Drinking Water Source and Wells for the City of Avon

DELINEATIONS – WELLHEAD PROTECTION AREA AND DRINKING WATER SUPPLY MANAGEMENT AREA

VULNERABILITY ASSESSMENTS – WELLS AND DRINKING WATER SUPPLY MANAGEMENT AREA

August 2, 2023

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

Public Water Supply ID: 1730002

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Contents

List of Tables

List of Figures

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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 Avon has two primary wells screened in a sand aquifer that is buried beneath a layer of clay-rich sediment. Such aquifers are known generically as Quaternary Buried Artesian Aquifers (QBAA). Regionally, groundwater flows towards Avon from the northwest and the south, draining to the northeast.

Table 1 – 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	242069	Emergency	12	50	70	1979	QWTA[1]	Vulnerable
Well #4	696861	Primary	12	231	251	9/26/2003	QBAA	Vulnerable
Well #5	696862	Primary	12	220	240	8/11/2003	QBAA	Not Vulnerable

Note[1]: QWTA = Quaternary Water Table Aquifer

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 #4 and #5 (696861 and 696862) meet current construction standards. Well #4 is considered vulnerable to contamination due to tritium being detected in the well water (Table 2). Detectable tritium indicates the presence of young (post-1953) water. This is reinforced by the chloride concentration and chloride/bromide ratios presented below (Mullaney et al., 2009). Higher concentrations or concentration ratios indicate recent recharge from the surface. Well #5 also shows evidence for human impact based on chloride and bromide, but apparently the proportion of young water at this well is lower due to the absence of detectable tritium.

Table 2 - Isotope and Water Quality Results (February 10, 2022)

Well Name (Unique Number)	Tritium	Nitrate (mg/L)	Chloride (mg/L)	Bromide (mg/L)	Chloride/ Bromide Ratio	Arsenic (µg/L)
Well #4 (696861)	1.1	< 0.05	17.8	0.0316	563	5.72
Well #5 (696862)	< 0.8	< 0.05	11.8	0.022	536	7.68

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 (Table 2). Based on this information MDH has assigned a moderate vulnerability to the DWSMA. This suggests that water and contaminants may travel from the land surface to the city's aquifer within a time span of years to decades. This rating reflects uncertainty about the pathway for young water reaching Well #4 (686861) and water elevated in chloride and chloride/bromide reaching both wells. Although this may be the result of a well casing problem, for the time being it is assumed that the clay-rich sediments that overlie the city's aquifer is leaky. Moderately vulnerable aquifers are prone to a variety of contaminant threats, including chemical storage tanks and abandoned wells which can provide conduits for contaminants to quickly reach the city's aquifer.

Water Quality Concerns - At present, none of the contaminants for which the Safe Drinking Water Act has established health-based standards is found above maximum allowable levels in the city's water supply. However, elevated levels of naturally occurring arsenic have been detected at both wells.

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: well locating, downhole well inspection, and water quality monitoring. Further details can be found in the Recommendations section of this report.

Stearns County
Minnesota

Figure 1
Drinking Water Supply Management Area and Vulnerability
City of Avon

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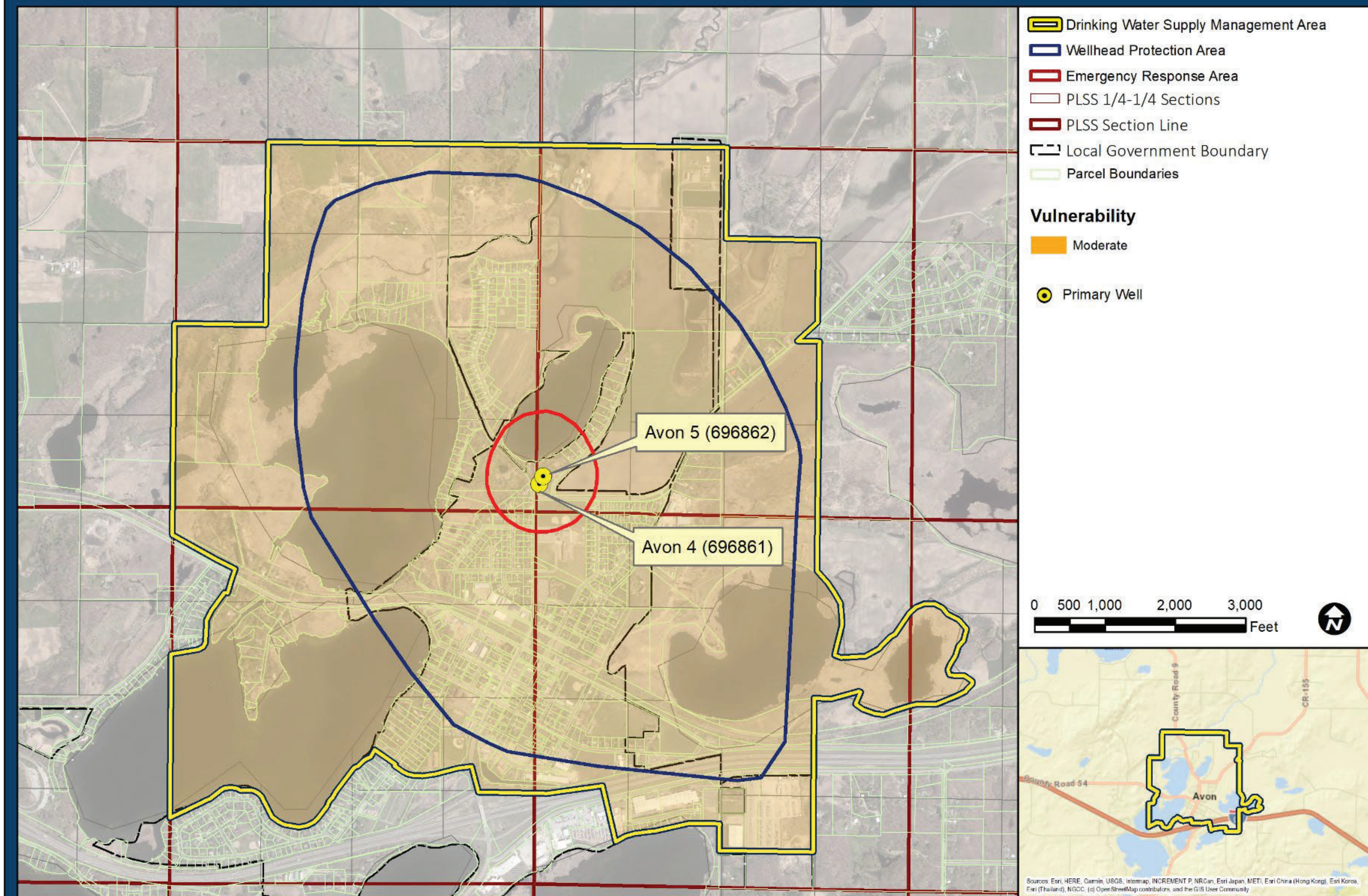

