GROUNDWATER AND RESIDENTIAL WELL EVALUATION
NORTH OAKS, MINNESOTA

FEBRUARY 2006 - JANUARY 2007

HIGHWAY 96 SITE
WHITE BEAR TOWNSHIP, MINNESOTA

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LIST OF ACRONYMS

AMSL	above mean sea level
bgs	below sea level
CRA	Conestoga-Rovers & Associates
CWA	Consolidated waste area
DNR	Department of Natural Resources
DO	Dissolved oxygen
Eh	Redox potential
Feet	ft.
HRL	Health risk limit
MCES	Metropolitan Council Environmental Services
MDH	Minnesota Department of Health
MEK	Methyl ethyl ketone
MGS	Minnesota geological survey
MPCA	Minnesota Pollution Control Agency
MPN	Mean probable number
MS/MSD	Matrix spike/matrix spike duplicate
NDA	North Disposal Area
NOHOA	North Oaks Homeowners Association
ORP	Oxidation reduction potential
QA/QC	Quality assurance/quality control
Reynolds	Reynolds Metals Company
SDA	South Disposal Area
STL	Severn Trent Laboratories
USEPA	US Environmental Protection Agency
VAP	Vertical Aquifer Profiling
VOC	Volatile organic compound
Whirlpool	Whirlpool Corporation

EXECUTIVE SUMMARY

Reynolds Metals Company (Reynolds) and Whirlpool Corporation (Whirlpool) have, as responsible parties, worked to remediate the Highway 96 Site in White Bear Township, Minnesota, and monitor the groundwater conditions downgradient of the Site, in North Oaks, Minnesota. In October 2004, during routine monitoring of residential wells in North Oaks, low levels of vinyl chloride were detected in water samples collected from two residential well locations (12 West Shore Road and 13 West Shore Road). Subsequent residential well sampling in 2005 of over 70 residential wells located in the southeast portion of North Oaks confirmed that vinyl chloride contamination in North Oaks is limited to three residential wells (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill) located near the west shore of Gilfillan Lake. To date, the vinyl chloride concentrations have remained at or below the health risk limit (HRL)[1] for vinyl chloride, established by the Minnesota Department of Health (MDH).

In January 2005, the Minnesota Pollution Control Agency (MPCA) requested that Reynolds and Whirlpool conduct a six-month residential well study to investigate the nature and extent of vinyl chloride contamination in residential wells located west of Gilfillan Lake. In June 2005, CRA submitted a report to MPCA that presented the results of the six month study and provided recommendations for continued monitoring and permanent solutions.

In September 2005, the MPCA requested that Reynolds and Whirlpool conduct a series of additional response actions as part of a continued groundwater and residential well evaluation in North Oaks. In February 2006, CRA submitted a report to the MPCA that presented a summary of results from the response actions completed during the period from June 2005 to January 2006.

This report presents a summary of work completed, as part of the continued groundwater and residential well evaluation, during the period from February 2006 to January 2007 and provides an updated evaluation of groundwater and residential wells in North Oaks, Minnesota.

[1] Health Risk Limit (HRL) is the health standard adopted by the MDH for the safe consumption of water from a private water supply over a lifetime

SUMMARY

CRA and the MPCA conducted three residential well sampling events in North Oaks during this reporting period. These sampling rounds were conducted in February, May, and October 2006.

A groundwater investigation was conducted at 15 West Shore Road during this reporting period, from October 2006 through January 2007. The groundwater investigation included vertical aquifer profiling, monitoring well installation, and groundwater sampling.

An extraction system pilot test was conducted in the Ski Lane Ravine during this reporting period, from November 2006 through December 2006. The pilot test included well installation, aquifer performance testing, and infiltration analysis.

CONCLUSIONS

Based on the work conducted during this reporting period and results from previous evaluations, CRA has reached the following conclusions:

- Continued residential well sampling of over 30 homes in North Oaks Area 3 (west of Gilfillan Lake) confirms that vinyl chloride contamination is limited to three residential wells (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill).
- The unconsolidated glacial drift aquifer in North Oaks is not contaminated by vinyl chloride.
- Groundwater samples from monitoring wells continue to indicate that vinyl chloride contamination west of Gilfillan Lake in the St. Peter Sandstone aquifer is of limited horizontal extent.
- The Prairie du Chien aquifer in North Oaks is not contaminated by vinyl chloride and remains a viable source of water supply.
- Performance testing of EW-3 has demonstrated that groundwater capture in the Ski Lane Ravine is feasible within the basal St. Peter Sandstone aquifer.
- Geotechnical and infiltration analyses indicate infiltration of extracted/treated groundwater in the Ski Lane Ravine is feasible using an infiltration gallery.

RECOMMENDATIONS

Based on the groundwater and residential well evaluation conducted during this reporting period and previous evaluations, CRA recommends the following:

- Residential well sampling should continue, as outlined in CRA's "Revised Residential Well Sampling Program", submitted to MPCA on September 11, 2006 and approved on October 2, 2006.
- Geophysical logging of selected residential wells should be conducted, as outlined in CRA's "Residential Well Geophysical Logging Work Plan", submitted to MPCA on October 10, 2006 and approved on October 16, 2006.
- A geophysical survey of the geology under Gilfillan Lake should be conducted, as outlined in CRA's "Geophysical Survey Work Plan", submitted to MPCA on January 15, 2007 and approved on February 1, 2007.
- CRA should meet with the MPCA to discuss operation of a groundwater extraction system in the Ski Lane Ravine.

1.0 INTRODUCTION

This report presents the results of a continued Groundwater and Residential Well Evaluation conducted during the period from February 2006 through January 2007 in North Oaks, Minnesota.

1.1 SCOPE OF REPORT

The following activities were conducted by Conestoga-Rovers & Associates (CRA), on behalf of Whirlpool Corporation (Whirlpool) and Reynolds Metals Company (Reynolds), as required and/or approved by the Minnesota Pollution Control Agency (MPCA) during the period from February 2006 to January 2007:

- Residential well sampling;
- Vertical aquifer profiling;
- Monitoring well installation and sampling;
- Extraction well installation and sampling; and
- Extraction system pilot test (aquifer and infiltration analyses).

This report presents the results of the work completed during this reporting period and provide an updated evaluation of groundwater and residential wells in North Oaks, Minnesota.

1.2 NORTH OAKS GEOGRAPHIC AREAS

In a letter dated September 1, 2005, the MPCA required that future groundwater and residential well evaluations focus on five geographic areas within North Oaks. The presentation of results by area is intended to assist the residents of North Oaks to understand the groundwater and residential well evaluations as they relate to their neighborhood. The five geographic areas are as follows:

- Area 1 - The immediate vicinity of the Highway 96 Site.
- Area 2 - The areas west and north of the Highway 96 Site and Gilfillan Lake (i.e. greater North Oaks).
- Area 3 - The area west of the Highway 96 Site and immediately east of Gilfillan Lake (e.g. Gilfillan Road) and west of Gilfillan Lake (e.g. West Shore Road).

- Area 4 - The area immediately north/northwest of the Highway 96 Site (e.g. Lily Pond Road), and north/northwest of Gilfillan Lake (e.g. Gadwall Lane).
- Area 5 - The area immediately south and southwest of the Highway 96 Site (e.g. Dove Lane) and Gilfillan Lake (e.g. Heron Lane).

A map showing the location of each geographic area is provided on Figure 1.1. A detailed map of North Oaks Areas 3 through 5 is shown on Figure 1.2.

2.0 BACKGROUND

The Highway 96 Site (Site) is located north of Highway 96 in White Bear Township, Minnesota (near the current intersection of Greenhaven Drive and Crescent Curve). A Site Plan associated with the Highway 96 Site is shown on Figure 2.1.

The Site operated as a small burning dump from the 1920s to 1973 and accepted primarily solid waste. In the late 1960s, the dump owners and operators also ran a business involving the transport of waste paints and solvents to other facilities for recycling, and some paints and solvents were disposed of at the Site. In 1986, a study conducted by the United States Environmental Protection Agency (USEPA) discovered that groundwater beneath the Highway 96 Site was contaminated with volatile organic compounds (VOCs), including industrial, solvent-like chemicals. As a result of the study, the MPCA placed the Site into the Minnesota Superfund program; identified Reynolds, Whirlpool, Mrs. Helen A. Krawczewski, and Red Arrow Waste Disposal Company as potentially responsible parties; and requested them to investigate and clean up the contamination. Wastes sent to the Site by Faberge were also evaluated by the MPCA, but Faberge was not named as a responsible party.

2.1 HIGHWAY 96 SITE REMEDIATION AND MONITORING PROGRAM

Remediation of the Highway 96 Site commenced in 1987 and consisted of four major components: source remediation, groundwater remediation, alternate water supply, and groundwater monitoring.

2.1.1 SOURCE REMEDIATION

During 1987 and 1988, contractors for the responsible parties removed drums containing hazardous substances from the North Disposal Area (NDA). In 1993, additional drums were removed from the South Disposal Area (SDA). In 1994, waste materials in the NDA and the SDA were screened using a backhoe to look for any remaining drums. Drums and drum-related waste identified during the screening process were removed and transported off-site for disposal. The contractors also drained the pond located within the NDA. All the pond water was discharged to the sanitary sewer, the sediment and material from the pond bottom were screened, and drums of waste were removed. After screening the NDA and the pond, the contractors transferred all waste material from the SDA to the NDA. Tests of the soils underlying the SDA showed no residual contamination, and the SDA was backfilled with clean soil. All waste material in the

NDA, including the waste material transferred from the SDA, was compacted, graded, and capped with two feet (ft.) of clean soil and remains on the property. Since the waste areas were combined, the NDA has been referred to as the Consolidated Waste Area (CWA).

2.1.2 GROUNDWATER REMEDIATION

Groundwater contamination present beneath the CWA migrates to the west, in the direction of groundwater flow. Since June 1989, a groundwater extraction system has been in operation at the Site. The extraction system collects groundwater from the Lower Sand aquifer and the St. Peter Sandstone aquifer. The contaminated groundwater is discharged to the sanitary sewer for treatment. Since its inception, the extraction system has been effective in removing contaminants from the groundwater and limiting the spread of contamination.

