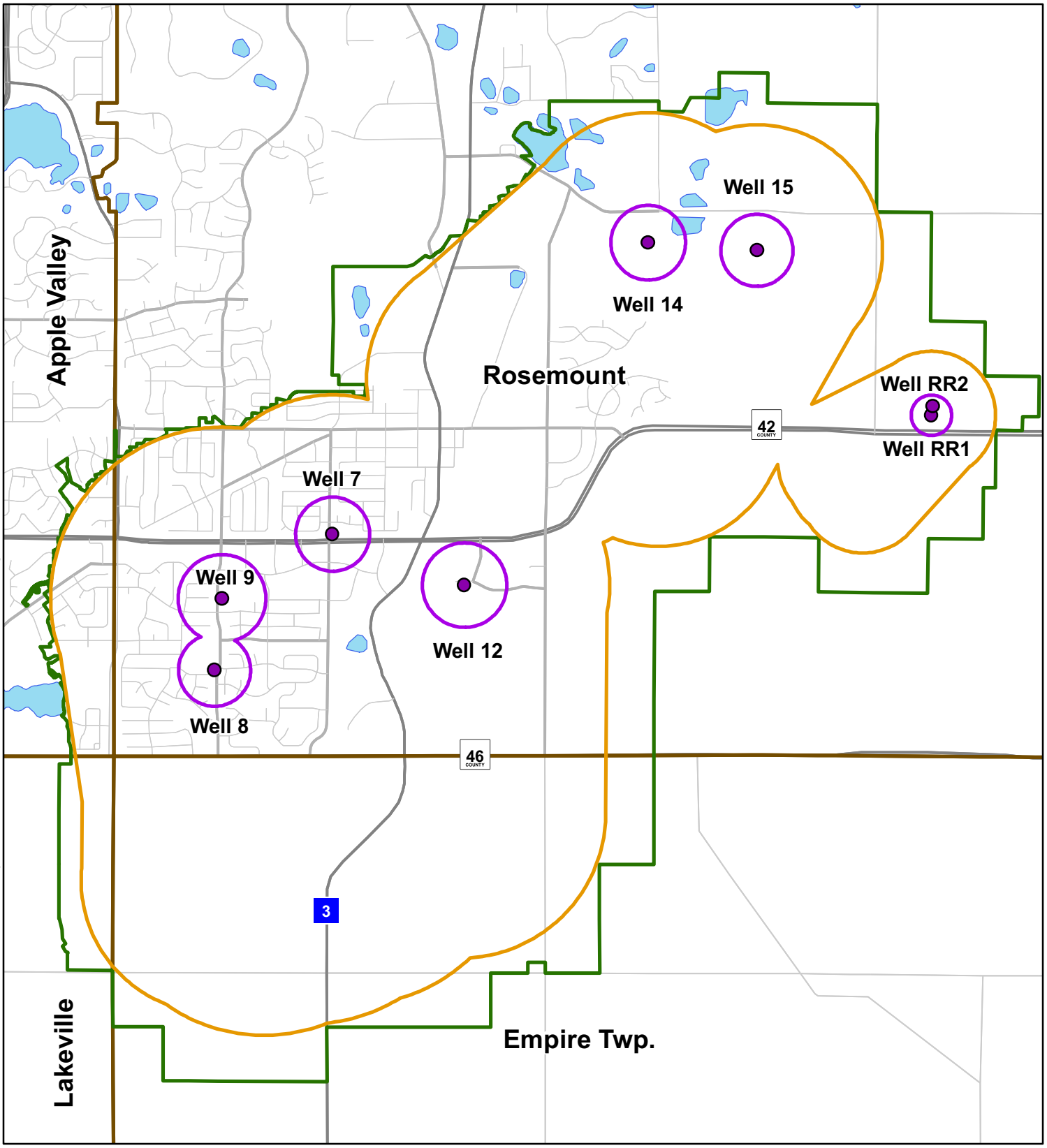
Miles
0 0.5 1

Kilometers
0 1 2

BARR

Figure 8

WELL CAPTURE ZONES
WHPP Amendment
City of Rosemount
Dakota County, MN



Barr Footer: Date: 12/30/2009 11:23:09 AM File: I:\Projects\23\19\1012\Maps\Reports\DWSMA_WHPA.mxd User: egc

Rosemount Supply Well
WHPA
DWSMA
Composite 1-Year Capture Zones
Muncipal Boundaries
Water Body

N

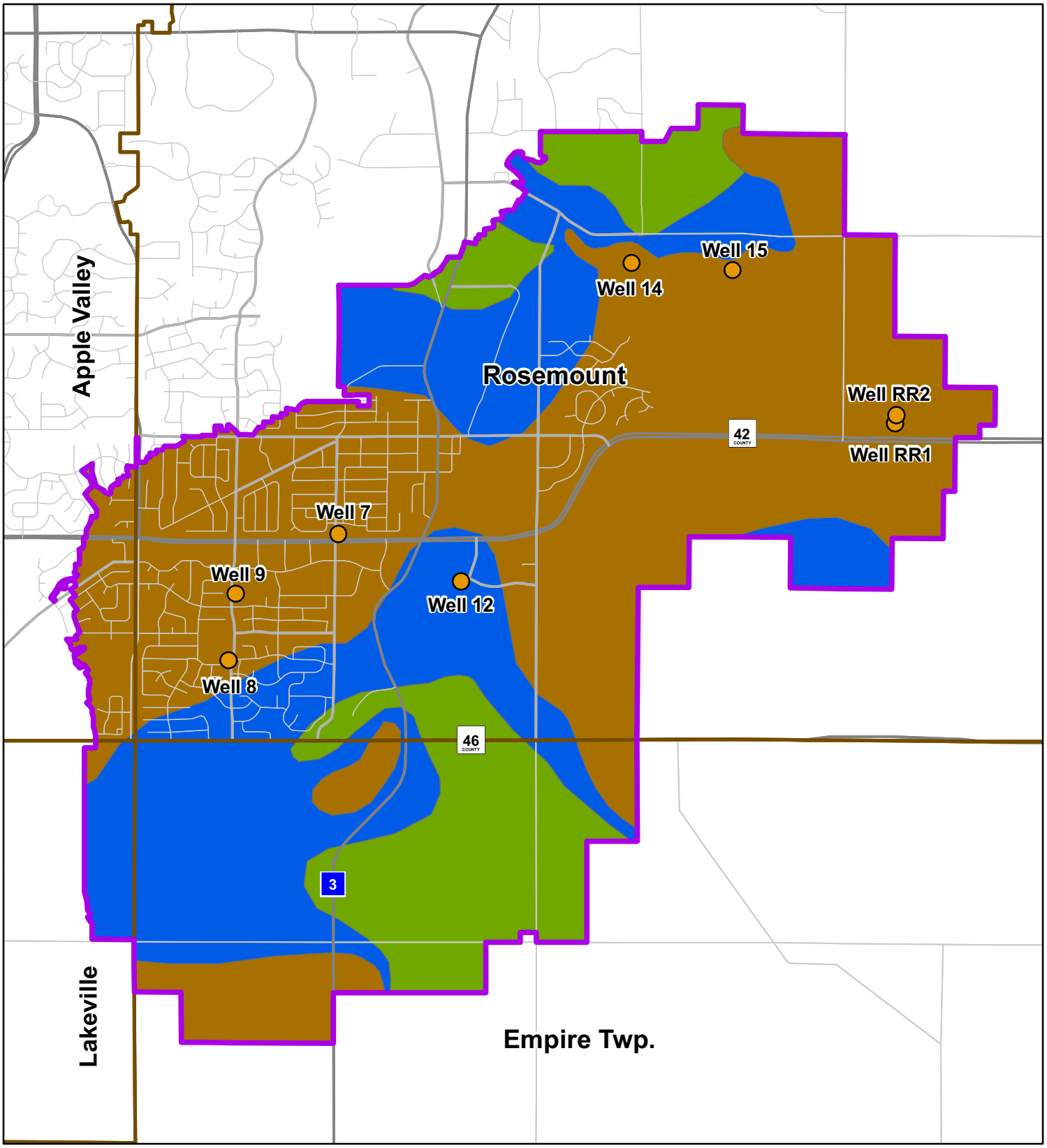
Miles
0 0.5 1

Kilometers
0 1 2

BARR

Figure 9

WHPA & DWSMA
WHPP Amendment
City of Rosemount
Dakota County, MN



Barr Footer: Date: 12/30/2009 11:24:36 AM File: I:\Projects\23\19\1012\Maps\Reports\Aquifer_Vunerability.mxd User: egc

Aquifer Vulnerability

- High
- Low
- Moderate

MDH Well Vulnerability

- Not Vulnerable
- Vulnerable

- DWSMA
- Muncipal Boundaries

Miles
0 0.5 1

Kilometers
0 1 2

BARR

Figure 10

AQUIFER VULNERABILITY
WHPP Amendment
City of Rosemount
Dakota County, MN

Attachment A

Well Records

Minnesota Unique Well No.

457167

County Dakota
Quad Coates
Quad ID 88A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 06/26/1992
Update Date 03/24/2006
Received Date

Well Name ROSEMOUNT 1 N

Township Range Dir Section Subsections Elevation 940 **ft.**

115 19 W 27 ADCBCC **Elevation Method** 7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
400 **ft.**	400 **ft.**	03/18/1989

Drilling Method Non-specified Rotary

Well Address
1367 145TH ST W
ROSEMOUNT MN 55068

Drilling Fluid Other

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

Use Community Supply **PWS ID** 1190019 **Source** S05

Geological Material	Color	Hardness	From	To
CLAY	BROWN	MEDIUM	0	4
GRAVEL	BROWN	MEDIUM	4	95
SANDROCK	YELLOW	SOFT	95	119
SANDROCK	WHITE	HARD	119	125
LIME	YELLOW	HARD	125	170
LIME	BROWN	MEDIUM	170	195
LIME	YELLOW	HARD	195	225
LIME	ORANGE	MEDIUM	225	260
LIME	WHITE	HARD	260	285
SANDROCK	YELLOW	SOFT	285	292
LIME	WHITE	HARD	292	312
LIME	BLUE	HARD	312	329
SANDROCK	WHITE	MEDIUM	329	345
SANDROCK	YELLOW	MEDIUM	345	370
SANDROCK	WHITE	MEDIUM	370	390
SANDROCK	BLUE	MEDIUM	390	400

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** 1 **ft.**

Casing Diameter	Weight	Hole Diameter
16 in. to 119 ft.	62.58 lbs./ft.	20 in. to 119 ft.
10 in. to 345 ft.	40.48 lbs./ft.	15 in. to 345 ft.

