Residential Well Water Samples Reviewed for Public Health Implications

GREENWOOD CHEMICAL COMPANY
NEWTOWN, VIRGINIA

Letter Health Consultation

October 31, 2017

Virginia Department of Health
Division of Environmental Epidemiology
109 Governor Street
Richmond, Virginia 23219

COMMONWEALTH of VIRGINIA

Department of Health

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October 31, 2017

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Dear Mr. Evans:

The Virginia Department of Environmental Quality (DEQ) asked the Division of Environmental Epidemiology (DEE) to review residential well water testing data from the Greenwood Chemical Company National Priority List site prior to the completion of the 2018 Five Year Review. We were asked to determine:

1. Are site-related contaminants of concern (COCs) migrating offsite and impacting surrounding residential wells?
2. If so, are the COCs detected in residential wells posing a health hazard to humans?

DEE concludes:

1. While groundwater on the eastern and southeastern property boundaries may be migrating past the property boundary, since the last time a contaminant was detected at elevated concentrations in residential wells was years ago it is unlikely site COCs are reaching residential wells.
2. The chemicals detected in residential wells (irrespective of their source) in the water testing 2013-2017 do not pose a hazard to human health.

DEE recommends:

1. Means to evaluate the hydraulic control of groundwater on the eastern and southeastern borders of the waste management area should be evaluated and implemented if feasible.
2. Means to reduce or remove residual soil contamination should be evaluated and implemented if feasible.
3. Continue encouraging the residents to participate in the voluntary monitoring of the adjacent residential drinking water wells as part of the Operation and Maintenance (O&M) plan.

BACKGROUND

Site History

The Greenwood site is located in Albemarle County, Virginia and is approximately 34 acres. A map of the site and its various buildings prior to EPA action can be found in *Appendix A: Map of site prior to EPA action*. From the 1940s to 1985 the company synthesized pharmaceutical and pesticide precursors, notably routinely using arsenic salts in chemical synthesis. The facility was closed in 1985 following a toluene vapor explosion and fire that killed four workers and destroyed the process building. Subsequent evaluation by the EPA revealed chemical contamination of the site. Chemical waste was stored in drums that were buried (400 drums) in trenches or left on the surface (100 drums), and aqueous chemical wastes were discharged through floor drains into a series of five unlined lagoons. A health assessment was carried out at the Greenwood Chemical Company site in May 1988 and the site was placed on the National Priorities List. The site underwent remediation including removal of drums and contaminated soil, demolition of buildings on site, drainage of lagoons, installation of a series of monitoring wells, and construction of an on-site water treatment facility for pump-and-treat operation to contain contaminated groundwater (see *Appendix B: Map of site following EPA action*). The on-site groundwater treatment facility has been in operation since 2001.

The EPA addressed the site in four operable units (OU):

- Operable Unit 1 (OU-1): Excavation and disposal of contaminated soils associated with lagoons and disposal areas on the site.
- Operable Unit 2 (OU-2): Recovery and treatment of contaminated ground water and lagoon water in the on-site treatment plant.
- Operable Unit 3 (OU-3): Demolition and removal of the manufacturing buildings and waste chemicals.
- Operable Unit 4 (OU-4): Designation of a waste management area for deep soil contamination sources and implementing the on-site treatment plant to restore ground water quality within the area of attainment.

The four OUs have been completed and are operational and functional. A Record of Decision was issued on September 22, 2005 establishing groundwater performance standards for the pump and treat system, defining an area of the site containing deep soil contamination as a "waste management area" ("that part of the Site which includes the former drum disposal and manufacturing areas and any residual soil contamination underlying the excavated limits of former Lagoons 4 and 5"), and implementing an improved pump and treat protocol to hydraulically contain this area.[1]

DEQ assumed responsibility for O&M of the site on March 15, 2012. After five years of O&M at the site they requested that the Agency for Toxic Substances and Disease Registry (ATSDR) review water testing data for residential wells near the Greenwood Chemical Company site and determine if there is a possible health risk. Since 2012, Environmental Alliance, Inc. has

[1] U.S. Environmental Protection Agency Region III Superfund Program. Record of Decision Operable Units 2 & 4. Greenwood Chemical Superfund Site, Newtown, Albemarle County, Virginia. September 2005.

performed the sampling for this site and samples are analyzed by Lancaster Laboratories in Lancaster, Pennsylvania.

