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Reilly Tar Site / Meadowbrook Groundwater Model Update

STS Project 200703587

June 30, 2008

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June 30, 2008

Mr. Nile Fellows
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, MN 55155

Re: Reilly Tar Site/Meadowbrook Ground Water Model Update – Letter Report;
STS Project 200703587, Task 1003

Dear Mr. Fellows:

We are pleased to present you with the Reilly Tar Site / Meadowbrook Ground Water Model Update - A Letter Report. The work was conducted as outlined in STS Proposal 200701405 submitted to the MPCA on June 29, 2007, with slight modifications as dictated by the progressing new data review and modeling work. The proposal was approved as stated in the Contract Work Order STST0802 issued by MPCA on July 9, 2007.

This letter report presents the summary of the development of Reilly Tar Site / Meadowbrook Ground Water Model and documents the model updating and recalibration using the new water level and water production data. It also presents and documents the model predictive simulations aimed at evaluating the effects of different pumping scenarios on the VOC plume migration from the area of St. Louis Park to Edina. Finally, the letter report presents discussion and recommendations as to further data collection and model adjustments.

If you have any questions, please contact Peter Rzepecki at 763-315-6345 or Bob DeGroot at 763-315-6317.

Sincerely,

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1.0 Introduction

The goal of the Groundwater Model Update (Task 1003) was to evaluate the newly accumulated continuous water level data and to utilize it to update the Reilly Tar Site / Meadowbrook Groundwater Model (the Model). The updated Model was then to be used to:

- Evaluate migration of the St. Louis Park centered OPCJ Aquifer Volatile Organic Compounds (VOC) plume toward the City of Edina during periods of time when groundwater flow from St. Louis Park to Edina is most pronounced.
- Evaluate various remedial actions to prevent the VOC plume from reaching the Edina OPCJ municipal wells.

2.0 Brief Review of the Reilly Tar Site / Meadowbrook Groundwater Model Development

The work on the Model development started in 2003 (STS, 2003). The issue under focus at this time was the effect of shutdown of the Methodist Hospital OPCJ Well (Methodist Well) and a concern that this shutdown might enhance the former Reilly Tar Site's related polyaromatic hydrocarbon (PAH) groundwater plume migration toward the municipal wells in the area. The Methodist Well was serving as one of the groundwater gradient control wells for the former Reilly Tar Site. Pumping from the Meadowbrook Golf Course Well (Meadowbrook Well), also completed in the OPCJ aquifer, was considered as a remedy to elimination of the Methodist Well from the gradient control system of wells.

The 2003 STS report prepared for the Minnesota Pollution Control Agency (MPCA) titled "Well Evaluation for Meadowbrook Golf Course" (STS, 2003) presents a chronological review of the groundwater modeling work conducted to date in the area. The 2003 report recommends collection of additional data and development of a new groundwater model dedicated to evaluation of pumping from the Meadowbrook Well.

In 2004, STS searched, reviewed and assembled the available and up-to-date water level, pumping, geological and hydrogeological data and regional publications relevant to development of the Model. The "Reilly Tar Site / Meadowbrook Groundwater Model – Model Database Summary Report" (STS, 2004a) also summarized the sources and use of data in three previous groundwater models covering the project area: MPCA Metro Model, MDH Model and USGS Metro Model.

The "Reilly Tar Site/Meadowbrook Ground Water Model, St. Louis Park, Minnesota - Project Phase II Report" (STS, 2004b) summarizes the analysis and interpretation of the previously assembled data and information, provided "Conceptual Hydrogeologic Model" and presented recommendations as to the set-up and development of the Model.

The modeling work commenced in 2005. The "Reilly Tar Site / Meadowbrook Groundwater Model Set-up and Calibration Report" (STS, 2005b) documents the Model set-up and calibration. Two parallel, steady-state models were developed: "Low Transmissivity Model" and "High Transmissivity Model". Each Model version was developed using the opposing ends of the range of the OPCJ aquifer transmissivity values (low and high end, respectively) obtained from several aquifer tests conducted in the area. The model domain in both versions of the Model embraced three hydro-stratigraphic units:

- St. Peter aquifer (Model Layer 1);
- Basal St. Peter Formation (aquitard) (Model Layer 2); and
- OPCJ aquifer system (Model Layer 3).

Transient Model version was also developed using a database of monthly water production from the St. Louis Park and Edina wells. However, it was concluded that representation of dynamic conditions in the aquifer over the period of time since the inception of the Reilly Tar operations till present time is not practical. Running the transient model representing the necessary number of stress periods would exceed the software and hardware limitations (STS, 2005b).

Preliminary MODPATH runs were conducted using forward particles to simulate groundwater contaminant pathways from the area near the Reilly Tar Site. These simulations were conducted to evaluate if the existing gradient control system intercepts groundwater contaminants. It was found that the Low Transmissivity Model predicted that some of the particles are intercepted by the Edina municipal wells. This finding coincided with detection of VOC contaminants in the Edina OPCJ wells. Edina Well No. 7 VOC contamination investigation (for summary of that multi-stage investigation, see STS, 2006b, 2006c and 2007) established the presence of a large VOC plume centered on the area within the boundaries of St. Louis Park. That VOC plume was found to coincide to a large extent with the PAH plume. Thus, the gradient control system of wells designated to control the expansion of the PAH plume was found to also affect the VOC plume.

However, neither the Low nor the High Transmissivity Model versions could be made to have the Edina Well No. 7 (ED-7) intercept the MODPATH particles. ED-7 was found to have significant VOC contamination since 2001. The conclusion was that the Model should be recalibrated using an improved water level data. Collection of VOC data from the area wells was also included in the recommendations of the 2005 report (STS, 2005b). This recommendation resulted in an initiation of a program of splitting groundwater samples collected periodically by ENSR into samples for PAH and VOC analysis.

STS has been operating transducer and data logger in the Meadowbrook Well since May 19, 2005. During the summer of 2005, the City of Edina conducted (at the request from STS) manual water level measurements in ED-7. These measurements revealed that during a short period of time, in June and July, water level in ED-7 was 20 to 30 feet lower than water level in Meadowbrook Well. This indicated a sharp increase in hydraulic gradient during summer months between St. Louis Park and Edina, inducing groundwater contaminant transport toward the Edina wells.

During 2005/2006, while sampling several St. Louis Park shallower wells for VOC analysis, STS took water level measurements from these same wells (STS, 2006a), building a database for the MPCA proposed expansion of the Model (to represent in the Model the shallower aquifers and aquitards).

STS expanded the Model in 2006 by adding four layers on top of the top-most layer of the original Model (STS, 2006a). The expanded Model domain embraces the Drift aquifer system (Model Layers 1 and 2), Platteville Limestone (Model Layer 3), Decorah- Glenwood Confining Unit (Model Layer 4), St. Peter Sandstone (Model Layer

5), Basal St. Peter Formation (Model Layer 6) and Prairie du Chien – Jordan aquifer system (OPCJ – Model Layer 7). Like the original Model, the expanded Model was developed in two versions – Low Transmissivity Model and High Transmissivity Model. Both model versions were calibrated in stages, the last stage of calibration involving the use of an automatic calibration program, PEST.

The developed and calibrated Low Transmissivity and High Transmissivity Model versions were next set as transient models. The transient models were set-up using the monthly water production data for the year of 2005/2006 and continuous water level measurements collected and for the first time available from the Meadowbrook Well. The transient model calibration process demonstrated that it is impossible to calibrate the High Transmissivity Model version to the Meadowbrook Well water level data. It was concluded that the Low Transmissivity model version represents a better approximation of the real groundwater system, compared to the High Transmissivity Model version.

The transient (low transmissivity version) Model was then set to simulate 160 half-year long stress periods (representing 80 years). Each pair of stress periods (per year) was representing the warmer and colder halves of the year. MODPATH program was used again to simulate groundwater contaminant pathways. These transient simulations showed that the model calculated particle pathlines do not differ from the pathlines calculated using the steady-state models. This result was interpreted as demonstrating that over longer periods of time, fluctuations of water levels are to a large extent synchronous. As a consequence, seasonal average hydraulic gradients do not vary significantly from the average hydraulic gradients as calculated for long periods of time and represented by a steady-state Model. This interpretation appeared to be also supported by the characteristics of hydrographs presented in the report (STS, 2006a).

Since the steady-state Model simulates an average water production from the high capacity wells in the area, it does not allow simulation of short-lived, increased hydraulic gradients observed between St. Louis Park and Edina during the Summer of 2005 (see Figure 1). In July of 2006 STS adjusted the Low Transmissivity version of the expanded Model to recreate the steep - June/July 2005 measured hydraulic gradients. This modified, “Summer of 2005 Conditions Model” was then used to run predictive simulations with the use of MODPATH particles (STS, 2006d). The results of these simulations indicate that under conditions of the steep, summer of 2005 measured gradient, a significant groundwater contaminant migration takes place from St. Louis Park to the Edina municipal wells. Additional predictive simulations demonstrated that pumping from Meadowbrook Well, Methodist Hospital Well and St. Louis Park Well No. 6 (SLP-6) would create partial hydraulic barrier, sufficient to intercept a large portion of contamination migrating from St. Louis Park to Edina.

The report (STS, 2006d) also concludes that the model calculated pathlines represent only a crude, conservative approximation of the contaminant transport. In addition to uncertainties associated with the model set-up, with the aquifer hydraulic parameters, several important processes, like hydrodynamic dispersion, contaminant retardation and degradation, the presence of multi-aquifer wells or contaminant migration along preferential pathlines in the fractured aquifer are not represented in this model.

3.0 New Data, Model Update and Recalibration

3.1 New Data

In June of 2008, for the first time continuous water level data covering significant length of time (nine months) were available from the three OPCJ wells straddling the boundary between St. Louis Park and Edina: Edina Municipal Well No. 7 (ED-7), Edina OPCJ Test Well (Edina Test Well) and Meadowbrook Golf Course Well (Meadowbrook Well) (STS, 2008a). The collected data revealed a highly dynamic nature to the OPCJ groundwater system in the area with frequently changing direction of groundwater flow and magnitude of a horizontal hydraulic gradient.

Analysis of the collected data revealed that the most persistent pattern of groundwater flow from St. Louis Park toward Edina (during a monitoring period lasting from June 21, 2007 through March 19, 2008) took place from September 22 through November 19, 2007. During that time period, the predominant OPCJ groundwater horizontal gradient direction was ESE, or from the area of the City of St. Louis Park toward the NE part of Edina. No steep gradient was detected between St. Louis Park and Edina during summer 2007 or winter 2008. Groundwater flow was predominantly in the ENE direction, away from Edina during these periods of time (STS, 2008a). The water level data demonstrating that there is a significant groundwater flow toward the NE part of Edina is supported by water quality data. Concentrations of several chlorinated VOCs, trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), trans-1,2-dichloroethene (trans-1,2-DCE) and vinyl chloride measured in Edina Municipal Well No. 2 (ED-2) over a period of time from 2004 to 2008 show an increasing trend (STS, 2008b).

3.2 Model Update

Monthly groundwater production data for 2007 were obtained from the Cities of St. Louis Park, Edina and Hopkins. Average pumping rates for the OPCJ municipal wells represented in the model were calculated using October and November of 2007 water production data (coinciding as close as possible with the September 22 through November 19, 2007 period of predominant groundwater flow toward NE portion of Edina). The updated pumping rates are presented in Table 1.

Three new observation wells were added to the Model in Layer 7 (representing OPCJ aquifer system) – ED-7, ED Test Well and Meadowbrook Well.

Forward MODPATH particles set-up was updated to reflect the up-to-date information about the boundaries of VOC plumes in Drift, Platteville, St. Peter and OPCJ aquifers represented in the model. The forward particles were distributed evenly within the boundaries of the plumes.

3.3 Model Recalibration

Since the purpose of this model update was to evaluate the groundwater system during periods of time when groundwater flows predominantly from St. Louis Park toward Edina, water level data collected during Fall of 2007 was used to recalibrate the model. The Model was calibrated using the average water levels calculated from water levels measured in the three wells, ED-7, ED Test Well and Meadowbrook Well, during a period of time from September 22 through November 19, 2007. The calculated average heads are as follows:

ED-7	- 802.99 ft = 244.75 m
ED OPCJ Test Well	- 804.50 ft = 245.21 m
Meadowbrook Well	- 804.79 ft = 245.30 m

The Model was calibrated to match (as closely as possible) these average calculated water levels at the three wells and to match the hydraulic gradient direction and magnitude calculated based on the average water levels calculated for the three wells:

- direction of horizontal hydraulic gradient - 342.4°
- magnitude of horizontal hydraulic gradient - 0.00046 ft/ft

This calculated calibration goal is based on the assumption of a uniform hydraulic gradient between the three wells – this is most likely an assumption only crudely corresponding to the real system conditions.

