



memo

DATE: 10/10/2025

TO: Greg Johnson, Metropolitan Council

FROM: John Oswald

SUBJECT: White Bear Lake Area Groundwater Flow Pathline Analysis for PFAS (Study 14A)

1. INTRODUCTION

The Minnesota Department of Natural Resources (DNR) previously completed a groundwater modeling study examining the effects of various water supply management scenarios on water levels in White Bear Lake using a MODFLOW model. The current pathline analysis was conducted to evaluate how these same scenarios affect groundwater flow direction and magnitude in relation to existing PFAS plumes in the region.

This memo summarizes the pathline analysis results for eight scenarios using the model developed by the DNR. These scenarios represent different configurations of municipal water systems being converted from groundwater to treated surface water supply, as well as scenarios involving wastewater injection and varying development demands.

2. MODEL DESCRIPTION

The pathline analysis utilized the DNR groundwater model output files for head and cell-by-cell flow information, with particle tracking performed using MODPATH 5 (Pollock, 2012). The model operates in steady-state mode and uses the same spatial domain as the DNR MODFLOW model.

The DNR MODFLOW model (DNR, 2018) was developed from a previous model by S.S. Papadopoulos and Associates (2017), which was itself based on an earlier United States Geological Survey (USGS) model (Jones et al., 2017), derived from Barr Engineering's Metro Model 3 (MM3) for the Metropolitan Council (2014). Because MM3 and all subsequent model iterations contain quasi-3D layers, MODPATH 5 was the only viable particle tracking option, as MODPATH versions 6 and 7, MP3DU, and the PRT (particle tracking) package in MODFLOW 6 do not support quasi-3D layer configurations.

3. METHODOLOGY

Pathline analysis was conducted for each of the eight scenarios described below. Particle starting locations consisted of a uniform grid of points spaced 750 meters apart, covering the area of interest within the model domain. All pathline starting locations were placed in the model layer corresponding to the Jordan aquifer. From each starting location, particles were tracked forward through the groundwater flow system for a 50-year time-of-travel period.

WHITE BEAR LAKE AREA GROUNDWATER FLOW PATHLINE ANALYSIS FOR PFAS (STUDY 14A)

The eight scenarios analyzed represent different water supply management approaches:

- Scenario 1 (DNR groundwater modeling scenario 2a) - Mahtomedi, Saputo Dairy Foods, Vadnais Heights, White Bear Lake, and White Bear Township (north and south systems) removed from groundwater and served with treated surface water
- Scenario 2 (DNR groundwater modeling scenario SW 3) - Mahtomedi, North St. Paul, Saputo Dairy Foods, Vadnais Heights, White Bear Lake, and White Bear Township (north and south systems) removed from groundwater and served with treated surface water
- Scenario 3 (DNR groundwater modeling scenario SW 5) - Mahtomedi, North Oaks, Saputo Dairy Foods, Vadnais Heights, White Bear Lake, and White Bear Township (north and south systems) removed from groundwater and served with treated surface water
- Scenario 4 (DNR groundwater modeling scenarios SW 4 and 4-2) - Mahtomedi, North Oaks, North St. Paul, Saputo Dairy Foods, Shoreview, Vadnais Heights, White Bear Lake, and White Bear Township (north and south systems) removed from groundwater and served with treated surface water
- Scenario 5 (DNR treated wastewater aquifer injection modeling scenarios) - Saputo Dairy Foods, White Bear Lake, and White Bear Township (north and south systems) removed from groundwater and served with treated wastewater with up to 2 MGD of treated wastewater injected into the aquifer
- Scenario 6 - Includes moving Lake Elmo to St. Paul Regional Water Services (SPRWS)
- Existing Scenario - Approximately current average pumping rates representing 'no growth'
- Ultimate Scenario - Ultimate development demand with no systems removed from groundwater

All pathline analyses were conducted using the steady-state model conditions corresponding to the DNR modeling study scenario withdrawals. Porosity values assigned to model materials in Modpath 5 were consistent with those originally established in MM3.

4. RESULTS

Pathline analysis results are presented in Figures 1 through 9, which show 50-year particle traces for all eight scenarios overlaid on the municipalities throughout the area of interest. Each scenario is represented by a different colored pathline, allowing direct visual comparison of how each scenario affects flow direction and distance traveled from the starting points.

General Flow Patterns

Across all scenarios, groundwater flow generally moves from recharge areas north and east of White Bear Lake toward two primary discharge locations: southwest toward the Mississippi River and south and east toward the St. Croix River. Flow velocities vary significantly across the model domain, with the slowest movement occurring in recharge areas north of White Bear Lake and along the groundwater divide east of the lake. Groundwater flow rates increase

WHITE BEAR LAKE AREA GROUNDWATER FLOW PATHLINE ANALYSIS FOR PFAS (STUDY 14A)

substantially near pumping wells and especially near discharge locations along the two major rivers.

Scenario-Specific Effects

Each scenario's influence on the flow field is most pronounced near wells that are either added or removed in that specific scenario. The color-coded pathlines illustrate these differences, showing variations in both direction and distance traveled over the 50-year period. Minor effects from these changes are visible throughout most of the area of interest, with typical flow direction deviations of less than 10 degrees. However, near the groundwater divide east of White Bear Lake, even these minor deviations can be significant enough to alter the regional flow direction, shifting flow from southwest toward the Mississippi River to southeast toward the St. Croix River, or vice versa.

