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Cover Photo: Washington County Sanitary Landfill cover looking northwest from the area north of the flare. Photo taken 29 October 2008.

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Executive Summary

This report provides an update on site activities for calendar year 2008 for the Washington County Landfill in Lake Elmo, Minnesota. These activities have included operating and maintaining the active gas extraction system and flare and tracking that methane concentrations at the property boundary do not exceed the Lower Explosive Limit and also do not migrate beyond the boundary of the landfill; operating the ground water gradient control system; sampling, analyzing and tracking contamination trends in gas condensate, ground water gradient control effluent and ground water both around the immediate vicinity of the landfill and downgradient of the site in the area impacted by perfluorochemical contamination from the site. Early design activities in preparation for constructing a lined cell in which to re-place the landfill's waste are also discussed.

The Closed Landfill Program has also tracked the contamination in domestic wells in the impacted area and has installed and maintained water treatment systems on impacted residences. The past year has not only included operation and maintenance of these systems but also the completion of investigations at the site to elucidate the flow in the karst bedrock aquifer and to determine the depth and volume of the waste to aid in designing a new lined facility.

Site Accomplishments

Landfill gas migration was controlled by the active gas extraction system and 933,000 pounds of methane were destroyed.

Ground water was extracted and aerated to remove 17 pounds of volatile organic compounds.

The mound of ground water at the southeast corner of the site continued to drop and surrounding monitoring and domestic wells showed decreasing trends in perfluorochemical contamination.

Bottled water and whole house water treatment systems were maintained for 55 residents within the impacted plume.

118 residential wells and 33 ground water monitoring wells were sampled in 2008 and indicate that the perfluorochemical plume is stable because concentration trends are either constant or decreasing with some exceptions.

Videologging and multi-tool geophysics logging of bedrock wells on-site indicated that flow ranged from 1100 to 7000 feet per day.

A waste boring investigation in the fall of 2008 indicated that there were 1.8 million cubic yards of waste rather than 2.5 million cubic yards of waste historically reported.

Site Challenges

Eighty pounds of PFCs were extracted from the ground water and returned to the unsaturated zone untreated.

PFC trends in a residential well south of the landfill continue to rise and have prompted the MPCA to hook them up to city water. This work should occur in the spring of 2009.

PFC standards were exceeded in 21 monitoring wells and 11 residential wells.
Site Background

The Washington County Sanitary Landfill (Landfill) located in Washington County, City of Lake Elmo (T 29 N, R 21 W, Sections 10 and 15), received its first permit to accept waste on May 12, 1969, and continued operating until May 1, 1975. The Washington County Sanitary Landfill is 35 Acres in size and contains approximately 2,570,000 cubic yards of waste (1.95 million cubic meters). The Landfill was under public ownership (Washington and Ramsey Counties) when in operation.

An abbreviated CERCLA (Comprehensive Environmental Response and Compensation and Liability Act of 1980) history of the site follows. Washington and Ramsey Counties (Counties) performed a Remedial Action at the site in accordance with a Response Order by Consent, dated October 24, 1984, between the MPCA and the Counties and in accordance with an Administrative Order issued by US EPA to the Counties pursuant to Section 106 (a) of CERCLA (Administrative Order), dated January 16, 1992 and amended February 17, 1993. The major component of the Remedial Action was the installation and operation of a ground water gradient control and treatment system. The Consent Order was executed under authority given to the MPCA by the Minnesota Environmental Response and Liability Act (MERLA). The Consent Order contained a liability limit for response actions taken by the Counties at the Site. The Counties reached the liability limit and the MPCA terminated the Consent Order on February 2, 1992. The US EPA issued the Administrative Order on January 16, 1992 to ensure that the response actions continued at the Site. The Administrative Order was amended on February 17, 1993 to address an explosive methane gas problem associated with the site. During that year, a barrier extraction vent system was installed to mitigate landfill gas migration to the west. The binding agreement was signed in November 1995 and the Notice of Compliance was issued January 8, 1996 that gave responsibility of the site to the MPCA. The US EPA terminated the Administrative Order on March 15, 1996. The first Five-Year Report was written in January 1994 to address the ground water remedial action taken in 1989. The second Five-Year Report addressed the ground water remedial action, the affect of the active gas extraction system and the enhanced cover in addressing public health and environmental issues around the Site and was written in 1999. The third Five Year Report was written in 2004 by US EPA staff to address ground water remedial action, the affect of the active gas extraction system and the enhanced cover in addressing public health and environmental issues around the Site.

In accordance with the legislation enacted in 1992 (Minn. Laws 1992, Ch. 513, Art. 2, Sec. 2, Subd.3), each year at an Annual Forum, Minnesota Pollution Control Agency (MPCA) staff assesses, classifies and discusses ongoing issues at landfills in the Closed Landfill Program. The site was reclassified and rescored on March 29, 2005 to A 24.2 because of perfluorochemical contamination in residential wells above the Health Based Value. Section III.C.1 provides more detail regarding residential well results.