Technical Report

Discussion

This document describes the amendments to Part 1 of the wellhead protection (WHP) plan for the city of Avon (PWSID 1730002). 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, the locations of the city's wells were adjusted for greater accuracy. The amended areas are slightly larger due to updated projected pumping and changes in modeling approach. 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. An inner wellhead management zone (IWMZ), which is the area within a 200-foot radius around the well, serves as the wellhead protection area for emergency wells and is not displayed in this report. 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 Avon on April 18, 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 Avon obtains its drinking water supply from two primary wells. Table 1 summarizes information regarding them.

Description of the Hydrogeologic Setting

The city of Avon is located west of St. Cloud along Highway 94 in Stearns County. The surrounding area is covered by sandy loam textured, unsorted sediment ranging from silty sand to cobbly gravel lenses associated with the Superior or Rainy Lobes (Meyer et al. 1995). The city of Avon wells draws groundwater from a Quaternary Buried Artesian Aquifer (QBAA) composed of sand found approximately 220 feet below land surface. The buried aquifer is separated from the land surface by clay-rich sediments that act as natural geologic protection against surficial contaminants. The aquifer thickness is estimated to be approximately 27 - 30 feet at the well sites but is spatially variable beneath the city of Avon and surrounding area.

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	Sand	CWI database
Porosity Type and Value	0.20	Fetter, 2001
Aquifer Thickness	Estimated 27 - 30 feet	Well #4 (696861) Well #5 (696862)
Stratigraphic Top Elevation	Estimated 919 feet AMSL	Well #4 (696861)
Stratigraphic Bottom Elevation	Estimated 889 feet AMSL	Well #4 (696861)
Hydraulic Confinement	Confined	Well #4 (696861)
Transmissivity	Range of Values: 1,323 – 14,013 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.

Attribute	Descriptor	Data Source
Hydraulic Conductivity	Range of Values: 49 - 519 ft/day	The range of values was derived using specific capacity data obtained from well records and/or from additional aquifer test results listed in the "Selected References" section of this report.
Groundwater Flow Field	Groundwater flows to the southeast (117°) and to the north (354°) converging upon Avon with a gradient of 0.006 (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 Avon 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	Descriptor	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, although changes in aquifer thickness were incorporated in the flow model.

Criterion	Descriptor	How the Criterion was Addressed
Flow Boundary	Other High Capacity Wells	No known high-capacity wells exist within two miles of the city of Avon's wells.
Daily Volume of Water Pumped	See Table 5	Pumping information was obtained from the DNR, Appropriations Permit Number 1962-0203, and was converted to a daily volume pumped by a well.
Groundwater Flow Field	See Table 3	The groundwater flow field was determined from local well data.
Aquifer Transmissivity	Reference Value: 3,618 ft^2/day	The aquifer test plan was approved on May 19, 2023, and T was determined from specific capacity data. Uncertainty regarding aquifer transmissivity was addressed as described in the "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 1962-0203. 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 increase in usage is based on the expected new housing developments on the west side of town to begin construction in the coming years. 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)	2018	2019	2020	2021	2022	5-Year Projection	Daily Volume (cubic meters)
Well #3 (242069)	0.011	0.015	0.022	0.030	0.011	-	Emergency
Well #4 (696861)	22.897	23.043	23.093	25.321	24.566	**32.500**	337
Well #5 (696862)	22.413	16.786	22.948	30.169	26.058	**32.500**	337
System Total	45.321	39.844	46.063	55.520	50.635	**65.000**	674

(Expressed in millions of gallons. Bolding indicates greatest annual pumping volume.)

Method Used to Delineate the Wellhead Protection Area

The WHPA for the city of Avon's wells was determined using the software code MODFLOW (McDonald and Harbaugh, 1988; Harbaugh et al., 2000; Harbaugh, 2005). The resulting WHPA boundaries are 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-2005 (Harbaugh, 2005). 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.

The numerical groundwater model that was constructed consisted of 180 rows, 205 columns, and three layers. The model incorporates a variable areal grid spacing ranging from 2 meters near the city's wells and grading to 160 meters at the boundaries of the model domain. Layer tops and bottoms were derived from CWI logs within the model domain. River head boundaries represent cells where water is flowing both into and out of the aquifer and were used to simulate the many lakes and rivers within the model domain within Layer 1. Vertical recharge was applied to Layer 1 of the model using modified values published by the U.S Geological Survey (Westenbrook et al., 2018).

Due to the heterogeneity of the unconsolidated sand and the lack of contiguous lenses for discretization of hydraulic conductivity zones, 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 be most effective. 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 alluvial 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 values in the model domain were derived from specific capacity data at domestic wells and aquifer test data for the city's wells. These values were then smoothed with the geostatistical method of kriging and input into the model. 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 groundwater flow model was 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 72 particles were launched at each well. A porosity of 20 percent was used and a reverse time of travel was calculated at 10 years.

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 and/or flux. The sensitivity analysis quantifies the differences in model results produced by the natural variability of a particular parameter. Uncertainty analysis addresses the effects of poor data quality (lack of local detailed information or deficiencies in the data) on the model results. Together, sensitivity and uncertainty analyses are commonly used to evaluate the effects that natural variability and uncertainties in the hydrogeologic data have on the size and shape of the capture zones. In regard to the WHPA delineation, these analyses are used to document that the delineation is optimal, conservative, and protective of public health based on existing information.

Model Calibration

A qualitative evaluation of the calibration can be made by comparing the simulated potentiometric surface (Figure 2) with observed water level targets obtained from the CWI database. Upon review the calibrated flow model generally captures the major features of the groundwater flow system along with the elevation, shape, magnitude, and gradient of the CWI database observed flow field.