The magnitude of flow field changes varies by location and scenario, with the most substantial alterations occurring in areas immediately surrounding wells affected by the water supply management changes described in Section 3.

5. CONCLUSIONS

The pathline analysis demonstrates that all eight water supply management scenarios affect groundwater flow patterns in the White Bear Lake area, with effects most pronounced near wells that are added or removed in each scenario. While flow direction deviations are typically minor (less than 10 degrees) across most of the study area, these changes can be significant near the groundwater divide east of White Bear Lake, where they may alter whether groundwater discharges to the Mississippi River or the St. Croix River. These flow pattern changes have implications for PFAS plume migration, as even small directional shifts can influence long-term contaminant transport pathways and potentially affect which water bodies or wells may be impacted over time.

6. RECOMMENDATIONS

Once some scenarios have been eliminated from consideration, it is recommended that more detailed information be obtained about specific PFAS (or other contaminant) plumes of interest. The existing groundwater flow model and MODPATH framework can then be used to perform a more comprehensive pathline analysis with starting points placed within these specific plume boundaries or in different aquifers of concern. This targeted approach would allow for more specific evaluation of how remaining scenarios might affect contaminant migration pathways and timeframes. Additional analyses could also examine smaller sub-areas in greater detail or evaluate alternative scenarios or even include potential remedial actions not included in the original DNR study.

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WHITE BEAR LAKE AREA GROUNDWATER FLOW PATHLINE ANALYSIS FOR PFAS (STUDY 14A)

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To obtain this information in a different format, call: 651-201-4698.

References:

Jones, P.M., Roth, J.L., Trost, J.J., Christenson, C.A., Diekoff, A.L., and Erickson, M.L., 2017, Simulation and assessment of groundwater flow and groundwater and surface-water exchanges in lakes in the Transient NMLG Model Analysis and Revisions 70 northeast Twin Cities Metropolitan Area, Minnesota, 2003 through 2013: U.S. Geological Survey Scientific Investigations Report 2016–5139–B, 88 p.

Metropolitan Council. 2014. Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0. Prepared by Barr Engineering. Metropolitan Council: Saint Paul, MN.

Minnesota Department of Natural Resources (DNR), 2018, Transient NMLG Model Analysis and Revisions: St. Paul, MN, August 2018. Available online at <https://www.dnr.state.mn.us/gwmp/area-ne-model.html>.

Pollock, D.W., 2012, User guide for MODPATH version 6—A particle-tracking model for MODFLOW: U.S. Geological Survey Techniques and Methods, book 6, chap. A41, 58 p. (not available for Modpath 5)

S.S. Papadopoulos & Associates, Inc. (2017). Development and Calibration of the North and East Metro Groundwater Flow Model.

WHITE BEAR LAKE AREA GROUNDWATER FLOW PATHLINE ANALYSIS FOR PFAS
(STUDY 14A)

ATTACHMENTS

- Figure 1: Scenario pathlines in White Bear Lake and White Bear Township
- Figure 2: Scenario pathlines in Shoreview, North Oaks, and Vadnais Heights
- Figure 3: Scenario pathlines in Centerville and Lino Lakes
- Figure 4: Scenario pathlines in Hugo
- Figure 5: Scenario pathlines in Grant and Stillwater
- Figure 6: Scenario pathlines in Oakdale and Lake Elmo
- Figure 7: Scenario pathlines in Woodbury
- Figure 8: Scenario pathlines in south Maplewood, Oakdale, Lake Elmo and Woodbury
- Figure 9: Scenario pathlines in Little Canada, north Maplewood, and North St. Paul

WHITE BEAR LAKE AREA GROUNDWATER FLOW PATHLINE ANALYSIS FOR PFAS
(STUDY 14A)

