Hydrogeologic Assessment of the Drinking Water Source and Wells for the City of Sherburn

DELINEATIONS – WELLHEAD PROTECTION AREA AND DRINKING WATER SUPPLY MANAGEMENT AREA

VULNERABILITY ASSESSMENTS – WELLS AND DRINKING WATER SUPPLY MANAGEMENT AREA

December 14, 2023

Wellhead Protection Plan

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Public Water Supply ID: 1460007

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Glossary of Terms

Data Element. A specific type of information required by the Minnesota Department of Health to prepare a wellhead protection plan.

Drinking Water Supply Management Area (DWSMA). The area delineated using identifiable landmarks that reflects the scientifically calculated wellhead protection area boundaries as closely as possible (Minnesota Rules, part 4720.5100, subpart 13).

Drinking Water Supply Management Area Vulnerability. An assessment of the likelihood that the aquifer within the DWSMA is subject to impact from land and water uses within the wellhead protection area. It is based upon criteria that are specified under Minnesota Rules, part 4720.5210, subpart 3.

Emergency Response Area (ERA). The part of the wellhead protection area that is defined by a one-year time of travel within the aquifer that is used by the public water supply well (Minnesota Rules, part 4720.5250, subpart 3). It is used to set priorities for managing potential contamination sources within the DWSMA.

Inner Wellhead Management Zone (IWMZ). The land that is within 200 feet of a public water supply well (Minnesota Rules, part 4720.5100, subpart 19). The public water supplier must manage the IWMZ to help protect it from sources of pathogen or chemical contamination that may cause an acute health effect.

Wellhead Protection (WHP). A method of preventing well contamination by effectively managing potential contamination sources in all or a portion of the well's recharge area.

Wellhead Protection Area (WHPA). The surface and subsurface area surrounding a well or well field that supplies a public water system, through which contaminants are likely to move toward and reach the well or well field (Minnesota Statutes, section 103I.005, subdivision 24).

Well Vulnerability. An assessment of the likelihood that a well is at risk to human-caused contamination, either due to its construction or indicated by criteria that are specified under Minnesota Rules, part 4720.5550, subpart 2.

Acronyms

CWI - County Well Index

DNR - Minnesota Department of Natural Resources

EPA - United States Environmental Protection Agency

FSA - Farm Security Administration

MDA - Minnesota Department of Agriculture

MDH - Minnesota Department of Health

MGS - Minnesota Geological Survey

MnDOT - Minnesota Department of Transportation

MnGEO - Minnesota Geospatial Information Office

MODFLOW - Three-Dimensional Finite-Difference Groundwater Model

MPCA - Minnesota Pollution Control Agency

NRCS - Natural Resource Conservation Service

SWCD - Soil and Water Conservation District

UMN - University of Minnesota

USDA - United States Department of Agriculture

USGS - United States Geological Survey

Summary

Protection Areas - The recharge area for the wells is known as the wellhead protection area, or WHPA, and represents the area that contributes water to the city's wells within a 10-year time period. The area that contributes water within a one-year time period is known as the emergency response area, or ERA. Practical reasons require the designation of a management area that fully envelops the wellhead protection area, called the drinking water supply management area, or DWSMA. Each of these areas is shown in Figure 1.

Geology and Groundwater Flow – The city of Sherburn has two primary wells screened in a sand and gravel aquifer that is buried beneath a layer of clay-rich sediment. Such aquifers are known generically as Quaternary Buried Artesian Aquifers (QBAA). The depths of the wells are approximately 275 feet deep (Table 1). Regionally, groundwater flow is to the northeast.

Table 1 - Water Supply Well Information

Local Well ID	Unique Number	Use/ Status	Casing Diameter (inches)	Casing Depth (feet)	Well Depth (feet)	Date Constructed/ Reconstructed	Aquifer	Well Vulnerability
Well #3	810229	Primary	12	239	279	2017	Quaternary Buried Artesian Aquifer	Nonvulnerable
Well #4	850991	Primary	12	243	273	2021	Quaternary Buried Artesian Aquifer	Nonvulnerable

Well Vulnerability - The vulnerability of each well has been assessed based on 1) well construction details, especially conformance with standards required by the state well code, 2) the geologic sensitivity of the aquifer, and 3) past monitoring results. Both wells meet construction standards as stated in the Minnesota Well Code. Additionally, the wells draw from an aquifer that is geologically protected. Additionally, water samples from two previous public water supply wells (Well #1 (217092) and Well #2 (217093)) completed in the source aquifer as the current two PWS wells, lacked detectable tritium (detection indicates the presence of young water), so they are not considered vulnerable at this time (Table 2). This is reinforced by the low chloride/bromide ratios presented below.

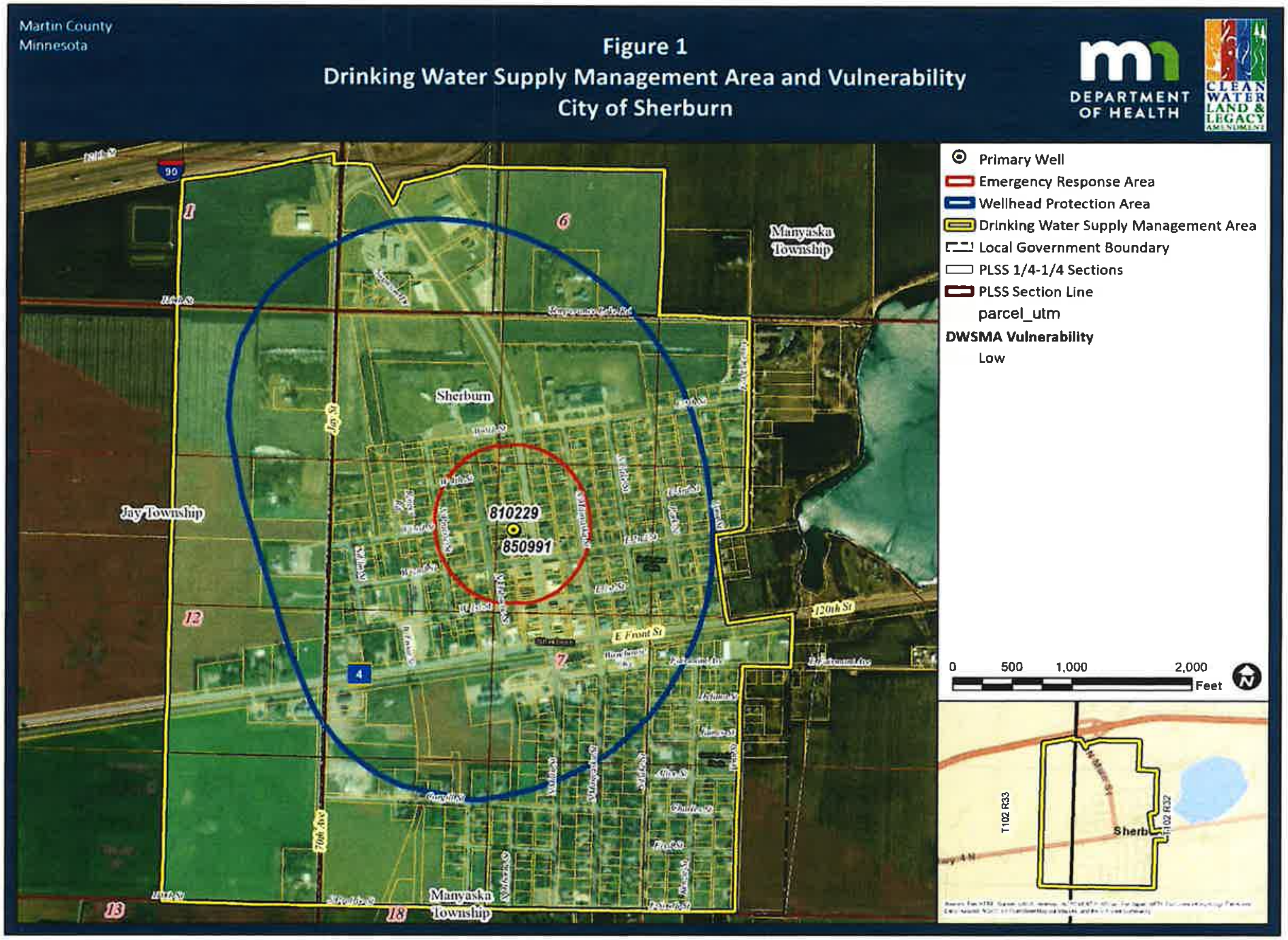
Table 2 – Isotope and Water Quality Results