Open Hole from 345 ft. to 400 ft.

Screen NO **Make** **Type**

Diameter	Slot/Gauze	Length	Set Between

Static Water Level
73 ft. from Land surface Date Measured 03/18/1989

PUMPING LEVEL (below land surface)
200 ft. after 3 hrs. pumping 500 g.p.m.

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

NO REMARKS

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 345 ft. 42 yrds.

Located by: Minnesota Geological Survey

Method: GPS Differentially Corrected

Unique Number Verification: Information from owner

Input Date: 12/28/1994

System: *UTM - Nad83, Zone15, Meters*

X: 493652 **Y:** 4954085

Nearest Known Source of Contamination
300 feet S direction Septic tank/drain field type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP 0 Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

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

First Bedrock St.Peter
Last Strat Jordan
Aquifer Jordan
Depth to Bedrock 95 **ft.**

Well Contractor Certification

License Business Name	Lic. Or Reg. No.	Name of Driller
Kimmes-Bauer	19521	ANDERSON, L.

County Well Index Online Report **457167** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

474335

County Dakota
Quad Coates
Quad ID 88A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 01/04/1993
Update Date 03/24/2006
Received Date

Well Name ROSEMOUNT RURAL 2 S

Township Range Dir Section Subsections Elevation 941 **ft.**

115 19 W 27 ADCBBC **Elevation Method** 7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
400 **ft.**	400 **ft.**	01/09/1990

Drilling Method Cable Tool

Well Address
1367 145HT ST W
ROSEMOUNT MN 55068

Drilling Fluid Foam

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

Use Community Supply **PWS ID** 1190019 **Source** S06

Geological Material	Color	Hardness	From	To
CLAY SAND	YELLOW	MEDIUM	0	40
SAND GRAVEL	BROWN	SOFT	40	90
SANDROCK	BROWN	SOFT	90	120
SANDROCK	BROWN	HARD	120	127
LIME	YELLOW	HARD	127	240
SANDROCK	BROWN	SOFT	240	250
LIME	GRAY	HARD	250	335
SANDROCK	GRAY	MEDIUM	335	380
SANDROCK	BLUE	MEDIUM	380	400

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** 1 **ft.**

Casing Diameter	Weight	Hole Diameter
16 in. to 128 ft.	62.58 lbs./ft.	20 in. to 128 ft.
10 in. to 345 ft.	40.48 lbs./ft.	15 in. to 345 ft.

Open Hole from 345 ft. to 400 ft.

Screen NO **Make** **Type**

Diameter	Slot/Gauze	Length	Set Between

Static Water Level
75 ft. from Land surface Date Measured 01/09/1990

PUMPING LEVEL (below land surface)
200 ft. after 3 hrs. pumping 500 g.p.m.

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

NO REMARKS

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 345 ft. 18.5 yrds.

Located by: Minnesota Geological Survey

Method: GPS Differentially Corrected

Unique Number Verification: Information from owner

Input Date: 12/28/1994

System: *UTM - Nad83, Zone15, Meters*

X: 493662 **Y:** 4954152

Nearest Known Source of Contamination
__feet __direction __type

Well disinfected upon completion? ☑ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP 0 Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☑ No

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

First Bedrock St.Peter

Last Strat Jordan

Aquifer Jordan

Depth to Bedrock 90 **ft.**

Well Contractor Certification

Kimmes-Bauer	19521	ANDERSON, L.
License Business Name	Lic. Or Reg. No.	Name of Driller

County Well Index Online Report **474335** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

112212

County Dakota
Quad Farmington
Quad ID 88B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 12/27/1989
Update Date 03/24/2006
Received Date

Well Name ROSEMOUNT 7

Township	Range	Dir	Section	Subsections	Elevation	Elevation Method
115	19	W	29	CCCCCC	959 ft.	7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
490 ft.	490 ft.	04/13/1976

Drilling Method Cable Tool

Well Address
42 CR
ROSEMOUNT MN 55068

Drilling Fluid
--

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

Use Community Supply **PWS ID** 1190019 **Source** S03

Geological Material	Color	Hardness	From	To
SAND & GRAVEL			0	99
SHALE	BLU/GRY		99	104
MUDDY SAND & GRAVEL			104	170
LIMEROCK			170	379
LIMEROCK & SANDROCK			379	384
HARD ROCK			384	490

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** 2 **ft.**

Casing Diameter	Weight	Hole Diameter
20 in. to 175 ft.	78 lbs./ft.	
16 in. to 400 ft.	lbs./ft.	

Open Hole from 400 ft. to 490 ft.

Screen NO **Make** **Type**

Diameter	Slot/Gauze	Length	Set Between

Static Water Level
74 ft. from Land surface Date Measured 04/13/1976

PUMPING LEVEL (below land surface)
125 ft. after hrs. pumping 1600 g.p.m.

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

NO REMARKS

Located by: Minnesota Geological Survey
Method: Digitization (Screen) - Map (1:12,000)
Unique Number Verification: Information from owner
Input Date: 02/02/2001
System: *UTM - Nad83, Zone15, Meters*
X: 489226 **Y:** 4953206

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 400 ft.

Nearest Known Source of Contamination
__feet __direction __type

Well disinfected upon completion? ☑ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP 0 Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

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

Well Contractor Certification

License Business Name	Lic. Or Reg. No.	Name of Driller
Bergerson-Caswell	27058	HENRICH, E

First Bedrock Prairie Du Chien Group
Last Strat Jordan
Aquifer Jordan
Depth to Bedrock 170 **ft.**

County Well Index Online Report **112212** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

509060

County Dakota
Quad Farmington
Quad ID 88B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 06/13/1991
Update Date 03/24/2006
Received Date

Well Name ROSEMOUNT 8

Township	Range	Dir	Section	Subsections	Elevation	Elevation Method
115	19	W	31	CAADCA	949 ft.	7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
498 ft.	498 ft.	199001

Drilling Method Cable Tool

Well Address
2109 SHANNON PK
ROSEMOUNT MN 55068

Drilling Fluid --

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

Use Community Supply **PWS ID** 1190019 **Source** S04

Geological Material	Color	Hardness	From	To
SAND AND GRAVEL	BROWN	SOFT	0	167
SAND, GRAVEL & CLAY	BROWN	SOFT	167	174
LIMEROCK	GRAY	HARD	174	378
SANDROCK	GRAY	MEDIUM	378	495
SANDROCK & SHALE	GRAY	MEDIUM	495	498

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** 2 **ft.**

Casing Diameter	Weight	Hole Diameter
30 in. to 65 ft.	118.6 lbs./ft.	30 in. to 65 ft.
24 in. to 177 ft.	94.6 lbs./ft.	23 in. to 498 ft.

Open Hole from 389 ft. to 498 ft.

Screen NO **Make** **Type**

Diameter **Slot/Gauze** **Length** **Set Between**

Static Water Level
53 ft. from Land surface Date Measured 01/10/1990

PUMPING LEVEL (below land surface)
86.33 ft. after 8 hrs. pumping 1016 g.p.m.

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

REMARKS
M.G.S. NO. 3371.

Located by: Minnesota Geological Survey
Method: Digitization (Screen) - Map (1:12,000)
Unique Number Verification: Information from owner
Input Date: 02/02/2001
System: *UTM - Nad83, Zone15, Meters*
X: 488353 **Y:** 4952200

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement	from 0 to 64 ft.	5 yrds.
Grout Material: Neat Cement	from 0 to 389 ft.	25 yrds.

Nearest Known Source of Contamination
_feet _direction _type

Well disinfected upon completion? ☑ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP _ Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

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

Cuttings Yes
First Bedrock Prairie Du Chien Group
Last Strat St.Lawrence
Aquifer Jordan
Depth to Bedrock 174 **ft.**

Well Contractor Certification

License Business Name	Lic. Or Reg. No.	Name of Driller
Keys Well Co.	62012	RUSSELL, J.

County Well Index Online Report **509060** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

554248

County Dakota
Quad Farmington
Quad ID 88B

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 01/10/1997
Update Date 03/27/2006
Received Date

Well Name ROSEMOUNT 9

Township Range Dir Section Subsections Elevation 938 **ft.**

115 19 W 31 ACBBBC **Elevation Method** 7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
481 **ft.**	481 **ft.**	11/22/1996

Drilling Method Cable Tool

Well Address
SHANNON PK
ROSEMOUNT MN 55068

Drilling Fluid Water

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

Use Community Supply **PWS ID** 1190019 **Source** S07

Geological Material	Color	Hardness	From	To
SAND AND GRAVEL	BROWN	SOFT	0	62
SAND	BROWN	SOFT	62	85
SAND AND GRAVEL	BROWN	SOFT	85	120
SAND	BROWN	SOFT	120	163
LIMESTONE	GRAY	HARD	163	364
SANDSTONE	GRY/WHT	MEDIUM	364	466
SANDROCK AND SHALE	GRAY	MEDIUM	466	481

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** 0 **ft.**

Casing Diameter	Weight	Hole Diameter
30 in. to 166 ft.	118.65 lbs./ft.	29 in. to 481 ft.
24 in. to 374 ft.	94.62 lbs./ft.	

Open Hole from 374 ft. to 481 ft.

Screen NO **Make** **Type**

Diameter **Slot/Gauze** **Length** **Set Between**

Static Water Level
42 ft. from Land surface Date Measured 11/07/1996

PUMPING LEVEL (below land surface)
51 ft. after 4 hrs. pumping 1056 g.p.m.