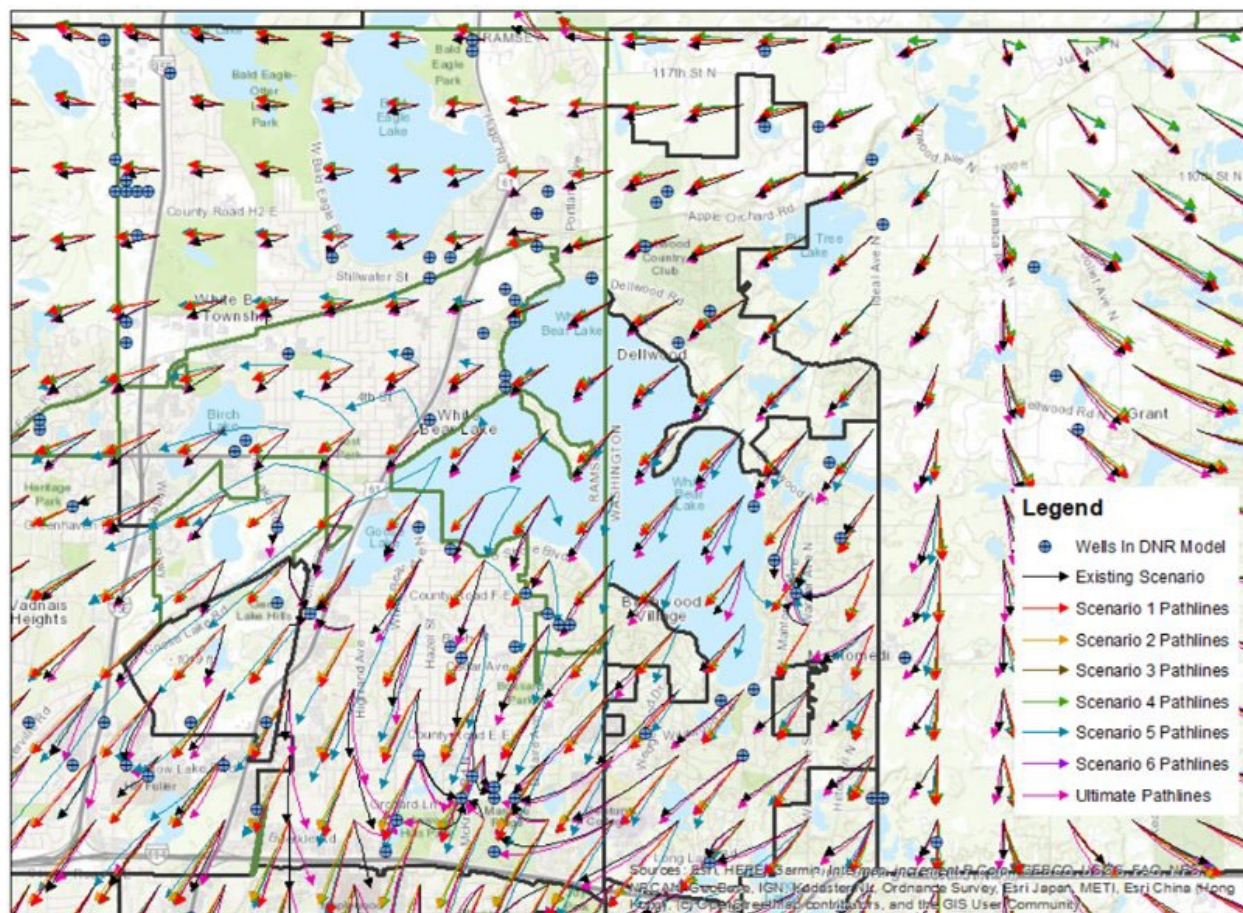


Figure 1: Scenario pathlines in White Bear Lake and White Bear Township

WHITE BEAR LAKE AREA GROUNDWATER FLOW PATHLINE ANALYSIS FOR PFAS
(STUDY 14A)

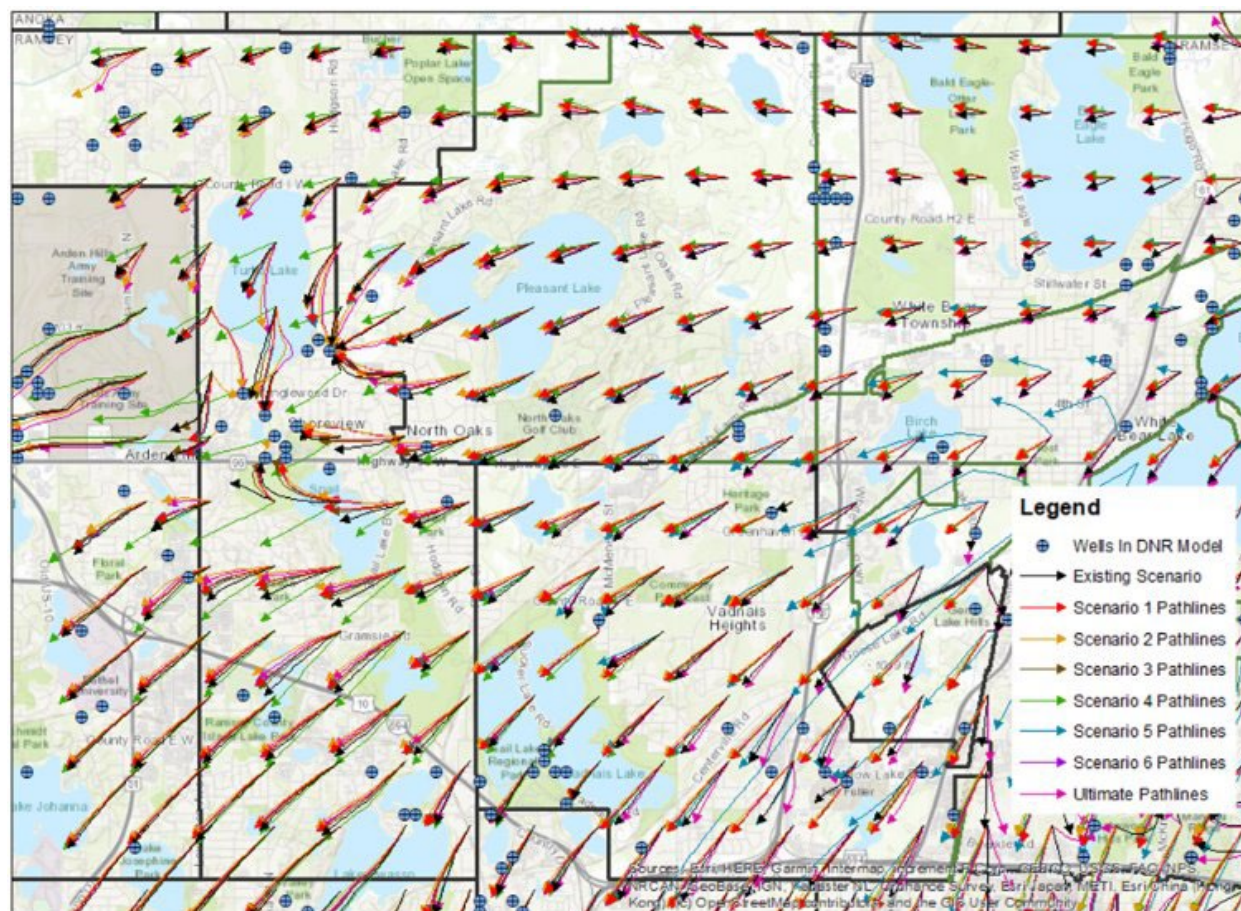


Figure 2: Scenario pathlines in Shoreview, North Oaks, and Vadnais Heights

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(STUDY 14A)