Unique Number (Well Name)	Tritium (TU)	Nitrate (mg/L)	Chloride (mg/L)	Bromide (mg/L)	Chloride/ Bromide Ratio
217092 (Well #1)	<0.8 6/24/2014	<0.05 6/24/2014	1.55 6/24/2014	0.04 6/24/2014	38.75
217093 (Well #2)	<0.8 6/24/2014	<0.05 6/24/2014	1.59 6/24/2014	0.03 6/24/2014	53

DWSMA Vulnerability -The vulnerability of the city's aquifer throughout the DWSMA is based on the geologic sensitivity ratings of wells and their monitoring data. Based on this information MDH has assigned a low vulnerability to the DWSMA. This suggests that the clay-rich sediments that overlie the city's aquifer prevent water and contaminants from moving quickly from the land surface into the city's aquifer and implies a time of travel of decades or longer. The principal threats to this aquifer are unsealed abandoned wells that penetrate through this clay layer. Such wells are 200 feet or greater in depth in the Sherburn area.

Water Quality Concerns - At present, none of the contaminants for which the Safe Drinking Water Act has established health-based standards has been found above maximum allowable levels in the city's water supply, nor are any present at one-half of those levels.

Recommendations - Recommendations have been generated to improve future delineations and vulnerability assessments and should be considered for inclusion as management strategies in the city's wellhead protection plan. These activities include wells locating, water quality monitoring, and wells sealing. Further details can be found in the Recommendations section of this report.


Martin County
Minnesota
Figure 1
Drinking Water Supply Management Area and Vulnerability
City of Sherburn
DEPARTMENT OF HEALTH
CLEAN WATER LAND & LEGACY AMENDMENT
Primary Well
Emergency Response Area
Wellhead Protection Area
Drinking Water Supply Management Area
Local Government Boundary
PLSS 1/4-1/4 Sections
PLSS Section Line
parcel_utm
DWSMA Vulnerability
Low
0
500
1,000
2,000
Feet
810229
850991
Sherburn
Jay Township
Manyaska Township
Manyaska Township
E Front St
120th St
Jay St
70th Ave
90
4
1
6
7
12
13
18
T102 R33
T102 R32

Technical Report

Discussion

This document describes the amendments to Part 1 of the wellhead protection (WHP) plan for The city of Sherburn (PWSID 1460007). The purpose for amending the plan is to address the changes that have occurred since the plan was last approved, in order to update the WHP measures that are needed to protect public drinking water. In addition, two new wells were drilled to replace the pervious two wells that were included in the current wellhead protection plan. The amended areas are somewhat smaller (Figure 6) due to increased knowledge of the local hydrogeology; the use of a different modeling sofware; and a different approach in addressing uncertainity relating to hydralic conductivity. The work was performed in accordance with the Minnesota Wellhead Protection Rule, parts 4720.5100 to 4720.5590.

This report presents delineations of the wellhead protection area (WHPA) and drinking water supply management area (DWSMA), and the vulnerability assessments for the public water supply wells and DWSMA. Figure 1 shows the boundaries for the WHPA and the DWSMA. The WHPA is defined by a 10-year time of travel. Figure 1 also shows the emergency response area (ERA), which is defined by a one-year time of travel. Definitions of rule-specific terms used are provided in the "Glossary of Terms."

In addition, this report documents the technical information required to prepare this portion of the WHP plan in accordance with the Minnesota Wellhead Protection Rule. Additional technical information is available from MDH.

Table 1 lists all the wells in the public water supply system. Only wells listed as primary are required to be included in the WHP plan.

Assessment of the Data Elements

MDH staff met with representatives of the city of Sherburn on April 20, 2023, for a scoping meeting that identified the data elements required to prepare Part I of the WHP plan. Appendix A presents the assessment of these data elements relative to the present and future implications of planning items specified in Minnesota Rules, part 4720.5210.

General Descriptions

Description of the Water Supply System

The city of Sherburn obtains its drinking water supply from two primary wells. Table 1 summarizes information regarding them.

Description of the Hydrogeologic Setting

The city of Sherburn is in Martin County. The area in the vicinity of the public water supply wells is covered with over 200 feet of glacial till consisting of sand, silt, and clay with lesser amount of gravel, cobble, and boulder (Quade, Rongstad, et al 1991). The glacial drift overlies a Cretaceous layer consisting of dolomite, limestone, sandstone siltstone and shale (Figures 4 and 5). Local groundwater flow is generally towards the northeast (Figure 2).

A description of the hydrogeologic setting for the aquifer used to supply drinking water is presented in Table 3.