Various options to address the PFC contamination problem have been pursued including design of a forcemain to transport pumped groundwater from the on-site extraction wells to a sanitary sewer lift station in Oakdale, feasibility and conceptual design of an on-site treatment system using various adsorptive media to remove contaminants from the pumped groundwater, and conceptual designs to excavate the waste and place it on a new lined landfill at the same location. A final decision for remedial action was formalized on June 18, 2008 with the MPCA Commissioner signing the Remedy Decision Document. The selected remedy, termed, Dig and Line, proposes to construct a lined landfill in the same location as the existing landfill.
Site Engineering Summary

Landfill Cover Maintenance/Construction Summary
When the landfill closed on May 1, 1975, 2 feet or more of final cover was in place. In 1996, the cover was upgraded to current standards including a geomembrane, sand drainage layer, rooting zone, and topsoil with shallow rooted grasses.

Major settlement has occurred over the years on the cover in several areas. Drainage is inadequate in the areas of settlement. Ponding was a problem around GEW-1 and the cable concrete channel, between GEW-9 and the cable concrete channel and along the cable concrete channel near GEW-6. No additional construction or cover maintenance was performed at the Landfill in 2008 pending the outcome of what remedial action is selected to address the long-term PFC contamination problem.

Leachate Management System Summary

Leachate Management System Maintenance Summary
The Washington County Sanitary Landfill does not have a Leachate Management System for leachate collection. The landfill is unlined.

Leachate Monitoring Summary
There are no leachate monitoring points at the Washington County Landfill.

Landfill Gas Management System Summary

Landfill Gas Management System Maintenance Summary
Fourteen active gas extraction wells located throughout the facility extract methane and other gases from the waste and combust them in an enclosed flare. The flare destroyed approximately 933,000 pounds of methane in fiscal year 2008.

Table 1 summarizes the results of operating the flare in 2008.

Landfill gas condensate is collected in one of three buried double-walled underground storage tanks.

Landfill Gas Monitoring Summary
There are 23 gas monitoring points to monitor for the presence of landfill gas generated by the Washington County Landfill (see Figure 1A). Landfill gas migration was controlled adequately by the active gas extraction system. The Operation and Maintenance contractor monitors the probes quarterly. The 2008 events occurred in February, April, May, August and November. Methane was not detected in the probes in 2008.

Inlet and Outlet Gas was sampled from the flare in November 2003. The results summarized in a report dated June, 2004, indicate the Washington County Landfill enclosed flare has a combustion efficiency of 99.99%.

Landfill Gas Condensate Summary
MPCA has an Industrial Discharge Permit Number 2192 issued by the Metropolitan Council Environmental Services (MCES) to allow discharge of landfill gas condensate from the Washington County Landfill to their wastewater treatment facility. No condensate was hauled from the Landfill during 2008. Therefore, no sampling and analysis of the condensate was required.

Electricity Generated
There is no electricity generated at the Washington County Landfill.
Additional Maintenance Summary

Mowing of the site entrance road shoulders, access trails and cover system were completed throughout the summer in 2008.

Site Engineering Recommendations

Proceed with the design and implementation of the Dig and Line Remedy to address PFC ground water contamination.

Site Hydrologic Monitoring Summary

Ground Water Monitoring/Remediation System Maintenance Summary

Repair was not required on dedicated sampling pumps installed in wells at the site in 2008.

Ground Water Monitoring System Maintenance Summary

Data collected in continuous water level recorders at the northwest corner of the landfill indicate that mounding impacts from discharge of treated ground water at the southeast corner of the landfill (up until November 22, 2006) has diminished. Figure 21 indicates that the relationship of the wells to one another has approached pre-mounding levels. The monitoring wells that are the farthest upgradient (well I and well 2003-B1) now have higher ground water elevations than wells 2003-B3 (well closest to the landfill and downgradient from I and 2003-B1). This is reflected in a slight downward trend in contamination at well I that has continued through 2008 (Figure 19). Figure 16 follows the ground water elevation and contaminant trends at well D1, a well that represents the flow conditions in the drift midway between the northwest corner and the southeast corner. Depth to the bottom of waste immediately west of this well was measured in November 2008 and is at elevation 929. Several interesting trends are observed at this well. There is a declining trend in ground water elevation since 1997 and since 2001 the waste at this location is no longer in ground water. The trend of individual volatile organic compounds was declining (several orders of magnitude) from 1997 until 2001 but during 2008 increased within the same order of magnitude despite the dry conditions. Figure 15 plots the ground water elevation in wells around the southeast corner of the landfill (old discharge area) and at the south boundary of the landfill. The piezometer in the old discharge area (P1 (plotted with green crosses) shows that the ground water elevation in this area has dropped below the bottom of waste that was measured at GC2R (see Figure 2) and has dropped more than 16 feet (4.9 meters) since the discharge location was moved. This trend is mirrored by monitoring wells that range in distance from 300 feet (well E-WT (91 meters)) to 645 feet (well R-WT (196 meters)) from P1. Well V-WT is the closest well to the new discharge location. The change in ground water elevation has been 2 feet over the last two years which probably reflects seasonal variation since Q-WT (800 feet (244 meters) west of V-WT) shows the same seasonal variation. In addition, both GC3-WT and E-WT have been dry since August 2007 through 2008.