The Model calibration was accomplished during twenty model calibration runs (see Table 2) by means of adjusting recharge (see Table 3), hydraulic conductivity in Zones 7, 14, 3 and 41 (see Table 4), and creating new hydraulic conductivity zones (Zone No. 51 in Layer 6 - see Figure 2; Zone No. 52 in Layer 7 – see Figure No. 3).

The calibration was assumed to be complete after the Model calculated Root Mean Square Error was 0.03 m and Normalized Root Mean Square Error was 5.35%.

4.0 Predictive Simulations

Ten scenarios were evaluated using the updated Model's predictive simulations. The updated Model was calibrated to October – November 2007 pumping conditions and water level data measured in the three wells in that period of time: ED-7, ED Test Well and Meadowbrook Well. The updated Model to be used for predictive simulations was further adjusted by assigning average pumping rates for the high capacity municipal wells as reported by the Cities of Edina, St. Louis Park and Hopkins for 2007. The adjusted pumping rates used for the model calibration are listed in Table 1. Pumping rates used during all ten predictive simulations are listed in Table 5.

Edina Well No. 15 (ED-15) was also added to the predictive simulations Model since, as opposed to its groundwater production during October-November 2007 (the calibration period), the reported annual production from that well is significant.

It is important to note that the results of predictive simulations discussed below are very conservative (they tend to over-predict VOC movement to the wells) because the simulations are based on assumption that the average hydraulic gradient in OPCJ aquifer near the boundary between St. Louis Park and Edina calculated for October-November of 2007 does not change. In fact, as the continuous water level monitoring data indicate (STS, 2008a), hydraulic gradients groundwater flow direction frequently change, contributing to a significant dispersion of the plume, which in turn results in decreasing contaminant concentrations. The predictive simulations explore and illustrate the worst case scenarios to identify the potential problems. However, such scenarios should be considered for the reasons discussed in the next paragraph.

There are many indicators that the OPCJ groundwater in the project area moves along preferential pathways (in the form of like solution openings and fractures along bedding planes, etc.). It is likely that these "groundwater preferential pathway channels" are characterized by very high hydraulic conductivity values. Consequently, there is a potential that during periods of time like September – November of 2007, the groundwater dissolved contaminants may be moving fast and considerable distances south and into Edina. During groundwater flow direction reversals, not all contaminants travel back and away from Edina - some are left in place, entrained in the rock pores and fractures and adsorbed to mineral grains of the aquifer's rock formation. These trace amounts of contaminants continue their migration further into Edina's interior during the consecutive periods of groundwater flow toward Edina. The net effect is a gradual dissipation / dispersion of the plume and its expansion into Edina. This is the reason that any remedial action should be aimed at reducing frequency, magnitude and duration of groundwater flow from St. Louis Park into Edina.

4.1 Baseline Simulation – Predictive Simulation No. 1 (Conditions Existing during October – November of 2007)

The updated Model adjusted for predictive simulations was then run using MODPATH forward particles to track movement of the VOC plume. The results of this simulation are presented on Figure 4. Inspection of Figure 4 reveals that the MODPATH particles representing the southern portion of the OPCJ aquifer's VOC plume are intercepted by ED-2, ED-13 and ED-15. A large portion of the particles intercepted by these wells are representing that VOC plume's portion that is already within the boundaries of Edina.

4.2 Pumping from the Two Edina New Wells – ED-20 and ED-21 (Garden Park location alternative) – Predictive Simulation No. 2

New municipal well, ED-20 is under construction (at Gleason Road, at the west edge of Bredsen Park). According to the City of Edina plans, production from this well will replace the lost production from ED-7. Review of the City water production records reveals that before ED-7 was shut down (because of the detected VOC contamination) the largest production from that well since 1998 occurred in 2003 – 72,720,000 gallons (138 gpm, or 754 m^3/day on average). A new well was added to the Model and assigned a discharge equivalent to that lost ED-7's production in 2003.

New municipal well, ED-21 is planned to be constructed. Two locations are considered –at Garden Park and Birch Chest Park. According to the City of Edina plans, production from this well will replace the lost production from ED-14. ED-14 will be shut down because of radium contamination. Review of the City water production records reveals the largest production from that well since 1998 occurred in 2005-2006 – the average for these two years is 82,924,000 gallons (158 gpm, or 860 m^3/day on average). A new well was added to the Model and assigned a discharge equivalent to that ED-14's production in 2005-2006 that will be lost. The well was located at the more northern of the two considered locations - at Garden Park.

The results of this simulation are presented on Figure 5. Inspection of Figure 5 reveals that the MODPATH particles representing the southern portion of the OPCJ aquifer's VOC plume are intercepted by ED-2, ED-13, ED-15 and the new well ED-21. Pumping from another new well, ED-20 does not appear to have any significant influence on MODPATH particles migration.

4.3 Pumping from the Two Edina New Wells – ED-20 and ED-21 (Birch Chest Park location alternative) – Predictive Simulation No. 3

Since the results of Simulation No. 2 indicate the possibility that the new well ED-21 may intercept some of the MODPATH particles, if located at Garden Park, this well was assigned pumping rate zero and one more well, ED-21A was added to the model at the alternative location considered for ED-21 – at Birch Chest Park, and assigned discharge equal to 158 gpm, or 860 m^3/day on average.

The results of this simulation are presented on Figure 6. Inspection of Figure 6 reveals that the MODPATH particles representing the southern portion of the OPCJ aquifer's VOC plume are intercepted by ED-2, ED-13, ED-15 and ED-4. The new well, ED-21A located at Birch Chest Park will not intercept any MODPATH particles, but will influence the flow field sufficient to cause ED-4 to intercept MODPATH particles located at the interpreted southern boundary of the VOC plume. It is possible that the southern boundary of the VOC plume is located further north. If such is the case, ED-4 would not intercept any MODPATH particles. One way to verify the location of a southern boundary of VOC plume would be to resample ED-7 – this well was sampled last time in 2005.

4.4 Pumping From SLP-6 – Predictive Simulation No. 4

The Model was modified by setting the pumping rate from SLP-6 to 2,078 m^3/day (381 gpm – half of an average annual pumping rate from that well in the years 1988-1992). The two new wells, ED-20 and ED-21 (at Birch Chest Park) were retained in the model.

The results of this simulation are presented on Figure 7. Inspection of Figure 7 reveals that pumping from SLP-6 would bring the following changes to the MODPATH particles pathlines pattern compared to predictive simulation 3 (discussed in the previous section):

- No particles are reaching ED-4.
- A lot fewer particles are reaching ED-2 – almost all particles reaching ED-2 are coming from within the boundaries of Edina – thus, pumping from SLP-6 creates an effective hydraulic barrier preventing particles seeded within the boundaries of St. Louis Park from reaching ED-2.
- No particles seeded within St. Louis Park are reaching ED-15.
- Not much effect on particles reaching ED-13.

4.5 Pumping from Meadowbrook Well – Predictive Simulation No. 5

The Model was modified by setting the pumping rate from Meadowbrook Well to 1,635 m^3/day (300 gpm). Like in predictive simulation No. 4, the two new wells, ED-20 and ED-21 (at Birch Chest Park) were retained in the model. However, discharge from SLP-6 was set to zero.

The results of this simulation are presented on Figure 8. Inspection of Figure 8 reveals that pumping from Meadowbrook Well would bring similar changes to the MODPATH particles pathlines pattern to the changes brought about by pumping form SLP-6 (predictive simulation No. 4 discussed in the previous section) except that the ED-2 zone of particles capture would extend to the southernmost area of St. Louis Park – this is the area of the OPCJ aquifer known to be considerably contaminated.

4.6 Pumping from both SLP-6 and Meadowbrook Well - Predictive Simulation No. 6

This simulation is a combination of predictive simulations No. 4 and 5 – both SLP-6 and Meadowbrook Well were set to pump at rates of 2,078 and 1,635 m^3/day, respectively.

The results of this simulation are presented on Figure 9. Inspection of Figure 9 reveals that pumping from both SLP-6 and Meadowbrook Well would create a significant hydraulic barrier preventing MODPATH particles seeded within the limits of St. Louis Park to be captured by ED-2 and ED-15. At the same time the particle capture zone of ED-13 would be significantly smaller compared to the model calculated zones from previous predictive simulations. Under this predictive simulation scenario No. 6, SLP-6 would capture some MODPATH particles seeded within the northern portions of the City of Edina.

4.7 Shifting Pumping from ED-2, ED-13 and ED-15 to ED-10, ED-16 and ED-20 - Predictive Simulation No. 7

Predictive simulations No. 1 through 6 indicate that three of the Edina municipal wells, ED-2, ED-13 and ED-15, are consistently capturing MODPATH particles seeded at locations where the southern portion of the OPCJ aquifer VOC plume is located. The model predictions are supported by the groundwater quality data – all the three wells are VOC contaminated. In addition, the measured contaminant concentrations show increasing trends (see STS, 2008b). STS asked representatives of the City of Edina if pumping from these three wells could be shifted to other Edina wells, further south and away from the VOC plume. The response was that four wells, ED-4, ED-10, ED-16 and ED-20, could be used for that purpose and could pump more water, thus replacing lost production from these four wells.

To simulate Predictive Simulation No. 7 scenario, the Model was modified in the following way:

- Pumping rates in Meadowbrook Well and SLP-6 were set to zero.
- The entire groundwater production reported for ED-2 in 2007 (625 gpm, or 3,407 m^3/day) was shifted to ED-20 – the discharge from ED-2 was set to zero. The total calculated discharge assigned to ED-20 is 763 gpm or 4,161 m^3/day – this is the sum total of water production reported for both ED-2 in 2007 and discharge assigned to ED-20 in the previous predictive simulations.
- The entire groundwater production reported for ED-13 in 2007 (875 gpm, or 4,770 m^3/day) was shifted to ED-16 – the discharge from ED-13 was set to zero. The total calculated discharge assigned to ED-16 is 1,193 gpm or 6,501 m^3/day – this is the sum total of water production reported for both ED-13 and ED-16 in 2007.
- The entire groundwater production reported for ED-15 in 2007 (148 gpm, or 805 m^3/day) was shifted to ED-10 – the discharge from ED-15 was set to zero. The total calculated discharge that would need to be assigned to ED-10 is 403 gpm or 2,196 m^3/day – this is the sum total of water production reported for both ED-10 and ED-15 in 2007. Since ED-10 is a deep, Mt. Simon aquifer well, it is not represented in the Model. However, increased pumping from this well will not affect the OPCJ aquifer's VOC plume.

The results of this simulation are presented on Figure 10. Inspection of Figure 10 reveals that increasing pumping from more southerly Edina municipal wells while ceasing to pump from ED-2, ED-13 and ED-15 will result in pulling VOC plume to most of the major water producing wells in central and southern parts of Edina. Some particles are shown to travel all the way to the Richfield wells. Additional Model simulation indicates that shifting ED-2 water production to ED-4, instead of ED-20, would produce a similar result.

4.8 Shifting Pumping from ED-2 and ED-15 to ED-10 and ED-16 - Predictive Simulation No. 8

Under this scenario, water production in ED-13 was left at production level reported for that well in 2007, while water production from ED-2 was shifted to ED-10, and water production from ED-15 was shifted to ED-16.

To simulate this scenario, the Model was modified in the following way:

- The entire groundwater production reported for ED-15 in 2007 (148 gpm, or 805 m^3/day) was shifted to ED-16 – the discharge from ED-13 was set to zero. The total calculated discharge assigned to ED-16 is 466 gpm or 2,537 m^3/day – this is the sum total of water production reported for both ED-13 and ED-16 in 2007.
- The entire groundwater production reported for ED-2 in 2007 (625 gpm, or 3407 m^3/day) was shifted to ED-10 – the discharge from ED-15 was set to zero. The total calculated discharge that would need to be assigned to ED-10 is 880 gpm or 4,797 m^3/day – this is the sum total of water production reported for both ED-10 and ED-2 in 2007. Since ED-10 is a deep, Mt. Simon aquifer well, it is not represented in the Model. However, increased pumping from this well will not affect the OPCJ aquifer's VOC plume.

The results of this simulation are presented on Figure 11. Inspection of Figure 11 reveals a similar pattern that was shown for the previous scenario – predictive simulation No. 7.