Community Interest

In addition to DEQ's request, there is community interest in the site. DEQ received an email from a woman who formerly had lived near the site to notify them of her cancer diagnosis, which she believed to be caused by drinking contaminated well water. She expressed a concern about unknown contaminants that might not be included in the laboratory analysis. She reported many of her previous neighbors had also been diagnosed with cancer. This previous resident unfortunately had a very aggressive cancer and has since died. Her email suggests there may be a perception among the community that living near the site poses a cancer risk. A news story in the discontinued Charlottesville weekly newspaper *The Hook* in 2012 regarding the transition from EPA to DEQ responsibility quotes several residents as still having concerns about their health and the site.[2]

Documents Reviewed[3]

In preparation of this Letter Health Consultation, the health assessor reviewed the following documents:

- Health Assessment for Greenwood Chemical Company, Newtown, Virginia, May 2, 1988
- Record of Decision, Greenwood Chemical Site Declaration, Operable Unit Two (1990)
- Record of Decision, Operable Units 2 & 4, Greenwood Chemical Superfund Site (September 2005)
- Superfund Proposed Remedial Action Plan, Operable Unit Two and Four (June 2005)
- Explanation of Significant Differences, Record of Decision—Operable Units 2 & 4, Greenwood Chemical Superfund Site (July 2013)
- First Five-year Review Report for Greenwood Chemical Superfund Site
- Second Five-year Review Report for Greenwood Chemical Superfund Site
- Third Five-year Review Report for Greenwood Chemical Superfund Site
- Fourth Five-year Review Report for Greenwood Chemical Superfund Site
- Annual Operation & Maintenance (O&M) and Monitoring Report January 2012 Through December 2012
- Annual Operation & Maintenance (O&M) and Monitoring Report January 2013 Through December 2013
- Annual Operation & Maintenance (O&M) and Monitoring Report January 2014 Through December 2014
- Annual Operation & Maintenance (O&M) and Monitoring Report January 2015 Through December 2015
- 2016 Semi-Annual Operation, Maintenance, and Monitoring Report for the Greenwood Chemical Superfund Site

[2] Provence, L. (2012, October 11). Greenwood: EPA leaves Superfund site 27 years after fatal disaster. *The Hook*, issue #1141. Retrieved January 10, 2017 from http://www.readthehook.com/107511/27-years-later-greenwood-superfund-site-moves

[3] Electronic copies of documents reviewed are available upon request. Send request to toxicology@vdh.virginia.gov

- Annual Operation & Maintenance (O&M) and Monitoring Report January 2016 through December 2016
- Annual Operation & Maintenance (O&M) and Monitoring Report January 2017 Through August 2017
- Sampling and Analysis Plan Greenwood Chemical Superfund Site, March 13, 2017
- Residential well testing results for 2013-2017

Residential Water Testing Results

A map showing the site and general location of residential monitoring wells can be found in *Appendix C: Residential well distribution*. Residential well samples were collected annually 2013 through 2017 and analyzed for a variety of volatile and semivolatile organic compounds. The full list of chemical compounds analyzed in the residential wells can be found in *Appendix D: Volatile and Semivolatile Chemicals Assessed in Residential Sampling*. The chemical compound analysis includes the six COC identified at the site in 2005[4]:

- Bis(2-chloroethyl)ether
- Carbon tetrachloride
- 1,2-Dichloroethane
- Tetrachloroethylene
- Trichloroethylene
- Vinyl chloride

Since 2013 water testing has found chemical compounds at detectable concentrations in four residential wells, discounting one round of testing on March 14, 2013 that appeared to contain methylene chloride, a common laboratory contaminant (detected in all samples collected that day, including the blank). One of these detections was for one of the COCs, bis(2-chloroethyl)ether, found in RW-3 in 2013.