In late 1994, after the consolidation of the NDA and SDA, a leachate collection well (dewatering sump) was installed directly into and under the CWA. The sump collects landfill leachate and discharges the leachate to the sanitary sewer for treatment. Leachate is produced when rain and melting snow filter through the waste and dissolve chemicals from the waste. The responsible parties continue to operate the leachate collection well to reduce the potential for contamination of groundwater in the deeper drinking-water aquifers.

2.1.3 ALTERNATE WATER SUPPLY

In 1993, the MDH issued drinking water well advisories to 12 homes in North Oaks located between the Highway 96 Site and Gilfillan Lake, because vinyl chloride had been detected in their wells at concentrations exceeding the health-based risk level that was in place in 1993. Reynolds and Whirlpool chose to address this off-site contamination by connecting all 60 homes with private wells on the east side of Gilfillan Lake to the White Bear Township municipal water system. The connections were completed in 1994. The area east of Gilfillan Lake serviced by municipal water is shown on Figure 2.2.

Residential wells within the municipal water service area were sealed. Five residential wells within the water service area were converted to long-term groundwater monitoring wells. One of these monitoring wells was sealed in 2000. The MPCA requires the responsible parties to undertake ongoing monitoring of the four remaining converted residential monitoring wells and periodic monitoring of residential wells that are not connected to the municipal water system.

2.1.4 GROUNDWATER MONITORING PROGRAM

The MPCA and the responsible parties continue to monitor the groundwater at the Highway 96 Site and in downgradient areas in North Oaks, Minnesota.

2.1.4.1 MONITORING AT THE HIGHWAY 96 SITE

The on-site groundwater-monitoring network includes 13 monitoring wells and 3 extraction wells screened in the perched groundwater, the unconsolidated glacial drift aquifer (Lower Sand aquifer), and the St. Peter Sandstone aquifer. The current on-Site groundwater monitoring network is shown on Figure 2.1.

Groundwater samples are collected from on-site extraction wells on a quarterly basis and from monitoring wells on an annual basis. Six of the 16 on-site monitoring wells are designated as compliance wells and are used to evaluate the effectiveness of the groundwater extraction system.

2.1.4.2 MONITORING IN NORTH OAKS – EAST OF GILFILLAN LAKE

The groundwater-monitoring network east of Gilfillan Lake includes residential wells, former residential wells that have been converted into monitoring wells, and other monitoring wells that have been installed by the responsible parties. The current groundwater monitoring network east of Gilfillan Lake is shown on Figure 2.2.

Twenty residential wells located outside the municipal water service area and in North Oaks Area 4 (east of Gilfillan Lake), have been monitored by Whirlpool/Reynolds and the MPCA on a regular basis since 1993. These residential well locations are currently monitored on a biennial basis (odd years).

Five former residential wells located east of Gilfillan Lake were converted to monitoring wells following installation of the municipal water system in 1994. The five converted residential monitoring wells are located at 6 Blue Goose Road, 1 Lily Pond Road, 11 Lily Pond Road, 11 Robb Farm Road, and 6 Wren Lane. The converted residential monitoring well at 6 Wren Lane was abandoned in May 2000, at the request of the

property owner (and under MPCA approval). The other four converted residential monitoring wells remain in place and are monitored on an annual basis.

Nine monitoring wells have been installed east of Gilfillan Lake to monitor groundwater conditions downgradient from the Highway 96 Site in the Glacial Drift/Lower Sand, St. Peter Sandstone, and Prairie du Chien aquifers. Groundwater samples are collected from these monitoring wells on an annual basis. Six of these monitoring wells are also designated as compliance wells and are used to evaluate the effectiveness of the groundwater extraction system.

2.1.4.3 MONITORING IN NORTH OAKS - WEST OF GILFILLAN LAKE

The groundwater-monitoring network west of Gilfillan Lake includes residential wells and other monitoring wells that have been installed by the responsible parties. The current groundwater monitoring network west of Gilfillan Lake is shown on Figure 2.2.

From 1993 to 2004, Whirlpool/Reynolds and the MPCA monitored 31 residential wells located west of Gilfillan Lake on a regular basis. In 2005, the residential well monitoring network west of Gilfillan Lake was expanded to include an additional 31 residential well locations. The current residential well monitoring network west of Gilfillan Lake includes 62 residential wells. Thirty-three of these residential wells are located in North Oaks Area 3 (west of Gilfillan Lake) and are currently monitored on a semi-annual basis. The remaining 29 residential wells are located in North Oaks Areas 4 and 5 (west of Gilfillan Lake) and are currently monitored on a biennial basis (odd years).

Six monitoring wells and one extraction well have been installed west of Gilfillan Lake to monitor groundwater conditions downgradient from the Highway 96 Site in the St. Peter Sandstone and Prairie du Chien aquifers. Two of the six monitoring wells (MW-19B and MW-19L) were installed in 2005 and are sampled on an annual basis. The other four monitoring wells (MW-18A, MW-18B, MW-18L, MW-20B) and the extraction well (EW-3) were installed during this reporting period (see Section 4.0).

2.2 PREVIOUS GROUNDWATER AND RESIDENTIAL WELL EVALUATIONS

In October 2004, during routine monitoring of residential wells located west of Gilfillan Lake, low levels of vinyl chloride were detected in water samples collected from two residential wells: 12 West Shore Road (0.12 µg/L) and 13 West Shore Road (0.12 µg/L).

Although the concentrations detected were below the health risk limit (HRL)[2] for vinyl chloride (0.2 µg/L) established by the Minnesota Department of Health (MDH), the Minnesota Pollution Control Agency (MPCA) requested that Reynolds and Whirlpool conduct a six-month groundwater and residential well evaluation to investigate the nature and extent of vinyl chloride contamination west of Gilfillan Lake.

2.2.1 DECEMBER 2004 - MAY 2005

During the period from December 2004 through May 2005, CRA and MPCA conducted an expanded residential well sampling program to evaluate the extent of vinyl chloride west of Gilfillan Lake. Results from repeated sampling events of over 45 residential wells showed that the presence of vinyl chloride was limited to three well locations (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill). As an interim precautionary measure, Reynolds and Whirlpool began providing bottled water to the three locations where vinyl chloride had been detected.

CRA presented the results of all work completed during the period from December 2004 through May 2005 to the MPCA in a report titled "Groundwater and Residential Well Evaluation" (CRA, June 2005).

2.2.2 JUNE 2005 - JANUARY 2006

During the period from June 2005 through January 2006, residential well sampling and groundwater investigations were conducted to further characterize the groundwater conditions in North Oaks. Results from repeated sampling events of over 70 residential wells showed that the presence of vinyl chloride was limited to the same three well locations (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill). Vertical aquifer profiling and monitoring well installations were completed at locations east and west of Gilfillan Lake. A new groundwater extraction well was added to the extraction system at the Highway 96 Site. CRA also evaluated the feasibility of installing a groundwater extraction system west of Gilfillan Lake, in the Ski Lane Ravine.

CRA presented the results of all work completed during the period from June 2005 through January 2006 to the MPCA in a report titled "Groundwater and Residential Well Evaluation (June 2005 - January 2006)" (CRA, February 2006).

[2] Health Risk Limit (HRL) is the health standard adopted by the MDH for the safe consumption of water from a private water supply over a lifetime

3.0 RESIDENTIAL WELL SAMPLING PROGRAM

As part of the continued groundwater and residential well evaluation, CRA and the MPCA conducted three residential well sampling events in North Oaks during this reporting period. These sampling events were conducted in February, May, and October 2006.

3.1 SAMPLING PROCEDURES

Residential well samples were only collected from well locations where express permission was obtained from the resident. Where possible, samples were collected from an outside tap and/or from an untreated water source (i.e., not softened or filtered). Prior to sampling, the tap was allowed to run (purge) for at least 20 minutes to purge the water line and pressure tank of residual water. The purge rate was measured and recorded. If a sample was collected from an outside tap, the water was directed via a hose to an area that minimized the creation of pooled water or ice in an undesirable location. Field measurements of pH, conductivity, temperature, dissolved oxygen, and oxidation reduction potential (ORP) were collected after purging, at the time of sampling, and recorded. Water samples were collected directly from the tap after the purge hose was disconnected. Samples were places on ice immediately following sample collection and were either sent by courier or hand delivered to the laboratories for analysis. All samples were handled using standard chain-of-custody procedures.

A summary of field measurements and sampling notes for the February, May, and October 2006 residential well sampling events is provided in Appendix A.

3.2 SAMPLING EVENTS

3.2.1 FEBRUARY 2006

The February 2006 residential well sampling event was conducted as part of the Expanded Quarterly Residential Well Sampling Program (outlined in CRA's June 2005 Report). Samples were collected by CRA and the MPCA from 26 of 33 proposed sampling locations. A sampling summary is provided in Appendix A.

Residential well samples were collected for analysis of VOCs and chloride. A total of three duplicate samples were collected for quality assurance/quality control (QA/QC) purposes. Duplicate sample locations are noted in Appendix A. A trip blank was also included with each sample cooler containing VOC samples submitted to the laboratory.

VOC samples were submitted to the Minnesota Department of Health (MDH) Environmental Laboratory for analysis of low level vinyl chloride and VOCs by MDH methods 460 and 468, respectively. Chloride samples were submitted to Severn Trent Laboratories for analysis by method 300.0A.

3.2.2 MAY 2006

The May 2006 residential well sampling event was conducted as part of the Expanded Quarterly Residential Well Sampling Program (outlined in CRA's June 2005 Report). Samples were collected from 30 of 33 proposed sampling locations. A sampling summary is provided in Appendix A.

Residential well samples were collected for analysis of VOCs and chloride. A total of three duplicate samples were collected for QA/QC purposes. Duplicate sample locations are noted in Appendix A. A trip blank was also included with each sample cooler containing VOC samples submitted to the laboratory.

VOC samples were submitted to the MDH Environmental Laboratory for analysis of low level vinyl chloride and VOCs by MDH methods 460 and 468, respectively. Chloride samples were submitted to Severn Trent Laboratories for analysis by method 300.0A.

3.2.3 OCTOBER 2006

The October 2006 residential well sampling event was conducted as part of the Revised Residential Well Sampling Program (submitted to MPCA on September 11, 2006 and approved on October 2, 2006). Samples were collected from 27 of 33 proposed sampling locations. A sampling summary is provided in Appendix A.