Ground water samples were collected from the monitoring system for analysis during May, August and November 2008 at the Landfill. The landfill monitoring system consists of 43 monitoring wells and 1 ground water discharge station. Nine wells are located upgradient of the landfill and the remainder are either side gradient or downgradient of the landfill. A map showing the locations of the monitoring points is presented in Figure 2. A list of the wells and dates sampled during 2008 is included in Table 2. Figure 28 shows rainfall plotted since 1999. The wettest months in 2008 were June, April and August (1st, 2nd, and 3rd wettest respectively). One of the sampling events coincides with a wet month. However, the annual rainfall measured in the area of the site declined in 2008. Total annual rainfall in 2008 was 25.4 inches while annual rainfall in 2007 was 31.14 inches.
Tables 2, 3, and 4 have been prepared to show analytical parameters analyzed, field data, and total concentrations of Volatile Organic Compounds (VOCs) for each of the wells monitored. Figures 3 through 13 depict ground water contour maps at the water table in the Quaternary aquifer, upper Quaternary wells, mid-depth in the Quaternary aquifer and at the base of the Quaternary aquifer. These maps depict two to three ground water sampling events. Previous reports had flow maps of the Prairie du Chien aquifer. A geophysical and videologging study of the bedrock monitoring wells in the fall of 2008 revealed that well R3 was completed in the St. Peter aquifer. Therefore the direction of flow in the bedrock monitoring wells is unknown since there are only two wells in the Prairie du Chien aquifer. A graph (Figure 14) of continuous water level versus time indicates that flow in the northwest corner of the landfill followed the regional trend with an additional component of flow to the east-northeast.

The impact of mounding at the old discharge area (TA-1) has diminished through 2008 and a mound has shifted to the southwest. This is seen in Figures 3 through 5. Residual impacts of infiltration in the old discharge area are still observed at the water table along the south boundary of the fill area. The water table at the south boundary of the fill area (28 to 51 feet (9 to 16 meters) below the ground surface) flows to the west, south and northeast in a localized area. The regional gradient in the quaternary aquifer is resumed at 656 feet (200 meters) to the east of the former discharge area as seen by ground water elevations measurements at P3. The regional gradient is resumed to the west in the upper part of the quaternary aquifer 63 feet (19 meters) below the ground surface. The flow at mid-depth Quaternary aquifer wells is impacted by the gradient control wells. Flow in May was controlled by GC5; flow in August and November was controlled by GC3. GC1 did not impact flow in 2008 because it pumped at a reduced rate (6.5 gallons per minute for the year) and it was not operating from July through November because of a hole in the drop pipe. These contour maps show that the impact covers an area of approximately 1,312 feet (400 meters (Figures 9 through 11)). Flow plotted at the base of the Quaternary aquifer is to the southeast (Figure 12 through 13). This plot is skewed because of the high elevation reading at well DD that appears to send flow to the east northeast from the intersection of Hwy 5 and Jamaica/Stillwater Boulevard.

The horizontal hydraulic gradient at the water table in the Quaternary aquifer varies around the landfill based on proximity to the discharge area and the south boundary of the fill. The horizontal hydraulic gradient averaged 0.006 underneath the middle of the landfill and averaged 0.02 near the gradient control wells. This flat gradient is consistent with vertical gradients measured in wells not impacted by infiltration of ground water in the treatment area. The next elevation monitored below the water table is the upper Quaternary aquifer. The horizontal gradient was measured at this level to average 0.0007 south of the fill but averaged 0.003 under the landfill. This is an order of magnitude less than at the water table and indicates that treated ground water recharging the unsaturated zone dissipates within 10 vertical feet (3 meters). Mid-depth Quaternary wells include the gradient control wells. The horizontal gradient at this level reflects capture of the gradient control wells. The average horizontal gradient measured was 0.014 near GC3; this value is an order of magnitude less than what is measured at this well vertically. The horizontal gradient from the middle to northwest corner is flat with an average of 0.005. The gradient at the base of the Quaternary aquifer was an order of magnitude less than seen historically and remained very flat to no gradient with an average of 0.004. This explains why flow directions change easily with the influx of treated water. Vertical flow may be the dominant mechanism of flow near GC3 and the area east of TA-1. The area around well nest R has moderate downward flow at the water table that may be influenced by past and present discharge from the gradient control system. The horizontal hydraulic gradient in other areas of the facility are flattening out in the Quaternary aquifer and this may be due to removal of discharge so close to the facility.

The vertical hydraulic gradient may be influenced by proximity to gradient control wells and to the discharge area (see Table 5). The vertical gradients measured between the water table and the next lower level all indicate a downward gradient regardless of whether the wells are up- or downgradient of the fill area. However, the gradients measured downgradient are steeper by two orders of magnitude because they are near gradient control wells or the discharge area. There are strong vertical gradients measured at well nest V, well nest R and well nest GC3; these gradients show that vertical flow is stronger than horizontal flow and that downward movement has shifted in the aquifer to the south and southeast of the landfill. The vertical gradients measured between mid-depth and the base of the
surficial aquifer downgradient of the fill area indicated flat to very flat downward gradients with the exception of well nest V. At well nest V there is a flat upward gradient. There may be two explanations for this, this nest is close to GC5 and this nest is directly north of the discharge area. The data is not as strong as seen at the water table and is up to three orders of magnitude weaker.