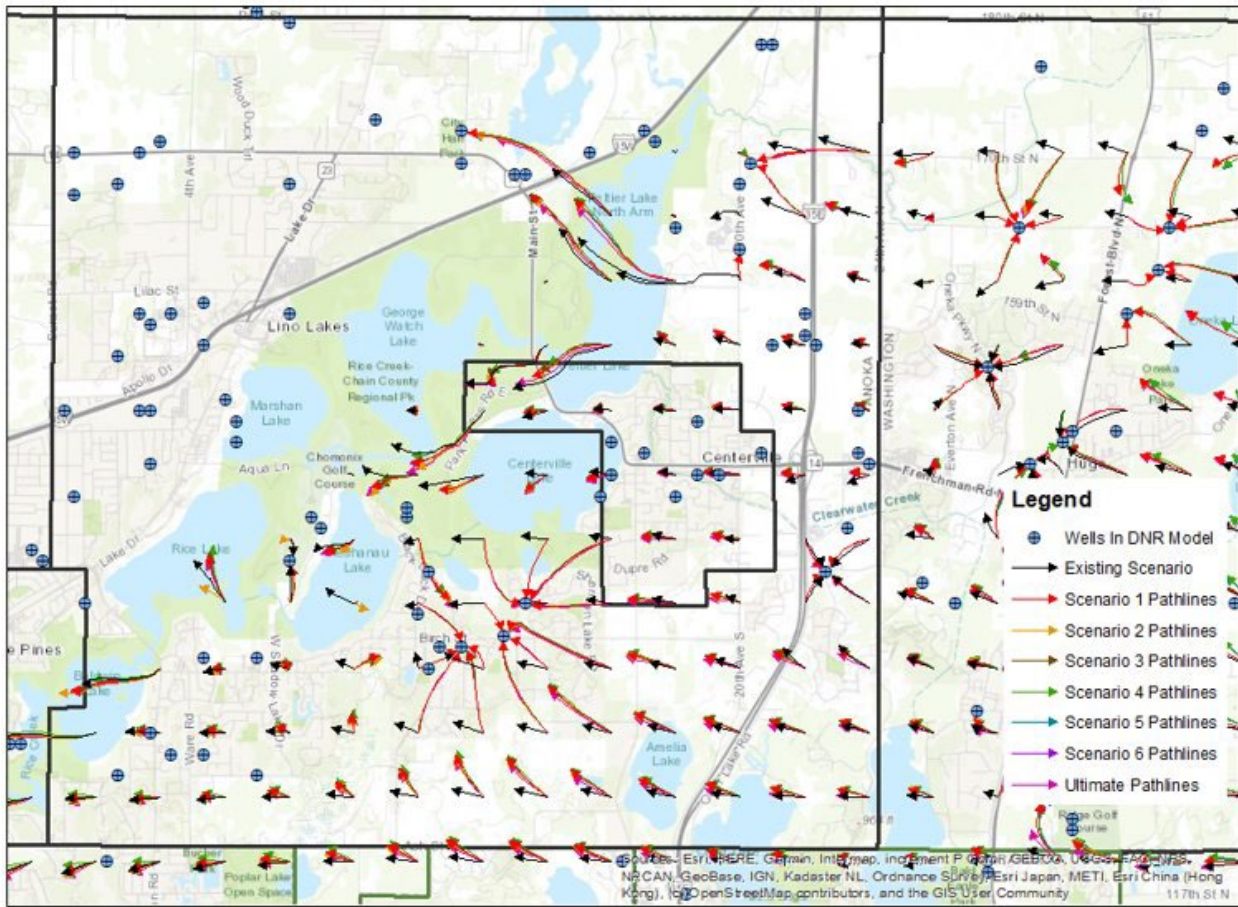


Figure 3: Scenario pathlines in Centerville and Lino Lakes

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