4.9 Shifting Pumping from ED-2 and ED-15 to ED-10 and ED-16, Pumping from SLP-6 and Meadowbrook Well - Predictive Simulation No. 9

Pumping configuration under this scenario No. 9 is the same as under scenario No. 8 (discussed in the previous section), except that (like under scenario No. 6) both SLP-6 and Meadowbrook Well were set to pump at rates of 2,078 and 1,635 m^3/day, respectively.

The results of this simulation are presented on Figure 12. Inspection of Figure 12 reveals that under this pumping configuration most of the MODPATH particles are intercepted by SLP-6, Meadowbrook Well and ED-13. A small number of particles are intercepted by ED-4 and ED-6, or migrate past ED-2 toward the east. Since most of the year hydraulic gradients are away from Edina, in a real aquifer system contaminants may never be intercepted by ED-4 and ED-6 and, also, may never migrate far east, beyond ED-2.

4.10 Shifting Pumping from ED-2, ED-13 and ED-15 to ED-10, ED-16 and ED-20, Pumping from SLP-6 and Meadowbrook Well - Predictive Simulation No. 10

Under this simulation both SLP-6 and Meadowbrook Well were set to pump at rates of 2,078 and 1,635 m^3/day, respectively (like under simulation No. 9). In addition, pumping from ED-2, ED-13 and ED-15 was shifted to ED-10, ED-16 and ED-20 in the following way:

- The entire groundwater production reported for ED-2 in 2007 (625 gpm, or 3,407 m^3/day) was shifted to ED-16 – the discharge from ED-2 was set to zero. The total calculated discharge assigned to ED-16 is 943 gpm or 5,138 m^3/day – this is the sum total of water production reported for both ED-2 in 2007 and discharge assigned to ED-16 in the baseline predictive simulation.
- The entire groundwater production reported for ED-13 in 2007 (875 gpm, or 4,770 m^3/day) was shifted to ED-10 – the discharge from ED-13 was set to zero. The total calculated discharge assigned to ED-10 is 1,130 gpm or 6,160 m^3/day – this is the sum total of water production reported for both ED-13 and ED-10 in 2007. Since ED-10 is a deep, Mt. Simon aquifer well, it is not represented in the Model. However, increased pumping from this well will not affect the OPCJ aquifer's VOC plume (it is questionable, however, if groundwater can be produced from ED-10 at such high rate).
- The entire groundwater production reported for ED-15 in 2007 (148 gpm, or 805 m^3/day) was shifted to ED-20 – the discharge from ED-15 was set to zero. The total calculated discharge that would need to be assigned to ED-20 is 286 gpm or 1,560 m^3/day – this is the sum total of water production reported for ED-15 in 2007 and assigned in baseline simulation (No. 1) to ED-20.

The results of this simulation are presented on Figure 13. Inspection of Figure 13 reveals that under this pumping configuration a large number of the MODPATH particles are intercepted by ED-4, ED-6, ED-21 and also significant number of particles migrate past ED-2 and ED-17 in the eastern direction. This simulation indicates that applying this pumping configuration would likely result in pulling the VOC plume further south, compared to the plume's current southern boundary – a highly undesirable outcome.

5.0 Summary and Recommendations

The Use of Model for Evaluation of Groundwater Plume Movement and Control

The predictive simulations used the MODPATH forward particulate tracking method to examine municipal wells' capture zones and their potential to draw groundwater contaminants under different pumping configurations. These simulations are based on assumption that the average hydraulic gradient measured in the OPCJ aquifer in the area near the boundary between St. Louis Park and Edina during October and November of 2007 is sustained for many years. In reality, as evidenced by the accumulated water level data (see STS, 2008a), hydraulic gradients in the area frequently shift. These shifts result in a large dispersion of groundwater contaminants and in limiting consistent contaminant movement in one direction.

However, a documented period of groundwater flow toward Edina (late September through November of 2007) is long enough to point to the possibility that VOC contaminants may travel a considerable distance toward the south, unless captured by production wells like ED-2, ED-13, ED-15, SLP-6 or Meadowbrook Well. This is likely particularly because the accumulated data (STS reports listed in a Reference Section – Section 6.0) points to the possibility of groundwater and dissolved contaminants moving within the OPCJ aquifer system along preferential pathways created by fractures and dissolution cavities within bedding planes of Prairie du Chien Formation.

Therefore, the steady-state simulations of MODPATH particle movement represent a reasonable tool for evaluating VOC movement under different pumping configurations.

The results of all ten predictive simulations show that the Edina wells ED-2, ED-13 and ED-15 intercept the MODPATH particulates from the southern area of the St. Louis Park centered VOC plume. As demonstrated by simulations 7 and 8, shifting pumping from ED-2, ED-13 and ED-15, to more southern Edina wells pulls the particulates further south – a highly undesirable outcome. Pumping SLP-6 and Meadowbrook Wells helps controlling the southerly migration of the particulates, as demonstrated by simulations 4, 5, 6 and 9. Simulation No. 9 demonstrated that pumping from SLP-6 and Meadowbrook Wells might allow shifting production from ED-2 and ED-15 to more southern wells without pulling the particulates further south. However, any scenario explored that involved shifting production from ED-13 to more southern wells resulted in MODPATH particulates being pulled toward the south.

General Comments Related to the Model Development and Calibration

This updated Model is only valid for evaluation of the OPCJ groundwater flow between St. Louis Park and Edina during the Fall of 2007. Adequate water level data for October-November 2007 were not available to calibrate the entire Model. The updated Model was developed by adjusting the Expanded Model documented in the STS 2006 Report (STS, 2006b). During the updated Model's calibration, the Model was calibrated to the calculated average October – November of 2007 water levels for the three wells (ED-7, ED Test Well and Meadowbrook Well). At the same time, the Model was de-calibrated with regard to the average, long-term water levels measured in numerous other monitoring wells – the data that served to calibrate the Expanded Model. Collection of continuous water levels at a larger number of monitoring wells would allow an improved Model calibration to a selected part of the year.

It is recommended that continuous water level monitoring in the three wells, ED-7, ED Test Well and Meadowbrook Well be continued to verify if seasonal pattern of changing OPCJ groundwater gradients measured during 2007/2008 is representative of longer-term patterns, or if these patterns significantly change from year to year.

It is also recommended that additional OPCJ monitoring wells be installed near the boundary between St. Louis Park and Edina to allow an improved monitoring of hydraulic gradient in the OPCJ aquifer in the area around the boundary between the Cities.

6.0 General Qualifications

STS professional services have been performed, findings obtained, and recommendations prepared in accordance with generally accepted engineering and hydrogeologic principles and standard practices. No other warranty, either expressed or implied, is made. STS assumes no responsibility for data or interpretations made by others. STS accepts no responsibility for application or interpretation of the results by anyone other than the client.

7.0 References

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Tables

Table 1 Puming Wells Represented in the Model - Calibration of Updated Model

Reilly Tar Site /
Meadowbrook Ground Water Model Update/Recallibration
STS Project No. 200703587

Well Name	MN Unique No.	UTME	UTMN	Screen ID	Top of Screen (m)	Bottom of Screen (m)	Screen Radius (m)	Casing Radius (m)	Stop time (days)	Pumping Rate (m^3/day)	Pumping Rate Changed (?)
ABBOTT_NW_HOSP_1	00201082	479284	4977987	1	190	130	0.1	0.1	36500	-2065	No
ABBOTT_NW_HOSP_2	00201083	479316	4978023	1	190	130	0.1	0.1	36500	-1199	No
ABBOTT_NW_HOSP_3	00112248	479357	4977968	1	190	130	0.1	0.1	36500	-539	No
EDINA_13	00203613	468828	4974188	1	190	130	0.1	0.1	36500	-5005	Yes
EDINA_16	00203101	469482	4970571	1	190	130	0.1	0.1	36500	-113	Yes
EDINA_17	00200914	473563	4971458	1	190	130	0.1	0.1	36500	0	Yes
EDINA_2	00208399	473163	4973279	1	190	130	0.1	0.1	36500	-3524	Yes
EDINA_4	00200561	472788	4971862	1	190	130	0.1	0.1	36500	-98	Yes
EDINA_6	00200564	472600	4971537	1	190	130	0.1	0.1	36500	-2293	Yes
EDINA_7	00206474	471863	4972656	1	190	130	0.1	0.1	36500	0	Yes
GM_1	00224098	468695	4980440	1	190	130	0.1	0.1	36500	-1566	No
GM_3	00226208	468692	4980554	1	190	130	0.1	0.1	36500	-870	No
GM_4	00161405	468697	4980747	1	190	130	0.1	0.1	36500	-779	No
GM_OP_1	00223780	469156	4982350	1	190	130	0.1	0.1	36500	-212	No
HINES_1	00201007	478633	4980399	1	190	130	0.1	0.1	36500	0	No
HONEYWELL_INC_1	00203892	471370	4982906	1	190	130	0.1	0.1	36500	-1662	No
HONEYWELL_INC_2	00203878	471512	4983298	1	190	130	0.1	0.1	36500	-703	No
HOPKINS_1	00204573	467416	4974181	1	190	130	0.1	0.1	36500	0	No
HOPKINS_4	00204068	466990	4975893	1	190	130	0.1	0.1	36500	-8040	Yes
HOPKINS_5	00204570	467294	4975820	1	190	130	0.1	0.1	36500	-57	Yes
HOPKINS_6	00112228	467675	4975792	1	190	130	0.1	0.1	36500	0	Yes
MINNETONKA_10	00204140	463477	4976644	1	190	130	0.1	0.1	36500	-1773	No
MINNETONKA_10A	00150356	463474	4976738	1	190	130	0.1	0.1	36500	-1647	No
MINNETONKA_11	00208014	463643	4972738	1	190	130	0.1	0.1	36500	-2411	No
MINNETONKA_11A	00439797	463604	4972839	1	190	130	0.1	0.1	36500	-2888	No
MINNETONKA_12	00203717	464596	4979633	1	190	130	0.1	0.1	36500	-2663	No
MINNETONKA_12A	00191939	464621	4979538	1	190	130	0.1	0.1	36500	-2452	No
MINNETONKA_13	00205165	465661	4971682	1	190	130	0.1	0.1	36500	-3612	No
MINNETONKA_13A	00132263	465602	4971607	1	190	130	0.1	0.1	36500	-2795	No
MINNETONKA_14	00204537	464647	4974689	1	190	130	0.1	0.1	36500	-976	No
MINNETONKA_14A	00160021	464582	4974637	1	190	130	0.1	0.1	36500	-612	No
MINNETONKA_3	00204470	460973	4975336	1	190	130	0.1	0.1	36500	-421	No
MINNETONKA_3A	00171021	461016	4975374	1	190	130	0.1	0.1	36500	-783	No
MINNETONKA_6	00204054	467254	4977553	1	190	130	0.1	0.1	36500	-2898	No
MINNETONKA_7	00208012	467217	4977553	1	190	130	0.1	0.1	36500	-1734	No
NSP_XCEL_EN_1	00200362	478701	4980718	1	190	130	0.1	0.1	36500	-805	No
PLYMOUTH_12	00508300	463598	4983191	1	190	130	0.1	0.1	36500	-2320	No
PLYMOUTH_13	00462918	462850	4983141	1	190	130	0.1	0.1	36500	-3101	No
PLYMOUTH_7	00184882	463214	4983147	1	190	130	0.1	0.1	36500	-2908	No
REPUBLIC_CEROSOTE_(W23)	00216050	470787	4976659	1	190	130	0.1	0.1	36500	-253	No
RICHFIELD_1	00206353	478075	4970720	1	190	130	0.1	0.1	36500	-2629	No
RICHFIELD_2	00206353	478075	4970582	1	190	130	0.1	0.1	36500	-1758	No
RICHFIELD_3	00206361	478940	4970729	1	190	130	0.1	0.1	36500	-2374	No
RICHFIELD_4	00206276	478967	4970415	1	190	130	0.1	0.1	36500	-2080	No
RICHFIELD_6	00206279	479506	4970069	1	190	130	0.1	0.1	36500	-1782	No
SLP_10	00206442	470979	4977506	1	190	130	0.1	0.1	36500	-126	Yes
SLP_14	00227965	471881	4979130	1	190	130	0.1	0.1	36500	-2815	Yes
SLP_16	00203187	468730	4978917	1	190	130	0.1	0.1	36500	-2593	Yes
SLP_4	00200542	473203	4975132	1	190	130	0.1	0.1	36500	-4676	Yes
SLP_6	00206457	472079	4974462	1	190	130	0.1	0.1	36500	0	Yes
SLP_8	00203678	468215	4979510	1	190	130	0.1	0.1	36500	-5901	Yes
W410	00434042	471380	4976072	1	235	230	0.1	0.1	36500	-464	No
W420	00434045	471004	4976262	1	255	253	0.1	0.1	36500	-181	No
W421	00434044	471060	4976262	1	251	248	0.1	0.1	36500	-161	No
W439	?	471108	4976683	1	253	251	0.1	0.1	36500	-264	No
W434	00463012	471784	4976180	1	249	247.5	0.1	0.1	36500	-177	No
MEADOWBROOK_W119	00216009	471316	4974878	1	190	130	0.1	0.1	36500	0	No
METHODIST_W48	00216067	471504	4975536	1	190	130	0.1	0.1	36500	0	No