A quantitative measure by which to evaluate the success obtained during calibration is to compare the root mean square of the residuals (RMSE) and the maximum observed head difference of the calibration dataset. The calibration dataset included water level information from 291 wells in an approximate eight-mile radius of the city's wells. The residual root mean square (RMS) error of the calibration well set was approximately 2.6 meters with a normalized RMSE of 6.24 percent. It is noted that this error is smaller than the calibration target of 10 percent (Groundwater Calibration Policy, 2018). The calibration targets (wells) with the greatest residual difference between measured and simulated heads were generally at locations beyond the contribution area to the city's wells.

Sensitivity Analysis

Model sensitivity is the amount of change in model results caused by the variation of a particular input parameter. Because of the relative simplicity of this MODFLOW, 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 and an expanded capture zone, proportional to the porosity of the aquifer materials.

    How Addressed and Results – The pumping rate is based on the results presented in Table 5 and, therefore, is not considered a variable factor that will influence the delineation of the WHPA. The modeled pumping rate is based on the projected pumping rate, as shown in Table 5.

- The **direction of groundwater flow** determines the orientation of the capture zone. 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 contributing water to the well.

    How Addressed and Results – General flow direction was determined based upon static water levels of similarly screened wells in the area of the model. Overall, the sensitivity of the WHPA to the direction of groundwater flow should not be significant, given the current knowledge of the hydraulic head distribution in the aquifer.

- The **hydraulic gradient** (along with aquifer hydraulic conductivity) determines the rate at which water moves through the aquifer materials.

    How Addressed and Results – The flow field shown 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 each well. The regional model has been calibrated to hydraulic heads. The sensitivity of the WHPA to the hydraulic gradient should not be significant given the current knowledge of the hydraulic head distribution in the aquifer.

- The **hydraulic conductivity** influences the size and shape of the capture zone. A decrease in 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 on the well.

> **How Addressed and Results** – Initial hydraulic conductivity was calculated from specific capacity and aquifer tests conducted throughout the region. In the model these were set to vary by +/- 50% and geostatistically smoothed across the model domain.

- The **aquifer porosity** influences the size and shape of the capture zone.

> **How Addressed and Results** – Decreasing the porosity causes a linear, proportional increase in the areal extent of the capture zone. The porosity for the alluvial aquifer was chosen to be 0.20, which is consistent with commonly reported values for the aquifer material (Fetter, 2001). The porosity is not considered a variable for this study.

- The **aquifer thickness** influences the size and shape of the capture zone.

> **How Addressed and Results** – Final aquifer thicknesses used in this model were the result of a multi-step statistical analysis. A cross-sectional analysis was done to determine the thicknesses of the aquifer at well points throughout the modeled extent. Layer thicknesses were interpolated between wells and unrealistic values were identified and disposed of at all steps by comparing with adjacent well data, where available, and by using hydrogeologic judgment. As a result, the model layering closely follows the overall stratigraphy through the region. In the area surrounding the city's wells the aquifer thickness was defined using area well logs and should reasonably represent the actual aquifer conditions. Therefore, aquifer thickness is not considered a variable for this study.

- The **recharge** influences the size and shape of the capture zone.

> **How Addressed and Results** – The recharge applied to the surficial clay and sand in the model domain and ranged from 0 to 7 inches and was based on the values reported by the USGS (Westenbrook et al., 2018) within the central model domain. Higher values of recharge tend to produce longer and narrower capture areas while lower values lead to shorter and wider capture areas.

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 areas of the public water supply wells, 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 the five-year projection of pumping was used was used to represent the expected usage moving forward (Minnesota Rules, part 4720.5510, subpart 4).
2. Probability Analysis – The Monte Carlo approach was used to estimate capture zone probability as well as variability in hydraulic conductivity.

The input files for all realizations and related information are available at MDH upon request.

Table 6 – Model Parameters used in MODFLOW Base Case and Realizations

Well Name (Unique)	File Name	Discharge (m^3/day)	Hydraulic Conductivity (m/d)	Porosity (%)	Aquifer Thickness (meters)	Remarks
Well #4 (696861)	Base model	337	47.6	20	9.14	Base Case
Well #5 (696862)	Base model	337	49.9	20	9.14	Base Case

Note: 248 Final realizations

Conjunctive Delineation

The vulnerability of the ERA is not high; therefore, according to current MDH guidance, the need for a conjunctive delineation does not need to be assessed.

Delineation of the Drinking Water Supply Management Area

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

- Centerlines of highways, streets, or roads
- Parcel Boundaries
- Public Land Survey coordinates

Summary of Comparisons Between the Previous (2012) and Current WHPA and DWSMA Delineations

Overall, the new DWSMA (1,896 acres) is about 1.57 times larger than the previous delineation (1,208 acres) and expands more to the south and east (Figure 8). This is primarily due to the resolution of the modeling efforts. With the previous delineation effort, a single layer analytic element groundwater model was used to determine the base case. A second approach used the stochastic analytical groundwater flow method Oneka to evaluate the uncertainty of the 10-year capture area. This addressed uncertainty in hydraulic conductivity by frequency distribution around a known mean K value.

In the current three-layer MODFLOW, a more localized domain was used. Head boundaries consisted of a larger number of lakes, rivers, and streams transcribed explicitly as model cells providing an increased amount of nearby potentiometric data. In addition, the dimensionality of the three model layers were determined by interpolation of stratigraphic information across the entire model domain. This provided an overall higher resolution porous media model to better simulate the complex hydrogeology of the Avon area. The use of PEST++IES (White et al, 2020) to optimize hydraulic conductivity combined with a Monte Carlo approach to address uncertainty resulted in a significant increase in the protection areas compared to the previous modeling approach.

Vulnerability Assessments

The Part I wellhead protection plan includes the vulnerability assessments for the city of Avon'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 assessments for each well used by the city of Avon are listed in Table 1 and are 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 site include a cover of clay-rich geologic materials over the aquifer, however it is not sufficient to 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 well itself serves to draw contaminants into the aquifer as a result of pumping.
4. Water samples collected from both wells were analyzed for tritium, nitrate, chloride, and bromide (Table 2). Elevated tritium was detected in the sample from Well #4, confirming its vulnerable nature of the wells (Alexander and Alexander, 1989). In addition, the chloride and bromide results confirm that the well has been impacted by land-use activities (Table 2). Well #5 showed no detectable tritium but did show elevated chloride and chloride/bromide ratio, suggesting it is also capturing water impacted by human activities. It is presumed that it is capturing a smaller proportion of young, human-impacted water than Well #4 based on their differing tritium results.