In most instances, chemical compounds were detected in a single well in one year and did not appear again. Residential Well 7 (RW-7) is an exception, as methyl *tert*-butyl ether was detected from 2013-2016, but was not detected in 2017.

With the exception of bromoform, individual chemical compounds have not been detected in more than one residential well. Bromoform was detected on two occasions, once in RW-2 and once in RW-3. Since each well has had a unique set of chemical compounds detected in its water, each will be listed separately in Tables 1–4 below.

DEE uses ATSDR's comparison values (CVs) to evaluate groundwater contaminant concentrations. CVs are media-specific concentrations used to identify contaminants that require additional evaluation. They are derived using standard default exposure assumptions and are not site-specific. For contaminants detected below their respective CVs, exposure is not anticipated to result in adverse health effects. Concentrations above CVs do not mean that adverse health

[4] Environmental Protection Agency. Superfund Proposed Remedial Action Plan. Greenwood Chemical Site Operable Unit Two and Four, Albemarle County, Virginia. June 2005.

effects occurred or will occur, but that further investigation is needed. Therefore, the CVs should not be used to predict the occurrence of adverse health effects.

Table 1. 2013-2017 Residential Well 1 (RW-1) trichlorobenzene

Date	***1,2,3-Trichlorobenzene (µg/L)***	***1,2,4-Trichlorobenzene (µg/L)***
3/13/2013	ND	ND
2/27/2014	ND	ND
3/31/2015	0.1*	0.3*
2/9/2016	ND	ND
2/23/2017	ND	ND
RMEG (child)**	Not determined	70

* Concentration estimated
** Reference dose media evaluation guideline (child)
ND: Not detected
µg/L: micrograms/liter

Table 2. 2013-2017 Residential Well 2 (RW-2) bromoform

Date	***Bromoform (µg/L)***
3/13/2013	0.3*
2/27/2014	ND
3/31/2015	ND
2/9/2016	ND
2/23/2017	ND
CREG**	3.1

* Concentration estimated
** Cancer risk evaluation guide
ND: Not detected
µg/L: micrograms/liter

Table 3. 2013-2017 Residential Well 7 (RW-7) methyl tert-butyl ether (MTBE)

Date	***MTBE (µg/L)***
3/13/2013	0.1*
2/27/2014	0.4*
3/31/2015	0.5
2/10/2016	0.5
2/23/2017	0.4*
EMEG (child)**	2,100

* Concentration estimated
** Environmental media evaluation guide (child)
ND: Not detected
µg/L: micrograms/liter

Residential Well 3 (RW-3) has had the greatest range of chemical compounds detected, with nine different chemicals detected, but with each detected on only a single sample collection date. The majority of these were detected from the sample obtained March 13, 2013. RW-3 is the only well to have had detectable concentrations of one of the COC, bis(2-chloroethyl)ether, and this

was detected at levels exceeding the Cancer Risk Evaluation Guideline (CREG) in 2013 and never since.

Table 4. 2013-2017 Residential Well 3 (RW-3) multiple contaminants and comparison values

	Concentration on Date (µg/L)					
Compound	*3/13/2013*	*2/27/2014*	*5/22/2015*	*2/9/2016*	*2/23/2017*	***CV***
Bis(2-chloro-ethyl) ether	**0.066**	ND	ND	ND	ND	0.022[1]
Bromoform	4.0*	ND	ND	ND	ND	3.1[1]
Bromodichloro-methane	**2.9**	ND	ND	ND	ND	0.39[1]
2-Butanone	4.0*	ND	ND	ND	ND	4,200[2]
Chloroform	7.5	ND	ND	ND	ND	70[3]
Dibromochloro-methane	**1.1**	ND	ND	ND	ND	0.29[1]
Di-n-octyl phthalate	ND	ND	ND	ND	28	2,800[4]
Cyclohexane	ND	ND	0.2*	ND	ND	None
o-Xylene	ND	ND	0.1*	ND	ND	1,400[5]

* Concentration estimated
CV: comparison value
1 Cancer risk evaluation guide
2 Chronic reference dose media evaluation guide (child)
3 Chronic environmental media evaluation guide (child)
4 Intermediate environmental media evaluation guide (child)
5 Chronic environmental media evaluation guide (child) for total xylenes
ND: Not detected
µg/L: micrograms/liter