Residential well samples were collected for analysis of VOCs and chloride. A total of three duplicate samples and three field blank samples were collected for QA/QC purposes. Duplicate sample locations are noted in Appendix A. A trip blank was also included with each sample cooler containing VOC samples submitted to the laboratory.

VOC samples were submitted to the MDH Environmental Laboratory for analysis of low level vinyl chloride and VOCs by MDH methods 460 and 468, respectively. Chloride samples were submitted to Severn Trent Laboratories for analysis by method 300.0A.

3.3 SAMPLING RESULTS (FEBRUARY 2006 – OCTOBER 2006)

Laboratory analytical reports and data quality assessment memos associated with the February, May, and October 2006 residential well sampling events are provided in Appendix B. Table 3.1 presents a summary of detected compounds in residential wells from February 2006 through October 2006. Table 3.1 also provides the current HRLs for comparison.

3.3.1 VINYL CHLORIDE

Vinyl chloride concentrations associated with residential well samples collected during the February, May, and October 2006 residential well sampling events are presented on Figures 3.1, 3.2, and 3.3, respectively. Vinyl chloride was detected in samples collected from three of the 31 residential well locations sampled during this reporting period (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill). The maximum concentration of vinyl chloride detected during this reporting period was 0.2 µg/L at 12 West Shore Road in October 2006. The HRL for vinyl chloride is 0.2 µg/L. To date, vinyl chloride has never been detected above the HRL in any residential well located west of Gilfillan Lake.

The vinyl chloride results are consistent with results from previous sampling events conducted from October 2004 through November 2005. The vinyl chloride contamination detected in the area of 12/13 West Shore Road and 2 Hummingbird Hill is part of the Highway 96 Site remnant plume. The vinyl chloride contamination observed west of Gilfillan Lake since October 2004 migrated from the Highway 96 Site many years prior to discovery of contamination at the Site in 1986 and many years prior to the start of groundwater remediation in 1989.

3.3.2 OTHER VOCs

Seven other VOCs were detected in water samples collected from residential well locations samples during the period from February 2006 through October 2006. The detected concentrations of these VOCs were below their respective HRLs (where HRLs have been established).

1,1-dichloroethane was detected in samples collected from three of the 31 residential well locations sampled during this reporting period (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill). The maximum concentration detected was 0.3 µg/L at 12 West Shore Road in October 2006. The HRL for 1,1-dichloroethane is 70 µg/L. The

1,1-dichloroethane results are consistent with results from previous sampling events conducted from October 2004 through November 2005. The detections of 1,1-dichloroethane in the area of 12/13 West Shore Road and 2 Hummingbird Hill are attributed to the remnant plume from the Highway 96 Site.

Cis-1,2-dichloroethene was detected in samples collected from three of the 31 residential well locations sampled during this reporting period (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill). The maximum concentration detected was 0.2 µg/L (estimated) at 12 West Shore Road in October 2006. The HRL for cis-1,2-dichloroethene is 70 µg/L. The cis-1,2-dichloroethene results are consistent with results from previous sampling events conducted from October 2004 through November 2005. The detections of cis-1,2-dichloroethene in the area of 12/13 West Shore Road and 2 Hummingbird Hill are also attributed to the remnant plume from the Highway 96 Site.

The remaining five VOCs detected in water samples collected from residential well locations samples between February 2006 and October 2006 are common bi-products associated with the use of chlorine to disinfect drinking water wells.

Chloromethane was detected in a sample collected from one of the 31 residential well locations sampled during this reporting period (16 Ski Lane). The maximum concentration detected was 0.8 µg/L (estimated) in February 2006. There is no HRL established for chloromethane. Chloromethane was not detected in subsequent samples collected from 16 Ski Lane in May 2006 and October 2006. Periodic detections of chloromethane in samples collected from residential wells are consistent with results from previous sampling events conducted from October 2004 through November 2005.

Bromodichloromethane was detected in two of the 31 residential well locations sampled during this reporting period (1 Thompson Lane and 13 West Shore Road). The maximum concentration detected was 1.8 µg/L at 1 Thompson Lane in October 2006. The HRL for bromodichloromethane is 6 µg/L.

Chloroform was detected in two of the 31 residential well locations sampled during this reporting period (1 Thompson Lane and 13 West Shore Road). The maximum concentration detected was 9.2 µg/L at 1 Thompson Lane in October 2006. The HRL for chloroform is 60 µg/L.

Dibromochloromethane was detected in one of the 31 residential well locations sampled during this reporting period (1 Thompson Lane). The maximum concentration detected was 0.9 µg/L (estimated) in May 2006. The HRL for dibromochloromethane is 10 µg/L.

Bromoform was detected in one of the 31 residential well locations sampled during this reporting period (1 Thompson Lane). The maximum concentration detected was 0.5 µg/L (estimated) in May 2006. The HRL for bromoform is 40 µg/L.

The consistent detections of chlorination bi-products in samples collected from 1 Thompson Lane result from the homeowner's use of an in-home chlorination treatment system. As noted in the sampling summaries presented in Appendix A, a sampling point prior to the chlorination system does not exist and water samples can only be collected from this location post-treatment.

3.3.3 CHLORIDE

Chloride is an inorganic chemical that occurs naturally in all groundwater, but can also be related to landfills, road salt, and septic systems. Chloride concentrations associated with residential well samples collected during the February, May, and October 2006 residential well sampling events are presented on Figure 3.4.

3.4 FUTURE SAMPLING SCHEDULE

Residential well sampling in North Oaks is currently being conducted, as outlined in CRA's "Revised Residential Well Sampling Program", submitted to MPCA on September 11, 2006 and approved on October 2, 2006. The Revised Residential Well Sampling Program is depicted on Figure 3.5.

4.0 ADDITIONAL FIELD PROGRAMS

This section discusses the additional field activities, beyond residential well sampling, that were conducted during this reporting period to further evaluate groundwater conditions in North Oaks Area 3, west of Gilfillan Lake. Two separate field programs were conducted in North Oaks during this reporting period.

A groundwater investigation was conducted at 15 West Shore Road, as outlined in CRA's work plan submitted to the MPCA on October 10, 2006 and approved on October 16, 2006. The groundwater investigation at 15 West Shore Road was conducted during the period from October 2006 through January 2007.

An extraction system pilot test was conducted in the Ski Lane Ravine, as outlined in CRA's work plan submitted to the MPCA on April 5, 2006 and approved on May 5, 2006. The extraction system pilot test was conducted during the period from November 2006 through December 2006.

A combined summary of field activities and results associated with these field programs is provided in the following sub-sections.

4.1 FIELD ACTIVITIES

The following field activities were conducted during the period from October 2006 through January 2007:

1. Vertical aquifer profiling (VAP);
2. Monitoring well installation;
3. Extraction well installation;
4. Surveying;
5. Groundwater level monitoring;
6. Aquifer pumping test;
7. Single well response testing;
8. Monitoring well sampling; and
9. Geotechnical soil sampling.

4.1.1 VERTICAL AQUIFER PROFILING (VAP)

During this reporting period, VAP was conducted at 15 West Shore Road and in the Ski Lane Ravine.

The purpose of VAP at 15 West Shore Road was to characterize the water quality in the three major water bearing units (the glacial drift aquifer, the St. Peter Sandstone aquifer, and the Prairie du Chien aquifer) west of Gilfillan Lake.

The purpose of VAP in the Ski Lane Ravine was to provide additional characterization of the water quality in the upper St. Peter Sandstone aquifer.

VAP locations are shown on Figure 4.1. A VAP sampling summary is provided in Appendix C.

4.1.1.1 VAP DRILLING

VAP was conducted at 15 West Shore Road during installation of monitoring well MW-18L. The VAP borehole was initially advanced using a 6-inch inside diameter rotosonic drill. As the VAP borehole was advanced, continuous soil cores were collected for geologic classification. The VAP borehole was advanced to predetermined intervals for groundwater sample collection in the glacial drift and in the upper, middle, and basal portions of the St. Peter Sandstone aquifer. The VAP borehole at MW-18L was extended into the competent portion of the Prairie du Chien aquifer, approximately 260 ft. below ground surface. The 6-inch borehole was then overdrilled using an 8-inch inside diameter rotosonic drill. A 4-inch low carbon steel casing was set inside the borehole and its annulus was tremie grouted to surface with a neat bentonite cement. After a minimum of 48 hours, a 3.5-inch borehole was advanced into the middle portion of the Prairie du Chien aquifer. The VAP borehole was advanced to a predetermined interval for groundwater sample collection in the middle portion of the Prairie du Chien aquifer.

Because the depth of the competent portion of the Prairie du Chien was greater than expected, a VAP sample from the portion of the Prairie du Chien was not collected during the drilling of MW-18L. Instead, a VAP sample from the upper Prairie du Chien was collected during drilling of MW-18B. The borehole at MW-18B was extended into the upper portion of the Prairie du Chien (approximately 230 ft. bgs.). After the VAP sample was collected, the extended portion of the borehole (33 ft.) was tremie grouted with neat bentonite cement.

VAP was conducted in the Ski Lane Ravine during installation of extraction well EW-3 and monitoring well MW-20B. The VAP boreholes were advanced using a 6-inch inside diameter rotosonic drill. At MW-20B, continuous soil cores were collected for geologic classification as the VAP borehole was advanced. The VAP boreholes were advanced to predetermined intervals for groundwater sample collection in the upper St. Peter Sandstone aquifer. One VAP sample was collected from the upper St. Peter Sandstone aquifer at each location.

4.1.1.2 VAP SAMPLING

VAP groundwater samples were collected using a temporary well screen, sample pump, and inflatable packer system to isolate the VAP sample interval. Once the desired depth was reached, the temporary screen was placed at the bottom of the borehole and the casing was pulled back to expose the screen. For the samples collected in the Prairie du Chien aquifer, the temporary screen was set inside the open borehole.

Prior to VAP sampling at each designated interval, water in the borehole (including water used for drilling) was pumped out in order to obtain a representative groundwater sample. The volume of water removed was based on the recorded amount of drilling water used during drilling of each VAP interval. A minimum of two times the volume of water introduced during each interval was removed. The volume of water purged prior to each VAP sample interval is included in the VAP sampling summary provided in Appendix C. Purge water generated during VAP at 15 West Shore Road was containerized and discharged to the sanitary sewer located near the intersection of Blue Goose Road and Robb Farm Road, under a Metropolitan Council Environmental Services (MCES) special discharge permit. Purge water generated during VAP in the Ski Lane Ravine was discharged to the ground surface, away from the borehole.