Assessment of Drinking Water Supply Management Area Vulnerability

The vulnerability of the DWSMA is shown in Figure 7 and is based upon the following information:

1. Isotopic and water chemistry data from the Avon wells indicate that the aquifer is a mix of old and younger water with some evidence of human-caused contamination. The groundwater age as determined from tritium is mixed (DNR-MDH, 2020). Human-caused contamination is evidenced by elevated chloride and chloride/bromide.
2. Review of the geologic logs contained in the CWI database, geological maps, and reports indicate that the deep source aquifer exhibits a low geologic sensitivity throughout the DWSMA.

Therefore, given the information currently available, it is prudent to assign a moderate 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 Avon's Wellhead Protection Plan.

1. Well Locating: This delineation is based on very little 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 aquifer, and could result in a more refined WHPA in the future.
2. Water Quality Monitoring: The standard assessment monitoring package of the primary wells should be analyzed during year six, 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.
3. Well Casing Investigation: A video inspection of the city wells might reveal whether any casing flaws might be contributing to the low-level tritium detections seen at these wells. This would likely occur during routine well servicing and could be eligible for a Source Water Protection Implementation Grant if this measure is included in the city's wellhead protection plan. If such an investigation is to occur, MDH should be contacted in advance in the event additional down hole investigations can be conducted while the well is open.

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Figures

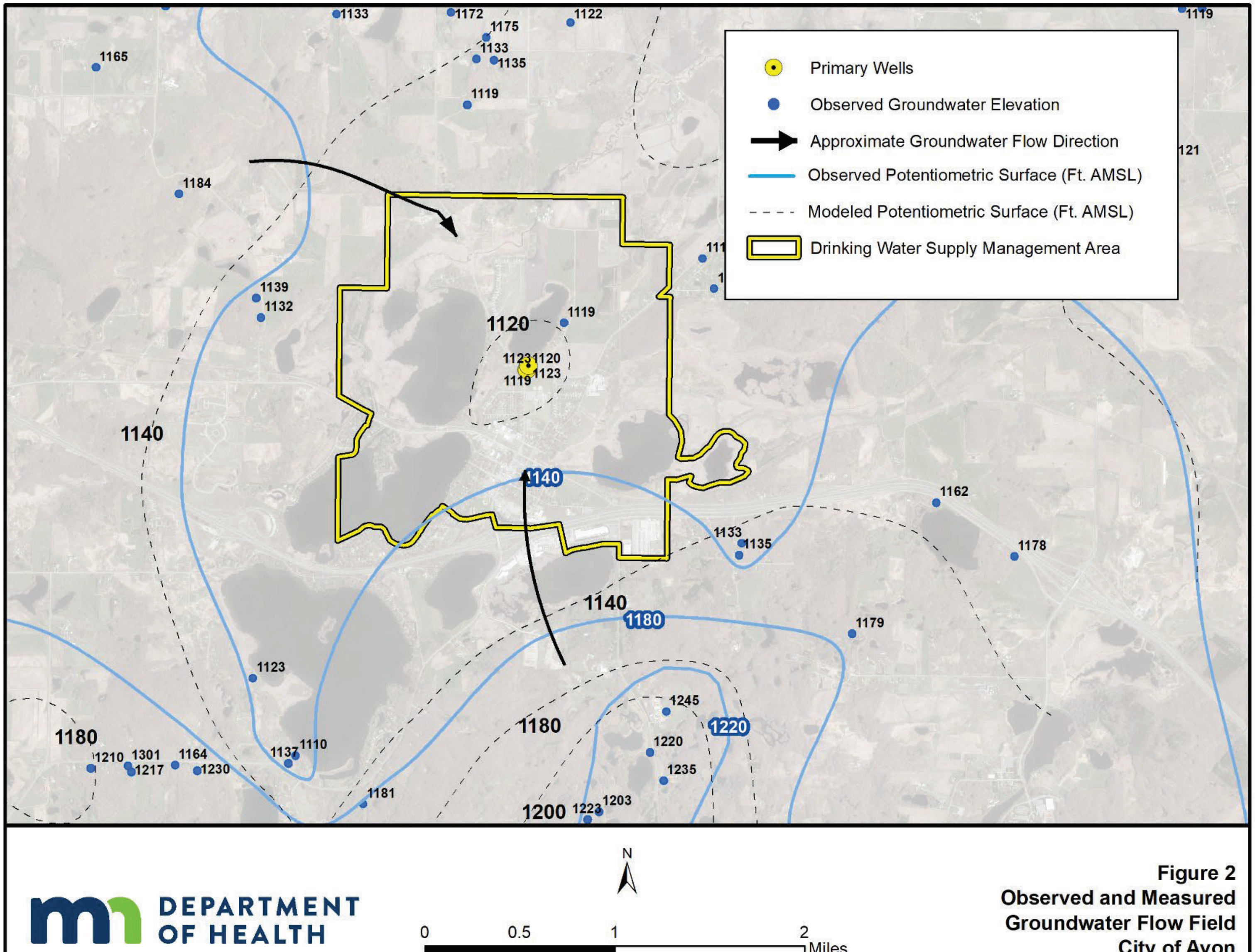

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Figure 2
Observed and Measured Groundwater Flow Field
City of Avon