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

REMARKS
M.G.S. NO. 3820.

Located by: Minnesota Department of Health **Method:** GPS SA On (averaged)
Unique Number Verification: N/A **Input Date:** 09/19/1996
System: *UTM - Nad83, Zone15, Meters* **X:** 488408 **Y:** 4952731

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 374 ft. 35 yrds.

Nearest Known Source of Contamination
100 feet W direction Septic tank/drain field type
Well disinfected upon completion? ☑ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP 0 Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☐ No

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

Cuttings Yes
First Bedrock Prairie Du Chien Group **Aquifer** Jordan
Last Strat St.Lawrence **Depth to Bedrock** 163 **ft.**

Well Contractor Certification

License Business Name	Lic. Or Reg. No.	Name of Driller
Keys Well Co.	62012	UNERTL, S.

County Well Index Online Report **554248** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

706804

County Dakota
Quad Coates
Quad ID 88A

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 0
Update Date 03/24/2006
Received Date 12/06/2004

Well Name ROSEMOUNT 12

Township Range Dir Section Subsections Elevation 965 **ft.**

115 19 W 32 ABCDAD **Elevation Method** 7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
475 **ft.**	475 **ft.**	10/12/2004

Drilling Method Cable Tool

Well Address
15150 BOULDER AV
ROSEMOUNT MN 55068

Drilling Fluid Bentonite

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

Use Community Supply **PWS ID** **Source**

Geological Material	Color	Hardness	From	To
CLAY & SAND & GRAVEL	BROWN	HARD	0	165
PDC/DOLOMITE	TAN	V.HARD	165	191
SANDSTONE/DOLOMITE	GRY/TAN	V.HARD	191	270
ONEOTA DOLOMITE	GRY/TAN	V.HARD	270	384
JORDAN S.S.	LT. GRY	M.HARD	384	469
ST. LAWRENCE SHALE	GRN/GRY	HARD	469	475

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** **ft.**

Casing Diameter	Weight	Hole Diameter
30 in. to 178.1 ft.	118.65 lbs./ft.	29 in. to 398 ft.
24 in. to 401.2 ft.	94.63 lbs./ft.	23 in. to 475 ft.

Open Hole from 395 ft. to 475 ft.

Screen NO **Make** **Type**

Diameter **Slot/Gauze** **Length** **Set Between**

Static Water Level
76.4 ft. from Land surface Date Measured 10/04/2004

PUMPING LEVEL (below land surface)
112.71 ft. after 15 hrs. pumping 1500 g.p.m.

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

NO REMARKS

Located by: Minnesota Department of Health **Method:** GPS SA Off (averaged)
Unique Number Verification: N/A **Input Date:** 12/22/2004
System: *UTM - Nad83, Zone15, Meters* **X:** 490201 **Y:** 4952829

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from to 395 ft. 34.62 yrds.

Nearest Known Source of Contamination
120 feet N direction Septic tank/drain field type

Well disinfected upon completion? ☑ Yes ☐ No

Pump ☐ Not Installed Date Installed
Manufacturer's name Model number __ HP _ Volts
Length of drop Pipe _ft. Capacity _g.p.m Type Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☑ No

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

Well Contractor Certification

Renner E.H. Well	71015	STAN/JIM
License Business Name	Lic. Or Reg. No.	Name of Driller

First Bedrock Prairie Du Chien Group **Aquifer** Jordan
Last Strat St.Lawrence **Depth to Bedrock** 165 **ft.**

County Well Index Online Report **706804** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

722623

County Dakota
Quad Inver Grove Heights
Quad ID 103D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date
Update Date 03/24/2009
Received Date 12/29/2005

Well Name ROSEMOUNT 14

Township	Range	Dir	Section	Subsections	Elevation	Elevation Method
115	19	W	21	CADABD	991 ft.	7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
485 ft.	485 ft.	12/29/2005

Drilling Method Cable Tool

Well Address
13599 AZALEA AV
ROSEMOUNT MN 55068

Drilling Fluid Additive (+ Bentonite)

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

Use Community Supply **PWS ID** **Source**

Geological Material	Color	Hardness	From	To
SAND & GRAVEL	BROWN	SOFT	0	170
SANDY CLAY	GRAY	MEDIUM	170	184
PRAIRIE DU CHIEN	ORANGE	MEDIUM	184	217
PRAIRIE DU CHIEN	ORANGE	V.HARD	217	410
JORDAN SANDSTONE	GRAY	M.SOFT	410	485

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☐ Yes ☐ No **Above/Below** **ft.**

Casing Diameter	Weight	Hole Diameter
30 in. to 137.6 ft.	94.62 lbs./ft.	30 in. to 143 ft.
24 in. to 218 ft.	94.62 lbs./ft.	24 in. to 413 ft.

Open Hole from 413 ft. to 485 ft.

Screen NO **Make** **Type**

Diameter **Slot/Gauze** **Length** **Set Between**

Static Water Level
131 ft. from Land surface Date Measured 12/29/2005

PUMPING LEVEL (below land surface)
166.45 ft. after 8 hrs. pumping 1250 g.p.m.

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

REMARKS
M..G.S. NO. 4508.
ENGINEER: WSB, NANCY ZIEGLER (651) 287-8316.
ROGER E. RENNER, MGWC.

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 137 ft. 8.5 yrds.
Grout Material: Neat Cement from 0 to 413 ft. 47.5 yrds.

Located by: Minnesota Department of Health **Method:** GPS SA Off (averaged)
Unique Number Verification: N/A **Input Date:** 12/22/2005
System: *UTM - Nad83, Zone15, Meters* **X:** 491558 **Y:** 4955361

Nearest Known Source of Contamination
100 feet W direction Septic tank/drain field type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed 07/12/2006
Manufacturer's name GOULD Model number 12CHC-5 HP 125 Volts 480
Length of drop Pipe 200 ft. Capacity 1200 g.p.m Type Submersible Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☑ No

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

Cuttings Yes
First Bedrock Prairie Du Chien Group **Aquifer** Jordan
Last Strat Jordan **Depth to Bedrock** **ft.**

Well Contractor Certification

License Business Name	Lic. Or Reg. No.	Name of Driller
Renner E.H. Well	71015	COLBURN, S.

County Well Index Online Report **722623** Printed 7/21/2009
HE-01205-07

Minnesota Unique Well No.

753663

County Dakota
Quad Inver Grove Heights
Quad ID 103D

MINNESOTA DEPARTMENT OF HEALTH

WELL AND BORING RECORD

Minnesota Statutes Chapter 103I

Entry Date 09/25/2007
Update Date 06/25/2009
Received Date 12/01/2008

Well Name ROSEMOUNT 15

Township	Range	Dir	Section	Subsections	Elevation	Elevation Method
115	19	W	21	DADACD	962 ft.	7.5 minute topographic map (+/- 5 feet)

Well Depth	Depth Completed	Date Well Completed
487 ft.	487 ft.	05/16/2008

Drilling Method Cable Tool

Well Address
13610 AUTUMN PA
ROSEMOUNT MN 550684941

Drilling Fluid Bentonite

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

Use Community Supply **PWS ID** 1190019 **Source** 019

Geological Material	Color	Hardness	From	To
SANDY CLAY	BROWN	SOFT	0	10
SAND & GRAVEL	BROWN	SFT-MED	10	145
ST. PETER SANDSTONE	WHT/BRN	MEDIUM	145	170
PDC	ORANGE	HARD	170	380
JORDAN SANDSTONE	TAN	SOFT	380	420
JORDAN SANDSTONE	GRAY	MED-HRD	420	483
ST. LAWRENCE S.S.	GRAY	HARD	483	487

Casing Type Steel (black or low carbon) **Joint** Welded **Drive Shoe?** ☑ Yes ☐ No **Above/Below** ft.

Casing Diameter	Weight	Hole Diameter
30 in. to 180 ft.	118.65 lbs./ft.	30 in. to 390 ft.
24 in. to 390 ft.	94.62 lbs./ft.	24 in. to 487 ft.

Open Hole from 390 ft. to 487 ft.

Screen NO **Make** **Type**

Diameter	Slot/Gauze	Length	Set Between

Static Water Level
107 ft. from Land surface Date Measured 05/09/2008

PUMPING LEVEL (below land surface)
127.3 ft. after 24 hrs. pumping 1330 g.p.m.

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

REMARKS
MULTI TOOL LOGGED 10-26-2007. WATER WAS ABNORNALLY WARM AND FOAMY.
M.G.S. NO. 4793.

Located by: Minnesota Department of Health **Method:** GPS SA Off (averaged)
Unique Number Verification: N/A **Input Date:** 09/21/2007
System: *UTM - Nad83, Zone15, Meters* **X:** 492362 **Y:** 4955305

Grouting Information Well Grouted? ☑ Yes ☐ No

Grout Material: Neat Cement from 0 to 390 ft. 42.75 yrds.

Nearest Known Source of Contamination
120 feet North West direction Sewer type
Well disinfected upon completion? ☐ Yes ☐ No

Pump ☐ Not Installed Date Installed 10/07/2008
Manufacturer's name GOULD Model number 12CHC5 HP 150 Volts 460
Length of drop Pipe 180 ft. Capacity g.p.m Type Turbine Material

Abandoned Wells Does property have any not in use and not sealed well(s)? ☐ Yes ☑ No

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

Cuttings Yes **Borehole Geophysics** Yes
First Bedrock St.Peter **Aquifer** Jordan
Last Strat St.Lawrence **Depth to Bedrock** 145 ft.

Well Contractor Certification

License Business Name	Lic. Or Reg. No.	Name of Driller
EH Renner and Sons, Inc.	1431	COLBURN, S.

County Well Index Online Report **753663** Printed 7/21/2009
HE-01205-07

Attachment B

List of Parcels in DWSMA

A list of parcels within the Rosemount DWSMA can be found on the CD that accompanies this amendment.