Table 2 Updated Model's Calibration to Average Fall 2007 Heads Measured in ED-7, ED OPCJ Test Well and Meadowbrook Golf Course Well

Reilly Tar Site /
Meadowbrook Ground Water Model Update/Recallibration
STS Project No. 200703587

		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Run 16	Run 17	Run 18	Run 19	Run 20
Well	Measured Values	Model Calculated Values																			
ED-7	244.75	253.95	254	242.24	242.72	243.1	244.34	244.34	244.33	245.14	244.22	244.08	244.59	244.05	243.34	244.66	244.27	244.08	244.43	244.85	244.7
ED_OPCJ_TEST	245.21	257.19	257.12	245.25	244.18	244.62	245.9	245.9	245.9	246.42	245.5	245.35	245.86	245.26	244.36	245.53	245.14	244.92	245.23	245.33	245.21
MEADOWBROOK	245.30	253.26	253.34	241.46	242.38	242.92	244.36	244.36	244.35	246	244.87	244.77	245.39	244.81	244.04	245.77	245.24	245.16	245.68	245.49	245.29
Gradient Direction (deg)	342	27	27	28	27	23	18	18	18	356	1	360	357	357	355	341	344	340	335	339	343
Gradient Magnitude (m/m)	0.0005	0.00249	0.0024	0.00232	0.001125	0.001166	0.0012	0.0012	0.0012	0.00109	0.00105	0.00105	0.00107	0.00102	0.00088	0.00089	0.00085	0.00086	0.0009	0.0005	0.0005
Mean Error	ME (m):	9.71	9.73	-2.10	-1.99	-1.54	-0.22	-0.22	-0.22	0.77	-0.22	-0.35	0.19	-0.38	-1.17	0.23	-0.20	-0.37	0.03	0.14	-0.02
Mean Absolute Error	MAE (m):	9.71	9.73	2.13	1.99	1.54	0.68	0.68	0.68	0.77	0.42	0.45	0.30	0.41	1.17	0.29	0.20	0.37	0.24	0.14	0.02
Root Mean Squared Error	RMS (m):	9.86	9.87	2.65	2.14	1.71	0.71	0.71	0.71	0.84	0.43	0.50	0.39	0.49	1.20	0.33	0.28	0.43	0.29	0.14	0.03
Norm. Root Mean Sq. Error	Norm. RMS (%):	1792.31%	1793.94%	481.59%	388.66%	310.25%	129.75%	129.75%	129.75%	152.34%	77.84%	90.87%	70.90%	89.85%	217.63%	60.43%	51.31%	78.03%	52.19%	25.82%	5.35%
Notes, changes made in model for the next run:		need to decrease K in Zone 41	decr rech by half	incr K in in zone 14	Update Q from Hopkins wells	incr recharge	incr K in aquitards around Meadowbr : Z 38, Z 7	incr K in aquitards around Meadowbr : Z 38	create Z 51 in L6 around Meadowbr with higher K	decr rech, incr K in Z 51	decr K in Z 7, incr K in Z 51	incr rech	decr rech in Z 10	decr rech in Z 10 and 7, incr rech in Z 4	expand rech Z 4 south, incr rech Z 4	decr rech in Z from 110 to 100, extend rech Z 10	create K zone in L7 SW of Ed7 with K higher than in	incr rech in Z 4	extend K zone 51 to ED-7	decr rech in Z 4	model calibrated to three wells!!

Table 3 Recharge Values Used in the Updated Model

Recharge Zone	Model Layer	Recharge Values used in the Updated / Recalibrated Model [mm/year]
Zone 1	1	130
Zone 2	1	155
Zone 3	1	50
Zone 4	1	330
Zone 5	1	102
Zone 6	1	10
Zone 7	1	200
Zone 8	1	391
Zone 9	1	6
Zone 10	1	100
Zone 11	1	100
Zone 12	1	-183
Zone 13	1	34

Table 4 Aquifer Hydraulic Conductivity Values Used in the Updated / Recalibrated Model

Aquifer Zone	Kx [cm/sec]	Ky [cm/sec]	Kz [cm/sec]
Zone 1	5.0E-03	5.0E-03	5.0E-04
Zone 2	2.0E-04	2.0E-04	1.0E-04
Zone 3	1.2E-03	2.8E-04	7.7E-06
Zone 4	1.0E-04	1.0E-04	1.0E-04
Zone 5	1.0E-04	1.0E-04	1.0E-04
Zone 6	5.0E-05	3.0E-06	2.8E-05
Zone 7	3.8E-06	2.3E-05	1.0E-07
Zone 8	1.8E-05	2.0E-05	7.6E-08
Zone 9	2.2E-05	2.9E-05	1.3E-07
Zone 10	1.6E-05	3.1E-05	2.3E-07
Zone 11	1.6E-02	1.6E-02	1.6E-04
Zone 12	2.8E-02	2.8E-02	2.8E-04
Zone 13	3.8E-03	3.8E-03	3.8E-05
Zone 14	1.7E-02	1.7E-02	1.7E-04
Zone 15	1.2E-02	1.2E-02	1.2E-04
Zone 16	1.5E-02	1.5E-02	1.5E-04
Zone 17	1.0E-02	1.0E-02	1.0E-04
Zone 18	1.8E-02	1.8E-02	1.8E-04
Zone 19	7.0E-05	1.1E-05	6.8E-06
Zone 20	3.0E-03	3.0E-03	1.0E-03
Zone 21	2.0E-04	2.0E-04	7.0E-05
Zone 22	5.0E-04	5.0E-04	1.0E-04
Zone 23	5.0E-04	5.0E-04	1.0E-04
Zone 24	5.0E-04	5.0E-04	1.0E-04
Zone 25	1.0E-02	1.0E-02	3.0E-03
Zone 26	1.0E-02	1.0E-02	3.0E-03
Zone 27	1.0E-02	1.0E-02	3.0E-03
Zone 28	1.0E-02	1.0E-02	3.0E-03
Zone 29	1.0E-02	1.0E-02	3.0E-03
Zone 30	3.0E-04	3.0E-04	1.0E-04
Zone 31	2.0E-03	2.0E-03	7.0E-04
Zone 32	2.4E-02	2.4E-02	1.2E-02
Zone 33	2.0E-03	2.0E-03	7.0E-04
Zone 34	3.0E-03	3.0E-03	1.0E-03
Zone 35	3.0E-03	3.0E-03	1.0E-03
Zone 36	3.0E-03	3.0E-03	1.0E-03
Zone 37	3.0E-03	3.0E-03	1.0E-03
Zone 38	5.0E-02	5.0E-02	1.0E-02
Zone 39	5.0E-04	5.0E-04	1.0E-04
Zone 40	1.0E-03	1.0E-03	4.0E-04
Zone 41	3.0E-05	3.0E-05	1.0E-05
Zone 42	5.0E-06	5.0E-06	2.0E-06
Zone 43	5.0E-07	5.0E-07	1.0E-07
Zone 44	5.0E-07	5.0E-07	1.0E-07
Zone 45	5.0E-06	5.0E-06	2.0E-06
Zone 46	2.0E-02	2.0E-02	8.0E-03
Zone 47	5.0E-03	5.0E-03	5.0E-04
Zone 48	2.0E-04	2.0E-04	7.0E-05
Zone 49	3.0E-02	3.0E-02	2.0E-03
Zone 50	1.0E-02	1.0E-02	3.0E-03
Zone 51	3.0E-04	3.0E-04	4.0E-04
Zone 52	3.0E-02	3.0E-02	3.0E-04

Table 5 Puming Wells Represented in the Updated Model - Discharges from Wells in Each Predictive Simulation

Reilly Tar Site /
Meadowbrook Ground Water Model Update/Recallibration
STS Project No. 200703587

		Pumping Rates Used in Predictive Simulations 1 - 10 (m^3/day)									
Well Name	MN Unique No.	1	2	3	4	5	6	7	8	9	10
ABBOTT_NW_HOSP_1	00201082	-2065	-2065	-2065	-2065	-2065	-2065	-2065	-2065	-2065	-2065
ABBOTT_NW_HOSP_2	00201083	-1199	-1199	-1199	-1199	-1199	-1199	-1199	-1199	-1199	-1199
ABBOTT_NW_HOSP_3	00112248	-539	-539	-539	-539	-539	-539	-539	-539	-539	-539
EDINA_13	**00203613**	**-4770**	**-4770**	**-4770**	**-4770**	**-4770**	**-4770**	**0**	**-4770**	**-4770**	**0**
EDINA_15	**00207674**	**-805**	**-805**	**-805**	**-805**	**-805**	**-805**	**0**	**0**	**0**	**0**
EDINA_16	**00203101**	**-1732**	**-1732**	**-1732**	**-1732**	**-1732**	**-1732**	**-6501**	**-2537**	**-2537**	**-5138**
EDINA_17	00200914	-112	-112	-112	-112	-112	-112	-112	-112	-112	-112
EDINA_2	**00208399**	**-3407**	**-3407**	**-3407**	**-3407**	**-3407**	**-3407**	**0**	**0**	**0**	**0**
EDINA_4	00200561	-767	-767	-767	-767	-767	-767	-767	-767	-767	-767
EDINA_6	00200564	-3255	-3255	-3255	-3255	-3255	-3255	-3255	-3255	-3255	-3255
EDINA_7	00206474	0	0	0	0	0	0	0	0	0	0
EDINA_20	**new well (under construction)**	**--**	**-754**	**-754**	**-754**	**-754**	**-754**	**-4161**	**-754**	**-754**	**-1560**
EDINA_21	**future new well - Garden Park location**	**--**	**-860**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
EDINA_21A	**future new well - Birch Chest Park location**	**--**	**--**	**-860**	**-860**	**-860**	**-860**	**-860**	**-860**	**-860**	**-860**
GM_1	00224098	-1566	-1566	-1566	-1566	-1566	-1566	-1566	-1566	-1566	-1566
GM_3	00226208	-870	-870	-870	-870	-870	-870	-870	-870	-870	-870
GM_4	00161405	-779	-779	-779	-779	-779	-779	-779	-779	-779	-779
GM_OP_1	00223780	-212	-212	-212	-212	-212	-212	-212	-212	-212	-212
HINES_1	00201007	0	0	0	0	0	0	0	0	0	0
HONEYWELL_INC_1	00203892	-1662	-1662	-1662	-1662	-1662	-1662	-1662	-1662	-1662	-1662
HONEYWELL_INC_2	00203878	-703	-703	-703	-703	-703	-703	-703	-703	-703	-703
HOPKINS_1	00204573	0	0	0	0	0	0	0	0	0	0
HOPKINS_4	00204068	-7999	-7999	-7999	-7999	-7999	-7999	-7999	-7999	-7999	-7999
HOPKINS_5	00204570	-234	-234	-234	-234	-234	-234	-234	-234	-234	-234
HOPKINS_6	00112228	-1317	-1317	-1317	-1317	-1317	-1317	-1317	-1317	-1317	-1317
MINNETONKA_10	00204140	-1773	-1773	-1773	-1773	-1773	-1773	-1773	-1773	-1773	-1773
MINNETONKA_10A	00150356	-1647	-1647	-1647	-1647	-1647	-1647	-1647	-1647	-1647	-1647
MINNETONKA_11	00208014	-2411	-2411	-2411	-2411	-2411	-2411	-2411	-2411	-2411	-2411
MINNETONKA_11A	00439797	-2888	-2888	-2888	-2888	-2888	-2888	-2888	-2888	-2888	-2888
MINNETONKA_12	00203717	-2663	-2663	-2663	-2663	-2663	-2663	-2663	-2663	-2663	-2663
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METHODIST_W48	00216067	0	0	0	0	0	0	0	0	0	0