The vertical gradient trends between the Quaternary aquifer and the bedrock did not match the magnitude of data historically observed. The vertical gradient near Q at the bedrock interface was downward and was higher than measured in previous years. At well nest R the vertical gradient was upward and flat. Vertical gradients at R reflect either residual influence by recharge in the former discharge area or influence from the new discharge area since the bedrock is the St. Peter and not the Prairie du Chien. The vertical gradient near BB2/BB3 at the bedrock interface was flat and downward.

Ground water quality data collected from the monitoring system at the landfill site is tabulated and presented in Table 2 and 3. The Minnesota Department of Health Environmental Laboratory analyzed the samples for inorganic, organic and perfluorochemical parameters. Graphs showing trends in water quality and ground water elevations are included in Figures 16 through 27. Ground water samples collected from monitoring wells are impacted by organic and perfluorochemical parameters (Tables 2, 6 and 8). However, there are downward trends of volatile organic compound contamination in wells I, and V. The PFC trend in well V is increasing while it is decreasing in V2. The volatile organic compound trend in V2 varies within the same order of magnitude. There are constant trends or variation within the same order of magnitude of a specific contaminant in wells 2003-B2, BB2, BB3, EE, AA and Z. The constant trends may reflect attenuation for the chlorinated compounds. There is generally an absence of VOC contamination at the Q nest but detections of PFBA vary from 0.2 to 2.4 μg/L. The trend of contamination in D1 and 2003-B3 are erratic, these trends may be due to proximity to either a gradient control well or the waste. The Quaternary well at the southern edge of the monitoring system (DD) had an increasing trend with Freon but a declining trend for PFBA and PFOA. The elevation at this well has a long term erratic trend suggesting other pressure forces may be impacting the well. The increase in Freon may suggest movement of the plume downgradient in the Quaternary aquifer.

Table 6 details drinking water standards that were exceeded in 2008. Twenty monitoring wells exceeded the standards in 2008; this is consistent with 2007 data. Vinyl chloride, trichloroethene and tetrachloroethene are the volatile organic compounds that exceed the Health Risk Limit in 2008. Vinyl chloride, trichloroethene and tetrachloroethene exceeded the standard in wells 2003-B3 and well I (only trichloroethene). The average concentration continued to drop within the same order of magnitude for trichloroethene and tetrachloroethene but increased for vinyl chloride.

Perfluorochemical compounds were detected in the ground water monitoring system during 2008 (Table 2, 8 and Figures 18 through 24 (with exceptions)). The MDH Laboratory lowered the method detection limit in September 2007. In addition the Health Risk Limits for PFOA and PFOS were lowered in September 2007 to 0.5 μg/L and 0.3 μg/L respectively. A Health Based Value of 7 μg/L was issued for PFBA in February 2008. All other PFCs have a well advisory guideline of 1 μg/L. The HRL, HBV or well advisory guideline was exceeded in 21 wells and are detailed in Table 6. The average concentration in micrograms per liter for the PFCs dropped within the same order of magnitude for instances where there was an exceedance. The exceptions were AA, EE, GC3, R1, R2, R-WT, V and V-WT. The average concentration in these wells increased within the same order of magnitude. The PFC plume appears to be stable because the concentrations are comparable to historical concentrations.

**Ground Water Remediation System Maintenance Summary**

A ground water remediation system is in operation at the Washington County Landfill that treats volatile organic compounds in the ground water. The ground water remediation system includes 3 gradient control wells. The wells are GC-1, GC3 and GC5. GC3 is used as a backup well to the other two gradient control wells. Table 7 provides pumping rates and volume pumped of the gradient control wells. In 2004, 50,208,630 gallons were pumped from GC-1 and treated by the spray irrigator.
The volume pumped from GC-1 and treated by the spray irrigator in 2005 was 32,618,680 gallons. The volume pumped from the 3 gradient control wells for 2006 was 56,891,357 gallons. The volume pumped from GC1 and GC5 in 2007 was 22,342,740 gallons. The volume pumped from GC1, GC3 and GC5 in 2008 was 24,274,745 gallons. Forty eight percent of the volume was extracted by well GC3. GC1 did not operate from July through November 2008 because of a hole in the drop pipe of the well.

**Ground Water Remediation Summary**

Gradient control of the volatile organic compound plume was accomplished with three gradient control wells in 2008. Pumping rates were lowered in order to limit the capture to the heart of the plume. Capture of volatile organic compounds was complete with the system in place (see Figures 10-13). The volume of ground water removed in 2008 was 24,274,745 gallons; this amount represents the second lowest volume extracted over the past 5 years. Using concentrations of Volatile Organic Compounds (VOCs) found in V2, it was estimated that a maximum of 17 pounds of VOCs were removed from the ground water in 2008 through the gradient control system. A historical summary is provided in Table 7. The pounds of PFCs pumped out and discharged to the ground surface in 2008 was 80; this is a reduction from 2007.