Attachment C

MDH Well Vulnerability Scoring Sheets

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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Rural Well #1 North

TIER: 2
WHP RANK:
UNIQUE WELL #: 00457167

COUNTY: Dakota | TOWNSHIP NUMBER: 115 | RANGE: 19 W | SECTION: 27 | QUARTERS: CDD

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Low	20
L Score	:	1	
Geologic Data From	:	Well Record	
Year Constructed	:	1989	
Construction Method	:	Rotary/Drilled	0
Casing Depth	:	345	5
Well Depth	:	400	
Casing grouted into borehole?		Unknown	5
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	:	0	0
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	Unknown	0
Maximum tritium detected	:	15.1 02/26/2001	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	:		Jim Walsh

COMMENTS
FORCED ASSESSMENT TO VULNERABLE BASED ON TRITIUM DATA FOR OTHER CITY WELL.

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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Rural Well #2 South

TIER: 2
WHP RANK:
UNIQUE WELL #: 00474335

COUNTY: Dakota | TOWNSHIP NUMBER: 115 | RANGE: 19 W | SECTION: 27 | QUARTERS: ADC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	VULNERABLE
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1990	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	345	5
Well Depth	:	400	
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	:	500	5
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	Unknown	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		10
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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Well #7

TIER: 2
WHP RANK:
UNIQUE WELL #: 00112212

COUNTY: Dakota | TOWNSHIP NUMBER: 115 | RANGE: 19 W | SECTION: 29 | QUARTERS: CCCC

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	0
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1976	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	400	5
Well Depth	:	490	
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	:	1100	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	.4 06/01/1978	0
Maximum tritium detected	:	11.6	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	M	0
Wellhead Protection Score	:		25
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		

COMMENTS

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

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

PWSID: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Well #8

TIER: 2
WHP RANK:
UNIQUE WELL #: 00509060

COUNTY: Dakota | TOWNSHIP NUMBER: 115 | RANGE: 19 W | SECTION: 31 | QUARTERS: CAA

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	0
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1990	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	389	5
Well Depth	:	498	
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	:	1000	10
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.4 11/26/1990	0
Maximum tritium detected	:	8.1 02/26/2001	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		15
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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Well #9

TIER: 2
WHP RANK:
UNIQUE WELL #: 00554248

COUNTY: Dakota | TOWNSHIP NUMBER: 115 | RANGE: 19 W | SECTION: 31 | QUARTERS:

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	High	0
L Score	:	0	
Geologic Data From	:	Well Record	
Year Constructed	:	1996	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	374	5
Well Depth	:	481	
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	:	1056	20
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.05 05/07/1998	0
Maximum tritium detected	:	1.2 02/26/2001	VULNERABLE
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		25
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		Jim Walsh

COMMENTS
Moderate geologic sensitivity rating based on 40 feet of clay-sand plus base of St. Peter Fm.

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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Well #12

TIER: 2
WHP RANK:
UNIQUE WELL #: 00706804

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

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Medium	25
L Score	:	1	
Geologic Data From	:	Well Record	
Year Constructed	:	2004	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	401	0
Well Depth	:	475	
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	:		0
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	<.05 04/25/2007	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	:		VULNERABLE
Vulnerability Overridden	:		Steve Robertson 12/29/2008 13:58:11

COMMENTS
Vulnerability assigned on basis of 3H results from other Rosemount wells,

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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Well #14

TIER: 2
WHP RANK:
UNIQUE WELL #: 00722623

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

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Medium	25
L Score	:	1	
Geologic Data From	:	Well Record	
Year Constructed	:	2005	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	413	0
Well Depth	:	485	
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	:		0
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	.05 04/22/2008	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	:		VULNERABLE
Vulnerability Overridden	:		Steve Robertson 12/29/2008 13:59:35

COMMENTS
Vulnerability assigned on basis of 3H results from other Rosemount wells.

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: 1190019
SYSTEM NAME: Rosemount
WELL NAME: Well #15

TIER: 1
WHP RANK:
UNIQUE WELL #: 00753663

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

CRITERIA		DESCRIPTION	POINTS
Aquifer Name(s)	:	Jordan	
DNR Geologic Sensitivity Rating	:	Medium	25
L Score	:	1	
Geologic Data From	:	Well Record	
Year Constructed	:	2008	
Construction Method	:	Cable Tool/Bored	0
Casing Depth	:	390	5
Well Depth	:	487	
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	:		0
Pathogen Detected?			0
Surface Water Characteristics?			0
Maximum nitrate detected	:	Unknown	0
Maximum tritium detected	:	Unknown	0
Non-THMS VOCs detected?			0
Pesticides detected?			0
Carbon 14 age	:	Unknown	0
Wellhead Protection Score	:		30
Wellhead Protection Vulnerability Rating	:		VULNERABLE
Vulnerability Overridden	:		Steve Robertson 12/29/2008 14:01:51

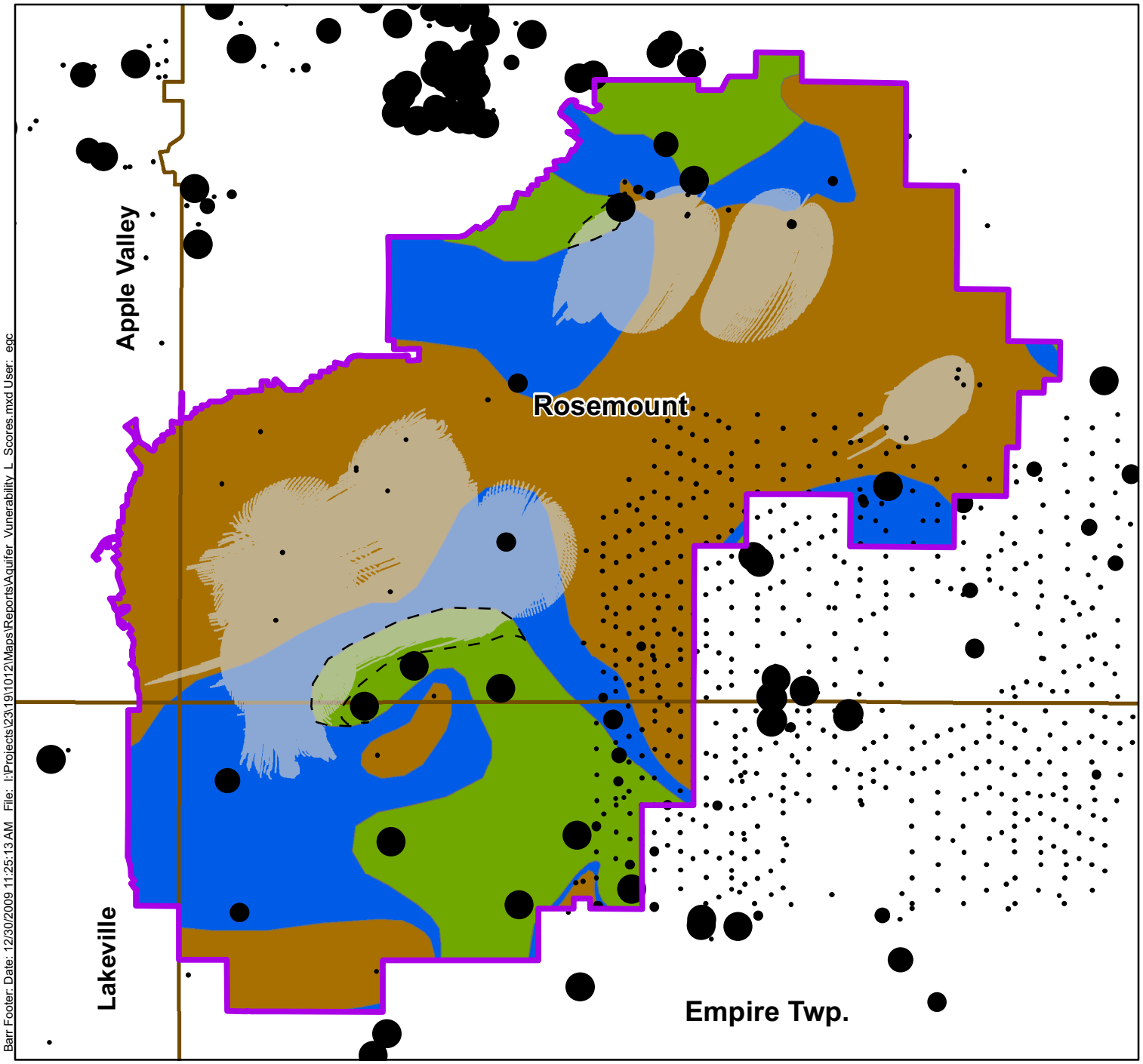
COMMENTS
Vulnerability assigned on basis of 3H results from other Rosemount wells.

Attachment D

DWSMA Vulnerability

Modification to Aquifer Vulnerability

Particle tracking from the groundwater flow model showed that particles from many of the Rosemount wells reached the Quaternary sand and gravel sediments within the 10-year time of travel. While portions of the DWSMA contain sufficient fine-grained sediments to protect the aquifer from contaminates flowing vertically, much of the groundwater flow in the sand and gravel units above the fine-grained confining units is likely horizontal. In areas where the fine-grained confining sediments are not present potential exists for contaminates to reach the lower aquifers via vertical leakage. Areas of the DWSMA that were initially classified has having a low aquifer vulnerability based on L-scores, but where particle tracking indicated potential groundwater flow in the Quaternary sediments, were reclassified as having a moderate aquifer vulnerability (Figure D-1 and Figure 10).