Table 3 - Description of the Local Hydrogeologic Setting

Attribute	Descriptor	Data Source
Aquifer Material	Quaternary Buried Sand and Gravel	Well Logs (810229, 850991), CWI
Porosity Type and Value	30	Fetter, 2001
Aquifer Thickness	59 feet	CWI, Figures 4 and 5, local well logs
Stratigraphic Top Elevation	Range: 1060 - 1100ft. (MSL)	CWI, Figures 4 and 5, local well logs
Stratigraphic Bottom Elevation	Range: 950 - 1022 ft. (MSL)	CWI, Figures 4 and 5, local well logs
Hydraulic Confinement	Confined	CWI, Figures 4 and 5

Attribute	Descriptor	Data Source
Transmissivity	Range of Values: 98 -18,288 ft^2/day	A range of transmissivity values was used to reflect changes in aquifer composition and thickness as well as uncertainties related to the quality of existing aquifer test data. See Table 4 for the reference value.
Hydraulic Conductivity	Range of Values: 3.77 -351.71 ft/day	The range of values was derived using specific capacity data obtained from well records.
Groundwater Flow Field	Groundwater flow is (compass direction), with an approximate compass direction of 78º and gradient of 0.0021 (Figure 2).	Defined by using static water level elevations from well records in the CWI database and documents listed in the "Selected References" section of this report.

The distribution of the aquifer and its stratigraphic relationships with adjacent geologic materials are shown in Figures 3, 4, and 5. They were prepared using well record data contained in the CWI database. The geological maps and studies used to further define local hydrogeologic conditions are provided in the "Selected References" section of this report.

Delineation of the Wellhead Protection Area

Delineation Criteria

The boundaries of the WHPA for the city of Sherburn are shown in Figure 1. Table 4 describes how the delineation criteria specified under Minnesota Rules, part 4720.5510, were addressed.

Table 4 - Description of WHPA Delineation Criteria

Criterion	Description	How the Criterion was Addressed
Flow Boundary	None	There are no flow boundaries close enough to the public water supply wells that may have an impact on their capture areas.
Flow Boundary	Other High-Capacity Wells	No known high-capacity wells exist within two miles of the city of Sherburn wells.
Daily Volume of Water Pumped	See Table 5	Pumping information was obtained from the DNR, Appropriations Permit Number 1960-0357, and was converted to a daily volume pumped by a well.
Groundwater Flow Field	Groundwater flow is to the northeast, with an approximate compass direction of 78º and gradient of 0.0021 (Figure 2).	The groundwater flow field was determined from local well data and input explicitly into MODFLOW and capture zones were calculated based on the flow field.
Aquifer Transmissivity (T)	Reference Value: 18,289 ft^2/day	The aquifer test plan was approved on June 26, 2023, and T was determined from specific capacity data for city well #3 (810229). Uncertainty regarding aquifer transmissivity was addressed as described in Addressing Model Uncertainty section.
Time of Travel	10 years	The public water supplier selected a 10-year time of travel.

Pumping data was obtained from the DNR Permit and Reporting System (MPARS) for the public water supply's Appropriation Permit Number 1960-0357. These values, confirmed by the public water supplier, were used to identify the maximum volume of water pumped annually by each well over the previous five-year period, as shown in Table 5. An estimate of the pumping for the next five years is also shown. The maximum daily volume of discharge used as an input parameter in the model was calculated by dividing the greatest annual pumping volume by 365 days.

Table 5 - Annual Volume of Water Discharged from Water Supply Wells

Well Name	Unique Number	2018	2019	2020	2021	2022	(2027) Pumping	Daily Volume (cubic meters)
Well #2	217093	8,314,000	16,820,000	27,020,000	57,941,000	Sealed		
Well #3	810229	22,951,000	20,809,000	33,479,000	18,192,000	58,749,000		
Well #4	850991					30,972,000		
System Total		31,265,000	37,628,910	60,499,000	76,133,000	89,721,000	89,721,000	930.5

(Expressed as gallons. 2022 has greatest annual pumping volume.)

Method Used to Delineate the Wellhead Protection Area

The WHPA for the city of Sherburn wells was determined using the software code MODFLOW (McDonald and Harbaugh, 1988; Harbaugh et al., 2000; Harbaugh, 2005). The resulting WHPA boundary is a composite of the capture zones calculated from several different model scenarios using a stochastic method (Figure 1).

MODFLOW was developed by the United States Geological Survey and is publicly available. The specific software code used for this delineation was MODFLOW-USG (USG -Unstructured Grid). The software has a smoothed quadtree refinement within it. The program has been thoroughly documented, is widely used by consultants, government agencies, and researchers and consistently accepted in regulatory proceedings. MODFLOW is also an extremely versatile program capable of simulating groundwater flow in up to three dimensions while offering a variety of boundary condition options, confined or unconfined aquifer conditions and allowing for vertical discretization through the use of layering.

A deterministic model typically uses a fixed set of parameters and boundary conditions to simulate a "best guess" at what is occurring in the groundwater flow system. However, such models often fail to address uncertainty in parameter distributions and how much that uncertainty may affect predictions. Hydraulic conductivity, for example, is particularly prone to uncertainty as aquifers are typically not homogeneous and limited data on the subsurface in the form of specific capacity and aquifer tests is often spatially distant from one another and/or has uncertain data quality. One method for dealing with this uncertainty is using a stochastic method. A stochastic method, in this case known as a Monte Carlo approach, using PEST++IES (White et al, 2020) uses a range of feasible parameter values and generates possible calibrated "realizations" that are equally probable. Each realization is then used to make a prediction and estimate the probability of capture at any given well.

The numerical groundwater model constructed for the city has a grid of 117 rows and 117 columns, and is a single layer. The model incorporates a variable areal grid spacing ranging from four meters subdivided smaller cells near the city well, increasing 100 meters towards the boundaries of the domain, without having that refinement carried throughout the model grid, and having some of the cells remain inactive. The layer top and bottom were inputed in the model.

The city of Sherburn primary wells pump from a sand and gravel aquifer. The sand and gravel lens from which the city wells pump, is overlain by Quaternary clay in the vicinity of the city wellfield. As a result of the hydrogeology of the area, a single layer model was developed for the city. Horizontal hydraulic conductivity (Kx) was obtained from specific capacity data for the city's wells and from other existing wells in the area completed within similar aquifers. Aquifer recharge was not used as an input parameter due to the confinement of the aquifer. The gradient and angle of groundwater flow were determined and input to the model. The approach use for this delineation is appropriate because of the absence of flow boundaries in the area around the city's well as observed in well logs and the hydrogeology of the area.