With the exception of the detection of MTBE in RW-7, no chemical compounds were detected in any other residential wells in 2016. In 2017 di-n-octyl phthalate was detected for the first time at a low concentration in RW-3. Di-n-ocytl phthalate is commonly detected in multiple monitoring wells near the center of the site. However, it is not present at significant concentrations in peripheral wells. Migration from the site cannot be excluded, but di-n-octyl phthalate is a commonly-used plasticizer and there is a possibility this is a lab contaminant or originates from some other groundwater contamination source. The concentration found was two orders of magnitude below the CV.

Contaminants of Concern

In 2005 six COC were identified and targeted for reduction below site-specific Groundwater Performance Standards (GPSs).[5] The Groundwater Performance Standards were designed to produce cumulative cancer risk less than 1×10^{-4}, the risk level considered acceptable by EPA. These GPSs may be more stringent than the EPA maximum contaminant level (MCL) because the water contains multiple contaminants and the risk of health effects when all of these are added together may be excessive even if each chemical does not exceed the MCL typically applied to public water systems.

[5] U.S. Environmental Protection Agency Region III Superfund Program. Record of Decision, Operable Units 2 & 4. Greenwood Chemical Superfund Site, Newtown, Albemarle County, Virginia. September 2005.

The COC are listed in Table 5 below, including their GPS, CV, and CV type. The EPA MCL for tetrachloroethylene is lower than ATSDR's CREG, so the MCL is shown instead. EPA chose to use the site-specific GPS for this compound, which is lower than the MCL, due to the cumulative risk of multiple contaminants. In the event that these compounds are detected in a residential well DEE will use the CV to screen for the possibility of health effects. Only one COC, bis(2-chloroethyl)ether, has been detected in residential wells since 2013 (see Residential Water Testing Results on page 4).

Table 5. Site-specific contaminants of concern and their comparison values

Contaminant of Concern	*Groundwater Performance Standard (µg/L)*	*Comparison Value (ppb)*	*Comparison Value Type*
1,2-Dichloroethane	5.0	0.27	CREG
Bis(2-chloroethyl) ether	0.5	0.022	CREG
Carbon tetrachloride	4.0	0.36	CREG
Tetrachloroethylene	0.8	5	EPA MCL
Trichloroethylene	1.0	0.43	CREG
Vinyl chloride	0.5	0.017	CREG

µg/L: micrograms/liter
ppb: parts per billion
CREG: cancer risk evaluation guide
EPA MCL: U.S. Environmental Protection Agency maximum contaminant level

Although arsenic in soil was addressed in OU-1 and OU-4, it was not identified as a COC in the 2005 Record of Decision, which states that:

> The contaminants of concern ("COC") detected in the ground water at one or more of the wells outside the waste management area are bis(2-chloroethyl)ether (up to 1.4 ug/1), carbon tetrachloride (up to 19 ug/1), 1,2-dichloroethane (up to 20 ug/1), tetrachloroethene (up to 25 ug/1), trichloroethene (up to 120 ug/1) and vinyl chloride (up to 4.8 ug/1). In addition, arsenic was detected in one perimeter well at 6.0 ug/1.[5]

The EPA-established MCL for arsenic in drinking water is 10 µg/L, so the concentration detected was below the MCL. Arsenic was determined to not be a risk for off-site groundwater contamination and no further testing has been done.

Waste Management Area Capture Zone Analysis

The northern end of the site is approximately 1,000 feet above sea level, and slopes away in a generally southeastern direction to approximately 850 feet above sea level at the southern end of the site.[6] To the north of the site north of Interstate 64 the elevation rises rapidly to about 2,800 feet.[6]

[6] US Geological Service, The National Map topographical maps. https://viewer.nationalmap.gov:443/basic/?basemap=b1&category=ustopo&q=&zoom=16&bbox=-78.80023820,38.03715130,-78.76916749,38.04840604&preview=&avail=&refpoly=, accessed January 20, 2017.