Barr Footer: Date: 12/30/2009 11:25:13 AM File: I:\Projects\23\19\1012\Maps\Reports\Aquifer Vunerability L Scores.mxd User: egc

DWSMA

10-Year Particle Paths

Area where aquifer vulnerability was modified

Muncipal Boundaries

Aquifer Vulnerability Prior to Modification

High

Low

Moderate

L-Scores

0

1

2

3

4

> 4

N

Miles

0 0.5 1

Kilometers

0 1 2

Note: Many L-Scores on the east side of the DWSMA are artificially low becuase they are shallow borings

BARR

Figure D-1

AQUIFER VULNERABILITY
& L-SCORES
WHPP Amendment
City of Rosemount
Dakota County, MN

Attachment E

High Capacity Well In Model

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
18246	208392	-4052.423	6	5	496835	4956993
18247	208390	-3775.494	6	5	496499	4957344
18248	208391	-4821.522	11	8	496464	4957233
18296	208407	-1.872646	6	5	497577	4956420
18297	208411	-467.7118	6	5	497760	4956226
18356	208324	-447.8997	6	5	484006	4969490
18397		-14.04864	6	6	501850	4966635
18421	205594	-4.051946	6	5	485466	4966013
18431	200049	-40.14328	7	5	492123	4976801
18462	200932	-762.1151	6	5	488565	4942916
18464	235586	-2068.258	6	6	485945	4947549
18465	200044	-524.7292	6	5	492122	4977245
18497	236439	-5953.071	10	5	484565	4978340
18518	208322	-614.0432	6	5	483690	4970017
18519	208321	-487.6703	6	5	483683	4970035
18520	151585	-636.9985	6	5	483660	4970036
18521	509084	-278.2009	6	5	483704	4969945
18564	200402	-506.5843	6	5	491437	4976605
18565	233504	-669.4901	6	4	491511	4976671
18590	231871	-4409.033	4	4	506756	4959166
18679	200828	-68.9791	6	6	489510	4972415
18792	200401	-12.29445	5	5	491487	4976919
18845	200494	-530.3003	6	5	492617	4978183
18846	200495	-496.0615	6	5	492617	4978178
18898	208804	-667.0303	7	6	501269	4964583
18899	431603	-533.6676	6	6	501233	4964415
18907	200871	-27.76989	6	6	489129	4968330
19080	200434	-0.000943	6	5	488033	4972615
19081	208811	-120.361	6	5	487969	4972672
19082	151572	-1223.106	7	5	488106	4972778
19125	151554	-2041.864	6	5	496447	4974637
19126	226583	-2741.505	7	5	496356	4974778
19239	207652	-13.01535	8	7	505037	4938741
19240	474331	-16.45779	8	7	505058	4938723
19244	200434	-45.15812	6	5	488033	4972615
19254	200028	-641.8872	5	5	492560	4976963
19268	452757	-2.022532	3	3	483673	4953495
19339	200061	-247.5668	7	6	499151	4971442
19360	208410	-278.4976	6	6	498117	4956269
19361	255723	-203.9364	6	6	498162	4956072
19373	207515	-112.1623	5	5	487504	4941078
19470	205588	-730.7919	6	6	487788	4967022
19625		-270.2105	6	5	493299	4944817

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
19738	201089	-1755.656	6	5	482161	4977904
19775	541763	-3618.891	7	6	506221	4974006
19776	208422	-133.8857	6	6	504826	4973887
19777	208423	-314.2005	7	6	504438	4974114
19778	208005	-905.1103	6	5	504436	4974356
19779	150353	-563.4475	6	6	504632	4974109
19780	433281	-1093.876	6	6	503964	4974693
19781	463539	-3164.897	7	6	504912	4974413
19863	200421	-245.6492	5	5	491545	4975578
19932		-85.6274	6	5	505540	4943166
20391	242332	-179.3625	6	6	482474	4967200
20419	208353	-667.1027	6	6	500195	4968920
20420	225904	-568.3652	7	6	499936	4968173
20440	208394	-140.4164	11	11	496852	4957116
20441	213584	-660.1632	11	11	496813	4956961
20554	216372	-334.3175	7	6	503208	4943091
20555	226842	-119.8992	6	5	496815	4943354
20863	216365	-16.0279	6	5	501151	4952058
20898	207288	-315.4826	4	4	487512	4957427
20905	216361	-206.824	6	5	504002	4952545
20906	200674	-3244.475	6	6	496467	4969823
20907	208347	-7403.858	7	5	497224	4968992
20908	200664	-424.9752	7	6	495483	4971990
20909	200676	-19.32776	7	6	497879	4969948
20910	127251	-7.542539	6	6	495294	4970436
20918	151563	-1711.252	6	6	485376	4954757
20919	449257	-1451.956	6	6	485223	4954396
20920	433284	-1896.431	6	6	485613	4954385
20921	509056	-56.25886	11	11	485319	4954770
20922	205825	-38.63006	6	6	480653	4953369
20923	205812	-17.29599	6	6	482014	4956851
20924	205820	-1825.866	6	6	484540	4954771
20925	207677	-617.1975	6	6	484413	4954356
20926	127263	-4318.301	6	5	484418	4954576
20927	127297	-1318.209	6	6	484847	4954776
20928	151561	-1506.329	6	6	484084	4954839
21486	232246	-0.008485	5	5	489588	4951611
21495	127256	-53.53883	6	5	500426	4978318
21498	216366	-391.5842	6	5	505534	4947168
21500	121850	-414.2391	6	5	505605	4947549
21501	224647	-95.03599	5	5	505139	4961044
21504	121813	-14.00797	5	5	505788	4950479
21506	121812	-239.4914	7	6	504869	4952242

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
21525	121816	-90.36339	6	5	505846	4948475
21526	256278	-278.0307	6	5	504082	4943619
21565		-11.65499	6	6	492332	4977143
21595		-4.412385	6	5	487802	4969432
21596		-51.28035	6	5	487807	4969830
21606	200432	-17.09209	6	6	487592	4972632
21612	247176	-2979.056	7	5	499783	4966625
21613	247170	-1950.971	6	5	499633	4966450
21614	247171	-476.3482	6	5	499643	4966583
21615	247172	-1072.061	7	5	499797	4966450
21616	247175	-409.8441	7	5	499668	4966448
21619	247175	-64.91183	7	5	499668	4966448
21644	125904	-52.72235	5	5	503298	4952586
22385	212278	-0.191392	6	6	488237	4953670
22386	112212	-2207	6	6	489226	4953206
22387	509060	-2087	6	6	488353	4952200
22388	554248	-3090	6	6	488408	4952731
22389	457467	-330	6	6	493652	4954085
22390	474335	-330	6	6	493662	4954152
22391		-163.6848	6	5	494689	4942194
22398		-186.2095	6	5	502376	4944728
22401		-142.948	6	5	497661	4939820
22408	121849	-158.7346	6	5	505637	4948713
22417	159510	-257.3492	8	6	503219	4949415
22432		-276.4718	6	5	499396	4952922
22435	107045	-79.51345	6	5	503984	4960756
22437	129237	-138.0756	6	5	500365	4946236
22438	251488	-325.869	6	5	497918	4943995
22442		-285.108	6	5	504948	4949597
22457	256784	-239.9897	6	5	498803	4954336
22460		-128.0995	6	5	490568	4941719
22465		-384.0568	6	5	500866	4953669
22466	242105	-211.3364	7	5	500785	4943535
22467	251909	-145.5056	6	5	500446	4943061
22471	249927	-181.7781	6	5	503731	4942357
22472		-9.426194	6	5	498856	4951979
22478		-118.3905	6	5	501329	4948601
22480	194224	-166.0421	6	5	503978	4941106
22482	200602	-9.390659	5	5	481971	4975730
22500	225686	-1.595247	6	5	492383	4976610
22507		-313.3881	6	5	491521	4940649
22508		-304.3388	6	5	491924	4940646
22509		-131.6661	6	5	499168	4949461

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
22512		-134.0267	6	5	506396	4945420
23804	255952	-215.4432	6	5	500777	4949460
23808		-277.094	6	5	500828	4951106
23819	250188	-278.945	6	5	501170	4943024
23820		-129.6544	6	5	498668	4949161
23821		-85.1251	6	5	496477	4946265
23822		-151.2128	6	5	499566	4946351
23824	170866	-149.4243	6	5	502446	4950195
23827	255665	-3.321263	6	5	504377	4939307
23837	129239	-167.3454	5	5	499450	4948237
23838	214194	-310.4523	6	5	501612	4954750
23840		-220.1582	6	5	504790	4947034
23841		-122.257	6	5	506101	4951049
23843		-76.23338	6	5	500774	4948655
23845	250034	-153.3889	6	5	499109	4942181
23855	256084	-2.223729	6	5	499097	4953457
23856		-209.6864	6	5	503181	4945531
23870		-130.3049	6	5	504485	4954268
23875		-122.0113	6	5	506580	4955771
23887		-57.09384	6	5	499269	4950268
23889		-121.9526	6	6	502079	4943828
23892		-96.29371	6	5	502377	4943928
23895		-43.2959	3	3	494458	4944961
23906		-175.2885	6	5	490307	4940764
23909		-74.29118	6	5	499972	4950370
23912		-165.9566	6	5	499117	4947802
23918	131919	-15.60174	7	5	504359	4959229
23920		-5.253756	6	5	502514	4962741
23921	131970	-8.835387	7	5	502408	4962423
23932	208808	-1233.401	7	6	502484	4964113
23933	191904	-406.7581	6	6	503625	4962078
23934	208805	-1058.15	6	6	504946	4964047
23935	208806	-1254.448	6	5	504928	4963900
23936	201238	-2144.213	7	6	505294	4964195
23937	110464	-2571.502	6	6	505232	4963928
23938	165602	-2158.662	6	6	505543	4964044
23974		-42.44866	6	5	497709	4942583
23980	249861	-134.6909	6	5	502416	4953518
23981	132226	-246.5071	6	5	500003	4951915
23993	233118	-9.345206	5	5	495820	4954906
23995	207706	-109.3299	6	5	493414	4945121
24004	207615	-32.357491	6	6	492112	4952660
24005	207617	-11.82293	6	6	491284	4951930