A graph of select volatile organic compounds, perfluorochemical compounds and ground water elevation in the well nest (V and V2) nearest to the gradient control well indicates several things (see Figures 26 and 27). The gradient control system is effective for the removal of the chlorinated organic compounds which show either a declining or constant trend. A graph of organic compounds at EE can be used as a measure of the behavior of wells outside of the fill area and still impacted by contamination (Figure 20). The trend at EE through 2008 has been slightly declining or constant suggesting that higher contamination is not escaping the system. The graphs of wells BB2 and DD (Figures 22 and 24) show the behavior of ground water elevations and contamination at the edge of the plume. The progression from EE to BB2 indicates that the chlorinated compounds are attenuating since the amount decreases from 7 chlorinated compounds to 1 chlorinated compound. There are no chlorinated compounds detected at DD. The plume that escaped the system in 1996 reached the outer edge of the monitoring system in 2007. This means that the empirical velocity of flow in the drift aquifer was 407 feet/year. The concentration of perfluorochemicals at well AA (Figure 25) has slightly varied over the last several years with minor changes in concentration due to fluctuating ground water. The erratic behavior of both ground water elevation and dichlorodifluoromethane at well DD may suggest that there are other impacts to this well. A recent presentation on the Platteville suggests that train traffic may influence water elevations in a well (Barr, 2009). Samples from DD were first analyzed for PFOA on April 27, 2004, at that time the method detection limit was 0.196 μg/L and the RL was 1, PFOA was detected in the well on March 15, 2006 when the method was expanded and PFBA was also detected. The trend of PFCs in the well is on a declining trend. The puzzling aspect of that trend is that PFOA should have been found the first time it was analyzed. This may support that DD is impacted by flow from the west that dilute the plume or that PFCs are not released continually from the Washington County Landfill.

Moving the discharge location has reduced the mound and shifted it southwest.

**Upgradient Study near Well I**

Water levels were tracked at 4 hour increments in 2008 in 4 upgradient monitoring wells. Ground water elevation varied by about 3 feet (1 meter) in one of the four wells and their elevations varied consistently with each other (Figure 14) and continued to drop throughout the year except for well I which increased by 2 feet after August 2008. Flow in this area is to the northeast and southeast based on these elevations. Well 2003-B3 was impacted by mounding but ground water elevation dropped throughout the year. Well 2003-B3 is the monitoring well closest to fill and the landfill (and possibly the gas extraction system) exerts pressure changes on this well. The contamination graphed in Figures 17, 18 and 19 show the relationship between the compounds detected in wells I, 2003-B3 and 2003-B2. Well I has a declining trend in both elevation and contamination. Well 2003-B2 and 2003-B3
have narrowly fluctuating trends within the same order of magnitude over a 4 year trend. In the last year, the ground water elevation has dropped and the contamination has slightly increased. Mounding may not be impacting this area and the contaminants found around the wells are not diluted. This localized scale is restricted to these three wells since wells J and 2003-B1 do not show contamination. A geoprobe study in June 2001 also indicated that the water table between wells I, 2003-B3, and 2003-B2 is separated by a lateral facies change to clay till where flow does not appear to occur.

**Videologging of Bedrock Monitoring Wells**

Video logging of bedrock monitoring wells occurred on September 4, 2008. A report of the logging and conclusions is presented in Appendix A. The next two paragraphs are conclusions and recommendations from that report.

**Discussion**

There is a distinct difference in the character of the bedrock aquifer from the west side of the landfill to the east side. Qualitative indicators, such as degree of clarity in the water column, movement of globules, and the density and type of fractures noted, can be used to infer flow. Higher flow was associated with increased clarity, downward movement of globules not associated with gravity and larger and a denser concentration of both bedding plane fractures and high angle fractures. These qualitative indicators used to presume flow should be verified by quantitative measurement of flow.

The west side appears to be characterized by lower flow and less density of fractured bedrock. In addition, the appearance of the Prairie du Chien occurs lower in elevation. The bedrock on the east side of the landfill is characterized by highly fractured bedrock that may allow higher rates of flow. The Prairie du Chien aquifer also appears to occur higher in the stratigraphic column. The competent unit on the east side may be correlated with the competent unit on the west side.

Flow was inferred on the west side of the landfill to occur at elevations ranging from 821 to 823. Flow on the east side of the landfill was inferred at elevation 834 and elevation 837 to 838. Most of the residential wells in the Hamlet on Sunfish Lake development have screened intervals that range from 820 to 855 interval and may be correlated to well R3 on the east side. Wells Q3 and BB3 on the west side of the landfill however are more easily correlated to the Prairie du Chien wells along 31st Street.

**Recommendations**

The following recommendations result from this study.

1. Quantify flow rates in the bedrock wells on site in order to gauge movement of the perfluorochemicals to the east and south.

2. Install more bedrock wells to the south and east to track perfluorochemicals moving in the aquifer. Video log each well after installation and development.

**Washington County Landfill Logging Project**

After completion of the Videologging project, the MPCA contracted with the Minnesota Geological Survey to collect data in the three bedrock wells using borehole geophysical tools. This work took place in late October 2008. Two of the three wells were also logged for flow (well Q3 and well BB3). Gamma logs revealed that well R3 was open hole at the bottom of the St. Peter formation and not the Prairie du Chien as had been previously reported. Wells Q3 and BB3 are open hole in the Shakopee member of the Prairie du Chien formation.