Due to the heterogeneity of the aquifer, site specific data within the model domain was interpolated using the Parameter Estimation (PEST) tool. PEST is a calibration tool developed by John Doherty of Watermark Computing and is most commonly used to estimate aquifer hydraulic conductivity (Doherty, 2010). Typical zonation of hydraulic conductivity introduces zones of different hydraulic conductivity in the model domain at locations where the modeler feels they would do the most good. The parameter zonation process would then be repeated until the fit between model outcomes and field observations was acceptable.Characterization of geologic heterogeneity in the model domain by zones of piecewise uniformity is not in harmony with the nature of the surrounding aquifer material, therefore any zonation pattern that is finally decided upon is only defensible on the basis that it is better to employ such a zonation scheme than to ignore geologic heterogeneity altogether. To overcome this problem the distribution of hydraulic conductivity within the model domain was described by a set of pilot points. The pilot point locations and range of values in the model domain were derived from specific capacity data. These values were than imported into the RANDom PARameter (RANDPAR) utility, which is used to generate the random parameter set realizations. The realizations and the values associated with them were then smoothed with the geostatistical method of kriging and input into the model runs. The pilot point method allowed for hydraulic conductivity values to be representative of the city's well data proximal to the well field and then be smoothed further away.

To determine the WHPA, the many MODFLOW realizations were used along with a particle tracking program called MODPATH (Pollock, 2012). MODPATH is used to evaluate advective transport of simulated particles moving through the simulated flow system. A series of 36 particles were launched at the well. A porosity of 30 percent was used and a reverse time of travel was calculated at 10 years. Each of these potential capture zones were composited into a probability of capture based on the number of times any specific location is included in the capture areas generated, divided by the total number of realizations. The combined output of all model results was composited to create the final WHPA (Figure 1).

Results of Model Calibration and Sensitivity Analysis

Model calibration is a procedure that compares the results of a model based on estimated input values to measured or known values. This procedure can be used to define model validity over a range of input values, or it helps determine the level of confidence with which model results may be used. As a matter of practice, groundwater flow models are usually calibrated using water elevation or flux.

Model sensitivity is the amount of change in model results caused by the variation of a particular input parameter. Because of the simplicity of the MODFLOW model, the direction and extent of the modeled capture zone may be very sensitive to any of the input parameters:

- The pumping rate directly affects the volume of the aquifer that contributes water to the well. An increase in pumping rate leads to an equivalent increase in the volume of aquifer within the capture zone, proportional to the porosity of the aquifer materials. However, the pumping rate is based on the results presented in Table 5 and, therefore, is not a variable factor that will influence the delineation of the WHPA.
- The direction of groundwater flow determines the orientation of the capture area. Variations in the direction of groundwater flow will not affect the size of the capture zone but are important for defining the areas that are the source of water to the well. The ambient groundwater flow field defined in Figure 2 provides the basis for determining the extent to which each model run reflects the conceptual understanding of the orientation of the capture area for a well.
- A hydraulic gradient of zero produces a circular capture zone, centered on the well. As the hydraulic gradient increases, the capture zone changes into an elliptical shape, with the well centered on the down-gradient focal point. The hydraulic gradient was determined by using water level elevations that were taken from wells that have verified locations (Figure 2). Generally, the accuracy of the hydraulic gradient determination is directly proportional to the amount of available data that describes the distribution of hydraulic head in the aquifer.
- The aquifer thickness, hydraulic conductivity, and porosity influence the size and shape of the capture zone. A decrease in porosity causes a linear, proportional increase in the areal extent of the capture zone, whereas thickness and hydraulic conductivity each

factor into the transmissivity, which defines the relative proportions of the capture zone width to length. A decrease in thickness or hydraulic conductivity decreases the length of the capture zone and increases the distance to the stagnation point, making the capture zone more circular in shape and centered around the well.

Addressing Model Uncertainty

Using computer models to simulate groundwater flow involves representing a complicated natural system in a simplified manner. Local geologic conditions may vary within the capture area of the public water supply well, but the amount of existing information needed to accurately define this degree of variability is often not available for portions of the WHPA. In addition, the current capabilities of groundwater flow models may not be sufficient to represent the natural flow system exactly. However, the results are valid within a range defined by the reasonable variation of input parameters for this delineation setting.

The steps employed for this delineation to address model uncertainty were:

1. Pumping Rate - For each well, a maximum historical (five-year) pumping rate or an engineering estimate of future pumping, whichever is greater (Minnesota Rules, part 4720.5510, subpart 4).
2. Ambient Flow Field - A composite of capture zones created from angles of flow that are 10 degrees greater and 10 degrees lesser than the representative angle of ambient flow (Minnesota Rules, part 4720.5510, subpart 5, B(2).
3. Aquifer Thickness - The smaller open-hole intervals of the wells were used rather than a representative thickness of the aquifer.
4. Probability Analysis - The Monte Carlo approach was used to estimate capture zone probability as well as variability in hydraulic conductivity.

Capture areas were developed for a range of groundwater flow directions, aquifer permeabilities, and times of travel of one and 10 years (Figure 6). As the model code uses constant input values for each run, multiple runs were required to include all variations in input parameters. Table 6 documents the variables used to address MODFLOW uncertainty.

Table 6 - Model Parameters Used in MODFLOW Base Case and Uncertainty Runs

Well Name (Unique Number)	File Name	Discharge (cubic meters per day)	Transmissivity (meters squared per day)	Gradient	Flow Angle	Porosity (%)	Aquifer Thickness (meters)	Remarks
Well #3 (810229)	Final_Prob_C Z1	465.3	1699.103	0.0021	78	30	17.98	Base
Well #3 (810229)	Final_Prob_C Z2	465.3	9.11 – 1699.103	0.0021	78	30	17.98	150 Realizati ons
Well #3 (810229)	Final_Prob_C Z3	465.3	1699.103	0.0021	78	30	17.98	Plus 10 degrees
Well #3 (810229)	Final_Prob_C Z4	465.3	9.11 – 1699.103	0.0021	78	30	17.98	150 Realizati ons
Well #3 (810229)	Final_Prob_C Z5	465.3	1699.103	0.0021	78	30	17.98	Minus 10 degrees
Well #3 (810229)	Final_Prob_C Z6	465.3	9.11 – 1699.103	0.0021	78	30	17.98	150 Realizati ons
Well #4 (850991)	Final_Prob_C Z1	465.3	1699.103	0.0021	78	30	17.98	Base
Well #4 (850991)	Final_Prob_C Z2	465.3	9.11 – 1699.103	0.0021	78	30	17.98	150 Realizati ons
Well #4 (850991)	Final_Prob_C Z3	465.3	1699.103	0.0021	78	30	17.98	Plus 10 degrees

Well Name (Unique Number)	File Name	Discharge (cubic meters per day)	Transmissivity (meters squared per day)	Gradient	Flow Angle	Porosity (%)	Aquifer Thickness (meters)	Remarks
Well #4 (850991)	Final_Prob_CZ4	465.3	9.11 – 1699.103	0.0021	78	30	17.98	150 Realizations
Well #4 (850991)	Final_Prob_CZ5	465.3	1699.103	0.0021	78	30	17.98	Minus 10 degrees
Well #4 (850991)	Final_Prob_CZ6	465.3	9.11 – 1699.103	0.0021	78	30	17.98	150 Realizations

Delineation of the Drinking Water Supply Management Area

The boundaries of the Drinking Water Supply Management Area (DWSMA) were defined by the city of Sherburn using the following features (Figure 1):

- Centerlines of highways, streets, roads rights-of-ways.
- Public Land Survey coordinates.
- Property or fence lines.
- Political boundaries.