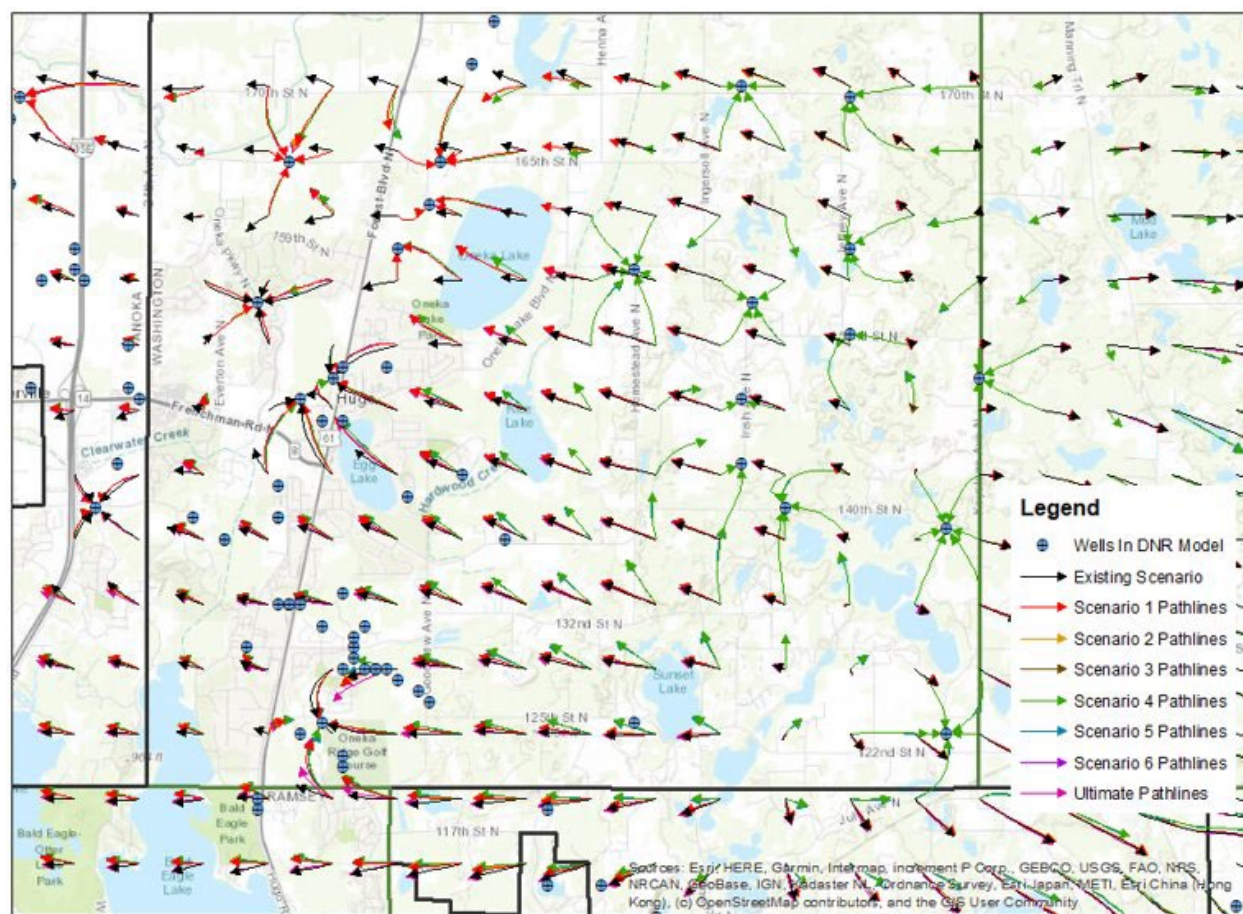


Figure 4: Scenario pathlines in Hugo

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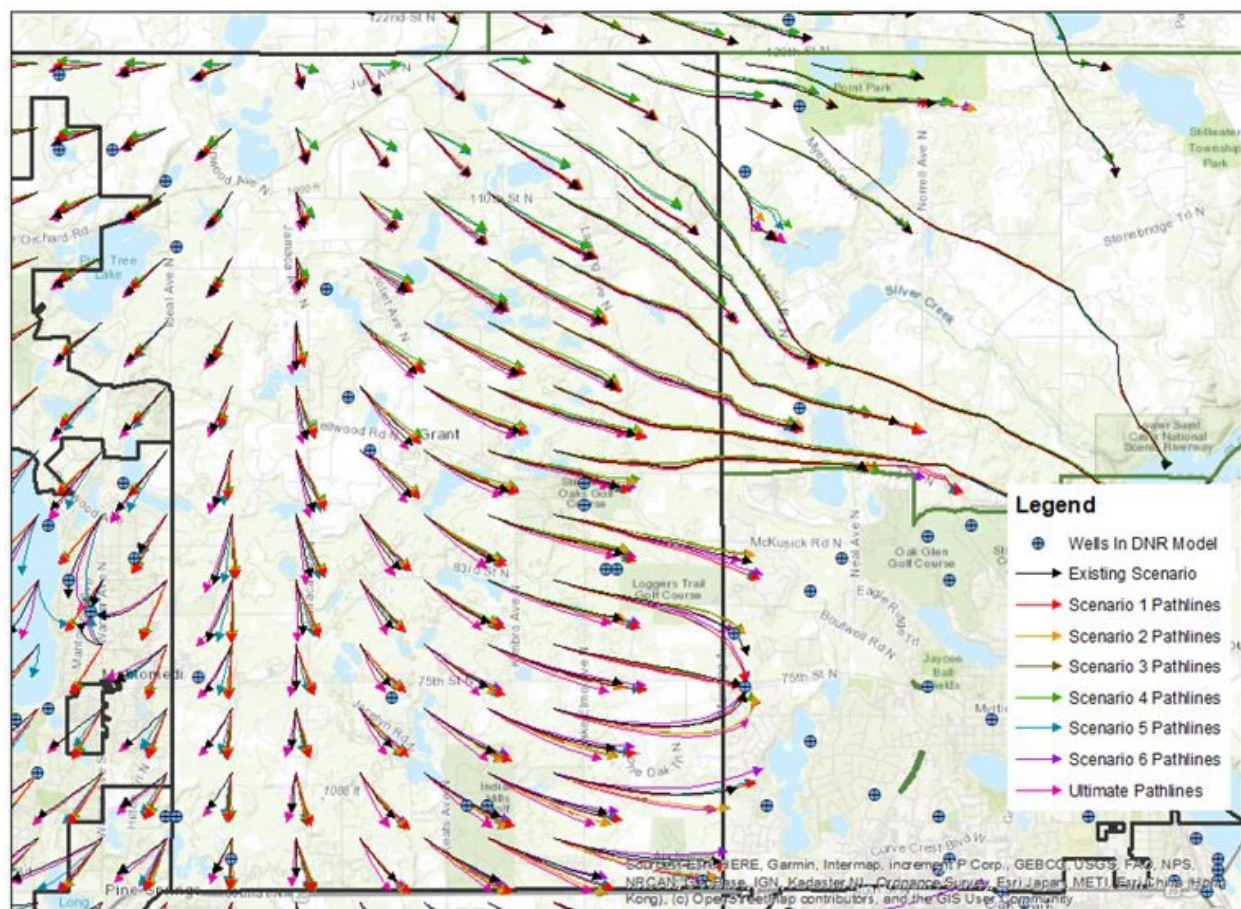