The hydraulic conductivity of a fracture in well Q3 at elevation 821.86 was 7000 feet per day. This correlates with fractures noted during videologging and shown in Figure 3 of the report in Appendix A. The hydraulic conductivity of a fracture in well BB3 at elevation 824.5 was 1100 feet per day (fracture opening of 0.5 feet and 10 feet radius of influence). This fracture is within 0.5 foot of a fracture noted during well installation by the loss of drilling fluid and also correlates to fractures noted in the Lake Elmo downhole logging project study. Injection of water and changes in temperature and
fluid resistivity indicated that the hydraulic conductivity of a fracture at elevation 838.91 was 6200 feet per day (fracture opening of 0.5 feet and 10 feet radius of influence) in well R3. This is within 0.7 feet of a large fracture noted during videologging (see Table 1 in the report).

Detailed information from the study may be found in Runkel et al, 2008 (see citation in Table of Contents).

**Monitoring System Modifications**

Ground water gradient control wells GC-2R and GC-4 were sealed in the fall of 2008. These wells were located in the middle of the landfill and were used to collect monthly water levels.

**Surface Water Monitoring Summary**

The pump out water from gradient control wells was discharged directly south of the flare in the borrow area depression in order to decrease the mounding of treated ground water at its former location. It appears that moving the discharge further south has had the desired effect.

NPDES monitoring still occurs to ensure that extracted ground water water meets Health Risk Limits (or in their absence MCLs or HBVs) prior to infiltration and complies with nondegradation statutes (Minn. ch. 7060). PFCs do not comply with their standards since the ground water is pumped out to strip out the volatile organic compounds.

Perfluorochemical compounds were detected in the gradient control well effluent in 2008. PFOA exceeded the Health Risk Limit in the treatment area (TA-1) and the average concentration was 14 μg/L. This concentration is consistent with what was detected in 2004-2007. It was also found 200 meters downgradient in well nest EE at an average concentration of 7.1 micrograms per liter (again consistent with the 2005-2007 data). The average concentration of PFOA farther downgradient at BB2 was 2.9 micrograms per liter. PFBA exceeded the Health Based Value in the treatment area; the average concentration was 195 μg/L; when compared to 2007 data the average decreased. PFBA was detected at well EE at a concentration of 120 μg/L. PFOS exceeded the Health Risk Limit in the treatment area; the concentration was 0.5 μg/L; when compared to the 2007 data the concentration has decreased. PFOS is not detected at well EE.

Lakes within the Special Well Construction Area were also sampled in the fall of 2008. The results are consistent with what would be expected from the two disposal sites. The concentration of PFOS, PFOA and PFBA in Eagle Point Lake was consistent with historical detections found in Raleigh Creek that are attributed to the Oakdale Disposal Site. Samples from Sunfish Lake contained only PFBA which is consistent with the PFC found in wells in the Hamlet on Sunfish Lake development. Lake Elmo samples on the southern end were consistent with Lake Elmo Park Reserve well detections and these were attributed to the Oakdale Disposal Site. Detailed results are in Table 2.

**Additional Monitoring Summary**

**Residential Well Sampling**

Residential wells were sampled during 2008 and are detailed in Table 8. The MDH Laboratory expanded its perfluorochemical method in March 2006 to analyze for 4, 5, 6 and 8 chain carboxylic acids and 4, 6 and 8 chain sulfonates and officially lowered the Reporting Limits on September 10, 2007. One hundred thirty one samples were collected from 118 stations. Five samples were collected to measure the performance of granulated activated carbon units installed at impacted residences. Thirteen quality assurances samples were also collected and analyzed. MDH issued Health Risk Limits on August 27, 2007 for PFOS and PFOA. The limits are 0.3 and 0.5 μg/L, respectively. A Health Based Value of 7 μg/L was issued for PFBA in February 2008. In January, 2009 the United States Environmental Protection Agency (EPA) set short-term provisional health advisory values for PFOA and PFOS of 0.4 and 0.2 ug/L, respectively. These values may be applied to data collected in
2009 dependent on actions taken at the Minnesota Department of Health. Eleven of the wells sampled in 2008 exceed the standards set in 2008 either individually or by a calculation of the hazard index. Other wells that have historically exceeded the standards may not have been sampled in 2008.

The results of sampling in 2008 indicated that the plume (commonly only PFBA) was in the Prairie du Chien aquifer beyond the Whistling Valley and Stonegate developments near I-94 and Lake Elmo Avenue and has not changed from a December 2007 plume map (See Figure 29). The eastern limit of the PFBA plume is found in the Sunfish on Hamlet development (within 1 mile east of the site). The highest concentration detected of PFBA was 19 \( \mu \text{g/L} \) in a private well at the east of the intersection of Hwy 5 and Jamaica Avenue. The other PFCs ranged in maximum concentration from 0.05 to 0.6 \( \mu \text{g/L} \).

**Inspections**

Inspections were conducted on a weekly basis by MPCA staff and the Operation and Maintenance (O&M) contractor hired by the MPCA.

**Required Permits**

The National Pollutant Discharge Elimination System (NPDES) permit expired in 1994 and is no longer required at the site.