Comparison of Previous and Current WHPA and DWSMA Delineations

The updated WHPA and DWSMA for the city of Sherburn are smaller than those generated in 2013 (Figure 6). This reduction stems from a difference in the delineation method. As a result, the WHPA and DWSMA decreased in size.

The following is a brief synopsis of additional technical considerations that changed since the previous plan:

- A new groundwater flow model was developed using a different software code. MODFLOW is better able to simulate hydraulic connection of the leaky clay-rich till to and is also better supported, which increases the likelihood that it can be used for future amendments.
- The modeling approach to address uncertainty incorporated the PEST+++ process which was not used during the 2013 delineation process.

- New Wells #3 (810299) and #4 (850991) were drilled while Well #1 (217092) and Well #2 (217093) were sealed.
- The pumping rate increased over the last 10-year period. The increment showed over a 100 percent increase in pumping (44.6 MG/Y (2013), and 89.721 MG/Y (2022)).

Vulnerability Assessments

The Part I wellhead protection plan includes the vulnerability assessments for the city of Sherburn's wells and DWSMA. These vulnerability assessments are used to help define potential contamination sources within the DWSMA and select appropriate measures for reducing the risk that they present to the public water supply.

Assessment of Well Vulnerability

The vulnerability for each well used by the city of Sherburn is listed in Table 1 and based upon the following conditions:

1. Well construction meets current State Well Code specifications (Minnesota Rules, part 4725), meaning that the wells themselves should not provide a pathway for contaminants to enter the aquifer used by the public water supplier.
2. The geologic conditions at the well sites include a cover of clay-rich geologic materials over the aquifer that is sufficient to retard or prevent the vertical movement of contaminants.
3. None of the human-caused contaminants regulated under the federal Safe Drinking Water Act have been detected at levels indicating that the wells themselves serve to draw contaminants into the aquifer due to pumping.
4. Water samples were collected from the city's previous public water supply Well #1 (217092) and Well #2 (217093) on July 24, 2014 and were analyzed for nitrate, chloride and bromide (Table 2). Water sample was also collected from Well #2 (217093) July 24, 2006, and analyzed for tritium. No tritium or nitrate was detected in these samples, confirming the non-vulnerable nature of the well (Alexander and Alexander, 1989). In addition, the chloride and bromide results confirm that the well has not been impacted by land-use activities (Mullaney et. al, 2009). The previous two wells were completed in the same aquifer as the current two public water supply wells.

Assessment of Drinking Water Supply Management Area Vulnerability

The DWSMA vulnerability is shown in Figure 1 and is based upon the following information:

1. Isotopic and water chemistry data from wells located within the DWSMA indicate that the aquifer contains water that has no detectable levels of tritium or human-caused contamination.
2. Review of the geologic logs contained in the CWI database and geological maps and reports indicate that the aquifer exhibits a low geologic sensitivity throughout the DWSMA and is isolated from the direct vertical recharge of surface water.

Therefore, given the information currently available, it is prudent to assign a low vulnerability rating to the DWSMA, in accordance with the Minnesota Wellhead Protection Rule (parts 4720.5100 to 4720.5590).

Recommendations

The following recommendations have been generated to inform the next amendment of the city of Sherburn's Wellhead Protection Plan.

1. Well Locating: This delineation is based on limited well data. If wells are constructed within two miles of the city or one mile of the DWSMA, their locations should be verified. This information may allow a better understanding of the extent and thickness of the city's aquifers and the overlying clay confining units and result in a more refined WHPA in the future.
2. Water Quality Monitoring: The standard assessment monitoring package (nitrate, manganese, arsenic, total organic carbon, ammonia, bromide, chloride, iron anions, cations) should be analyzed currently and during years seven of the plan implementation. Sampling sites should include the primary wells and be contingent on funding assistance from MDH for sampling and analysis. The city may need to collect the samples and ship them to MDH. Information generated by this sampling will be used to refine vulnerability assessments for the next amendment.