After purging, an inflatable packer system was placed at the top of the temporary well screen. After the packer system was inflated, the sampling pump was lowered inside the temporary well screen. For VAP samples collected in the Prairie du Chien aquifer, the sampling pump was placed inside the open borehole. Before and after sampling at each interval, the pressure of the inflatable packer was recorded to verify the integrity of the seal. VAP samples were collected using low-flow purge and sampling methods and equipment (bladder pump or an electric submersible pump) capable of pumping at 250 to 500 mL/min. New polyethylene discharge tubing was used for each VAP sample.

Approximately every five minutes during the purging process, the following field parameters were measured and recorded: pH, temperature, conductivity, dissolved oxygen (DO), turbidity, redox potential (Eh), and the downhole water level. Field instruments were calibrated daily at the beginning of the day in accordance with manufacturer's specifications. Purging continued until stabilization occurred based on three consecutive readings within the following ranges:

+/- 0.1 unit for pH

+/- 0.1 degrees Celsius for temperature

+/- 5% for conductivity

+/- 0.5 mg/L for DO

+/- 10% for turbidity

+/- 20 mV for redox potential

Field parameters recorded during VAP sampling are included in the VAP sampling summary provided in Appendix C.

Once stabilized, samples were collected at a flow rate of 250 mL/min using the sampling procedures outlined in the work plan. After sample collection, the samples were placed in coolers with ice and submitted to the MDH Environmental Laboratory for analysis. VAP samples were analyzed for low-level vinyl chloride and VOCs by MDH methods 460 and 468, respectively.

Analytical data reports were provided to the MPCA, via e-mail, during the VAP field investigation as CRA received them from the laboratory. Based on the results of the VAP sampling, monitoring well screen placement intervals were proposed to the MPCA for their approval.

4.1.2 MONITORING WELL INSTALLATION

Three new monitoring wells were installed immediately west of Gilfillan Lake, in the upper St. Peter Sandstone aquifer (MW-18A), basal St. Peter Sandstone aquifer (MW-18B), and the Prairie du Chien aquifer (MW-18L). One new monitoring well was installed in the Ski Lane Ravine, in the basal St. Peter Sandstone aquifer (MW-20B).

Monitoring well locations are shown on Figure 4.1. Drilling and well installation activities were performed in accordance with MDH regulations. A well construction summary is presented on Table 4.1.

Well installation depths were determined based on the stratigraphy encountered and the results of VAP sample analyses described above. Prior to installation, analytical data and stratigraphic information were provided to the MPCA for concurrence and approval of screen depths.

The three St. Peter Sandstone monitoring wells (MW-18A, MW-18B, and MW-20B) were constructed with a 2-inch diameter, 10-foot long, stainless steel well screen attached to a 2-inch diameter low carbon steel well casing. A filter sand pack was placed around and approximately 2 to 3 ft. above the well screen. Above the filter sand, a minimum of 3 ft. of fine sand was used as a protective layer between the filter pack and grout. The remaining annulus was tremie grouted with a neat bentonite cement. A locking protective steel casing was placed over the well pipe to complete the well construction. Well construction and stratigraphic logs are presented in Appendix D.

As described in Section 4.1.1, the borehole associated with MW-18B was extended to collect a VAP sample from the upper portion of the Prairie du Chien aquifer. Once the VAP sample was collected, the extended portion of the borehole (33 ft.) was tremie grouted with a neat bentonite cement. The grout was allowed to set for a minimum of 48-hours. Sand was placed from the top of the grout to the bottom of the screen.

Monitoring well MW-18L was completed as an open-hole monitoring well in the middle portion of the Prairie du Chien. An 8-inch diameter borehole was advanced into the upper/competent portion of the Prairie du Chien. A 4-inch diameter low carbon steel casing was then placed inside the borehole and tremie grouted in place with a neat bentonite cement. After allowing a minimum of 48-hours for the grout to set, a 3.5-inch diameter borehole was advanced into the middle portion of the Prairie du Chien. A lockable protective cover was placed on the 4-inch casing to complete the well installation. A well construction and stratigraphic log is presented in Appendix D.

As approved by the North Oaks Homeowners Association (NOHOA), the Ski Lane Ravine was designated as a temporary storage and staging area for well installation materials. Drilling equipment was also decontaminated at this location. All drilling equipment was decontaminated by hot water, high pressure cleaning prior to use at each borehole location. All pumps, screens, and other sampling equipment were decontaminated by hot water, high pressure cleaning and rinsed with clean water prior to collecting each sample.

Decontamination fluids were containerized and discharged to the sanitary sewer near the intersection of Blue Goose Road and Robb Farm Road, under a MCES special

discharge permit. Borehole cuttings generated during installation of the MW-18 nest were containerized and later thin-spread on the Highway 96 landfill cap. Borehole cuttings generated during installation of EW-3 and MW-20B were thin-spread near each borehole location.

After installation, the monitoring wells were developed by the drilling contractor via pumping to a sand-free condition. During development, field parameters were collected to verify well stabilization. Well developments records are provided in Appendix E.

4.1.3 EXTRACTION WELL INSTALLATION

A new basal St. Peter Sandstone extraction well (EW-3) was installed in the Ski Lane Ravine.

A 6-inch diameter borehole was drilled using roto-sonic drilling methods. The borehole was advanced into the upper St. Peter Sandstone aquifer and a VAP sample was collected using the protocols outlined in Section 4.1.1. After the VAP sample was collected, a rotary drill rig was used to overdrill the existing 6-inch borehole with a 10-inch borehole. Soil cuttings were thin-spread on the ground surface near the borehole. The location of EW-3 is shown on Figure 4.1.

A 6-inch diameter, 10-foot long, stainless steel well screen (10 slot), with a 5-foot sump, attached to 6-inch diameter low-carbon steel well casing was installed to the bottom of the borehole. An appropriately sized filter sand pack was placed in the annulus to a minimum of 2 feet above the well screen. A 3-foot fine sand seal was placed above the filter sand pack. The remaining annulus was tremie grouted with a neat bentonite cement. A well construction and stratigraphic log are presented in Appendix D.

After installation of the sand pack and the bentonite grout, the extraction well was developed by the drilling contractor to a sand-free condition by mechanical surging and pumping. Development water was discharged onto the ground surface.

4.1.4 SURVEYING

After well construction was completed, each new monitoring well and the extraction well were surveyed for elevation and location by a licensed surveyor. The well survey map prepared by the surveyor is presented in Appendix F.

In addition to the well survey, a topographic/property line survey was conducted in the northern portion of the Ski Lane Ravine. The topographic/property line survey was conducted as part of the infiltration analysis associated with the Ski Lane Ravine extraction system evaluation (see Section 6.0). The topographic/property line survey map prepared by the surveyor is presented in Appendix F. The survey contours/property lines are also shown on Figure 4.2.

4.1.5 GROUNDWATER LEVEL MONITORING

Groundwater flow patterns were evaluated by measuring groundwater elevations at selected monitoring locations in North Oaks. In January 2007, groundwater elevation measurements were collected from the new monitoring wells (MW-18A, MW-18B, MW-18L, MW-20B, and EW-3), existing off-site monitoring wells (MW-12B, MW-13B, MW-16B, MW-17A, MW-17B, MW-17L, MW-19B, and MW-19L), the converted residential monitoring wells (1 Lily Pond Road, 11 Lily Pond Road, 6 Blue Goose Road, and 11 Robb Farm Road), and two active residential wells (6 West Shore Road and 38 East Oaks Road). Groundwater elevations were measured using an electric measuring tape. The depth to water was measured to the nearest 0.01 foot. Groundwater elevations measured in January 2007 are summarized in Table 4.2.

4.1.6 MONITORING WELL SAMPLING

A minimum of one week after well development was complete, each of the new monitoring wells (MW-18A, MW-18B, MW-18L, and MW-20B) were sampled. The new monitoring wells were sampled during the week of November 27, 2006. A second round of sampling was also conducted during the week of January 1, 2007.

Prior to sample collection, the monitoring wells were purged using an electric submersible pump or a bladder pump with dedicated polyethylene tubing. The pump was placed at the midpoint of the well screen or open hole interval. Low flow groundwater purging techniques were utilized in general accordance with USEPA guidance[3]. Purging was conducted at a steady flow rate of approximately 250 to 500 mL/min. Approximately every five minutes during the purging process, the following field parameters were measured and recorded: pH, temperature, conductivity, DO, turbidity, Eh, and the downhole water level. Field instruments were calibrated daily, at the beginning of the work day, in accordance with manufacturer's

[3] Puls, Robert W. and Barcelona, Michael J., Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures, USEPA Office of Solid Waste and Emergency Response, EPA/540/S-95/504, April 1996.

specifications. Purging continued until stabilization occurred based on three consecutive readings within the following ranges:

+/- 0.1 for pH

+/- 0.1 degrees Celsius for temperature

+/- 5% for conductivity

+/- 0.5 mg/L for DO

+/- 10% for turbidity

+/- 20 mV for redox potential

A monitoring well sampling summary is provided in Appendix G.

Once stabilized, samples were collected at a flow rate of 250 mL/min in accordance with the sampling procedures outlined in the associated work plans. Samples were collected for analysis of VOCs and chloride. For QA/QC purposes, field duplicate samples, rinsate samples, and MS/MSD samples were collected. QA/QC sample locations are noted in Appendix G. A trip blank was included and submitted to the laboratory with each sample cooler containing VOC samples.

After sample collection, monitoring well samples were placed in coolers with ice. VOC samples were submitted to the MDH Environmental Laboratory for analysis of low level vinyl chloride and VOCs by MDH Methods 460 and 468, respectively. Chloride samples were submitted to Severn Trent Laboratories for analysis by Method 300.0A.

4.1.7 EXTRACTION WELL SAMPLING

Following the constant rate pumping test performed at EW-3 (see Section 4.1.10.2), groundwater samples were collected for analysis of VOCs and chloride. Prior to sample collection, field measurements of pH, temperature, conductivity, and DO were recorded. A sampling summary is provided in Appendix G.