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
24303	205596	-3394.959	6	6	485718	4964429
24304	439839	-1923.652	6	6	487268	4959687
24305	433275	-971.8976	11	11	485574	4963706
24306	433287	-1501.116	6	6	486462	4960473
24307	449230	-2452.098	6	6	486444	4959637
24308	505636	-1053.029	6	6	486739	4960320
24309	420971	-1439.453	6	6	486844	4960502
24310	205595	-575.6777	6	6	485709	4964121
24311	207258	-937.646	6	6	485597	4963957
24312	235373	-2092.757	6	6	485639	4964285
24313	112234	-3594.548	6	6	486884	4959760
24314	151552	-2012.959	6	5	485824	4964669
24315	151564	-1433.291	6	6	485996	4965227
24316	434046	-826.7773	11	11	486105	4964061
24317	434030	-2354.335	6	6	486086	4964023
24320	205809	-4.097484	6	6	486344	4965692
24323		-130.2235	6	5	500263	4954779
24333	127289	-12.70644	9	9	497498	4958816
24346		-90.85639	6	5	505131	4954219
24351	208463	-686.7957	7	6	501954	4978446
24360	226049	-27.01628	5	5	495918	4976538
24361	226578	-359.1564	6	5	492564	4977292
24362	226579	-320.1967	7	5	492597	4977242
24363	226580	-315.9351	7	5	492521	4977186
24364	127300	-302.4771	6	5	492490	4977244
24371	141820	-354.7558	6	5	501652	4941512
24799	146857	-151.6562	6	5	502486	4950704
24809	170885	-0.566977	5	5	494145	4948630
24828	159539	-128.9774	6	5	503676	4948691
24835	120192	-13.71234	6	6	496325	4939704
24857	146815	-177.2167	6	5	505733	4943783
25160	207285	-1059.27	6	6	496441	4966018
25161	165640	-1716.256	6	6	496452	4965244
25162	433259	-476.1463	11	11	496423	4965170
25163	463527	-3575.548	6	6	494981	4965274
25165	231882	-295.3484	11	11	490216	4975111
25168	207708	-668.7027	6	6	483142	4950194
25169	207727	-511.6934	6	6	482055	4942986
25170	212650	-1027.542	6	6	483011	4950471
25207	207521	-218.5385	6	6	489114	4944481
25218	163616	-87.05976	3	3	490515	4944104
25491		-22.86294	6	5	492693	4946032
25504	171729	-129.4865	6	5	502518	4961532

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
25511	171743	-117.699	6	5	499324	4948673
25515	175910	-49.30699	3	3	486438	4942888
25519	171735	-280.6723	6	5	506449	4946287
25822	481262	-170.3226	6	6	501835	4961350
25827	196720	-0.061213	3	3	484483	4953294
25829	524054	-0.053255	3	3	484684	4953293
25830	495945	-0.254474	3	3	484483	4953294
25831	495946	-0.00935	3	3	484483	4953294
25834	448807	-1.157052	3	3	484685	4953494
25835	448809	-0.303131	3	3	484684	4953293
25836	448811	-0.180267	3	3	484684	4953293
25837	448812	-0.02325	3	3	484684	4953293
25840	448810	-0.270317	3	3	484684	4953293
26198	200032	-2226.155	6	5	492756	4976971
26220	151566	-25.16279	6	5	484473	4964390
26506	208810	-835.6105	6	5	490249	4975144
26507	200424	-499.4785	7	6	490242	4974972
26558		-230.0522	6	6	492722	4977347
26575	404814	-121.2313	4	4	487342	4970439
26580	200005	-32.05871	6	6	493681	4975729
26591	236024	-28.30623	5	5	482622	4974598
26598	151578	-414.343	6	5	506632	4971651
26602	200003	-232.6201	6	5	496045	4976752
26603	424921	-661.6308	6	6	496210	4976800
26616		-734.4876	11	11	488655	4943245
26642	205585	-4.061014	6	6	488933	4966922
26643	205583	-1.062866	6	6	488913	4966882
26880	236153	-147.6546	6	5	494167	4970123
26881	200679	-128.8681	6	5	494111	4970166
26905	251988	-125.0043	4	4	481087	4948605
26932	509077	-179.3863	6	5	489382	4969808
26952	208326	-36.49901	5	5	482417	4968836
26953	208325	-139.9117	7	5	482437	4968883
26965	205589	-28.1579	6	5	486223	4967278
26973	205799	-160.9276	6	6	500240	4939528
26974	207969	-327.3784	7	5	499725	4977747
27172	208000	-259.7502	5	5	501623	4971581
27173	179817	-343.8851	6	5	501102	4971181
27174	420951	-607.5788	7	5	492429	4977116
27175	420952	-797.8421	7	5	492392	4977187
27176	420953	-797.8327	6	5	492435	4977210
27195	208397	-68.76043	6	6	490548	4955622
27386	161497	-2538.63	6	5	483626	4972047

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
27416	462941	-0.030547	3	3	483129	4971351
27417	490081	-17.35619	3	3	483129	4971351
27418	409553	-6.855359	3	3	483129	4971351
27456	435224	-143.4591	5	5	485416	4941005
27459	453267	-0.242218	3	3	486852	4976648
27848	438525	-130.6783	5	5	497771	4954675
27872	185278	-37.7463	5	5	491000	4950815
27883	451550	-111.837	4	4	504155	4951716
27884	443888	-47.62114	5	5	481036	4940678
27890	443886	-338.1011	5	5	500889	4941811
27908	179822	-82.15861	5	5	506580	4948184
27914	437199	-225.5125	6	6	504033	4950296
27928	505619	-27.97716	6	5	491100	4966520
27930	205598	-153.135	6	6	489116	4961365
27938		-292.8197	5	5	499568	4967520
27939		-58.3887	5	5	500367	4967321
27940		-128.574	5	5	499576	4966343
27941		-166.5422	5	5	499773	4966932
28522	509065	-13.84117	4	4	497197	4957360
28523	509068	-2.759231	4	4	497194	4957407
28524	509070	-0.700002	4	4	497197	4957430
28525	509071	-0.92263	4	4	497199	4957450
28861	200822	-288.1105	6	6	482188	4977904
28881		-3993.218	3	3	483376	4963888
28918	462855	-154.079	6	5	486978	4973846
29281	449072	-48.36914	5	5	484911	4956514
29300	457205	-198.9873	5	5	505640	4952303
29303	478457	-244.3133	7	5	504870	4946121
29315	489220	-12.58788	3	3	480997	4978137
29316	489221	-3.811127	3	3	480998	4977941
29317	482702	-0.108471	3	3	480998	4977941
29319	557987	-6.663474	3	3	480997	4978137
29340	207512	-48.56273	6	5	483058	4940386
29341	207513	-152.7711	6	5	483043	4940388
29364	110499	-19.33673	3	3	488413	4978067
29370	513429	-0.223072	3	3	493736	4973320
29385	200848	-165.0895	6	5	491132	4972091
29386	450903	-1.481583	3	3	486121	4974954
29387	622792	-0.013776	3	3	486121	4974954
29647	179835	-474.2816	6	6	500656	4970637
29682	527350	-0.244753	3	3	487525	4977135
29683	527389	-1.949075	3	3	487525	4977135
29684	527390	-0.119795	3	3	487525	4977135

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
29685	527391	-0.092314	3	3	487525	4977135
29888	519942	-14.64587	3	3	485322	4977937
30165		-75.14138	5	5	500373	4966145
30169	541338	-0.821587	3	3	486923	4977132
30172	497931	-811.4717	3	3	484984	4952584
30184	524763	-61.9761	6	6	498957	4970913
30200	207675	-312.2224	6	6	485009	4953432
30497	557979	-101.0047	5	5	499780	4965947
30498	557977	-180.3841	5	5	499780	4965947
30499	557980	-146.4488	5	5	499780	4965947
30500	561416	-67.19326	5	5	499494	4965698
30501	200410	-20.79584	4	3	485973	4976283
30508	568161	-9.235794	3	3	489135	4973733
30519	570405	-234.2111	6	5	505126	4978087
30525	542938	-48.69927	5	5	494092	4971868
30547	174662	-29.11703	5	5	492915	4941790
30860	554230	-662.8845	6	6	491475	4975474
30866	580239	-1.287539	5	5	499146	4969508
30870	477691	-2.066442	4	4	496360	4970705
30879	207611	-4.148397	6	5	494253	4953387
30880	207618	-297.647455	7	5	494680	4952928
30975	603683	-0.099587	3	3	501174	4976428
30978	186301	-48.328817	6	6	486798	4950899
31065	594079	-52.51889	5	5	481197	4939835
31087	404849	-4.676238	6	6	499127	4956066
31120	585116	-21.6848	5	5	502038	4953699
31233	251989	-103.4179	4	3	493940	4972308
31262	624056	-1.930311	5	5	497202	4957273
31291	208394	-87.89521	11	11	496852	4957116
31292	213584	-913.503	11	11	496813	4956961
31293	524755	-2165.691	6	6	496597	4956471
31441	608186	-305.2055	5	5	493637	4942351
31474	405655	-500.2538	6	5	481780	4966721
31521	235755	-42.16917	5	5	498065	4954802
31598	622793	-0.032795	3	3	486121	4974954
31599	622794	-0.036212	3	3	486121	4974954
31746	603051	-1008.617	6	6	486212	4945773
31809		-1.650989	6	5	495933	4950853
31870		-6.813803	4	4	489538	4973929
31887	249861	-466.4382	6	5	502416	4953518
31888	585116	-94.79086	5	5	502038	4953699
32042		-225.050516	6	5	493320	4950252
32062		-33.44928	5	5	484029	4940838