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Figures

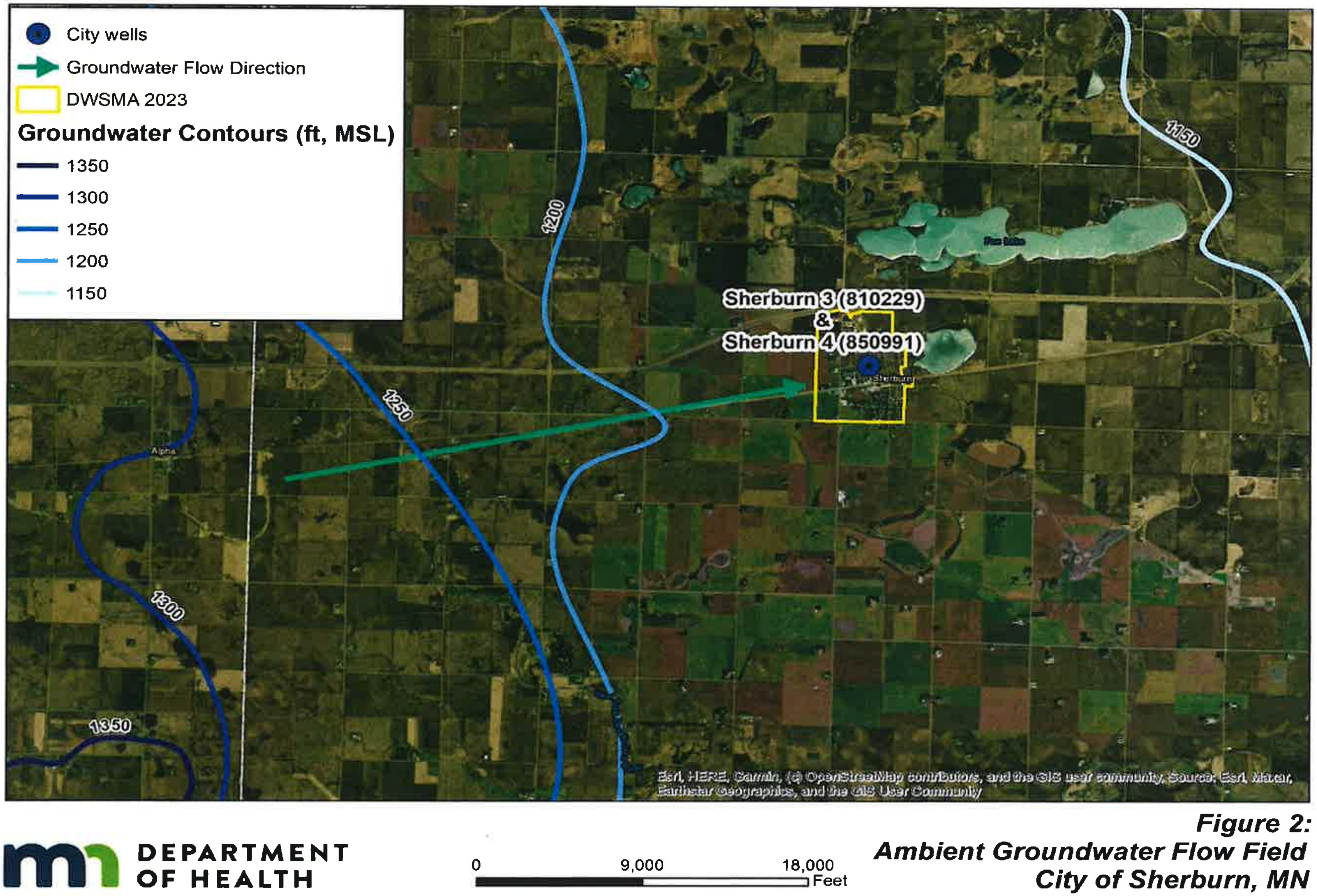

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Figure 2:
Ambient Groundwater Flow Field
City of Sherburn, MN

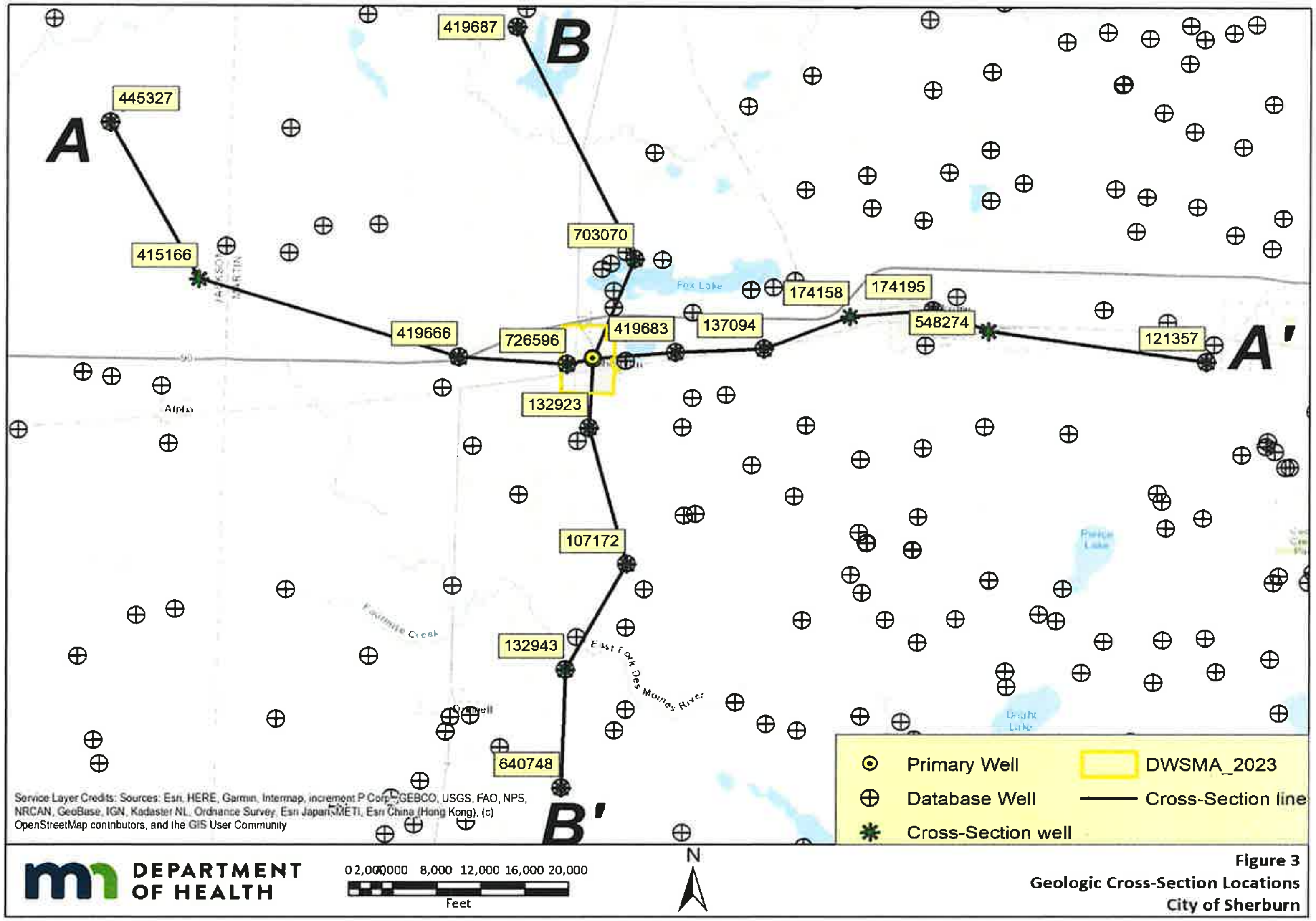
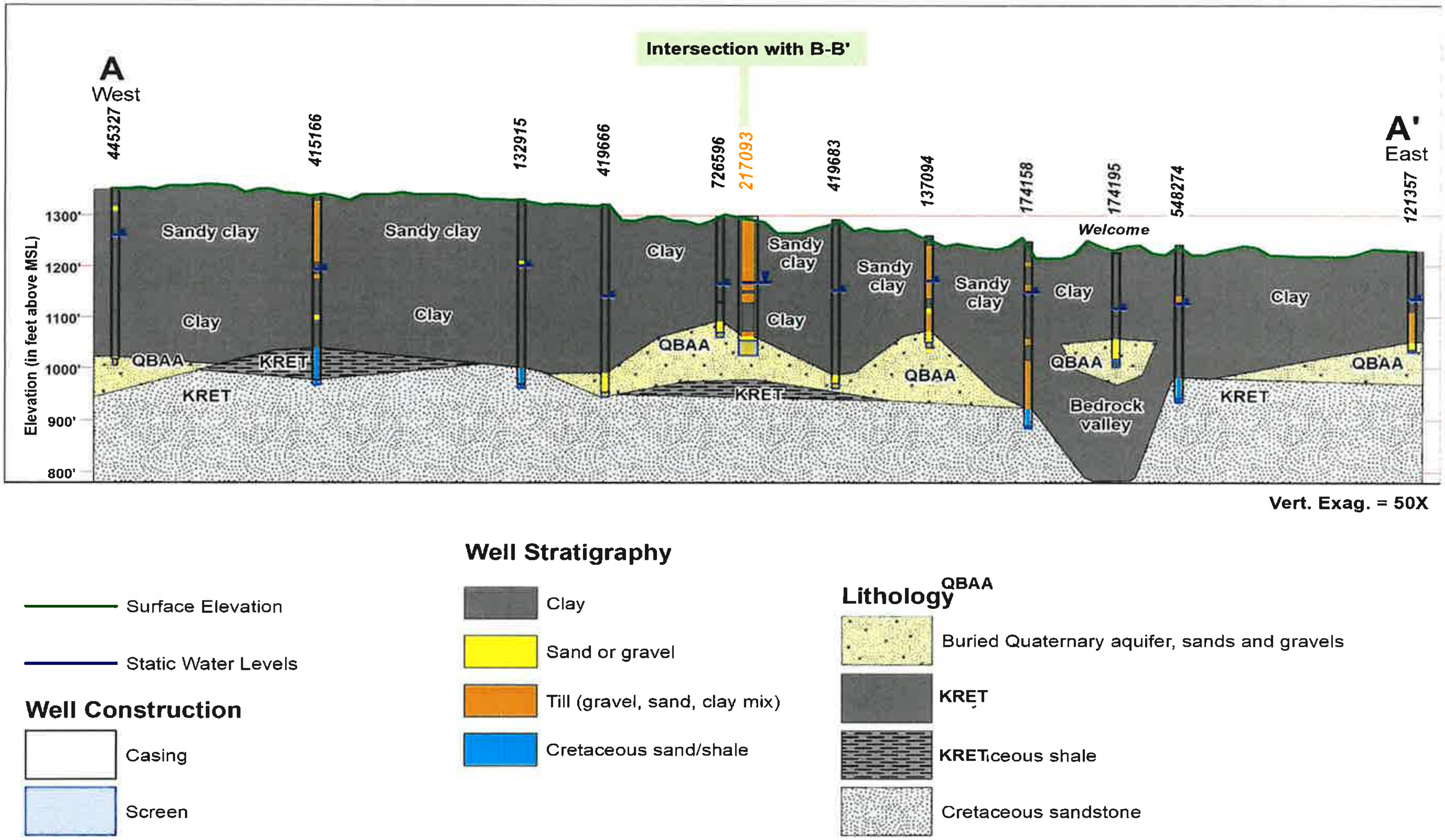