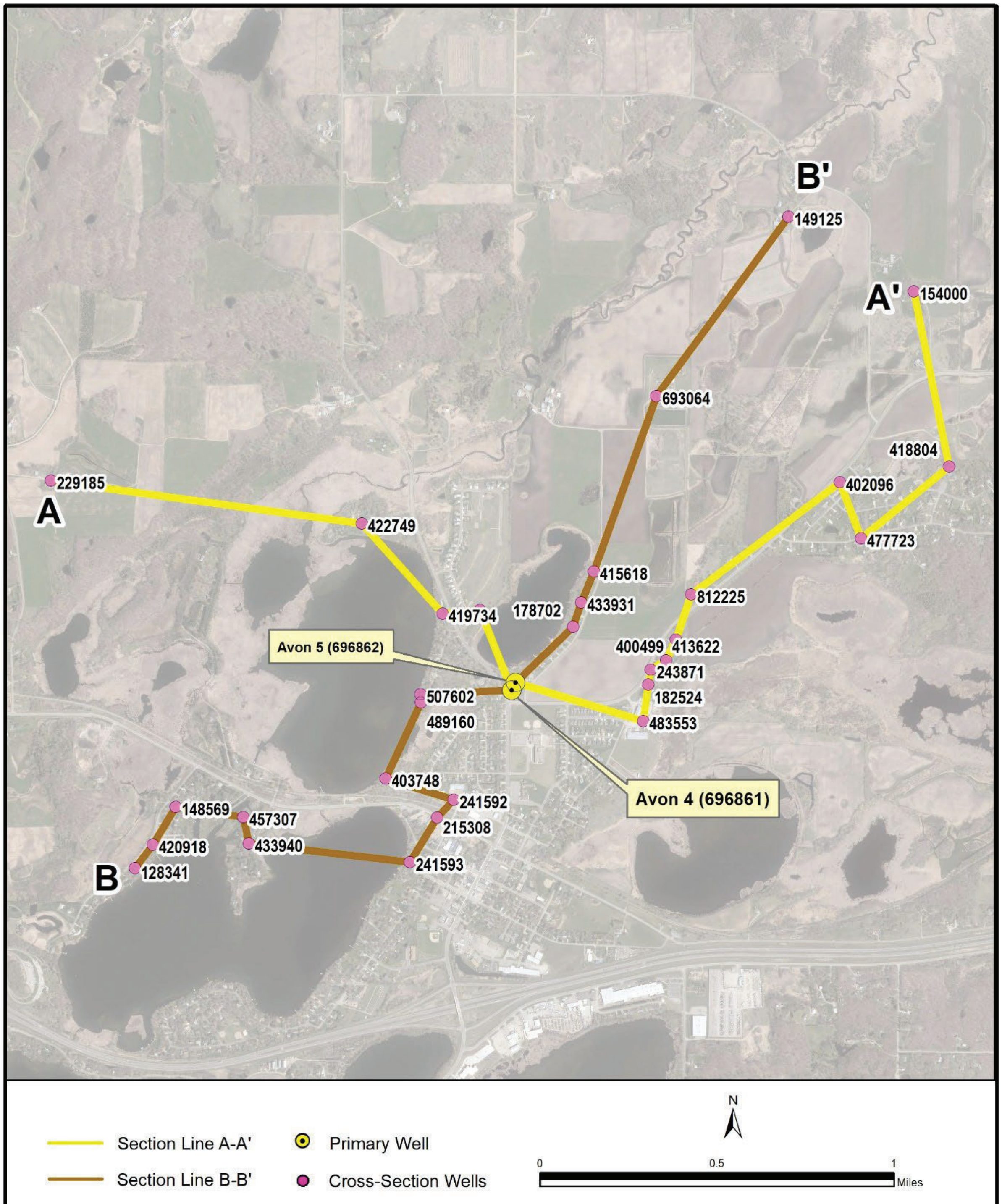

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Figure 3
Trends of Geologic Cross-Sections
City of Avon