Figure 5: Scenario pathlines in Grant and Stillwater

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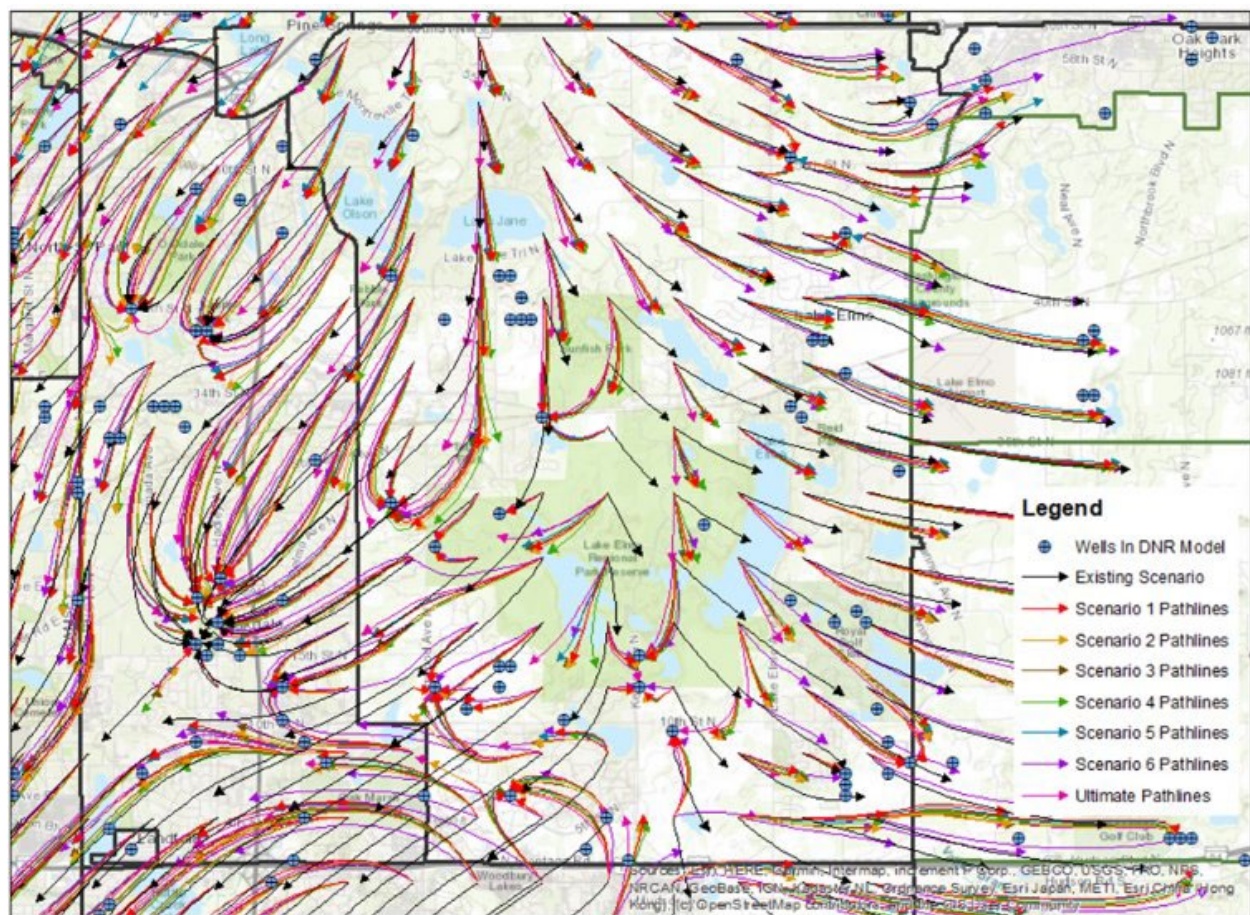