Groundwater elevation mapping in 2016 and prior years showed consistent groundwater flow in a southeastern direction.[7,8,9] The site contains a series of groundwater recovery wells, monitoring wells (MW) and perimeter monitoring wells (PMW) that have been used to model groundwater flow direction, develop potentiometric maps, and evaluate the effectiveness of the recovery well network in establishing hydraulic containment of the waste management area (*Appendix B: Map of site following EPA action*).

The waste management area is a region in the center of the site where manufacturing and disposal was done. As part of a plan to reduce concentrations of the COCs below risk-based performance standards within 30 years, a groundwater treatment plant was installed in 2001 to collect and treat groundwater pumped from 11 recovery wells on the site. The intent is to establish hydraulic containment of the waste management area so that groundwater performance standards are achieved. Hydraulic control is demonstrated by performing an analysis which relies on the weight of evidence approach in identifying the capture zone by evaluating flow rates, water quality data, potentiometric maps, monitoring data, and analytical data that has been collected from site monitoring and recovery wells.

In 2011 the EPA determined that hydraulic containment was demonstrated along the edges of the waste management area. Stable to decreasing trends in groundwater contaminant concentration in recovery wells indicated progress toward attainment of GPSs in groundwater below the waste management area. More recently plume modeling of the COC around the waste management area found that the trichloroethylene plume extends outside the site boundaries to the east (see *Appendix E: TCE plume modeling, February 2017*). However, the nearest perimeter monitoring wells, PMW-06 and PMW-07, had trichloroethylene at an estimated concentration of 0.3 ug/L in August 2017, below both the GPS and CV.

Water Testing Results for Site Perimeter Wells Outside of the Capture Zone

The waste management area is the source of continuing groundwater contamination on the property, so hydraulically containing it should prevent further contamination of groundwater outside the waste management area. However, prior to EPA action contaminated groundwater was able to flow out of the waste management area. Environmental Alliance, Inc.'s analysis starting in 2012 shows groundwater may be migrating off the property on the southeastern border, which is a potential concern if chemicals are present in the water at high enough concentrations.

Monitoring of perimeter wells outside the waste management area on the southern border of the site has found several contaminants at low concentrations. Water testing results for these wells for the COC and other contaminants are given in *Appendix F: Site perimeter groundwater monitoring well detections outside the capture zone, 2012 through 2016*. While some of these wells contain chemicals at concentrations exceeding their CVs, these wells are not used for

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[7] Environmental Protection Agency, Region III. Fourth Five-Year Review for Greenwood Chemical Superfund Site. September 9, 2013.
[8] Environmental Alliance, Inc. Semi-Annual Operation, Maintenance, and Monitoring Report. Period of January – June 2016. Greenwood Chemical Superfund Site, Operable Unit 2 (OU-2). August 24, 2016.
[9] Environmental Alliance, Inc. Annual Operation & Maintenance (O&M) and Monitoring Report January 2015 through December 2015 Greenwood Chemical Company Superfund Site. March 14, 2016.

drinking water, and these chemicals are not a potential hazard if diluted sufficiently prior to reaching residential wells.

Analysis of monitoring well water is limited to the chemicals found in Table 6 below. All of these organic compounds are included on the residential well testing.

Table 6. Monitoring well analytes

Volatile Organic Compounds	***Semi-volatile Organic Compounds***
1,2-Dichlorobenzene	Bis(2-chloroethyl) ether
1,2-Dichloroethane	Bis(2-ethylhexyl)phthalate
Benzene	Naphthalene
Carbon tetrachloride	
Chlorobenzene	
Chloroform	
Methylene chloride	
Tetrachloroethylene	
Toluene	
Trichloroethylene	
Vinyl chloride	

DISCUSSION

Implications for Contamination of Residential Wells

RW-7 has consistently shown detectable concentrations of methyl *tert*-butyl ether (MTBE). This well is located to the west of the site. While groundwater generally flows in a southeastern direction, the elevation and groundwater elevation mapping suggest it is possible that some groundwater could migrate from the northern end of the site and reach this well. A review of the site map (*Appendix A: Map of site prior to EPA action*) shows a warehouse ("Northern Warehouse") was located northwest of Monitoring Well 17D (MW-17D), and contamination resulting from this building could hypothetically appear in the water from this monitoring well. We were unable to determine whether groundwater in this location on the site was contaminated with MTBE since that chemical was not included in monitoring well testing, so off-site migration of MTBE to RW-7 cannot be ruled out. However, MTBE is a common groundwater contaminant due to the previous widespread use of MTBE in gasoline as an anti-knock agent, so the source could alternatively be a past off-site gasoline spill.