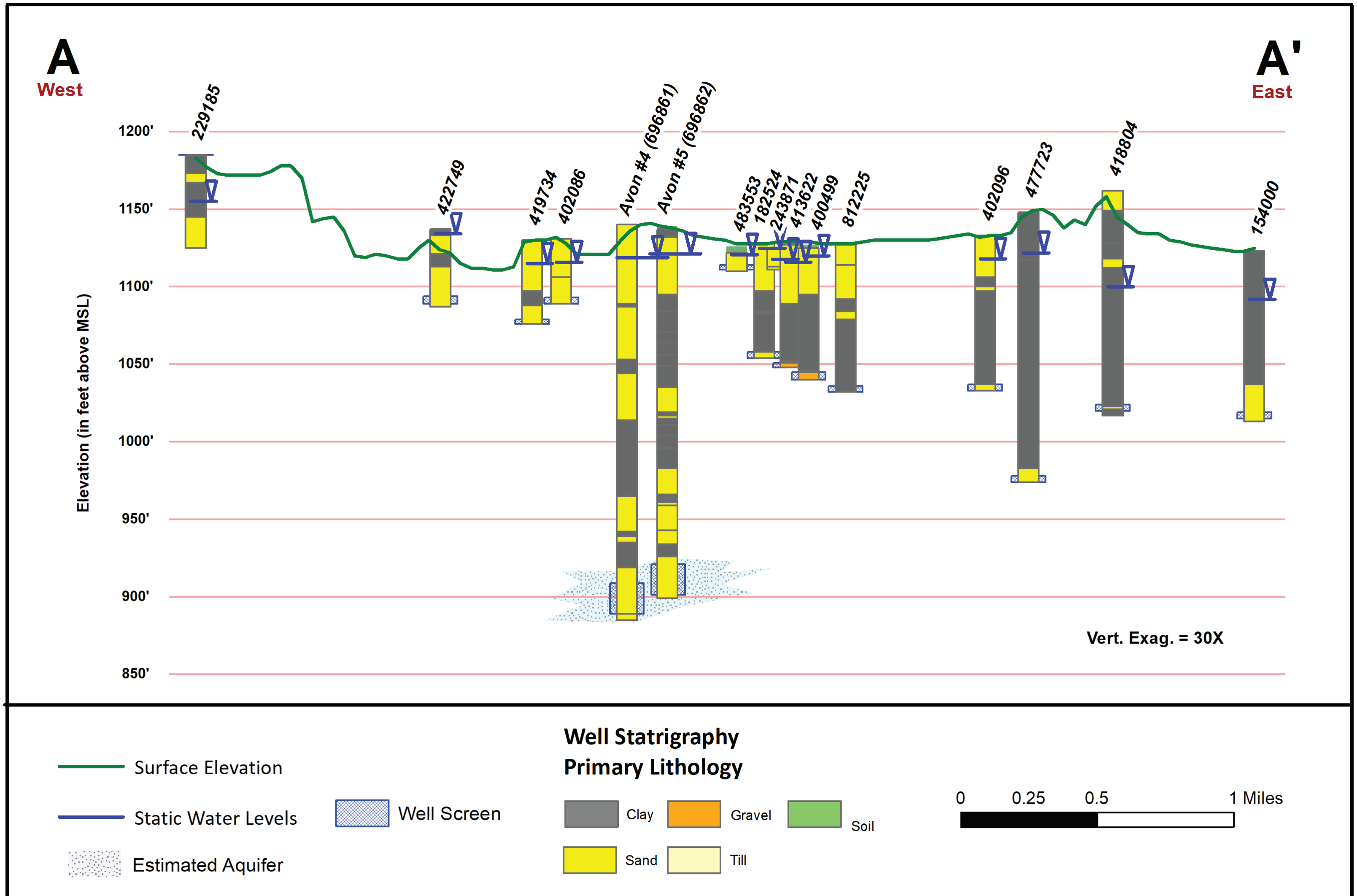

Figure 4
Geologic Cross-Section A-A'
City of Avon

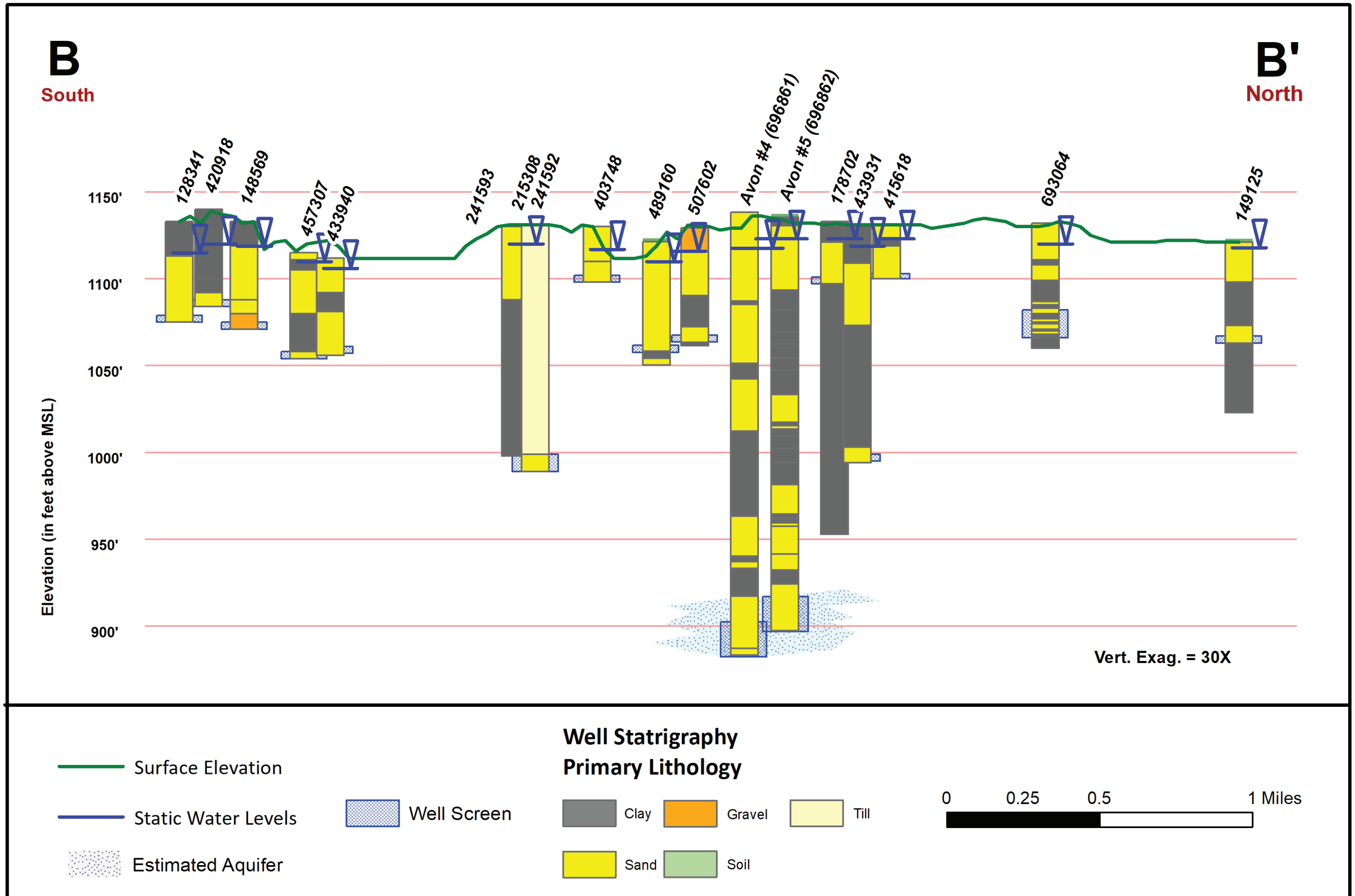

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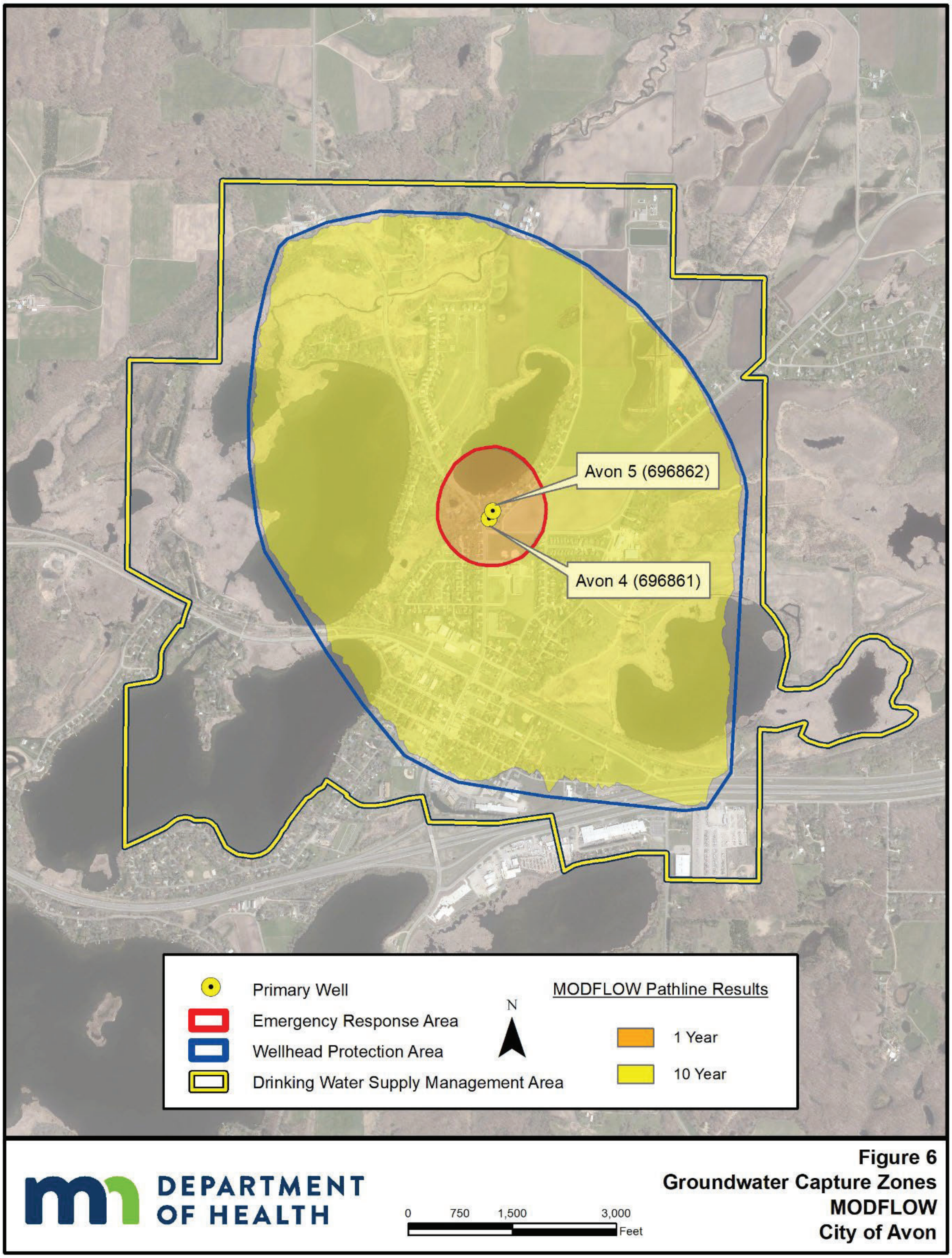
Figure 5
Geologic Cross-Section B-B'
City of Avon


Avon 5 (696862)
Avon 4 (696861)
Primary Well
Emergency Response Area
Wellhead Protection Area
Drinking Water Supply Management Area
N
MODFLOW Pathline Results
1 Year
10 Year
DEPARTMENT OF HEALTH
0 750 1,500 3,000
Feet
Figure 6
Groundwater Capture Zones
MODFLOW
City of Avon