Figure 6: Scenario pathlines in Oakdale and Lake Elmo

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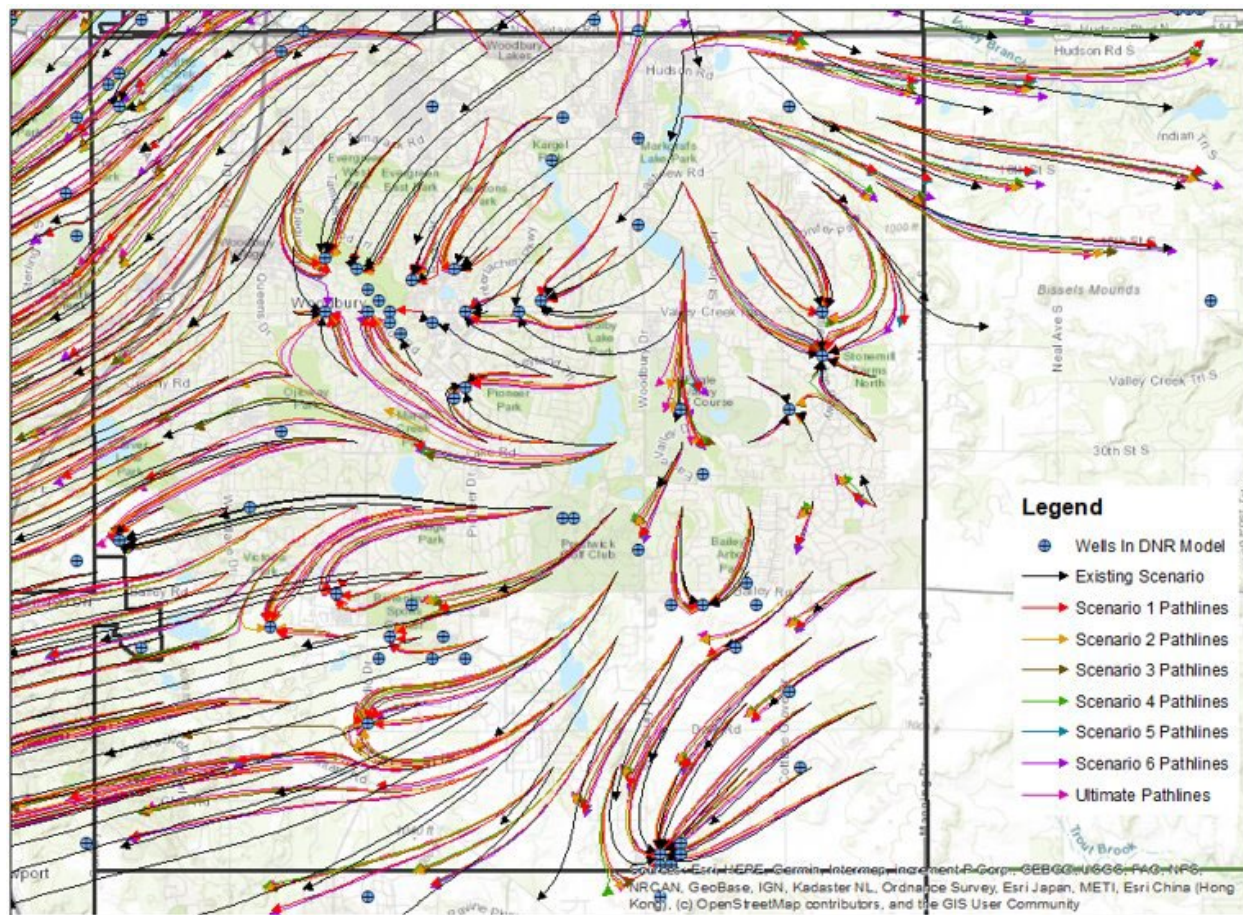


Figure 7: Scenario pathlines in Woodbury

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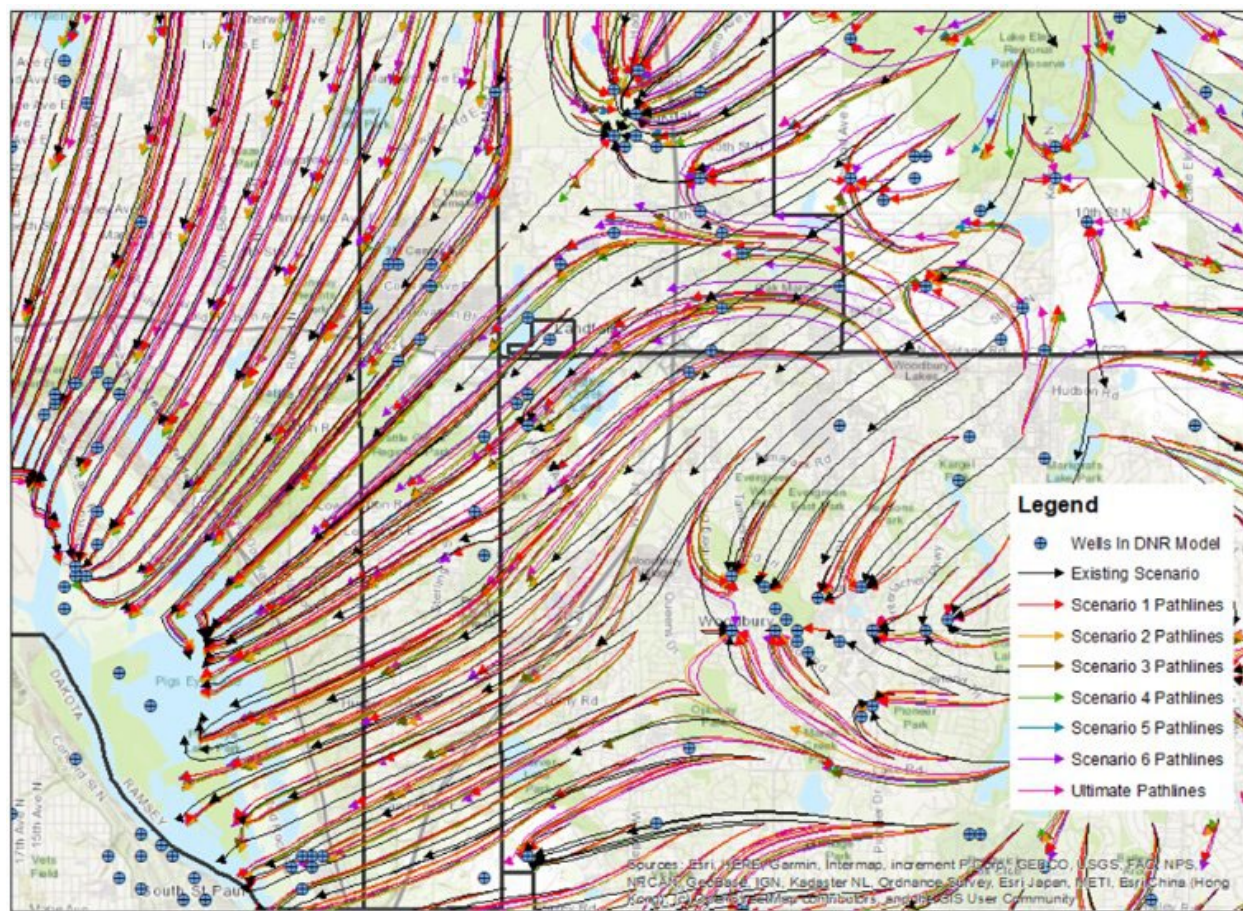