RW-3 had detectable concentrations of six contaminants in 2013, including one, bis(chloroethyl) ether (BCEE) that exceeded the ATSDR CREG. BCEE is a COC and has been detected in multiple monitoring wells, including perimeter wells in 2015. The distance between the site and RW-3 and its location southwest of the site (while groundwater flows southeast) suggests that the site is not the source of these contaminants. However, estimates of groundwater flow depend upon assumptions made regarding the underlying bedrock that may not hold true. We can neither rule out nor confirm the site as the source for contamination in RW-3 in 2013.

Bromodichloromethane and dibromochloromethane found in RW-3 can be byproducts of water chlorination and may have resulted from well disinfection. However, these chemicals are also

used in chemical syntheses. No sampling data is available from on-site wells for these chemicals so their presence on-site is unknown.

Health Hazards

Prior to evaluating a health hazard, we must establish that an exposure pathway of sufficient level and duration exists or existed.

A complete pathway requires the following five elements:

- **A source of exposure:** contaminated soil and groundwater on the site
- **An environmental transport medium:** contaminated groundwater flowing offsite
- **A route of exposure:** ingestion of well water
- **A point of exposure:** contaminated private well
- **A receptor population:** residents in surrounding homes

A pathway is *complete* if all components are currently present, are known to have been present in the past, or will be present in the future. A pathway is *potential* if any of the components are unknown but could be possible. A pathway is *eliminated* if any of the components are absent or removed.

There is a complete pathway for exposure to contaminants from Greenwood Chemicals. The groundwater elevation mapping in the 2012 through 2016 annual reports show groundwater migrates offsite on the southern border. It is unknown whether groundwater migrated in the same manner in previous years, though DEE considers this likely. Additionally, capture zone analysis shows a trichloroethylene plume that extends to the east off of the property, showing the waste management area is not completely hydraulically contained. Since the pathway is complete we evaluated the residential well testing data and used CVs to determine if there was a potential health risk from drinking the well water.

The only residential well with testing results suggesting the possibility of harm from drinking the water is RW-3. In 2013 three contaminants, bis(2-chloroethyl) ether, bromodichloromethane, and dibromochloromethane, were present at concentrations exceeding the CV. However, these chemicals were not detected at elevated levels in any year since. Drinking water from this well does not currently pose a health hazard.

LIMITATIONS

Monitoring wells were tested for a site-specific list of organic compounds, and residential wells were tested for these and a variety of other organic compounds. We cannot rule out the possibility for unlisted chemicals migrating from the site. Hydraulic containment may be impaired by rock features that we are unaware of, such as fissuring, which could allow water to sink deeper into the ground and migrate offsite. Changes in water table elevation and events such as earthquakes could possibly reduce hydraulic containment in the future. Since there are many emerging contaminants of concern that currently are not regulated, it is possible some of these emerging contaminants are present in groundwater.

CONCLUSIONS

Groundwater elevation mapping and peripheral monitoring well testing results suggest the site may not be hydraulically contained, but residential well testing has consistently shown there is no contamination at levels of concern for health. The most recent residential well testing found a single contaminant, 2-n-octyl phthalate, for the first time in RW-3. A variety of contaminants have been detected in RW-3 for single instances, but the last time any contaminants were detected above their CV was in 2013.

DEE concludes:

1. While groundwater on the eastern and southeastern property boundaries may be migrating past the property boundary, since the last time a contaminant was detected at elevated concentrations in residential wells was years ago it is unlikely site COC are reaching residential wells.
2. The chemicals detected in residential wells (irrespective of their source) in the water testing 2013-2017 do not pose a hazard to human health.