The VOC sample was submitted to the MDH Environmental Laboratory for analysis of low level vinyl chloride and VOCs by MDH Methods 460 and 468, respectively. The chloride sample was submitted to Severn Trent Laboratories for analysis by Method 300.0A.

4.1.8 GEOTECHNICAL SOIL SAMPLING

As part of the infiltration analysis associated with the Ski Lane Ravine extraction system evaluation, a total of six soil samples were collected from two soil borings (SB-01 and SB-02) collected in the northern part of the ravine. The soil boring locations are shown on Figure 4.2. At both locations, a hand auger was used to collect soil samples from the top two feet, between four and six feet, and from eight to ten feet below ground surface. The six soil samples were submitted to the lab for grain size distribution analysis using ASTM Method D 422 (sieve and hydrometer).

Upon discovering a 10-foot thick layer of clay in SB-02, 15 additional hand auger borings were completed to confirm the extent of the thick clay layer. Clay was not encountered below three feet in any of the additional 15 borings. The additional soil boring locations are shown on Figure 4.2.

4.1.9 SINGLE WELL RESPONSE TESTS

Single well response tests were performed at new monitoring wells MW-18A, MW-18B, and MW-18L to estimate the hydraulic conductivity of the upper and basal St. Peter Sandstone and the Prairie du Chien groundwater systems.

Both falling head and rising head single well response tests were performed at each of the new well locations. The tests were performed by introducing and removing a precleaned PVC slug of known volume into the column of water in the well. For the St. Peter Sandstone well locations, a 2.5-foot by 1.25-inch PVC slug was used. For the Prairie du Chien well locations, a 5-foot by 3-inch PVC slug was used. The water level response in the well was recorded using a pressure transducer with an electronic datalogger.

The single well response data were entered into the computer software AQTESOLV® for Windows (Version 4.01). The single well response test data were analyzed using the Bouwer-Rice Method (1976) for an unconfined aquifer (MW-18A) and for a confined aquifer (MW-18B and MW-18L). The single well response test results are summarized in Table 4.3 and the AQTESOLV® reports are provided in Appendix H.

As shown on Table 4.3, the hydraulic conductivity values vary between the St. Peter Sandstone and the Prairie du Chien groundwater systems. At the MW-18 well nest, the upper St. Peter Sandstone monitoring well location (MW-18A) has an expected higher hydraulic conductivity (approximately 0.004 ft/min) than the basal St. Peter Sandstone monitoring well location (MW-18B) (approximately 0.0004 ft/min). The Prairie du

Chien monitoring well location (MW-18L) exhibits the highest hydraulic conductivity value (approximately 0.05 ft/min).

The single well response testing results associated with MW-18A, MW-18B, and MW-18L are generally consistent with the 2005 single well response testing results associated with MW-17A, MW-17B, and MW-17L.

4.1.10 AQUIFER PERFORMANCE TESTING (EW-3)

As part of the Ski Lane Ravine extraction system evaluation, aquifer performance testing was conducted at EW-3. The aquifer analyses conducted under this program included a step-drawdown test, constant-rate discharge test, and recovery test.

4.1.10.1 STEP-DRAWDOWN TEST

A well performance step-drawdown test was conducted at EW-3 on November 20, 2006. The step-drawdown test was conducted to evaluate the hydraulic efficiency of EW-3 and determine an appropriate pumping rate for the constant rate pumping test.

Groundwater from the well performance step-drawdown test was pumped through a flow meter and discharged to the ground surface, away from EW-3. The step-drawdown test involved pumping the extraction well at three successively higher pumping rates of 10 gpm, 20 gpm, and 30 gpm. Each test ran for 60 minutes. During the step-drawdown test, water levels were measured at EW-3 at a minimum of 1 reading every 5 minutes.

The results of the step-drawdown test were used to determine the hydraulic characteristics of the extraction well (e.g., such as specific capacity), and were used to determine the pumping rate for the constant rate pumping test.

4.1.10.2 CONSTANT RATE PUMPING TEST

A 24-hour constant rate pumping test at EW-3 commenced on November 21, 2006, at 9:00 a.m. and ended on November 22, 2006 at 9:00 a.m. The constant rate pumping test involved pumping the extraction well at 20 gpm, as determined from the step-drawdown test. Groundwater from the pumping test was pumped through a flow meter and discharged to the ground surface, away from EW-3. Groundwater level measurements were collected from the extraction well (EW-3) and three observation

wells (MW-19B, MW-19L, and MW-20B). Water levels were recorded in each of the observation wells using electronic pressure transducers with data loggers. The transducers were set to record a water level every 30 seconds for the first 30 minutes and then every minute thereafter, for the duration of the test. During pumping, the water level (drawdown) inside the extraction well was measured using a hand-held electric water level tape. The drawdown inside EW-3 was measured and recorded at the following intervals:

Time Since Start of Pumping	*Time Interval*
0 to 5 minutes	0.5 minutes
5 to 15 minutes	1 minute
15 to 50 minutes	5 minutes
50 to 120 minutes	10 minutes
120 minutes to 5 hours	30 minutes
5 hours to 24 hours	60 minutes

During the 24-hour constant rate pumping test, the pumping rate at EW-3 was also measured at the above intervals to confirm that a constant pumping rate (i.e., 20 gpm) was maintained throughout the test.

4.1.10.3 RECOVERY TEST

The groundwater recovery test involved measuring the water levels in the extraction well and observation wells upon completion of the constant rate pumping test. The recovery water levels were monitored at the same frequency as during the constant rate pumping test. The recovery test was completed once 95% recovery to pre-pump water level conditions was observed in the extraction well and observation wells.

4.2 ANALYTICAL RESULTS

4.2.1 VAP SAMPLING RESULTS

Laboratory analytical reports and data validation memos associated with the VAP activities are provided in Appendix B and a summary of detected compounds is presented in Table 4.4.

Vinyl chloride or other site-related VOCs were not found in any of the VAP samples collected from the MW-18L, MW-18B, MW-20B, and EW-3. Vinyl chloride results from the VAP sampling are shown on Figure 4.3. A cross section of the VAP results is shown on Figure 4.4.

Bromodichloromethane, chloroform, and chloromethane were detected in a few of the VAP samples. These compounds were detected at low-level concentrations, well below their respective HRLs (where HRLs have been established). The presence of these compounds is considered to be unrelated to the Highway 96 Site remnant plume, similar to periodic detections of low-level VOCs in samples collected from residential wells.

4.2.2 MONITORING WELL SAMPLING RESULTS

Laboratory analytical reports and data validation memos associated with the monitoring well sampling are provided in Appendix B and a summary of detected compounds is presented in Table 4.5.

Vinyl chloride or other site-related VOCs were not found in any of the monitoring well samples collected from MW-18A, MW-18B, MW-18L, MW-20B, and EW-3 in November 2006 or January 2007.

Ethyl ether, toluene, and trichloroethene were detected in a few of the monitoring well samples collected in November 2006 and January 2007. These compounds were detected at low-level concentrations, well below their respective HRLs. The presence of these compounds is considered to be unrelated to the Highway 96 remnant plume, similar to periodic detections of low-level VOCs in samples collected from residential wells.

4.2.3 GEOTECHNICAL SOIL SAMPLING RESULTS

Laboratory analytical reports associated with the geotechnical soil sampling are provided in Appendix B.

The grain size distribution results associated with the soil samples collected from SB-01 and SB-02 are discussed in the infiltration analysis section of the Ski Lane Ravine extraction system evaluation (See Section 6.2).

5.0 UPDATED GROUNDWATER EVALUATION

An evaluation of the geology and hydrogeology in North Oaks, Minnesota is presented in the following section. A similar groundwater evaluation was provided in CRA's February 2006 Report. The evaluation has been updated to include new information obtained during this reporting period.

5.1 GEOLOGY

The geology of the North Oaks area consists of three significant stratigraphic units (from shallow to deep): unconsolidated glacial deposits, St. Peter Sandstone, and the Prairie du Chien Group (an interbedded limestone and sandstone unit). The upper most formation of the Prairie du Chien Group is the Shakopee Formation, which directly underlies the St. Peter Sandstone.

Two geologic cross-sections have previously been constructed to show the underlying geologic conditions and the depth of monitoring wells and residential wells in the area. Geologic cross-section locations are presented on Figure 5.1. Geologic cross section A-A' extends from the Highway 96 Site westward across Gilfillan Lake through the Ski Lane Ravine area to the North Oaks Golf Course. This cross section has been updated to include geologic conditions observed during installation of the new monitoring wells along West Shore Road (MW-18A, MW-18B, MW-18L) and the new extraction well in the Ski Lane Ravine (EW-3). Geologic cross-section B-B' extends from the Highway 96 Site northwest along Duck Pass Road the northern shore of Gilfillan Lake. Both geologic cross-sections are provided in Appendix I.

The variable topography of the eastern North Oaks area is typical of a glacial deposit terrain, and ranges in elevation from 910 ft above mean sea level (AMSL) to greater than 970 ft AMSL. The unconsolidated deposits are comprised of a mixture of sediment with appreciable amounts of clay, silt, sand, and gravel particles. This area has been identified by the MGS as a complex intermixed deposit of glacial till with sandy loam and sandy clay loam (Meyer, 1985[4]). The unconsolidated glacial deposit ranges from 50 to 150 ft and is rarely used as a potable water supply in the North Oaks area.

The unconsolidated glacial deposits are typically underlain by the St. Peter Sandstone unit. However, erosional remnants of the younger Platteville Limestone and Glenwood Shale formations are sporadically observed in this area.

[4] Meyer, G.N. 1985. Quaternary Geologic Map of the Minneapolis-St. Paul Urban Area; Minnesota Geological Survey, Misc. Map Series M-54.

Regionally, the St. Peter Sandstone is classified as a white, fine to medium grained, well sorted, silica sandstone. The St. Peter Sandstone typically ranges in thickness from 0 to 150 ft. The lower 5 to 50 ft of the St. Peter Sandstone exhibits varying amounts of siltstone and shale (Stone, 1965).