Figure 3
Geologic Cross-Section Locations
City of Sherburn



0 2.75 5.5 Miles

Figure 4:
Geologic Cross-Section A-A'
City of Sherburn

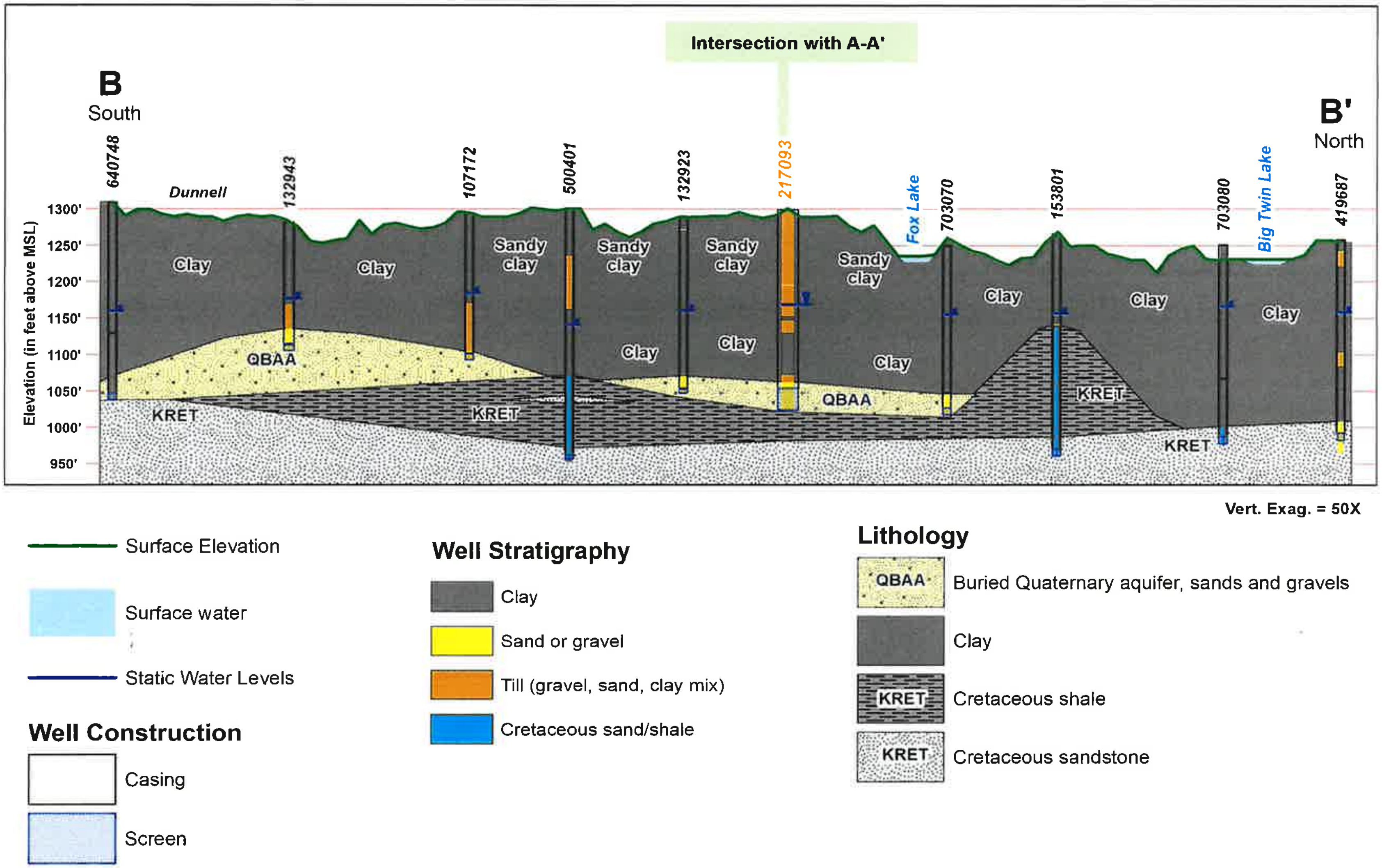


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Figure 5
Geologic Cross-Section B-B'
City of Sherburn