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
32077	563000	-2285.473	6	6	505388	4974525
32078	596646	-1883.63	7	6	505592	4974076
32079	593657	-1610.761	7	6	505548	4973269
32080	611094	-1553.451	6	6	506488	4974207
32092	547293	-96.10326	6	5	481351	4965995
32151	568594	-0.036885	3	3	487525	4977135
32185	562991	-793.8155	6	5	480343	4947659
32187	603073	-368.6058	6	5	480749	4947962
32217		-4.918283	5	5	499576	4966343
32218		-5.434325	5	5	499576	4966343
32219		-1.925549	5	5	499576	4966343
32220		-0.443577	5	5	499576	4966343
32221		-4.039694	5	5	499576	4966343
32295	658747	-170.9169	4	4	490605	4964572
32473	671647	-1.563779	5	5	498947	4969309
32474	671646	-0.815768	5	5	498947	4969309
32490	244730	-22.77933	6	5	491435	4975472
32543	680543	-23.48935	6	6	500282	4939453
32544		-2.109519	5	5	498906	4971063
32545		-1.02669	5	5	498906	4971063
32546		-1.577622	5	5	498906	4971063
32547		-1.54837	5	5	498906	4971063
32584	668484	-24.38124	6	4	501042	4974986
32613		-9.062361	5	5	486237	4940836
32689		-0.897232	4	4	489538	4973929
32690		-6.714774	4	4	489538	4973929
32698		-10.95554	6	6	486288	4965178
32720		-12.42863	6	5	496349	4967325
32767		-12.73101	6	5	496784	4962960
32769	457156	-13.42729	5	5	489575	4947975
32884	655912	-3.00565	9	8	506289	4959337
32896	420992	-1054.595	6	6	480553	4958036
33032	606785	-301.2707	6	6	486285	4945673
33033	655902	-269.6901	6	6	486456	4945915
33105		-43.09053	6	6	505140	4951002
33209	655944	-228.2636	6	6	504643	4966122
33265	208393	-3648.753	6	5	496670	4956984
33290	201154	-371.3541	6	5	488182	4942408
33306	231870	-2143.398	8	6	506623	4959845
33326	208388	-0.927831	11	8	491902	4960703
33336	208414	-247.8221	6	6	500300	4966130
33370	226584	-3351.627	6	5	496349	4974735
33417	151595	-1898.993	6	6	488034	4967076

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
33455	208420	-329.0197	6	6	501578	4976429
33456	151569	-713.1574	6	6	504254	4974591
33468		-237.8771	6	5	506593	4943512
33607	205824	-14.95874	6	6	481165	4953575
33608	519955	-32.37446	11	11	484543	4954746
33787		-119.2281	6	5	501572	4945537
33789	256785	-181.2644	6	5	499575	4954330
33790		-398.3705	6	5	502480	4945534
33969	132225	-169.4205	6	5	504853	4944650
33970		-227.7602	6	5	501121	4943981
33974		-128.1913	6	5	505683	4940107
33978		-174.2892	6	5	499718	4947002
33980		-8.625931	6	5	502324	4962139
33984	208807	-909.4675	7	5	504790	4963993
34022	207258	-2081.146	6	6	485597	4963957
34024		-105.7155	6	5	506325	4956425
34231	208372	-177.6347	6	6	498422	4965214
34232	200412	-14.56902	9	4	485638	4974650
34233	200180	-134.4985	7	5	484591	4977518
34237		-30.33619	6	6	485322	4973951
34238	242346	-120.4118	6	5	488728	4943326
34245	165600	-107.8264	5	4	480816	4969223
34309	121826	-522.614	6	6	501590	4971504
34343	462233	-6.494187	3	3	483129	4971351
34401		-25.91446	5	5	499392	4964957
34402		-16.82179	5	5	499375	4966543
34475	509066	-6.084105	4	4	497194	4957382
34571	435223	-16.0279	5	5	491741	4949722
34579	502689	-0.109838	11	11	502576	4946403
34623	481814	-0.513812	3	3	485721	4974754
34656		-0.493982	3	3	486511	4971934
34690	497932	-7.127699	3	3	484984	4952584
34695	542924	-49.52624	6	6	498957	4970913
34788		-0.755173	3	3	481795	4977739
34808	603682	-0.099588	3	3	501195	4976429
34846	596626	-219.393	7	6	498999	4971464
34899		-11.4294	4	4	489538	4973929
34916	205589	-70.42643	6	4	486223	4967278
34920	603077	-96.10326	6	5	481372	4965945
34967		-16.80101	5	5	490670	4942223
35041	161421	-6650.328	11	11	497027	4956199
35050	208323	-317.9196	6	5	483812	4969590
35098	208418	-605.1505	6	5	500874	4964981

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
35137	224113	-151.2876	5	5	499022	4971419
35177	509051	-1943.069	6	6	505140	4973986
35246	205574	-433.5271	6	6	481729	4966692
35276	233121	-226.1783	7	7	504833	4953354
35280	200675	-738.9803	6	6	498041	4969914
35281	191943	-4376.218	6	6	485237	4955162
35282	127277	-1264.46	6	6	484371	4954021
35416	255852	-165.489	6	5	501734	4950404
35417	257124	-336.3218	6	5	504043	4949497
35424	253028	-2.189222	6	5	496571	4945663
35546		-68.13175	6	5	491682	4943216
35548	170864	-97.36777	7	5	501691	4949447
35550	127275	-47.20027	4	3	503501	4977087
35552		-225.3757	6	5	504893	4947836
35558	208809	-574.0611	6	6	502333	4963195
35559	201227	-280.3077	7	6	505457	4963737
35564	232245	-110.4892	3	3	493347	4944363
35594	489215	-2829.08	6	6	486000	4965611
35643		-0.871163	6	5	485193	4941496
35671	207284	-2614.429	6	6	496520	4966285
35675	171018	-213.3351	6	6	489128	4945713
35730	179806	-114.9994	6	5	502075	4961264
35731	448808	-2.30467	3	3	484685	4953494
35766	175913	-5.656904	3	3	485451	4941010
35794	433298	-90.4608	6	5	484559	4977507
35804	151553	-3.971298	11	10	497169	4958733
35829	161467	-2119.887	6	5	481316	4966020
35876	231861	-12.20504	5	5	501164	4967912
35921	441482	-6.472441	3	3	483778	4951651
35925	457135	-58.85924	5	5	497575	4939519
35926	457148	-172.117	6	5	503659	4960452
35980	509063	-0.165675	4	4	497196	4957338
35982	462149	-63.20918	5	5	487676	4949444
36016	462885	-0.216048	3	3	490118	4969929
36052	534094	-212.9856	5	5	502794	4946539
36111		-34.81591	5	5	500372	4966536
36169	557978	-129.5294	5	5	499780	4965947
36205	590107	-1.106035	5	5	499159	4969597
36215	603684	-0.099588	3	3	501184	4976428
36225	251594	-14.92182	6	6	499146	4955970
36255	120161	-53.82167	6	5	494002	4942539
36324		-2.832644	5	5	499576	4966343
36436	554225	-1541.528	6	6	487022	4959781

SWUDS Installation ID	Unique Number	Pumping Rate (m^3/day)	Bottom Layer	Top Layer	UTM X	UTM Y
36438	559401	-1292.113	6	6	486074	4960517
36439	626784	-55.06242	6	6	486691	4965186
36443	205823	-531.7254	6	5	483704	4953424
36444	603075	-860.8413	6	6	483954	4953655
36445	674495	-402.8414	6	6	484108	4955421
36463	655940	-304.7582	6	4	495347	4965434
	706804	-2865	6	6	490201	4952829
	722623	-2238	6	6	491558	4955361
	753663	-2087	6	6	492362	4955305

Attachment F

Summary of Fracture Flow Capture Zone Calculations

Well RR2 (474335) and RR1 (457167) Combined

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

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

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

Input variables	
Well Discharge, Q (gpm)	121.1
Aquifer Thickness, H (ft)	65
Aquifer Hydraulic Conductivity K (m/day)	12.7
Hydraulic Gradient, i	0.0027

Calculated Q/Qs (m)
972.5

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	660
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
473.9	43,017,857

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 7 (112212)

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

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

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

Input variables	
Well Discharge, Q (gpm)	404.9
Aquifer Thickness, H (ft)	106
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.006

Calculated Q/Qs (m)
1845.1

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2207
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
866.7	143,849,107

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 8 (554248)

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

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

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

Input variables	
Well Discharge, Q (gpm)	382.9
Aquifer Thickness, H (ft)	117
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.009

Calculated Q/Qs (m)
1053.8

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2087
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
842.8	136,027,679

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 9 (554248)

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

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

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

Input variables	
Well Discharge, Q (gpm)	566.9
Aquifer Thickness, H (ft)	102
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.007

Calculated Q/Qs (m)
2301.1

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	3090
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
1025.5	201,401,786

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 12 (706804)

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

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

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

Input variables	
Well Discharge, Q (gpm)	525.6
Aquifer Thickness, H (ft)	85
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.009

Calculated Q/Qs (m)
1991.3

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2865
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
987.5	186,736,607

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 14 (722623)

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

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

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

Input variables	
Well Discharge, Q (gpm)	410.6
Aquifer Thickness, H (ft)	75
Aquifer Hydraulic Conductivity K (m/day)	16.6
Hydraulic Gradient, i	0.0033

Calculated Q/Qs (m)
1783.0

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2238
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
872.7	145,869,643

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 15 (753663)

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

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

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

Input variables	
Well Discharge, Q (gpm)	382.9
Aquifer Thickness, H (ft)	103
Aquifer Hydraulic Conductivity K (m/day)	16.6
Hydraulic Gradient, i	0.003

Calculated Q/Qs (m)
1331.8

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2087
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
842.8	136,027,679

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 186301

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

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

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

Note: Fixed radius capture zone did not intersect fixed radius capture zone of Rosemount municipal wells so capture zone not evaluated further

Input variables	
Well Discharge, Q (gpm)	8.9
Aquifer Thickness, H (ft)	0
Aquifer Hydraulic Conductivity K (m/day)	0
Hydraulic Gradient, i	0

Calculated Q/Qs (m)
#DIV/0!

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	48.3
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	14.02

Calculated Fixed Radius (m)	Volume (m^3)
267.4	3,150,003

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

Where:

Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

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

Well 207617

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

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

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

Note: Fixed radius capture zone did not intersect fixed radius capture zone of Rosemount municipal wells so capture zone not evaluated further

Input variables	
Well Discharge, Q (gpm)	2.2
Aquifer Thickness, H (ft)	0
Aquifer Hydraulic Conductivity K (m/day)	0
Hydraulic Gradient, i	0

Calculated Q/Qs (m)
#DIV/0!