The St. Peter Sandstone consists of two stratigraphic sub-units: the upper St. Peter Sandstone and the basal St. Peter Sandstone. The division of St. Peter Sandstone into two sub-units is based on lithologic differences. The upper St. Peter Sandstone appears as a soft, white fine grained quartz sandstone, which typically fits the standard description of the St. Peter Sandstone. In the southeast portion of North Oaks, the upper St. Peter Sandstone is of variable thickness from approximately 10 ft. to 100 ft. The variable thickness is due primarily to glacial erosion.

The basal St. Peter Sandstone is first identified by the presence of a shale unit. The shale unit is a gray, weakly consolidated, shale that ranges in thickness from 10 to 20 ft. The shale layer is observed both east and west of Gilfillan Lake. In the southeast portion of the North Oaks area. This shale unit is encountered at an elevation between 770 and 750 ft. AMSL. During the groundwater investigation conducted during this reporting period at 15 West Shore Road, the shale unit was first encountered at an elevation of 762 ft AMSL, which is consistent with previous evaluations.

Below the shale unit the remaining basal St. Peter Sandstone described as a gray shaley sandstone that can be interbedded with thin shale layers. The basal portion of the St. Peter Sandstone, including the shale layer, is approximately 60 to 70 ft. thick.

As noted above, the bedrock surface of the St. Peter Sandstone in the eastern North Oaks area is highly variable due to glacial erosion. Figure 5.2 presents the bedrock topographic surface of the St. Peter Sandstone. As shown on Figure 5.2, the bedrock surface elevation can vary by more than 100 ft. Another noted feature is the presence of a bedrock trough underneath Gilfillan Lake. The depth of this trough likely extends beyond a depth of 765 ft. AMSL, which is the lowest recorded elevation of the top of the St. Peter Sandstone (at 15 Lily Pond Road). At that depth, the shale unit in the basal St. Peter Sandstone may have been exposed and possibly eroded away. The presence of the shale unit is significant. Because of its inherent hydraulic features, the shale unit is considered an aquitard that hydraulically separates the upper and lower portions of the St. Peter Sandstone. A series of three geophysical survey transects will be performed this winter at the locations shown on Figure 5.3, to evaluate the nature and extent of the bedrock trough.

The basal portion of the St. Peter Sandstone transitions into the Shakopee Formation of the Prairie du Chein Group. The transition zone consists of St. Peter Sandstone intermixed with gravel-size pieces of the Shakopee Formation, which represents the upper part of the Prairie du Chien Group.

The Prairie du Chien Group consists of the upper Shakopee Formation followed by the Oneta Dolomite and is classified as an interbedded dolomitic limestone and sandstone. Regionally, the Prairie du Chien Group ranges in thickness from 0 to 250 ft.

The Prairie du Chien Group and the underlying Jordan Sandstone together form the primary aquifer for municipal water supply in the Minneapolis-St. Paul metropolitan area. For example, White Bear Township and the City of Vadnais Heights municipal wells draw water from this combined bedrock formation.

5.2 HYDROGEOLOGY

5.2.1 GLACIAL DRIFT AQUIFER

At the Highway 96 Site, the natural groundwater flow direction is to the west. However, this westerly pattern is influenced by changes in the unconsolidated glacial drift lithology. The hydrogeology of the glacial drift is variable depending on its sand, silt and clay content. For instance at the Highway 96 Site, the glacial drift has a sufficient amount of sand such that it is classified as the Lower Sand aquifer. Immediately to the west of the Highway 96 Site, the percentage of silt and clay increases thereby reducing its ability to readily transmit groundwater. At MW-16D, single well response tests calculated an average hydraulic conductivity of 2×10^{-5} ft/min (0.03 ft/d) in the glacial drift, which is one to two orders of magnitude less than the values calculated for the underlying St. Peter Sandstone wells (CRA, 2006).

The reduction in permeability affects groundwater flow migration pattern by inducing a stronger downward flow component to the St. Peter Sandstone aquifer. This relationship is recognized by comparing groundwater elevation difference between the glacial drift and St. Peter Sandstone groundwater systems. At monitoring well nests MW-10, MW-12, and MW-13, and MW-16 there is substantial groundwater elevation differences between the glacial drift (D wells) and St. Peter Sandstone wells (B wells). The strong downward vertical gradients between the two systems are due to the low permeability of the glacial drift. The result of the low permeability is that groundwater originating from the Highway 96 Site in the Lower Sand aquifer, prior to remediation, was directed downwards into the St. Peter Sandstone aquifer. Hence, the glacial drift aquifer further to the west of the Highway 96 Site has not be affected by historical

groundwater plume migration. Figure 5.4 shows vinyl chloride concentrations at VAP locations and well locations screened within the glacial drift aquifer, west of the Highway 96 Site. As shown on Figure 5.4, vinyl chloride is not detected in the glacial drift aquifer west of the Highway 96 Site.

5.2.2 ST. PETER SANDSTONE AQUIFER

Groundwater flow in the St. Peter Sandstone aquifer is towards the west for both the upper and basal portion of the aquifer. For the upper St. Peter aquifer, groundwater flow is characterized by the St. Peter Sandstone monitoring wells at the Highway 96 Site along with MW-12B, MW-13B, MW-16B, MW-17A, and MW-18A. Figure 5.5 shows the upper St. Peter Sandstone aquifer groundwater contours observed in January 2007.

Groundwater flow in the basal St. Peter Sandstone aquifer is characterized by the four converted residential monitoring wells (1 Lily Pond Road, 11 Lily Pond Road, 6 Blue Goose and 11 Robb Farm Road), monitoring wells MW-17B, MW-18B, MW-19B, and MW-20B, and two residential wells located on the west side of Gilfillan Lake (6 West Shore Road and 38 East Oaks Road). Figure 5.6 shows the basal St. Peter Sandstone aquifer groundwater contours observed in January 2007. As shown on Figure 5.6, the groundwater contours steepen immediately west of the Site. The increased hydraulic gradient is attributed to lithologic changes in the glacial drift and the undulating thickness of the St. Peter Sandstone.

The hydrogeologic characteristics of the upper and basal portions of the St. Peter Sandstone aquifer are unique based on their respective lithology. The hydraulic conductivity of the upper St. Peter Sandstone aquifer has been characterized previously by work conducted at the Highway 96 Site and by the single well response tests performed at MW-16B and MW-17A. At the Highway 96 Site, the hydraulic conductivity analysis of the upper St. Peter Sandstone aquifer indicates an average value of 0.01 ft/min (15 ft/d). The single response tests conducted at MW-16B and MW-17A indicate a lower value ranging from 0.002 ft/min to 0.004 ft/min (3 to 6 ft/d). Hydraulic conductivity values from the single well response test conducted during this reporting period at MW-18A (0.004 ft/min) were consistent with values observed at MW-16B and MW-17A.

The upper portion of the St. Peter Sandstone has an overall higher permeability than the underlying basal St. Peter Sandstone.

The basal portion of the St. Peter Sandstone has an overall lower permeability compared to the upper St. Peter Sandstone due to its overall shale content. The shale unit is considered a confining layer that hydraulically separates the upper portion of the St. Peter Sandstone from the basal portion of the St. Peter Sandstone. At the MW-17 nest, a downward vertical hydraulic gradient of 0.07 ft/ft is observed between the upper and basal portions of the St. Peter Sandstone. During groundwater investigation conducted during this reporting period, a downward vertical gradient of 0.02 ft/ft was observed at the MW-18 nest. At both locations, MW-17 and MW-18, a downward vertical gradient exists due to the presence of the shale unit.

For the basal St. Peter Sandstone, single well response tests were previously conducted at MW-17B and MW-19B. The single well response tests presented hydraulic conductivity values ranging from 0.0002 ft/min to 0.005 ft/min (0.3 to 7 ft/d). During this reporting period, the hydraulic conductivity measured at MW-18B was 0.0004 ft/min and is consistent with previous calculations for the basal St. Peter Sandstone aquifer. The basal St. Peter Sandstone has a lower hydraulic conductivity compared to the upper St. Peter Sandstone. The single well response tests performed at the MW-17 and MW-18 well nests indicate the hydraulic conductivity observed in the upper St. Peter Sandstone is ten times greater than the hydraulic conductivity observed in basal St. Peter Sandstone (see Appendix H).

Figure 5.7 shows vinyl chloride concentrations at monitoring well locations and residential well locations screened within the St. Peter Sandstone aquifer, west of the Highway 96 Site. As shown on Figure 5.7, vinyl chloride was detected in this aquifer in only two locations in 2006: east of Gilfillan Lake at MW-17A (in the 15 Gilfillan Road/ 17 Gilfillan Road/8 Edgewater Lane area) and west of Gilfillan Lake in the 12 West Shore Road/13 West Shore Road/2 Hummingbird Hill area.

The presence of vinyl chloride in the St. Peter Sandstone aquifer on the east side of Gilfillan Lake in the 15 Gilfillan Road/17 Gilfillan Road/8 Edgewater Lane area is consistent with historical sampling results. However, vinyl chloride concentrations east of the lake have decreased since 1993. The decreasing vinyl chloride concentrations are attributed to two factors: the Highway 96 groundwater extraction system and natural attenuation. The Highway 96 Site groundwater extraction system has been capturing groundwater contamination at the site since 1989. Hence, no new vinyl chloride has migrated off Site. Natural attenuation is reducing the residual vinyl chloride concentrations by mechanical (i.e. dispersion) and chemical (biodegradation) processes.

In 1993/1994, the distance between the northernmost and southernmost well locations east of Gilfillan Lake where vinyl chloride was detected above 0.2 μg/L, was

approximately 1000 feet. However, the furthest distance between well locations where vinyl chloride was detected above 2 µg/L was only 200 feet (north to south). It is likely that vinyl chloride concentrations have attenuated such that the 200 foot wide area of vinyl chloride contamination above 2 µg/L observed east of Gilfillan Lake in 1993/1994 is indicative of a similar size area of contamination years before which, in turn, correlates to the approximate 200-foot wide area of vinyl chloride contamination observed west of Gilfillan Lake in 2006 (0.2 µg/L). Thus, as the contaminant plume continues to attenuate and move west, CRA expects it will continue to measure 200 feet wide and possibly narrow over time.