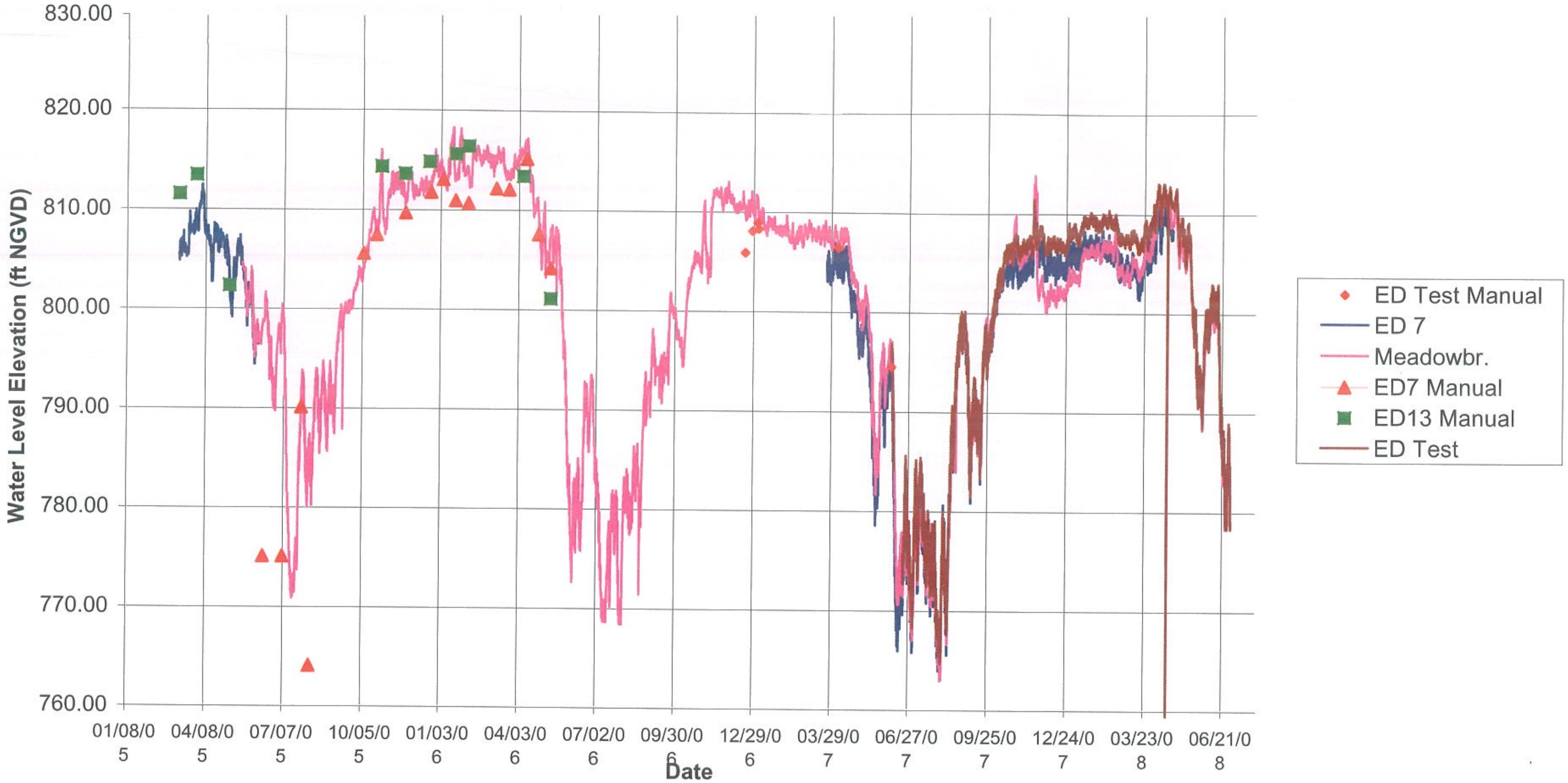
Notes:

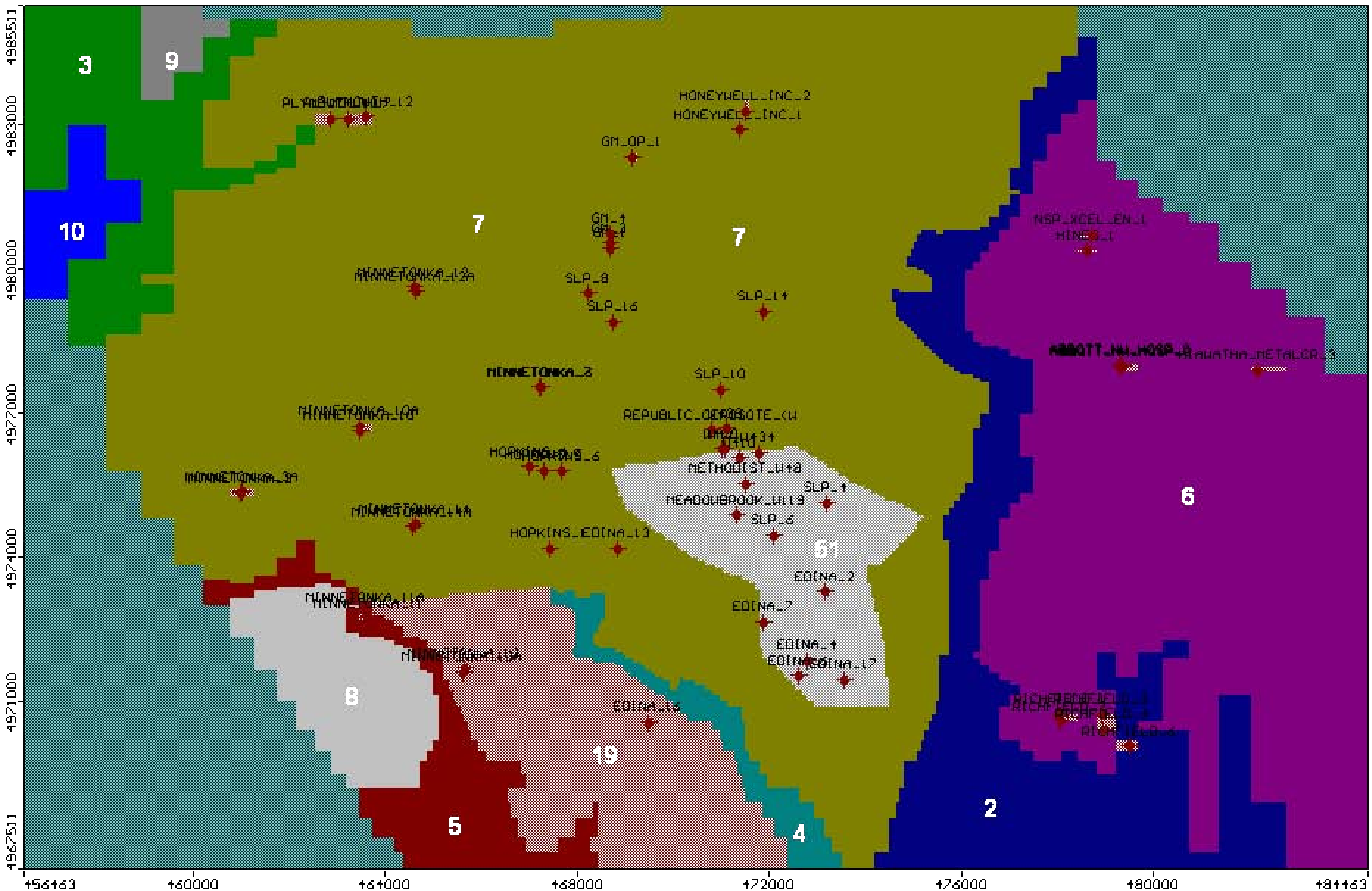
The wells for which pumping rates were varied during predictive simulations, compared to predictive simulation No. 1 (baseline simulation)

Figures

Figure 1. Edina Well No. 7, Edina Well No. 13, Meadowbrook Golf Course Well (W119) and Edina OPCJ Test Well Hydrographs