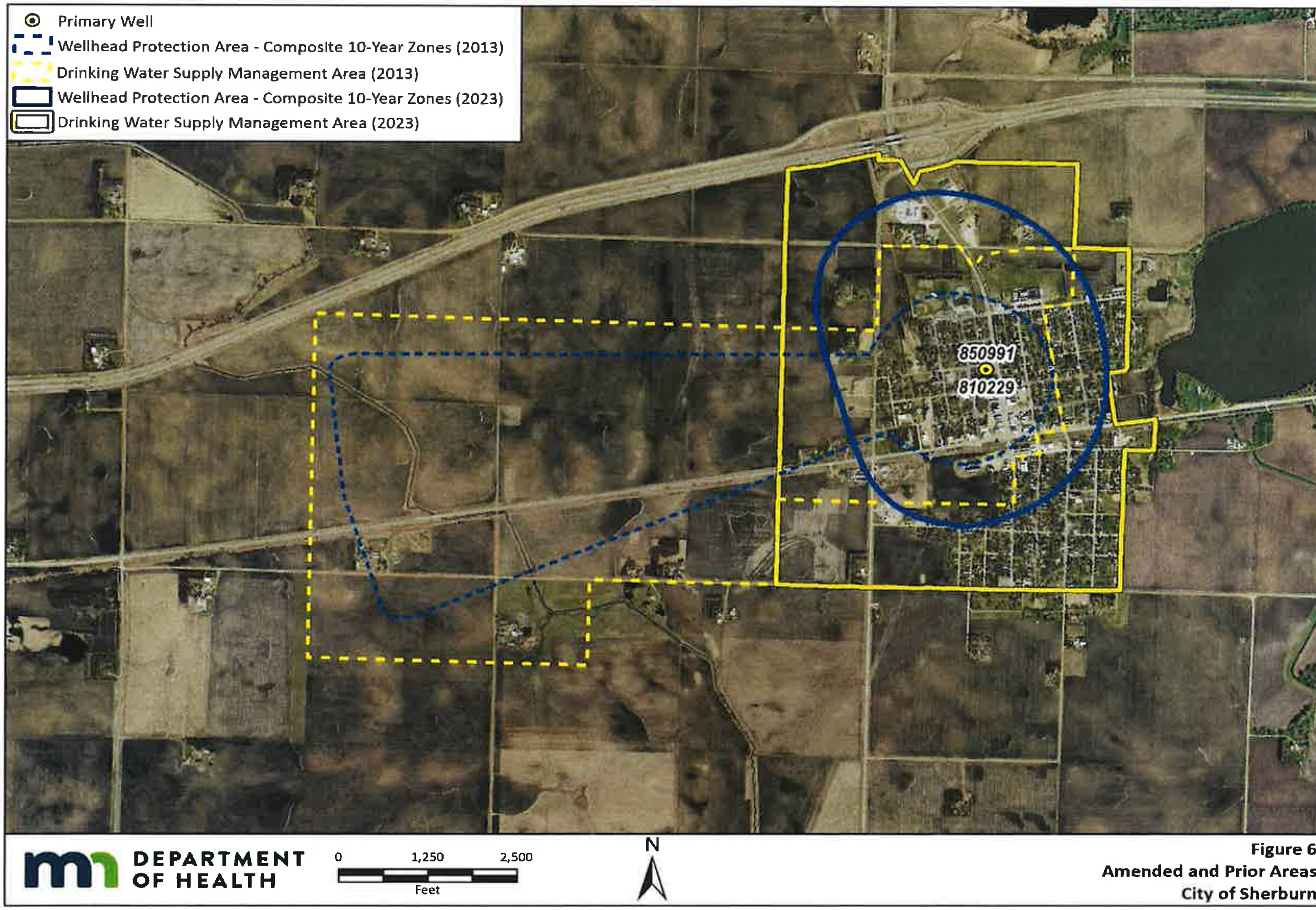

Figure 6
Amended and Prior Areas
City of Sherburn

Appendix A: Data Elements Assessment

Data Type	Data Element	Use of the Well(s)	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	Data Source
Climate	Precipitation					
Geology	Maps and geologic descriptions	M	H	H	H	MGS, DNR, USGS, MDH
Geology	Subsurface data	M	H	H	H	MGS, MDH, DNR
Geology	Borehole geophysics	M	H	H	H	MGS, MDH
Geology	Surface geophysics	L	L	L	L	None available
Soils	Maps and soil descriptions					
Soils	Eroding lands					
Water Resources	Watershed units					
Water Resources	List of public waters					
Water Resources	Shoreland classifications					
Water Resources	Wetlands map					
Water Resources	Floodplain map					
Land Use	Parcel boundaries map	L	H	L	L	Martin County
Land Use	Political boundaries map	L	H	L	L	MnGEO, City of Sherburn
Land Use	Public Land Survey map	L	H	L	L	MnGEO
Land Use	Land use map and inventory					
Land Use	Comprehensive land use map					
Land Use	Zoning map					
Public Utility Services	Transportation routes and corridors	L	L	L	L	MnDOT, MnGEO
Public Utility Services	Storm/sanitary sewers and PWS system map					
Public Utility Services	Oil and gas pipelines map					
Public Utility Services	Public drainage systems map or list					
Public Utility Services	Records of well construction, maintenance, and use	H	H	H	H	City of Sherburn, CWI, MDH
Surface Water Quantity	Stream flow data					
Surface Water Quantity	Ordinary high water mark data					
Surface Water Quantity	Permitted withdrawals					

Data Type	Data Element	Use of the Well(s)	Delineation Criteria	Quality and Quantity of Well Water	Land and Groundwater Use in DWSMA	Data Source
Surface Water Quantity	Protected levels/flows					
Surface Water Quantity	Water use conflicts					
Groundwater Quantity	Permitted withdrawals	H	H	H	H	DNR
Groundwater Quantity	Groundwater use conflicts	H	H	H	H	no relevant data found
Groundwater Quantity	Water Levels	H	H	H	H	DNR, City of Sherburn
Surface Water Quality	Stream and lake water quality management classifications					
Surface Water Quality	Monitoring data summary					
Groundwater Quality	Monitoring data	H	H	H	H	MPCA, MDH, MDA, USGS
Groundwater Quality	Isotopic data	H	H	H	H	MPCA, MDH, MDA, USGS, County, UMN
Groundwater Quality	Tracer studies	H	H	H	H	no relevant data found
Groundwater Quality	Contamination site data	M	M	M	M	MPCA, MDA
Groundwater Quality	Property audit data from contamination sites					
Groundwater Quality	MPCA and MDA spills/release reports	M	M	M	M	MPCA, MDA

Definitions Used for Assessing Data Elements

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

Acronyms used in this report are listed after the Glossary of Terms.