Vinyl chloride concentrations in the St. Peter Sandstone aquifer on the west side of Gilfillan Lake in the 12 West Shore Road/13 West Shore Road/2 Hummingbird Hill area have remained essentially unchanged since October 2004. Sampling results obtained during this reporting period continue to indicate the horizontal extent of vinyl chloride contamination west of Gilfillan Lake is limited (approximately 200 feet wide, north to south).

Additional study is under way to help further understand the groundwater flow system in the North Oaks area. One additional study includes geophysical logging of residential wells. The residential well geophysical logging program will determine the depth and screened/open hole intervals of selected residential wells in North Oaks Area 3 (west of Gilfillan Lake). The residential well geophysical logging program is depicted on Figure 5.8.

5.2.3 PRAIRIE DU CHIEN AQUIFER

Groundwater flow in the Prairie du Chien is regionally towards the west (Norvitch and others, 1973). The Shakopee Formation, which underlies the basal St. Peter Sandstone, has a substantially higher hydraulic conductivity compared to the St Peter Sandstone aquifer. Single well response tests previously conducted at MW-17L, MW-18L, and MW-19L determined hydraulic conductivity values of 0.05 ft/min to 0.13 ft/min (72 to 187 ft/d).

Figure 5.9 shows vinyl chloride concentrations at monitoring well locations and residential well locations screened within the Prairie du Chien aquifer, west of the Highway 96 Site. As shown on Figure 5.9, vinyl chloride is not detected in the Prairie du Chien aquifer.

During previous groundwater sampling events, vinyl chloride was detected in two residential wells screened within the Prairie du Chien aquifer (e.g. 19 Dove Lane, 21 Gilfillan Lane). However, the presence of VOCs in these wells does not indicate that the Prairie du Chien aquifer is contaminated, but rather is likely an isolated occurrence caused by poor well construction (i.e. the wells were improperly constructed allowing vertical leakage from the St. Peter Sandstone aquifer to the underlying Prairie du Chien aquifer).

The former residential well at 21 Gilfillan Road, where vinyl chloride was detected in 1993/1994 at an estimated (J) concentration of 0.11 J µg/L, was a dual cased well. The outer well casing extended into the basal St. Peter Sandstone while the inner well casing extended into the Prairie du Chien aquifer. The annulus between the inner and outer well casings was not properly sealed to prevent cross flow between the two aquifers, which is why during the abandonment process the inner well casing was perforated and pressure grouted to seal the annulus and eliminate the conduit between the two aquifers. The former residential well at 19 Dove Lane, where vinyl chloride was detected in 1994 at a concentration of 0.31 µg/L, was installed in an oversized borehole that extended through the St. Peter Sandstone aquifer into the Prairie du Chien aquifer. The annulus between the well casing and the borehole was not properly sealed to prevent cross flow between the two aquifers. This well was also perforated and pressure grouted as part of its abandonment process.

The conclusion that the presence of vinyl chloride in these former residential wells was isolated and due to improper well construction is further supported by the fact that vinyl chloride is not detected in properly constructed wells in the Prairie du Chien aquifer including monitoring well MW-17L, located east of Gilfillan Lake and beneath the area of known vinyl chloride contamination at MW-17A and MW-18 west of Gilfillan Lake.

5.3 GROUNDWATER FLOW ANALYSIS

Prior to the implementation of the groundwater extraction system in 1989, groundwater flow in both the glacial drift and St. Peter Sandstone aquifer was westward from the Highway 96 Site. Immediately west of the Highway 96 Site, groundwater in the glacial drift is directed downwards towards the St. Peter Sandstone, due to geologic changes. This condition is evidenced by the strong downward vertical gradients observed at monitoring well nests: MW-10, MW-12, and MW-13, and MW-16.

As the groundwater enters into the St. Peter Sandstone from the drift, the St. Peter Sandstone aquifer responds to the additional groundwater flux from the glacial drift with an enhanced horizontal hydraulic gradient. As groundwater from the glacial drift enters the St. Peter Sandstone aquifer, groundwater from both the glacial drift and the upper St. Peter Sandstone recharges the basal St. Peter Sandstone as it moves westward.

Groundwater flow in the St. Peter Sandstone aquifer east of Gilfillan Lake is influenced by the composition and thickness of the glacial drift on top of the undulating St. Peter Sandstone. These geologic features cause localized variations in groundwater flow. As St. Peter Sandstone groundwater approaches the east side of Gilfillan Lake, the flow direction appears to stabilize to a consistent westward direction, such that the horizontal hydraulic gradients decrease.

The hydraulic conductivity of the St. Peter Sandstone aquifer can vary based on the lithology. For instance, the upper St. Peter aquifer is more permeable than the basal St. Peter and differs by approximately an order of magnitude. While acknowledging that, the flow velocities in the St. Peter Sandstone aquifer can vary locally, depending on the hydraulic conductivity and hydraulic gradient the estimated groundwater flow rate in the upper St. Peter Sandstone aquifer can range up to approximately 80 ft/yr.

Based on the groundwater evaluation conducted during this reporting period, the estimated average groundwater flow in the basal St. Peter Sandstone ranges between 3 and 8 ft/yr.

6.0 EXTRACTION SYSTEM EVALUATION (SKI LANE RAVINE)

6.1 AQUIFER ANALYSIS

This section presents results of the aquifer performance tests conducted at EW-3 in the Ski Lane Ravine. The aquifer tests included a step-drawdown test, a constant-rate pumping test, and the recovery test.

6.1.1 STEP-DRAWDOWN TEST

To evaluate the hydraulic capabilities of EW-3, a series of three step tests were performed to determine the specific capacity of EW-3. The specific capacity represents the ratio of pumping rate (Q) in gpm to drawdown (Δh) in feet. During the step-drawdown tests, EW-3 was pumped at three successively higher pumping rates of 10 gpm, 20 gpm, and 30 gpm for periods of 60 minutes each. Table 6.1 summarizes the step test results and the calculated specific capacity. The specific capacity value for all three tests was 0.26 gpm/ft. The step-drawdown test data are presented in Appendix J.

Based on the results of the step test, it was determined that a pumping rate of 20 gpm would be sufficient for the constant rate pumping test. At the 20 gpm pumping rate, a significant hydraulic response would be observed in both the pumping well and surrounding monitoring wells (e.g., MW-19B) that would be applied to the aquifer analysis.

6.1.2 CONSTANT RATE PUMPING TEST

A 24-hour constant rate pumping test was conducted using EW-3. The purpose of the pumping test was to evaluate the feasibility of a hydraulic containment system in the Ski Lane ravine area and thereby prevent further westward migration of vinyl chloride contamination. The results of the pumping test show that basal St. Peter Sandstone aquifer responds quickly to pumping. The drawdown in the basal St. Peter Sandstone aquifer is substantial with over 10 ft of drawdown observed at MW-20B, which is distance of 141 ft. cross gradient from EW-3. However, after initial pumping of the basal St. Peter Sandstone aquifer a boundary condition develops due to the presence of the underlying Prairie du Chien aquifer. Figure 6.1 presents the maximum drawdown observed at the extraction well and three monitoring wells.

A summary of the pumping test drawdown is presented in Table 6.2.

Within 30 minutes of groundwater pumping, the drawdown rate quickly diminishes. This change is caused by the Prairie du Chien aquifer acting as a recharge boundary during pumping of EW-3, and thereby diminishes further drawdown in the basal St. Peter Sandstone aquifer. Because of this recharge boundary condition, the hydraulic properties of the basal St. Peter Sandstone under pumping conditions become a composite of both the basal St. Peter Sandstone aquifer and the upper portion of the Prairie du Chien aquifer. The hydraulic properties of the pumped layer (i.e., basal St. Peter Sandstone) can be ascertained from the early time response using standard analytical solutions (Javandel and Witherspoon, 1983). The hydraulic properties of the multi-layered/composite aquifer system were determined using two dimensional groundwater flow modeling. A discussion of the hydraulic properties associated with the basal St. Peter Sandstone is presented in Section 6.1.4, below.

Barometric pressure data were obtained for the period of the 24-hour pumping test to determine if changes in the barometric pressure affected the groundwater level data. In general, water levels in confined aquifers respond to atmospheric pressure changes such that a decrease in atmosphere pressure results in a rising water level. Barometric pressure data measured during the duration of the pumping test is presented in Appendix K. The barometric pressure changed less than 0.1 in. Hg during the pumping test and therefore did not have a significant influence on the water level data.

6.1.3 RECOVERY TEST

This section discusses the groundwater recovery after completion of the 24-hour pumping test. Groundwater recovery measurements were collected at the same frequency used during the drawdown phase of the pumping test. The recovery data provides an independent check on the pumping test results. The recovery test was complete after a minimum of 95% recovery was observed on the observation wells and the extraction well. Groundwater recovery at EW-3, MW-19B, and MW-20B was completed within 2 hours after pumping shutdown.

6.1.4 SUMMARY OF HYDRAULIC PARAMETERS

6.1.4.1 BASAL ST. PETER SANDSTONE AQUIFER

The Cooper-Jacob method (Cooper and Jacob, 1946) was applied to the drawdown data from the extraction well (EW-3) and the two basal St. Peter Sandstone aquifer monitoring wells (MW-19B and MW-20B). The Prairie du Chien aquifer monitoring well (MW-19L) did not exhibit any drawdown during the pumping test and, therefore, was

not evaluated under this program. The data were analyzed using the computer software program AQTESOLV, version 4.01, (HydroSOLV, 2006).

The Cooper-Jacob method is a semi-log plot of drawdown over time. Theoretically, these data should plot as a straight line on semi-logarithmic paper. Any breaks in the slope of this plot would be attributed to storage effects, partial penetration, or a boundary condition. As shown on the AQTESOLV reports, located in Appendix J, there are three distinct slopes.

The first slope occurs in the first two to three minutes of pumping. Typically, these early time data are ignored due to storage effects and partial penetration of the extraction well. The second slope extends from approximately 2 minutes to 30 minutes of the pumping test. The second slope shows the characteristics of the basal St. Peter Sandstone aquifer. After 30 minutes, the slope flattens out with essentially little or no drawdown over time. The flatter slope indicates a recharge boundary condition. These differences in the drawdown slope are explained by the hydrogeologic properties of the basal St. Peter Sandstone aquifer and the underlying Prairie du Chien aquifer.