STS Project No. 200703587

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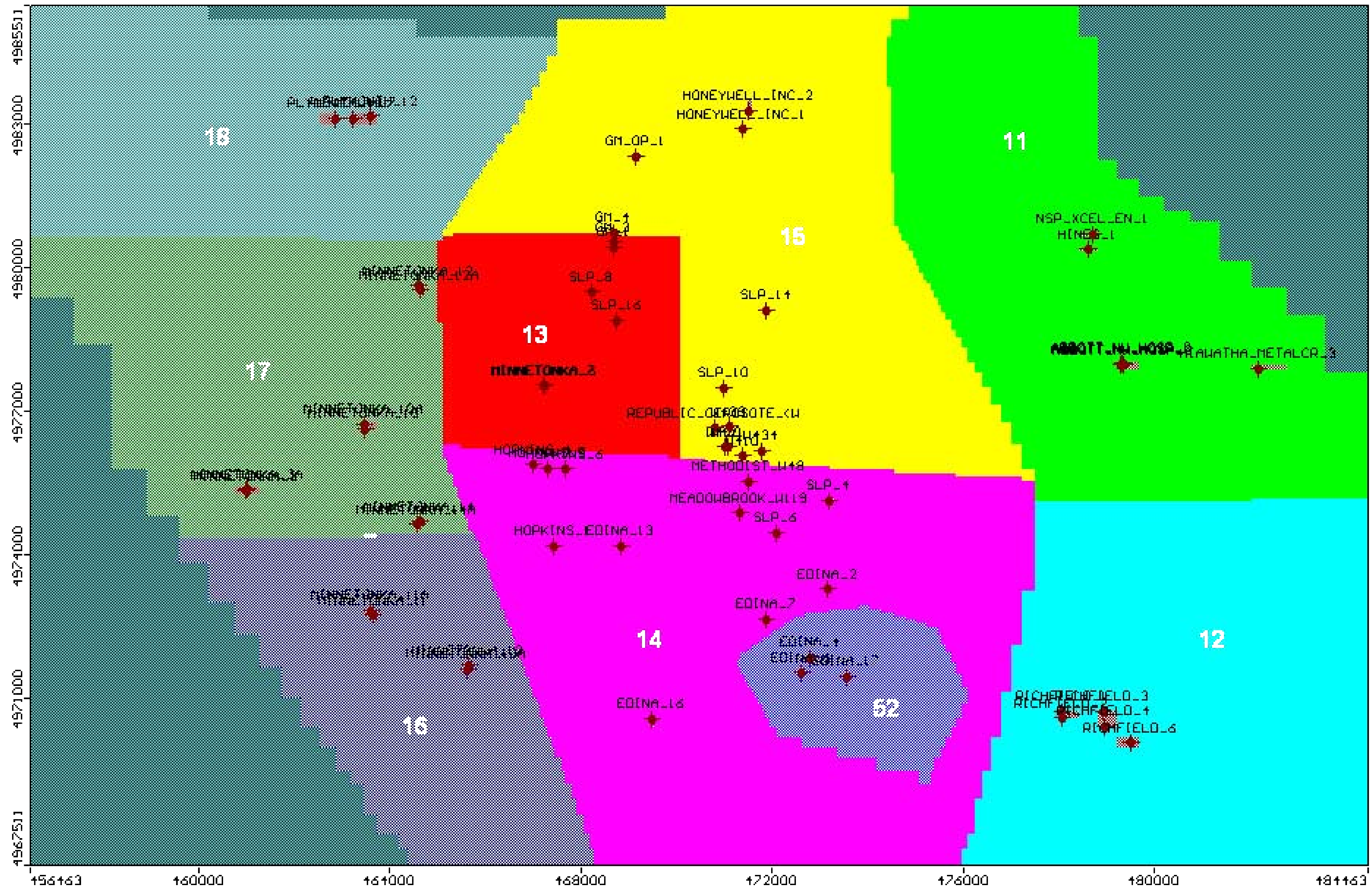
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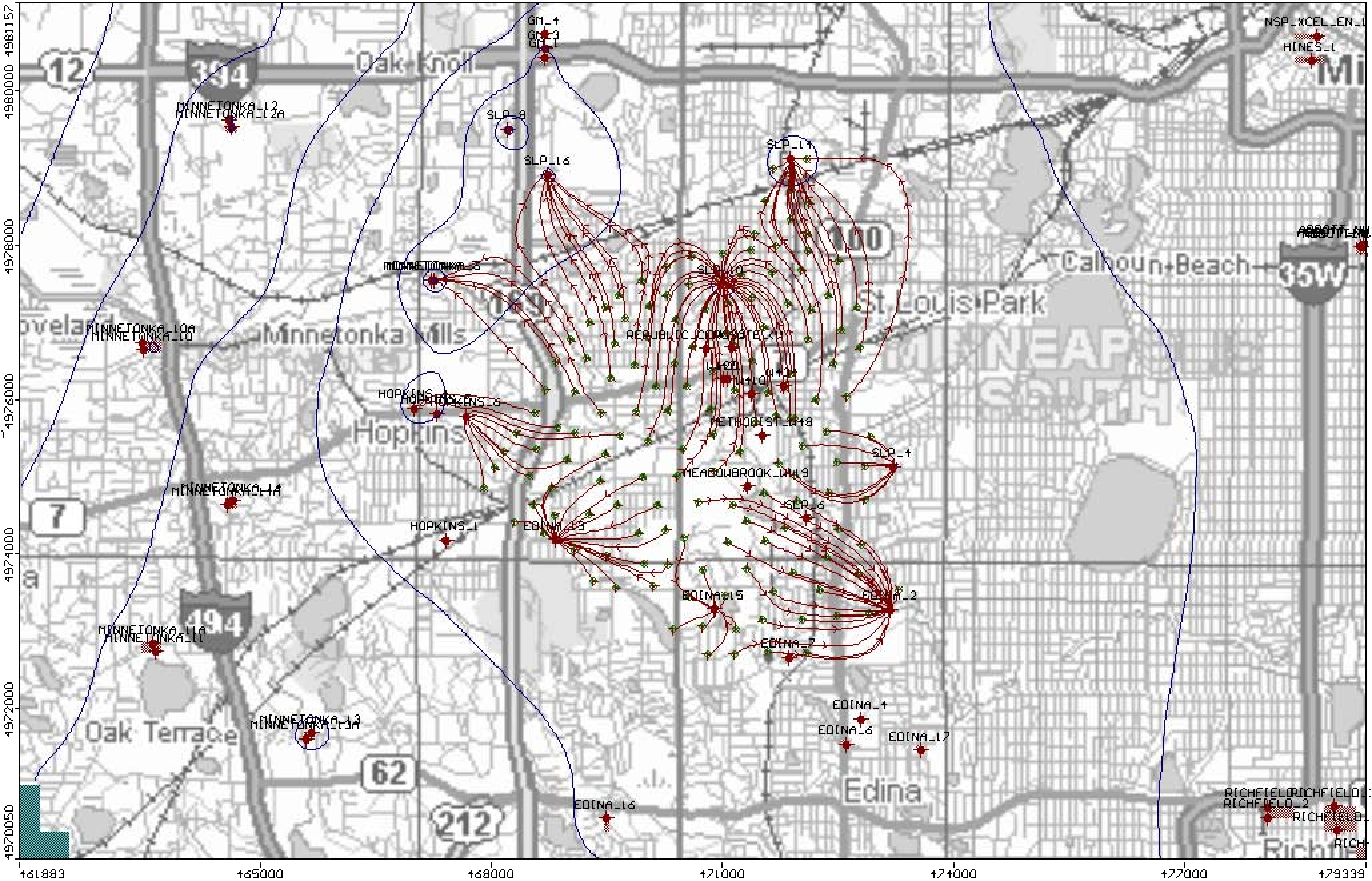
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St. Louis Park
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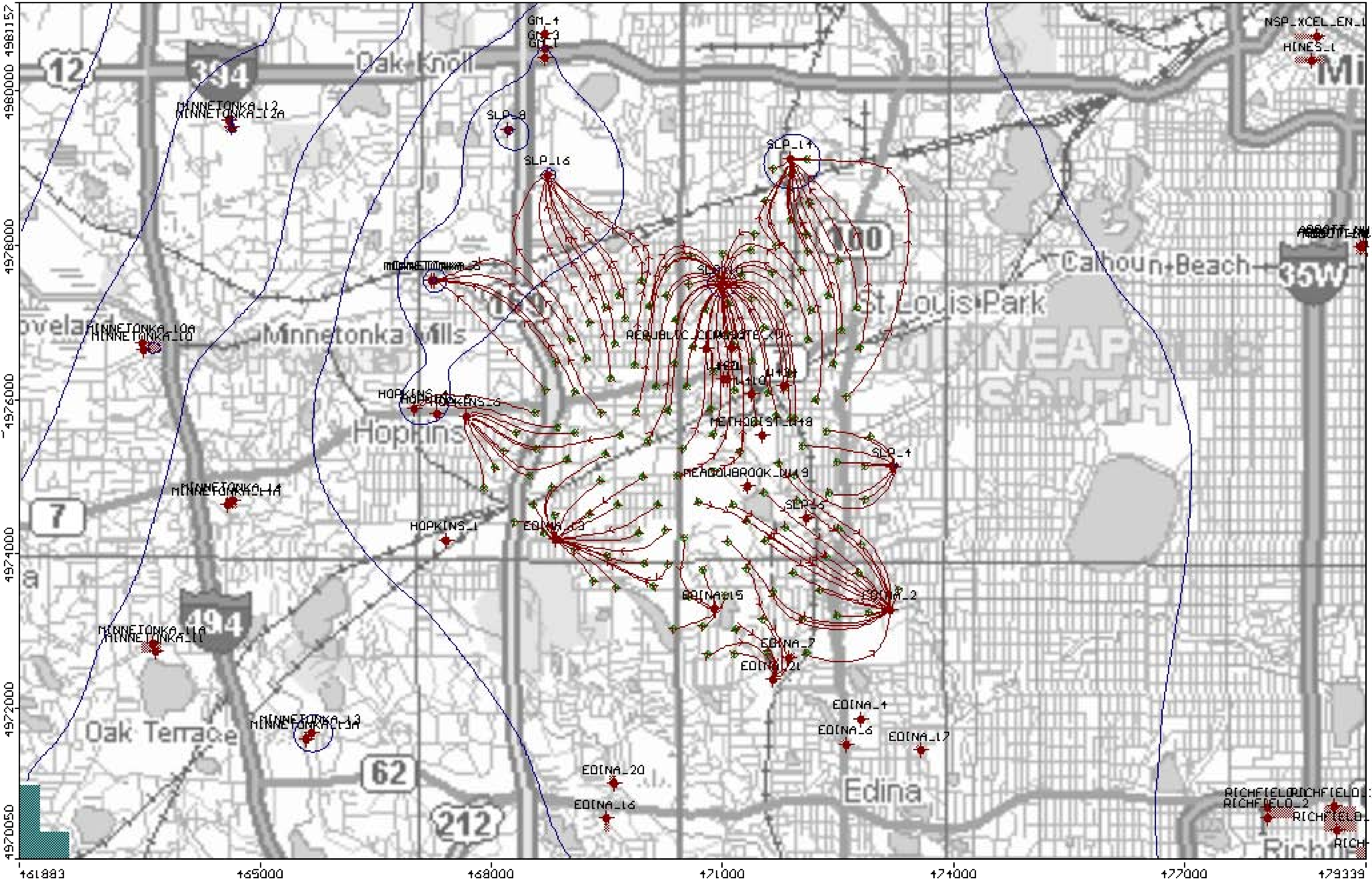

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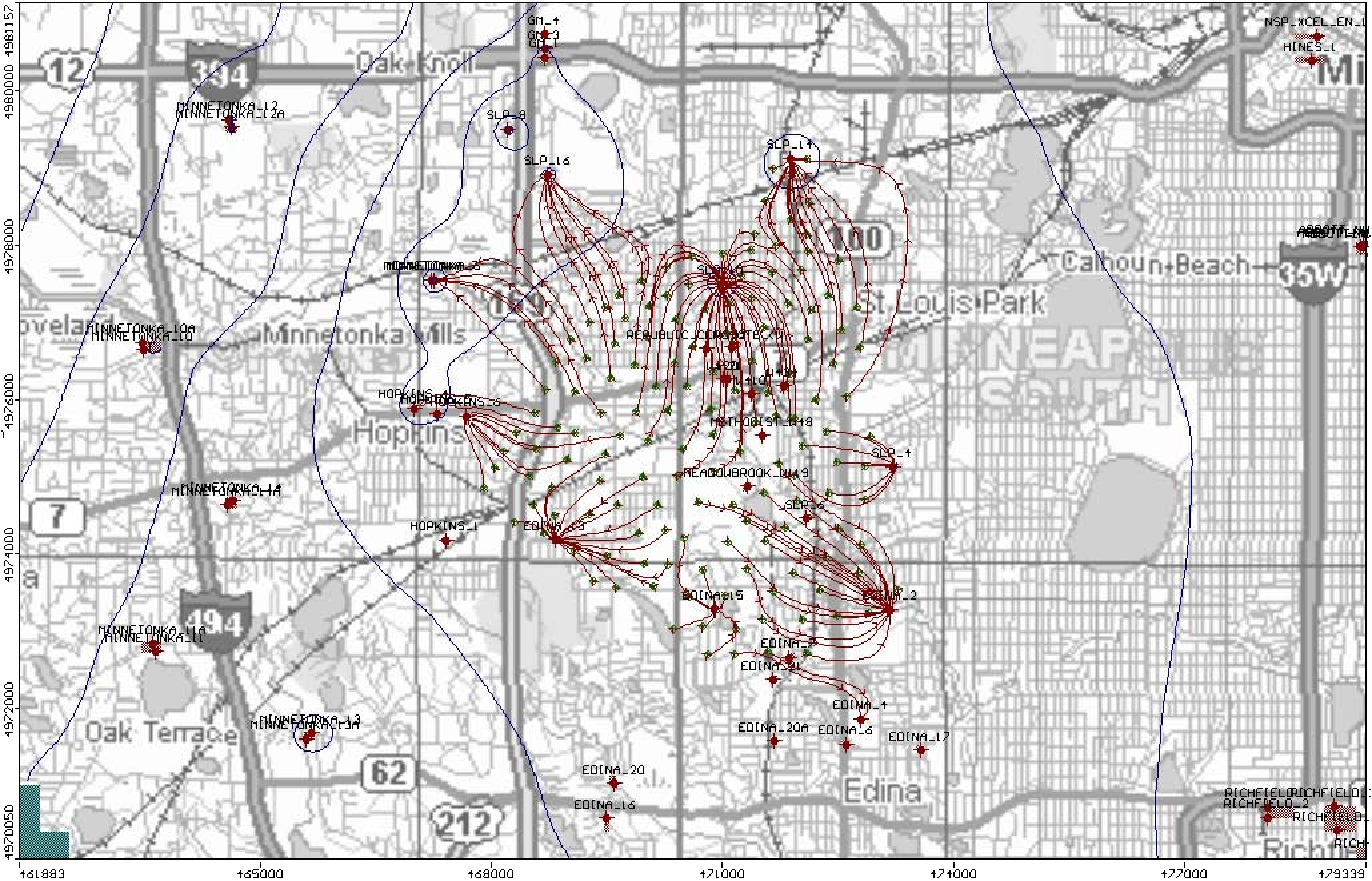

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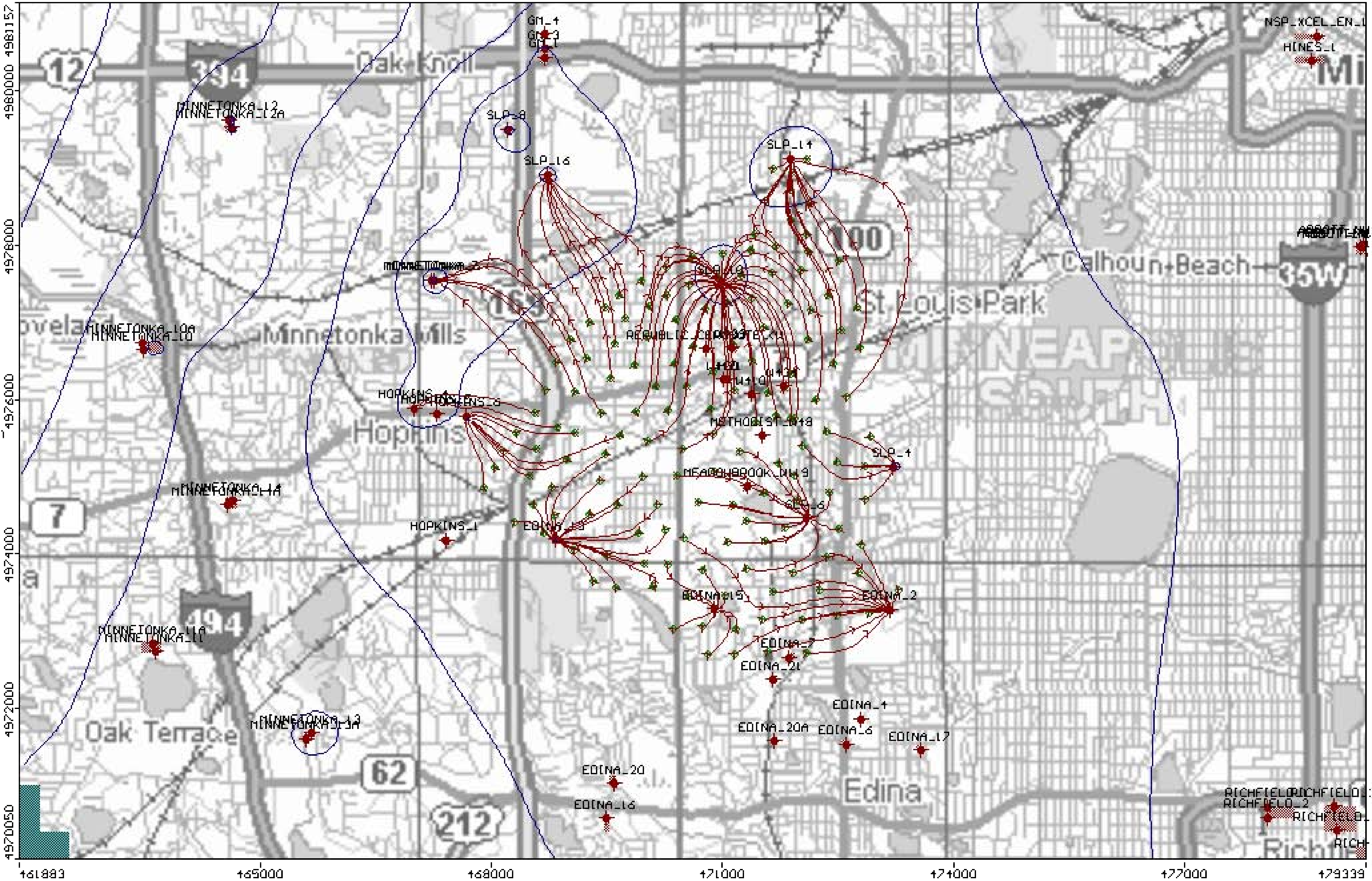