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	11.8
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
63.4	770,602

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

Where:

Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

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

Well 185278

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

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

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

Note: Fixed radius capture zone did not intersect fixed radius capture zone of Rosemount municipal wells so capture zone not evaluated further

Input variables	
Well Discharge, Q (gpm)	6.0
Aquifer Thickness, H (ft)	0
Aquifer Hydraulic Conductivity K (m/day)	0
Hydraulic Gradient, i	0

Calculated Q/Qs (m)
#DIV/0!

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	32.8
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	50.29

Calculated Fixed Radius (m)	Volume (m^3)
116.3	2,136,052

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

Where:

Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

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

Well 207615

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

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

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

Note: Fixed radius capture zone did not intersect fixed radius capture zone of Rosemount municipal wells so capture zone not evaluated further

Input variables	
Well Discharge, Q (gpm)	5.9
Aquifer Thickness, H (ft)	0
Aquifer Hydraulic Conductivity K (m/day)	0
Hydraulic Gradient, i	0

Calculated Q/Qs (m)
#DIV/0!

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	32.4
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	51.51

Calculated Fixed Radius (m)	Volume (m^3)
114.2	2,109,015

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

Where:

Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

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

Well 207618

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

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

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

Note: Fixed radius capture zone did not intersect fixed radius capture zone of Rosemount municipal wells so capture zone not evaluated further

Input variables	
Well Discharge, Q (gpm)	54.6
Aquifer Thickness, H (ft)	0
Aquifer Hydraulic Conductivity K (m/day)	0
Hydraulic Gradient, i	0

Calculated Q/Qs (m)
#DIV/0!

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	297.6
Pumping Period (years)	10
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	42.9768

Calculated Fixed Radius (m)	Volume (m^3)
379.1	19,400,236

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

Where:

Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)

n = effective porosity

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

Revised Fixed Radius for Well 8

Well	Volume of fixed radius capture zone (m^3) (No overlap)	Common interval with subject well (m)	Area of overlap with subject well (m^2)	Volume of overlap with subject well (m^3)	Revised Volume of Subject well (m^3)	Revised Radius of Subject Well (m)
8 (Subject Well)	136,006,175	60.96			186510236.4	986.9
9	201,375,751	60.96	1722355.033	104994762.8		
7	143,827,018	60.96	276032.603	16826947.48		

Revised Fixed Radius for Well 9

Well	Volume of fixed radius capture zone (m^3) (No overlap)	Common interval with subject well (m)	Area of overlap with subject well (m^2)	Volume of overlap with subject well (m^3)	Revised Volume of Subject well (m^3)	Revised Radius of Subject Well (m)
9 (Subject Well)	201,375,751	60.96			307043649	1266.2
8	136,006,175	60.96	1722355.033	104994762.8		
7	143,827,018	60.96	1090829.862	66496988.39		
12	186,711,449	60.96	133015.714	8108637.925		

Revised Fixed Radius for Well 7

Well	Volume of fixed radius capture zone (m^3) (No overlap)	Common interval with subject well (m)	Area of overlap with subject well (m^2)	Volume of overlap with subject well (m^3)	Revised Volume of Subject well (m^3)	Revised Radius of Subject Well (m)
7 (Subject Well)	143,827,018	60.96			203171183.8	1030.0
8	136,006,175	60.96	276032.603	16826947.48		
9	201,375,751	60.96	1090829.862	66496988.39		
12	186,711,449	60.96	866710.099	52834647.64		

Revised Fixed Radius for Well 12

Well	Volume of fixed radius capture zone (m^3) (No overlap)	Common interval with subject well (m)	Area of overlap with subject well (m^2)	Volume of overlap with subject well (m^3)	Revised Volume of Subject well (m^3)	Revised Radius of Subject Well (m)
12 (Subject Well)	186,711,449	60.96			220457308.1	1072.9
7	143,827,018	60.96	866710.099	52834647.64		
9	201,375,751	60.96	133015.714	8108637.925		

Revised Fixed Radius for Well 14

Well	Volume of fixed radius capture zone (m^3) (No overlap)	Common interval with subject well (m)	Area of overlap with subject well (m^2)	Volume of overlap with subject well (m^3)	Revised Volume of Subject well (m^3)	Revised Radius of Subject Well (m)
14 (Subject Well)	145,847,450	60.96			176799984	960.8
15	136,006,175	60.96	981241.789	59816499.46		

Revised Fixed Radius for Well 15

Well	Volume of fixed radius capture zone (m^3) (No overlap)	Common interval with subject well (m)	Area of overlap with subject well (m^2)	Volume of overlap with subject well (m^3)	Revised Volume of Subject well (m^3)	Revised Radius of Subject Well (m)
15 (Subject Well)	136,006,175	60.96			164870140.4	927.8
14	145,847,450	60.96	981241.789	59816499.46		

Well RR2 (474335) and RR1 (457167) Combined

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

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

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

Input variables	
Well Discharge, Q (gpm)	121.1
Aquifer Thickness, H (ft)	65
Aquifer Hydraulic Conductivity K (m/day)	12.7
Hydraulic Gradient, i	0.0027

Calculated Q/Qs (m)
972.5

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	660
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
149.9	4,301,786

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 7 (112212)

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

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

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

Input variables	
Well Discharge, Q (gpm)	404.9
Aquifer Thickness, H (ft)	106
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.006

Calculated Q/Qs (m)
1845.1

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2207
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
274.1	14,384,911

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 8 (554248)

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

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

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

Input variables	
Well Discharge, Q (gpm)	382.9
Aquifer Thickness, H (ft)	117
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.009

Calculated Q/Qs (m)
1053.8

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2087
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
266.5	13,602,768

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 9 (554248)

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

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

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

Input variables	
Well Discharge, Q (gpm)	566.9
Aquifer Thickness, H (ft)	102
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.007

Calculated Q/Qs (m)
2301.1

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	3090
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
324.3	20,140,179

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 12 (706804)

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

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

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

Input variables	
Well Discharge, Q (gpm)	525.6
Aquifer Thickness, H (ft)	85
Aquifer Hydraulic Conductivity K (m/day)	6.2
Hydraulic Gradient, i	0.009

Calculated Q/Qs (m)
1991.3

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2865
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
312.3	18,673,661

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 14 (722623)

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

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

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

Input variables	
Well Discharge, Q (gpm)	410.6
Aquifer Thickness, H (ft)	75
Aquifer Hydraulic Conductivity K (m/day)	16.6
Hydraulic Gradient, i	0.0033

Calculated Q/Qs (m)
1783.0

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2238
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
276.0	14,586,964

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Well 15 (753663)

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

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

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

Input variables	
Well Discharge, Q (gpm)	382.9
Aquifer Thickness, H (ft)	103
Aquifer Hydraulic Conductivity K (m/day)	16.6
Hydraulic Gradient, i	0.003

Calculated Q/Qs (m)
1331.8

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

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

Calculation for Fixed Radius with No Upgradient Extention

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

Input Variables	
Well Pumping Rate m^3/day	2087
Pumping Period (years)	1
Effective porosity, n	0.056
Thickness of saturated portion of aquifer, L (m)	60.96

Calculated Fixed Radius (m)	Volume (m^3)
266.5	13,602,768

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

Where:
Q = Well Discharge (L3/T)=(Well pumping rate)(pumping time period)
n = effective porosity
L = thickness of saturated portion of aquifer (L) note: lesser of open borehole or 200 ft

Upgradient Extension Well 509060

Well Location	
X	488353
Y	4952200
Length of extension (1.57 * radius of fixed radius capture zone)	1549.36
Flow Direction	170
Flow Direction + 10 degrees	180
Flow Direction - 10 degrees	160

Center of extension	
X	488622
Y	4950674

Center of extension +10 degrees	
X	488353
Y	4950651

Center of extension - 10 degrees	
X	488883
Y	4950744

Upgradient Extension Well 554248

Well Location	
X	488408
Y	4952731
Length of extension (1.57 * radius of fixed radius capture zone)	1987.9355
Flow Direction	161
Flow Direction + 10 degrees	171
Flow Direction - 10 degrees	151

Center of extension	
X	489055
Y	4950851

Center of extension +10 degrees	
X	488719
Y	4950768

Center of extension - 10 degrees	
X	489372
Y	4950992

Upgradient Extension Well 706804

Well Location	
X	490201
Y	4952829
Length of extension (1.57 * radius of fixed radius capture zone)	1684.4747
Flow Direction	191
Flow Direction + 10 degrees	201
Flow Direction - 10 degrees	181

Center of extension	
X	489880
Y	4951175

Center of extension +10 degrees	
X	489597
Y	4951256

Center of extension - 10 degrees	
X	490172
Y	4951145

Upgradient Extension Well 722623

Well Location		Center of extension	
X	491558	X	490629
Y	4955361	Y	4954172
Length of extension (1.57 * radius of fixed radius capture zone)	1508.4932	**Center of extension +10 degrees**	
Flow Direction	218	X	490437
Flow Direction + 10 degrees	228	Y	4954352
Flow Direction - 10 degrees	208	**Center of extension - 10 degrees**	
		X	490850
		Y	4954029

Upgradient Extension Well 753663

Well Location		Center of extension	
X	492362	X	491426
Y	4955305	Y	4954189
Length of extension (1.57 * radius of fixed radius capture zone)	1456.7105	**Center of extension +10 degrees**	
Flow Direction	220	X	491246
Flow Direction + 10 degrees	230	Y	4954369
Flow Direction - 10 degrees	210	**Center of extension - 10 degrees**	
		X	491634
		Y	4954043

Upgradient Extension Well 457167 and 474335

Well Location		Center of extension	
X	493652	X	493058
Y	4954085	Y	4953637
Length of extension (1.57 * radius of fixed radius capture zone)	744.09192	**Center of extension +10 degrees**	
Flow Direction	233	X	492989
Flow Direction + 10 degrees	243	Y	4953747
Flow Direction - 10 degrees	223	**Center of extension - 10 degrees**	
		X	493145
		Y	4953541