As described in Section 4.3, the basal St. Peter Sandstone aquifer is significantly less permeable than the underlying Prairie du Chien aquifer. Due to its low permeability, the basal St. Peter Sandstone aquifer quickly exhibited substantial drawdown at MW-19B and MW-20B. After a certain time (approximately 30 minutes), there is enough change to the potentiometric surface of the basal St. Peter Sandstone aquifer that the vertical hydraulic gradient is reversed.

Under non-pumping conditions, a downward vertical gradient of 0.06 ft/ft exists between the basal St. Peter Sandstone aquifer and the underlying Prairie du Chien aquifer. However during pumping at EW-3, the vertical hydraulic gradient was reversed such that an upward gradient of 0.2 ft/ft was observed at the MW-19 well nest. This upward groundwater movement reduced the rate of drawdown in the basal St. Peter Sandstone aquifer.

The transmissivity results for the basal St. Peter aquifer are summarized in Table 6.2 and Table 6.3. The basal St. Peter Sandstone aquifer transmissivity (T) values ranged from 0.01 ft^2/min to 0.06 ft^2/min. Storativity values ranged from 1.9×10^{-5} to 4.7×10^{-5}. The geometric mean value for transmissivity is 0.03 ft^2/min., which includes the EW-3 analysis, and 3.0×10^{-5} for storativity.

The recovery data were analyzed using the Theis (1935) recovery method provided in AQTESOLV, version 4.01, (HydroSOLV, 2006). The Theis method is a semi-logarithmic

plot of residual drawdown versus t/t`, which is the ratio of time since pumping started (t) to the time since pumping stopped (t`). The ratio t/t` is plotted on the logarithmic scale.

The AQTESOLV reports of the recovery data are presented in Appendix J. Aquifer analytical results are summarized in Table 6.3. The transmissivity values range from 0.01 ft^2/min to 0.06 ft^2/min. The geometric mean value for transmissivity is 0.03ft^2/min. The recovery data transmissivity results are similar to the pumping data.

The hydraulic conductivity (K) of the basal St. Peter Sandstone aquifer can be determined by the following formula:

$$K = T/b$$

where b is the thickness of the basal St. Peter Sandstone aquifer (41 ft.). Using the above equation, the calculated hydraulic conductivity value is 0.0007 ft/min, which is about a factor of 2 to 3 less than the single well response test data (Table 4.3).

6.1.4.1 BASAL ST. PETER SANDSTONE AQUIFER WITH RECHARGE FROM THE PRARIE DU CHIEN AQUIFER

The constant-rate pumping test determined that the underlying Prairie du Chien aquifer acted as a recharge boundary during the pumping of the basal St. Peter Sandstone aquifer. As a result of this boundary condition, standard aquifer analytical solutions could not be used to calculate the combined hydraulic properties of the basal St. Peter Sandstone aquifer and the portion of the Prairie du Chen aquifer that recharges the basal St. Peter Sandstone aquifer during pumping. Therefore, a two-dimensional (2-D) groundwater flow model was applied to interpret the hydraulic relationship of the two aquifers and evaluate the extent of hydraulic response in the basal St. Peter Sandstone aquifer due to pumping. This information was used to determine an appropriate long term pumping rate for EW-3. A technical memorandum is presented in Appendix L that provides additional details of the model.

The computer model, MODFLOW, was used to evaluate the hydraulic relationships between the basal St. Peter Sandstone aquifer and the Prairie du Chien aquifer. MODFLOW is a numerical model developed by the United States Geological Survey (USGS). The model area was developed using a rectangular area roughly 30,000 feet east to west and 26, 000 ft. north to south. The model was established as a three layered aquifer system. The uppermost layer in the model is the shale unit that hydraulically

separates the upper St. Peter Sandstone aquifer from the basal St. Peter Sandstone aquifer. The shale unit was modeled as a leaky aquitard. The second model layer is the basal St. Peter Sandstone, and the third layer is the upper 85-foot portion of the Prairie du Chien aquifer. The thickness of this formation was defined by the depth of MW-19L, which represents the maximum depth of possible hydraulic influence based on the EW-3 pumping test. Because MW-19L did not respond during the constant-rate pumping test; it was not necessary to incorporate the entire Prairie du Chien Group for this model.

Constant head boundaries were used to establish initial flow conditions, such as flow direction and hydraulic gradient for the two aquifers. No-flow boundaries were established for the north and south boundaries. A leakage factor was added to the shale layer to account for possible recharge effects. The model was calibrated to replicate the hydraulic response of the two observation wells MW-19B and MW-20B from the EW-3 pumping test.

Once the model was calibrated to replicate the drawdown observed at MW-19B and MW-20B, a pumping rate of 10 gpm was modeled to calculate the expected capture width in the basal St. Peter Sandstone aquifer. The complex interaction between the basal St. Peter Sandstone aquifer and upper portion of the Prairie du Chien aquifer during pumping conditions makes it difficult to predict the exact capture width at a given pumping rate. However, at a pumping rate of 10 gpm, the groundwater modeling results calculated an average capture width of 1,200 ft from the pumping well across the basal St. Peter Sandstone aquifer, which goes beyond the boundaries of the Ski Lane Ravine (800 feet wide). Upgradient from the pumping well, this capture width would extend further to a maximum width of 3,000 ft. and would therefore incorporate all of Area 3, west of Gilfillan Lake.

Based on the model's predicted capture width of 1,200 ft, the composite transmissivity (T) value, which incorporates the hydraulic parameters of the basal St. Peter Sandstone aquifer and the upper portion of the Prairie du Chien aquifer, was determined. The capture zone analysis equation was rearranged, as follows, to solve for T:

$$T = Q/2di$$

where "Q" is the pumping rate 10 gpm (1,925 ft3/d), "d" is the capture width 1,200 ft, and "i" is the regional hydraulic gradient of 0.003 ft/ft.

Based on the above parameters, the composite T value is 267 ft2/d., which is approximately five times greater than the transmissivity of the basal St. Peter Sandstone without recharge from the Prairie du Chien.

6.2 INFILTRATION ANALYSIS

An infiltration analysis was performed for the northern portion of Ski Lane Ravine area. The purpose of the analysis was to determine whether the ravine area could handle extracted groundwater if EW-3 were put into operation at a conservatively assumed rate of 50 gpm. This section summarizes the results of the Ski Lane Ravine Infiltration Analysis. A complete presentation of the infiltration analysis is presented as a technical memorandum in Appendix M.

As described in Section 4.1.4, a topographic survey and geotechnical soil sampling were performed in the northern portion of the Ski Lane Ravine to determine existing Site and soil conditions. The topographic survey was conducted to determine the contours of the low-lying area in the northern portion of the ravine. This information along with rainfall data were inputted into a hydrologic model to determine surface runoff coefficients and thereby calculate the annual runoff volume being handled by the northern portion of the ravine.

Based on the geotechnical soil sampling results, the soil in the northern portion of the ravine can be described as having a 5-foot thick topsoil/clay layer followed by a fine to medium grain sand to silty sand that extends 35 ft. to the water table. The hydraulic conductivity of both the upper clay layer and underlying sand layer were calculated based on their grain size distribution.

Based on the low hydraulic conductivity results for the clay layer (1×10^{-6} cm/s), it was determined that the clay layer would restrict the infiltration rate such that the area would not handle the current surface runoff and the added water from a groundwater extraction system without substantial ponding. Hence, a direct surface water discharge was deemed unsatisfactory and an infiltration gallery would be required.

The infiltration gallery would incorporate a series of trenches installed five feet below ground surface. These trenches would be backfilled with coarse stone. Based on a 50 gpm groundwater extraction system, the infiltration gallery would require an area of 1,700 ft^2. This size of an infiltration gallery can readily fit within the northern portion of the Ski Lane ravine.

7.0 CONCLUSIONS

Based on the work conducted during this reporting period and results from previous evaluations, CRA has reached the following conclusions:

- Continued residential well sampling of over 30 homes in North Oaks Area 3 (west of Gilfillan Lake) confirms that vinyl chloride contamination is limited to three residential wells (12 West Shore Road, 13 West Shore Road, and 2 Hummingbird Hill).
- The unconsolidated glacial drift aquifer in North Oaks is not contaminated by vinyl chloride.
- Groundwater samples from monitoring wells continue to indicate that vinyl chloride contamination west of Gilfillan Lake in the St. Peter Sandstone aquifer is of limited horizontal extent.
- The Prairie du Chien aquifer in North Oaks is not contaminated by vinyl chloride and remains a viable source of water supply.
- Performance testing of EW-3 has demonstrated that groundwater capture in the Ski Lane ravine is feasible within the basal St. Peter Sandstone aquifer.
- Geotechnical and infiltration analyses indicate infiltration of extracted/treated groundwater in the Ski Lane Ravine is feasible using an infiltration gallery.

8.0 RECOMMENDATIONS

Based on the groundwater and residential well evaluation conducted during this reporting period and during previous evaluations, CRA recommends the following:

- Residential well sampling should continue, as outlined in CRA's "Revised Residential Well Sampling Program", submitted to MPCA on September 11, 2006, and approved on October 2, 2006.
- Geophysical logging of selected residential wells should be conducted, as outlined in CRA's "Residential Well Geophysical Logging Work Plan", submitted to MPCA on October 10, 2006 and approved on October 16, 2006.
- A geophysical survey of the geology under Gilfillan Lake should be conducted, as outlined in CRA's "Geophysical Survey Work Plan", submitted to MPCA on January 15, 2007 and approved on February 1, 2007.
- CRA should meet with the MPCA to discuss operation of a groundwater extraction system in the Ski Lane Ravine.

9.0 REFERENCES

Respold, H. 1989. Well Logging in Groundwater Development; International Contributions to Hydrogeology, vol. 9; International Assoc. of Hydrogeologists, 136 pgs.

Norvitch, R.F., T. G. Ross, and A. Briethrietz. 1973. Water Resources Outlook for the Minneapolis-St. Paul Metropolitan Area, Minnesota; U.S. Geological Survey and Metropolitan Council, 219 pgs.

Bouwer, H. and R.C. Rice. 1976. A Slug Test Method for Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells; Water Resources Research, vol. 12, no. 3, pp. 423-428.

Stone, J.E. 1965. Status of Urban Geology In The Minneapolis-St. Paul Area; Minnesota Geological Survey, Reprint series-2, 13 pgs.