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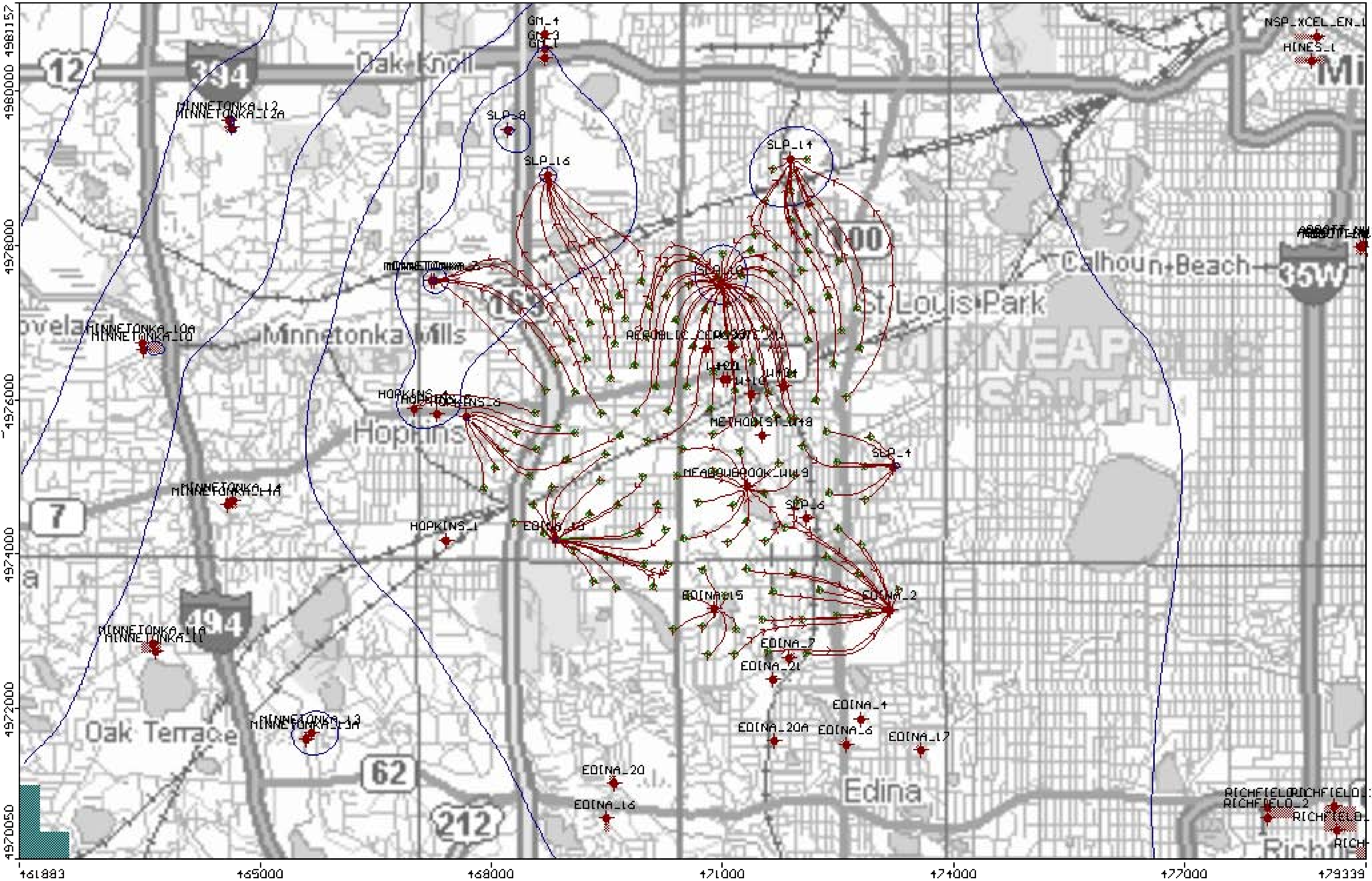
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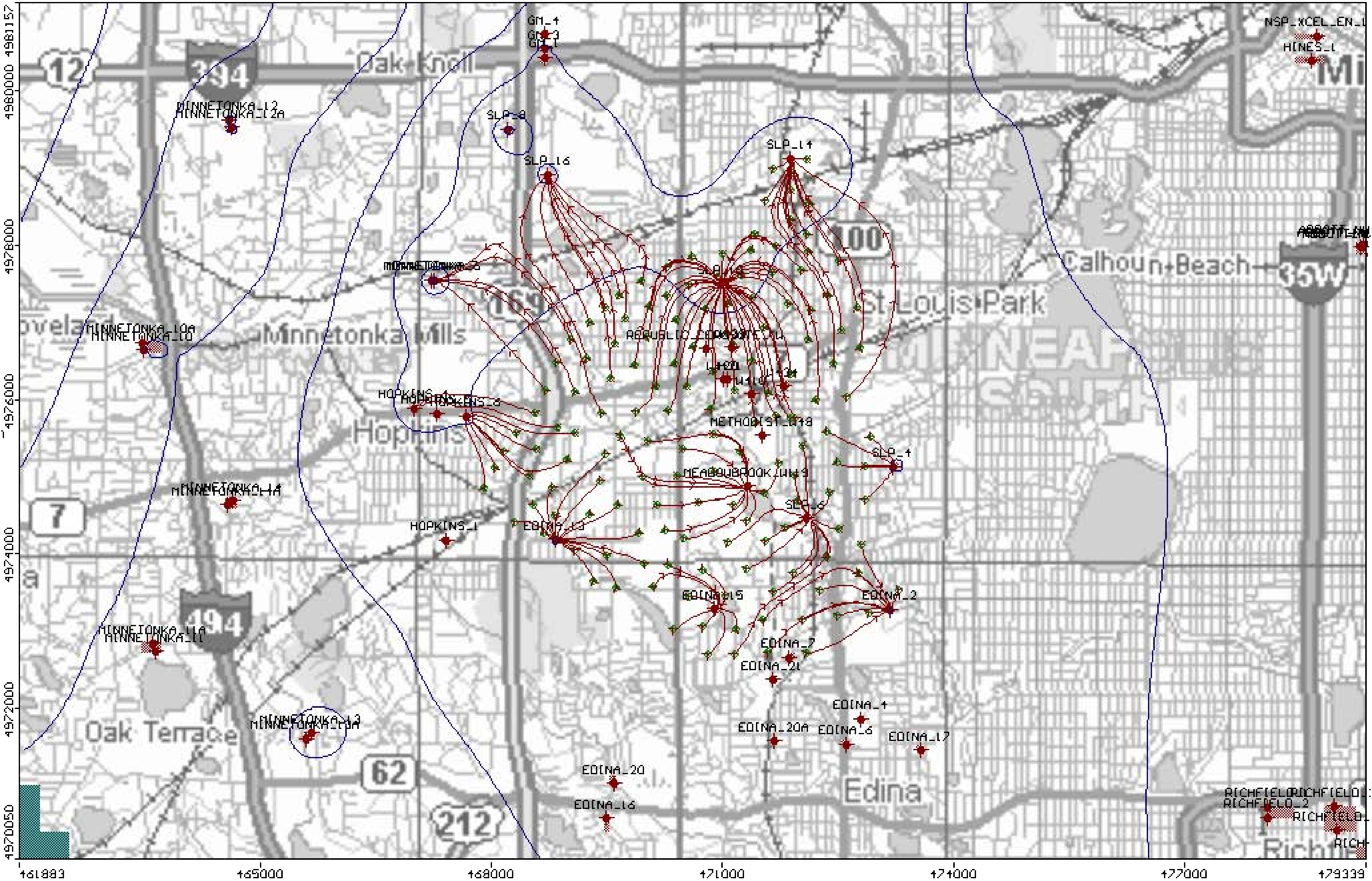

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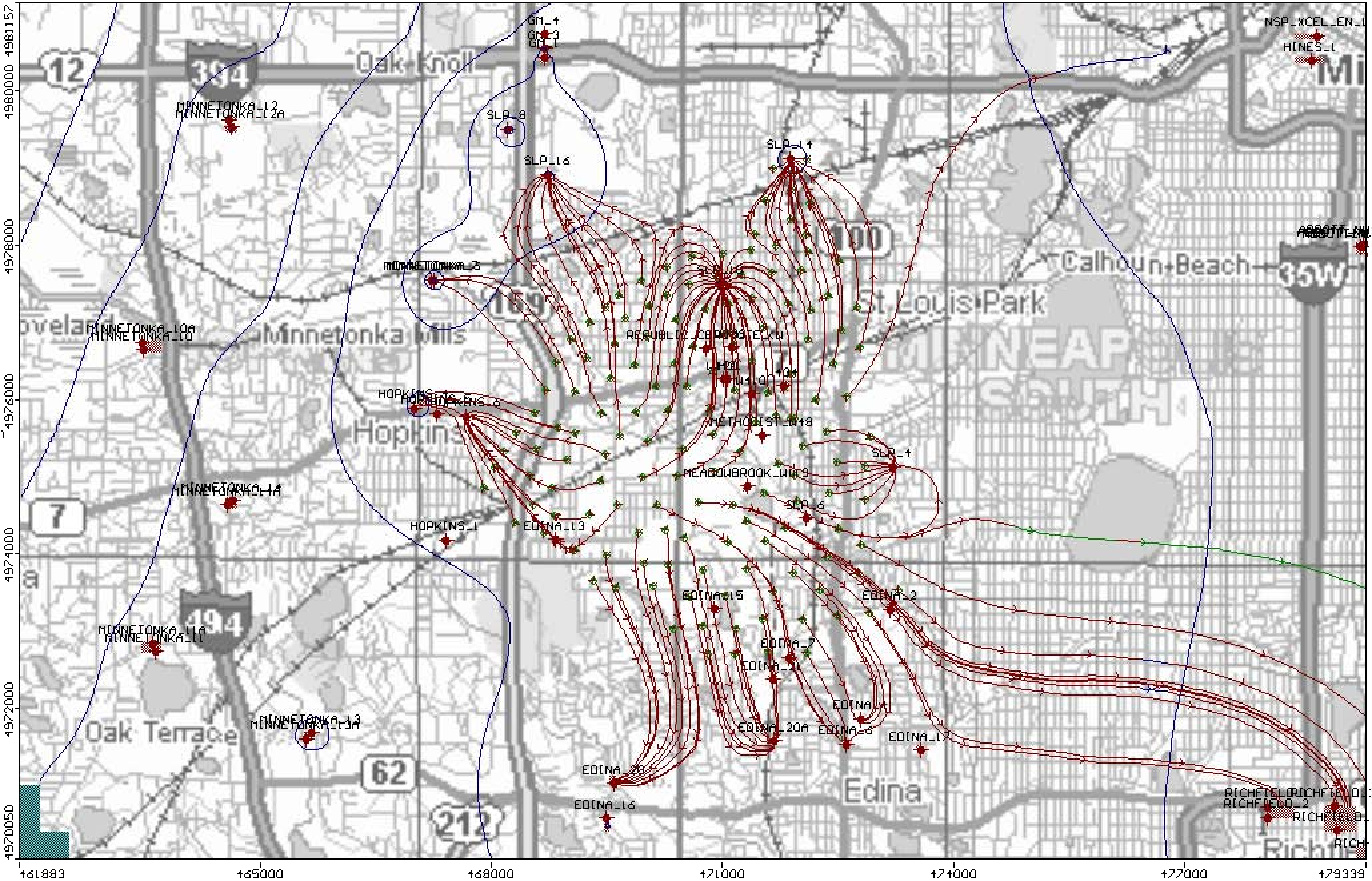