The Metropolitan Council Environmental Services (MCES) discharge permit for gas condensate expires November 30, 2011.

**Conclusions and Recommendations**

The gradient control system is effective for the removal of the chlorinated organic compounds which show either a declining or constant trend. A graph of organic compounds at EE can be used as a measure of the behavior of wells outside of the fill area and still impacted by contamination. The trend at EE through 2008 has been slightly declining or constant suggesting that higher contamination is not escaping the system. The graphs of wells BB2 and DD show the behavior of ground water elevations and contamination at the edge of the plume. The progression from EE to BB2 indicates that the chlorinated compounds are attenuating since the amount decreases from 7 chlorinated compounds to 1 chlorinated compound. There are no chlorinated compounds detected at DD.

Vinyl chloride, trichloroethene and tetrachloroethene are the volatile organic compounds that exceed the Health Risk Limit in 2008 only at the northwest corner of the landfill. Vinyl chloride, trichloroethene and tetrachloroethene exceeded the standard in wells 2003-B3 and well I (only trichloroethene). The average continued to drop within the same order of magnitude for trichloroethene and tetrachloroethene but increased for vinyl chloride.

Perfluorochemical compounds were detected in the ground water monitoring system during 2008. The Health Risk Limits for PFOA and PFOS were lowered in September 2007 to 0.5 \( \mu \text{g/L} \) and 0.3 \( \mu \text{g/L} \) respectively. A Health Based Value of 7 \( \mu \text{g/L} \) was issued for PFBA in February 2008. All other PFCs have a well advisory guideline of 1 \( \mu \text{g/L} \). The HRL, HBV or well advisory guideline was exceeded in 21 wells. The average concentration in micrograms per liter for the PFCs dropped within the same order of magnitude for instances where there was an exceedance. The exceptions were AA, EE, GC3, R1, R2, R-WT, V and V-WT. The average concentration in these wells increased within the same order of magnitude. The PFC plume appears to be stable because the concentrations are comparable to historical concentrations.

Perfluorochemical compounds were detected in the gradient control well effluent in 2008. PFOA exceeded the Health Risk Limit in the treatment area (TA-1) and the average concentration was 14 \( \mu \text{g/L} \). This concentration is consistent with what was detected in 2004-2007. It was also found 200 meters downgradient in well nest EE at an average concentration of 7.1 micrograms per liter (again consistent with the 2005-2007 data). The average concentration of PFOA farther downgradient at BB2
was 2.9 micrograms per liter. PFBA exceeded the Health Based Value in the treatment area; the average concentration was 195 μg/L; when compared to 2007 data the average decreased. PFBA was detected at well EE at a concentration of 120 μg/L. PFOS exceeded the Health Risk Limit in the treatment area; the concentration was 0.5 μg/L; when compared to the 2007 data the concentration has decreased. PFOS is not detected at well EE.

One hundred thirty one samples were collected from 118 residential wells in 2008. Five samples were collected to measure the performance of granulated activated carbon units installed at impacted residences. Thirteen quality assurances samples were also collected and analyzed. MDH issued Health Risk Limits on August 27, 2007 for PFOS and PFOA. The limits are 0.3 and 0.5 μg/L, respectively. A Health Based Value of 7 μg/L was issued for PFBA in February 2008. Eleven of the wells sampled in 2008 exceed the standards set in 2008 either individually or by a calculation of the hazard index. Other wells that have historically exceeded the standards may not have been sampled in 2008.

The results of sampling in 2008 indicated that the plume (commonly only PFBA) was in the Prairie du Chien aquifer beyond the Whistling Valley and Stonegate developments near I-94 and Lake Elmo Avenue and has not changed from a December 2007 plume map. The eastern limit of the PFBA plume is found in the Sunfish on Hamlet development (within 1 mile east of the site). The highest concentration detected of PFBA was 19 μg/L in a private well east of the intersection of Hwy 5 and Jamaica Avenue. The other PFCs ranged in maximum concentration from 0.05 to 0.6 μg/L.

Two related studies were completed in September and October 2008 on the bedrock monitoring wells at the site. The studies revealed that the west side of the site appears to be characterized by lower flow and less density of fractured bedrock. The bedrock on the east side of the landfill is characterized by highly fractured bedrock that may allow higher rates of flow. Gamma logs revealed that well R3 was open hole at the bottom of the St. Peter formation and not the Prairie du Chien as had been previously reported. Wells Q3 and BB3 are open hole in the Shakopee member of the Prairie du Chien formation.

Flow was inferred on the west side of the landfill to occur at elevations ranging from 821 to 825. The hydraulic conductivity of fractures on the west side ranged from 1100 to 7000 feet per day. Flow on the east side of the landfill was inferred at elevation 834 and elevation 837 to 838 and was measured at a rate of 6200 feet per day.

The PFC plume impacting the residential wells is the result of two disposal sites: the Oakdale Disposal site and the Washington County Landfill. This report only evaluates the data collected by the MPCA Closed Landfill Program.