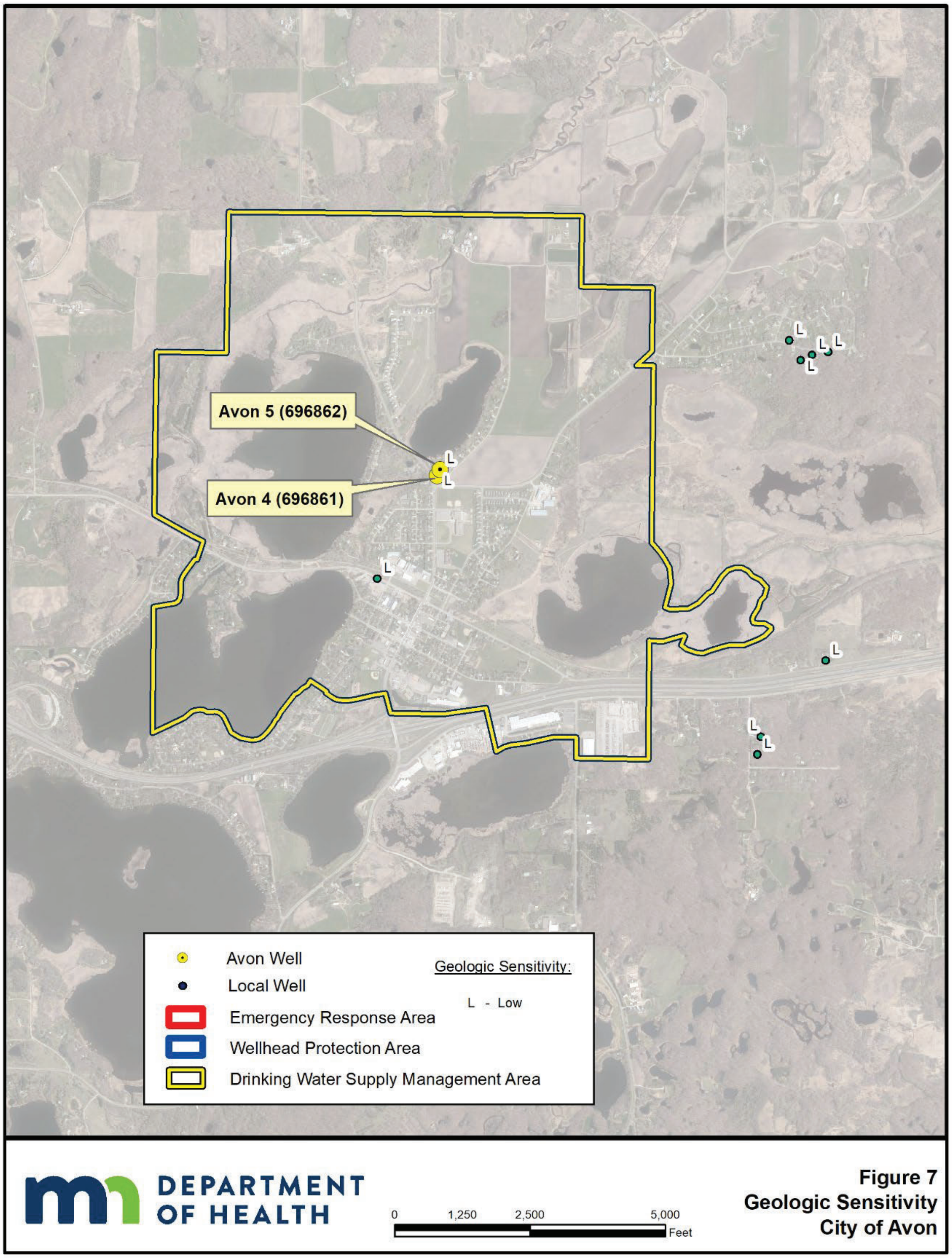


Figure 7
Geologic Sensitivity
City of Avon

Stearns County
Minnesota

Figure 8
Amended and Prior Areas
City of Avon

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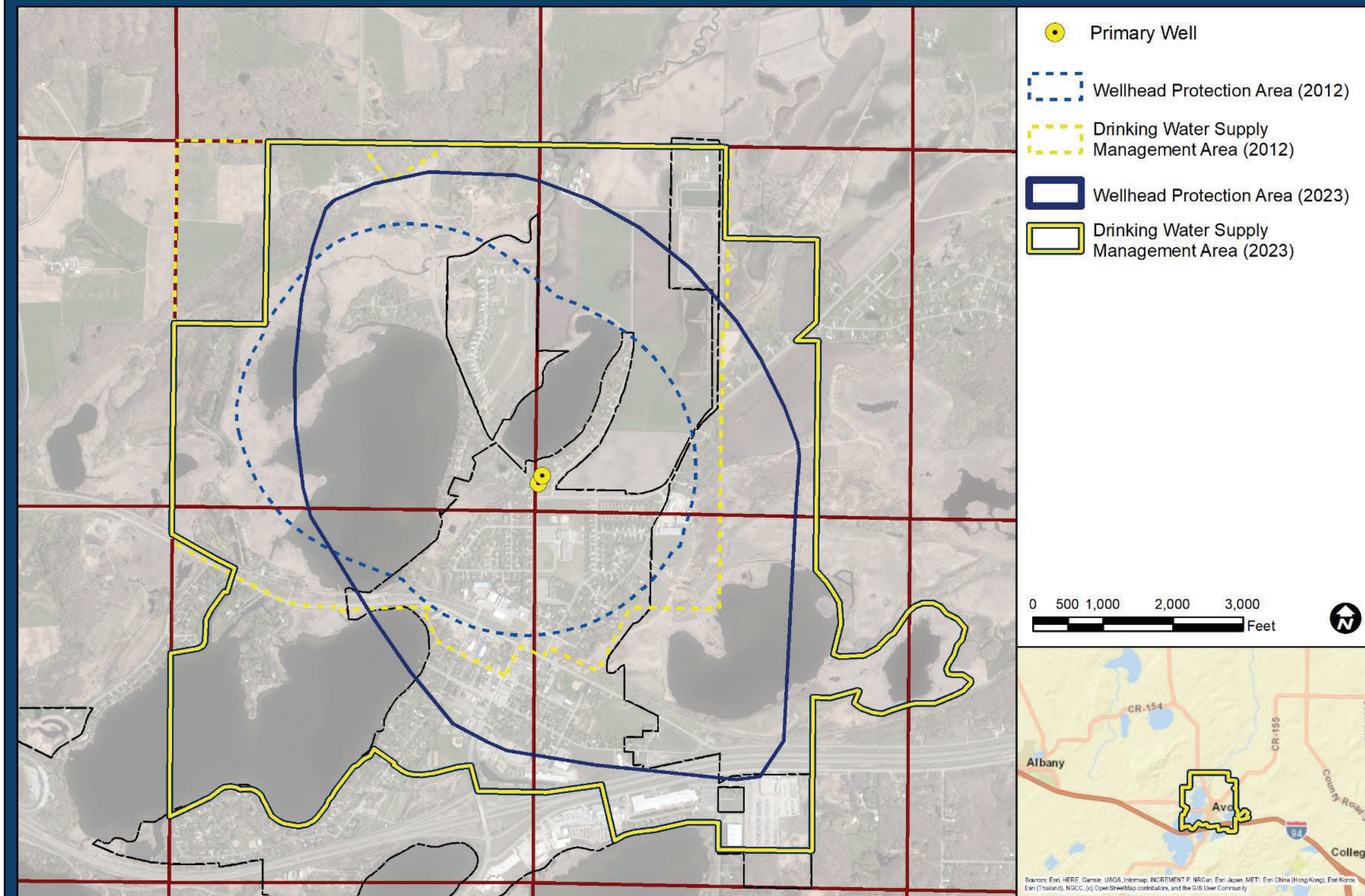
CLEAN WATER LAND & LEGACY AMENDMENT



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	H	H	H	H	MN Climatology Office, USGS
Geology	Maps and geologic descriptions	M	H	H	H	MGS
Geology	Subsurface data	M	H	H	H	MGS, MDH
Geology	Borehole geophysics	M	H	H	H	No relevant data found
Geology	Surface geophysics	L	L	L	L	No relevant data found
Soils	Maps and soil descriptions	L	H	M	L	NRCS
Soils	Eroding lands					
Water Resources	Watershed units	L	H	L	L	DNR, USGS
Water Resources	List of public waters	L	H	L	L	DNR, MDH
Water Resources	Shoreland classifications					
Water Resources	Wetlands map	L	H	L	L	No relevant data found
Water Resources	Floodplain map					
Land Use	Parcel boundaries map	L	H	L	L	Stearns County
Land Use	Political boundaries map	L	H	L	L	MnGEO
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	L	M	L	L	
Public Utility Services	Oil and gas pipelines map					
Public Utility Services	Public drainage systems map or list	L	H	L	L	No relevant data found
Public Utility Services	Records of well construction, maintenance, and use	H	H	H	H	City of Avon, CWI, MDH
Surface Water Quantity	Stream flow data	L	H	H	H	
Surface Water Quantity	Ordinary high water mark data	L	H	L	L	No relevant data found

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	Permitted withdrawals	L	H	L	L	
Surface Water Quantity	Protected levels/flows	L	H	L	L	No relevant data found
Surface Water Quantity	Water use conflicts	L	H	L	L	No relevant data found
Groundwater Quantity	Permitted withdrawals	H	H	H	H	DNR MPARS
Groundwater Quantity	Groundwater use conflicts	H	H	H	H	No relevant data found
Groundwater Quantity	Water Levels	H	H	H	H	MDH, DNR
Surface Water Quality	Stream and lake water quality management classifications					
Surface Water Quality	Monitoring data summary	L	H	L	L	No relevant data found
Groundwater Quality	Monitoring data	H	H	H	H	MDH
Groundwater Quality	Isotopic data	H	H	H	H	MDH
Groundwater Quality	Tracer studies	H	H	H	H	No relevant data found
Groundwater Quality	Contamination site data	M	M	M	M	No relevant data found
Groundwater Quality	Property audit data from contamination sites					
Groundwater Quality	MPCA and MDA spills/release reports	M	M	M	M	No relevant data found

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.