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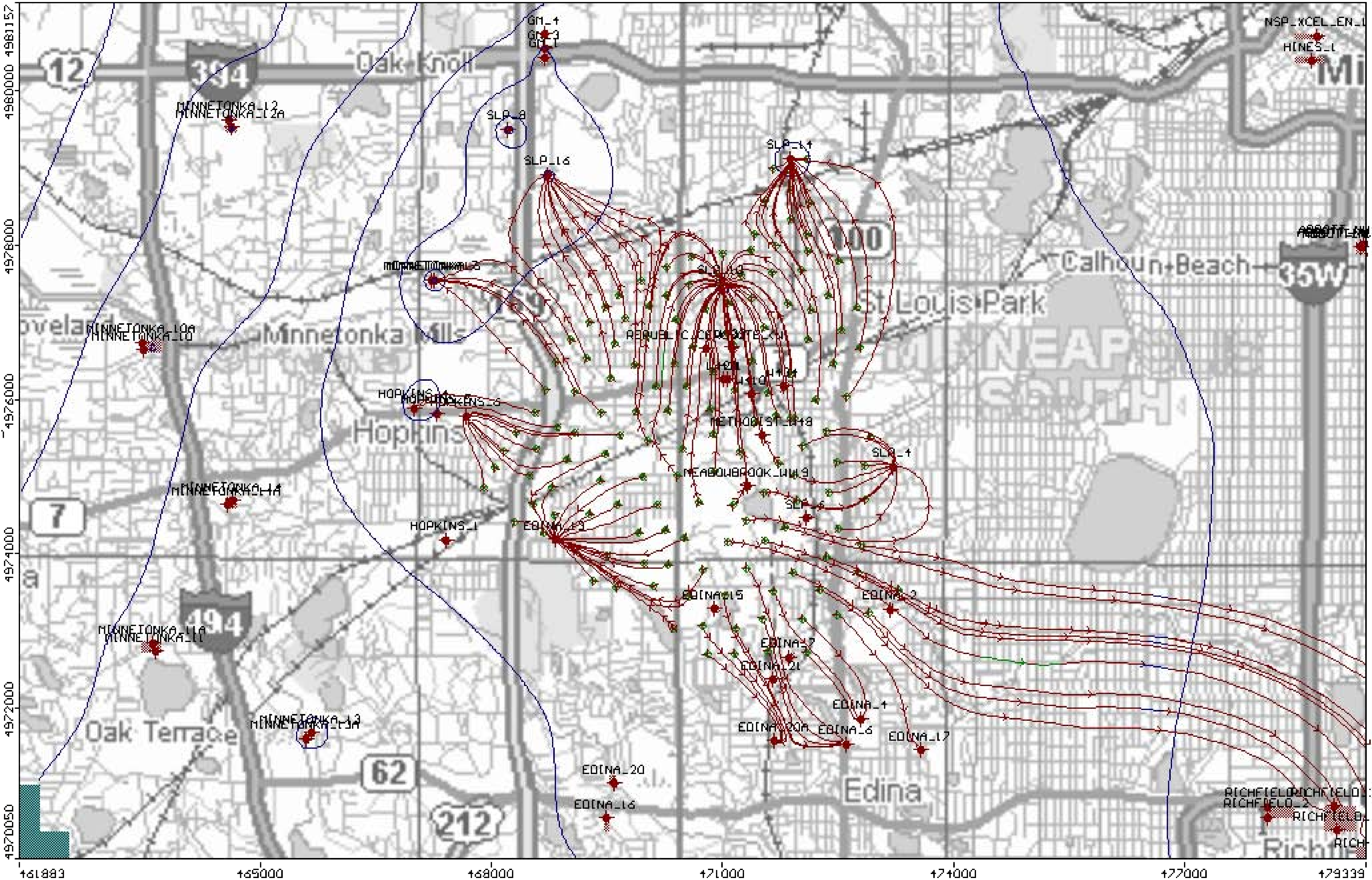

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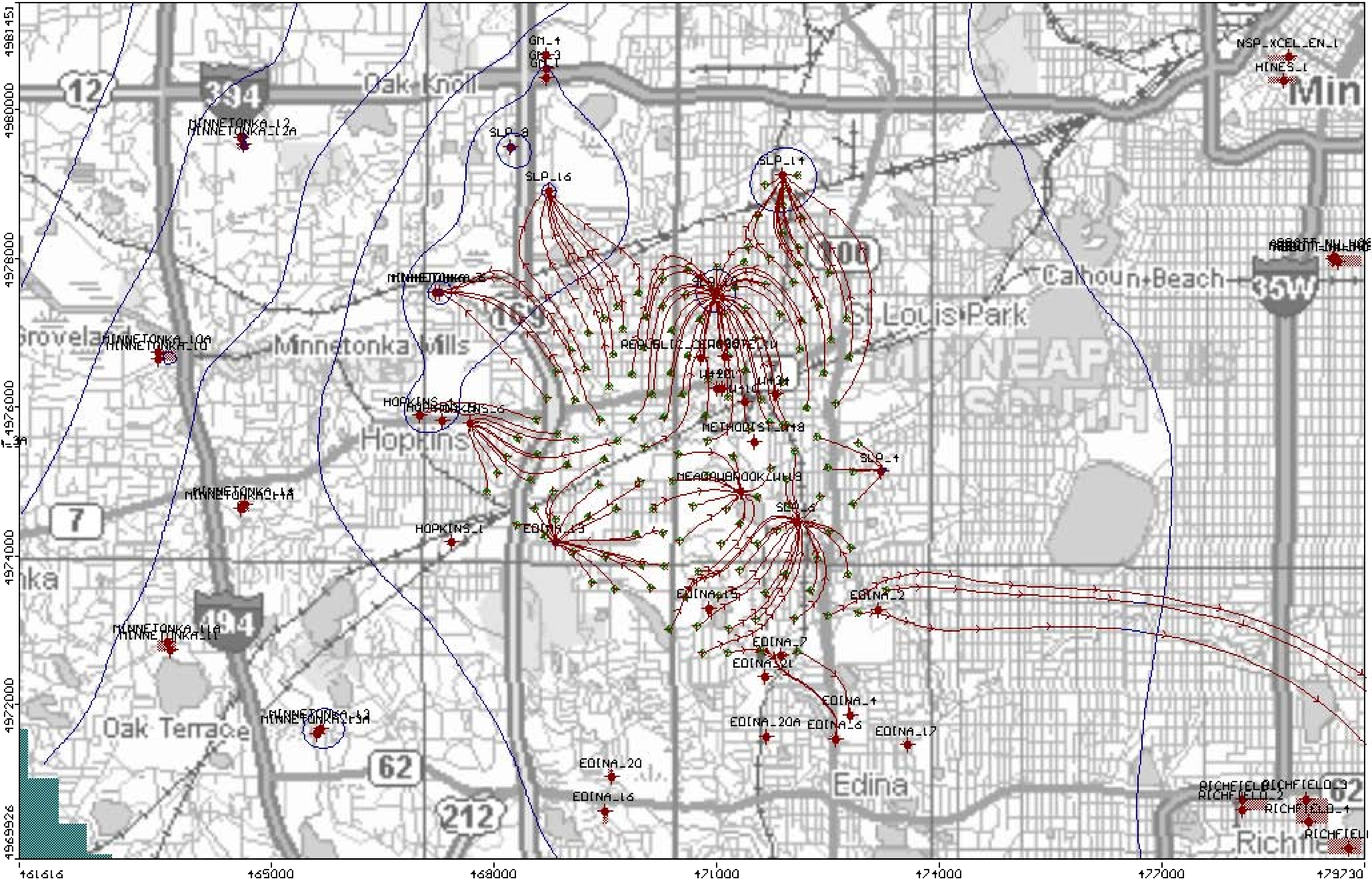

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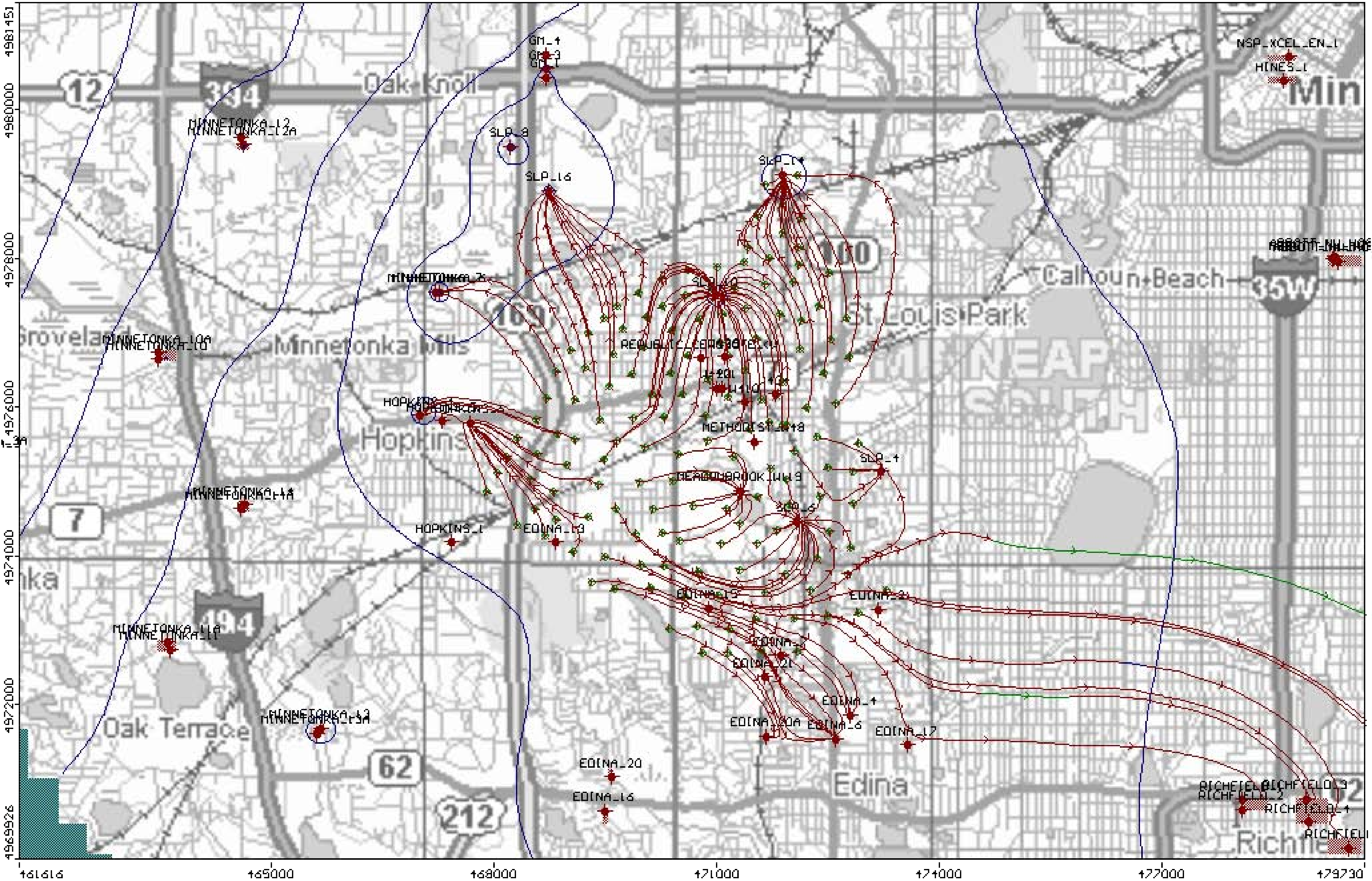

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Appendix A

Electronic Files (CDROM in Pocket)

The CDROM includes the two sets of model files:

- REILLY-UPD-08 – Updated Model calibrated to average September 22 through November 19, 2007 hydraulic gradient conditions;
- REILLY-UPD-08-PRED – Updated Model modified for running predictive simulations – three wells added: ED-20, ED-21 and ED-21A (ED-21A represents alternative location for ED-21).