Figure 8: Scenario pathlines in south Maplewood, Oakdale, Lake Elmo and Woodbury

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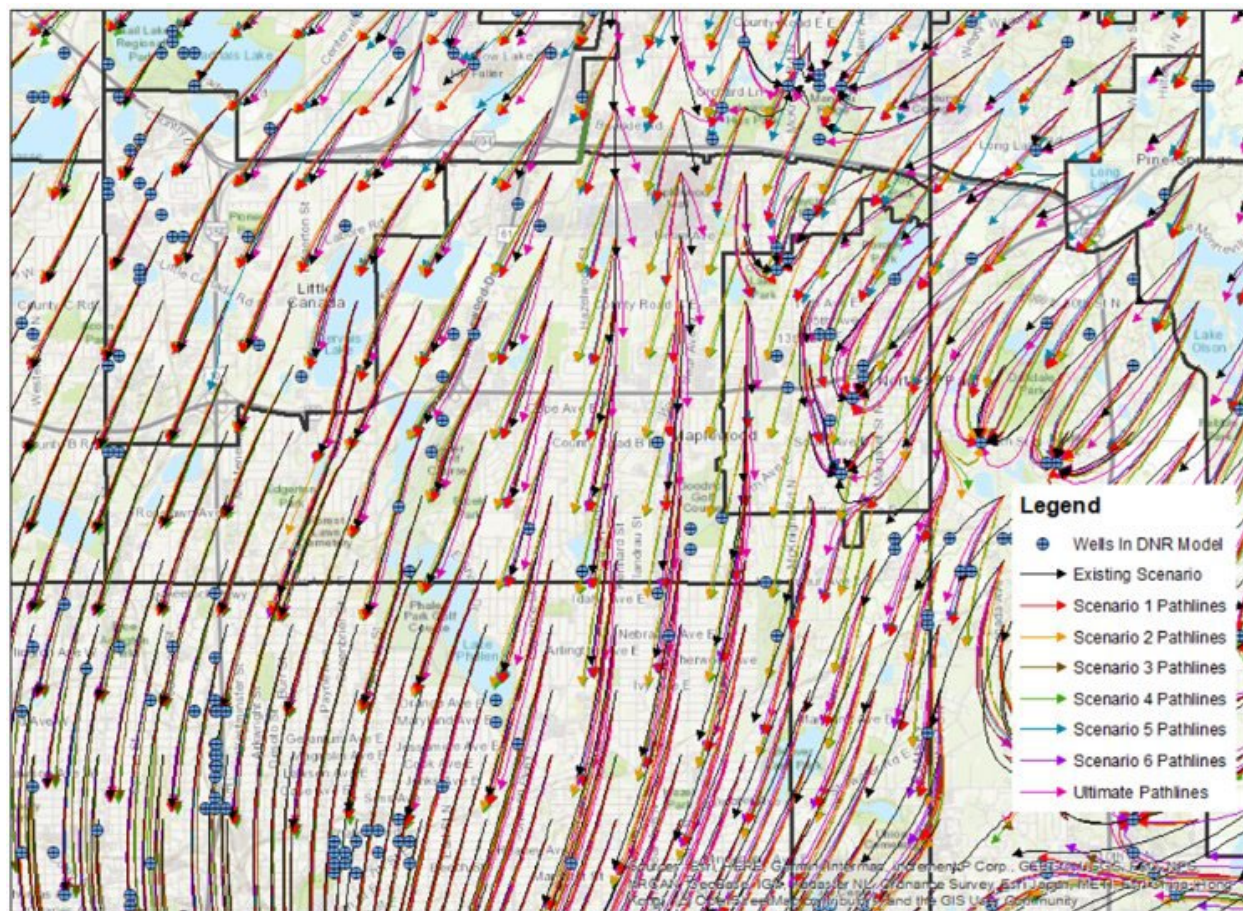


Figure 9: Scenario pathlines in Little Canada, north Maplewood, and North St. Paul