Data collected and studies completed in 2008 indicate that flow in the bedrock is rapid and that the contamination of the drift needs to be controlled since it is the source to the bedrock. Project staff recommends implementation of a liner system at the landfill and installation of more bedrock wells south and east of the landfill to track contamination to those aquifers and to determine flow in the bedrock from the site.

**Project Team**

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Figure 1  Gas Probe Monitoring Network around Washington County Landfill
Figure 2  Ground Water Monitoring Network around Washington County Landfill

Legend
- Wells_2007
- streets
- GC wells

4 February 2008

Minnesota Pollution Control Agency
Figure 3  Water Table flow on 28 May 2008

Legend

- WQ flow contour May 2008
- streets

10 July 2008
Contour interval is 1 meter
Horizontal Gradient varies from 0.02 to 0.005

Minnesota Pollution Control Agency
Figure 5 Water Table Flow—November 2008

Contour Interval is 0.3 meter. Horizontal hydraulic gradient is 0.005 to 0.019.

Legend
- WT_flow_contour_Nov_08
- Landfill Outline

2 February 2009
2003 Aerial Photo

Minnesota Pollution Control Agency

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Washington County Sanitary Landfill

Minnesota Pollution Control Agency
Closed Landfill Program
Figure 6  Flow in the upper Quaternary aquifer on 28 May 2008

10 July 2008
Contour Interval is 0.2 meter
Horizontal Hydraulic gradient varies from 0.0007 to 0.003

Legend
- Upper Q flow contour May 2008
- streets

Minnesota Pollution Control Agency
Figure 7: Upper Quaternary aquifer flow on 6 Aug 2008

Legend:
- Outline of Landfill
- Upper Q flow Aug 2008
- Streets

19 Sept 2008
Contour Interval is 0.2 meter
Horizontal Hydraulic Gradient varies from 0.0007 to 0.003

Minnesota Pollution Control Agency
Figure 8 Flow in the Upper Quaternary aquifer-November 2008

27 January 2009
Contour interval is 0.2 meter. Horizontal hydraulic gradient is 0.003.

Legend
- Landfill Outline
- Upper Q flow contour Nov 2008
- Streets

Minnesota Pollution Control Agency
Figure 9: Flow in the middle of the Quaternary aquifer on 28 May 2008

Legend:
- Mid Q flow contour May 2008
- streets

10 July 2008
Contour Interval is 0.5 meter
Horizontal Hydraulic Gradient vanes from 0.008-0.01

Minnesota Pollution Control Agency
Figure 10: Middle Quaternary aquifer flow on 8 Aug 2008

Legend:
- Outline of Landfill
- Mid Q flow Aug 2008
- streets

19 Sept 2006
Contour Interval is 0.5 meter
Horizontal Hydraulic Gradient varies from 0.002 to 0.02

Minnesota Pollution Control Agency
Figure 11 Middle Quaternary aquifer flow- November 2008

Legend:
- Landfill Outline
- Mid Q flow contour Nov 2008
- streets

27 January 2009
Contour Interval is 0.5 meter. Horizontal hydraulic gradient is 0.003 to 0.013.
Figure 12 Base Quaternary drift flow on 28 May 2008

10 July 2008
Contour Interval is 0.1 meter
Horizontal Hydraulic Gradient varies from 0.0006-0.0007

Legend
- Base Q May 2008 flow contour
- streets

Minnesota Pollution Control Agency
Figure 13 Base Quaternary aquifer flow on 8 Aug 2008

Legend
- Outline of Landfill
- Base Q Aug 2003 flow contour
- streets

19 Sept 2008
Contour Interval is 0.1 meter
Horizontal Hydraulic Gradient is 0.038
Figure 14 Continuous Ground Water Elevations in the Northwest Corner of Washington County Landfill (2007 through 2008)

Figure 15 Ground Water Elevation around former discharge area and at south boundary of landfill at the water table - NGVD
Figure 16 Plot of selected VOCs and ground water elevation at well D1

Figure 17 Plot of select VOCs and ground water elevation at well 2003-B2
Figure 18 Plot of VOCs, ground water elevation and PFBA in well 2003-B3

Figure 19 Plot of select VOCs detected and ground water elevation in well I
Figure 20 Plot of select VOCs, PFCs and Ground water elevation in well EE

Figure 21 Plot of contaminants detected and ground water elevation at well Z
Figure 22 Plot of contaminants detected and ground water elevation trends in well BB2

Figure 23 Plot of contaminants detected and ground water elevation at well BB3
Figure 24 Plot of contaminants detected and ground water elevation in well DD

Figure 25 Plot of contaminants detected and ground water elevation measured at well AA
Figure 26 Plot of ground water elevation and select contaminants detected at well V

Figure 27 Plot of ground water elevation and select contaminants detected in well V2
Figure 28. Daily and Monthly Precipitation around Washington County Landfill-1999 to 2008
FIGURE 29 PFBA PLUME NORTH OF I-94. MAP COURTESY OF MDH.

PFBA in the Prairie du Chien - N of I-94
December 2007

- Not detected
- 0.2 - 0.5 ppb
- 0.6 - 0.9 ppb
- 1.0 - 1.5 ppb
- 1.6 - 1.9 ppb
- > 2.0 ppb

○ Private well
△ Non-comm well
□ City well
☆ Monitoring well