RECOMMENDATIONS

DEE recommends:

1. Means to evaluate the hydraulic control of groundwater on the eastern and southeastern borders of the waste management area should be evaluated and implemented if feasible.
2. Means to reduce or remove residual soil contamination should be evaluated and implemented if feasible.
3. Continue encouraging the residents to participate in the voluntary monitoring of the adjacent residential drinking water wells as part of the Operation and Maintenance (O&M) plan.

Authors

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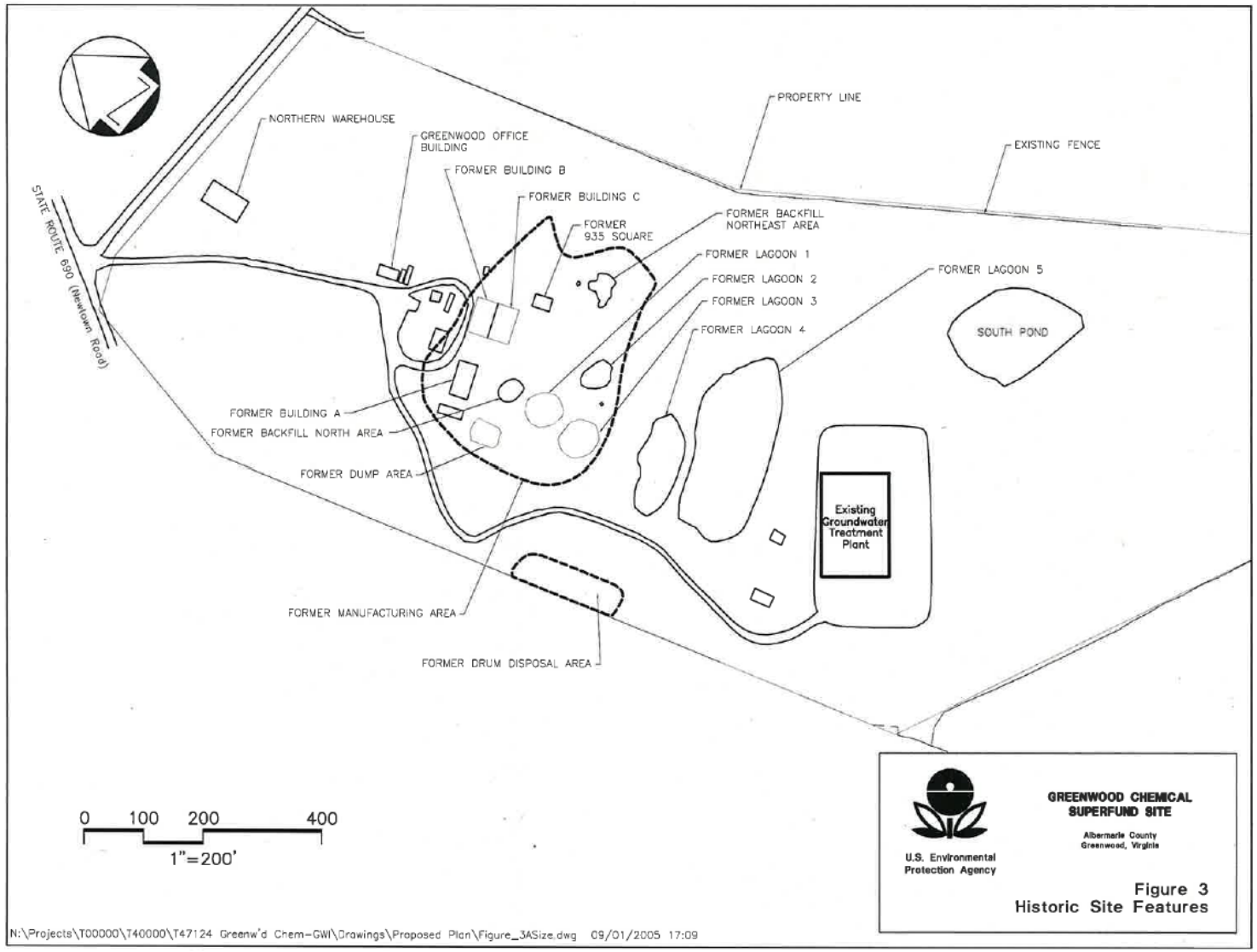
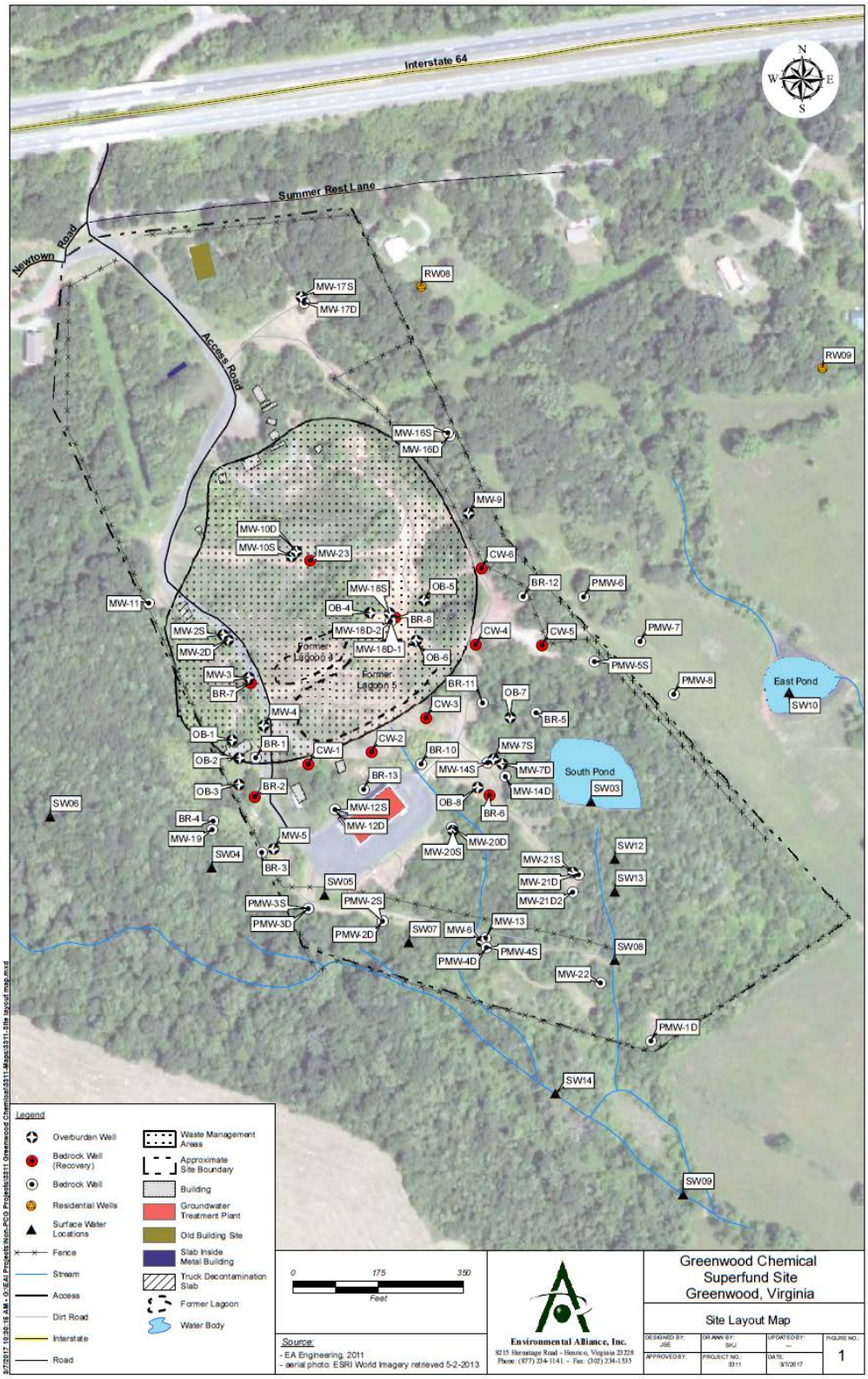
APPENDIX A: MAP OF SITE PRIOR TO EPA ACTION



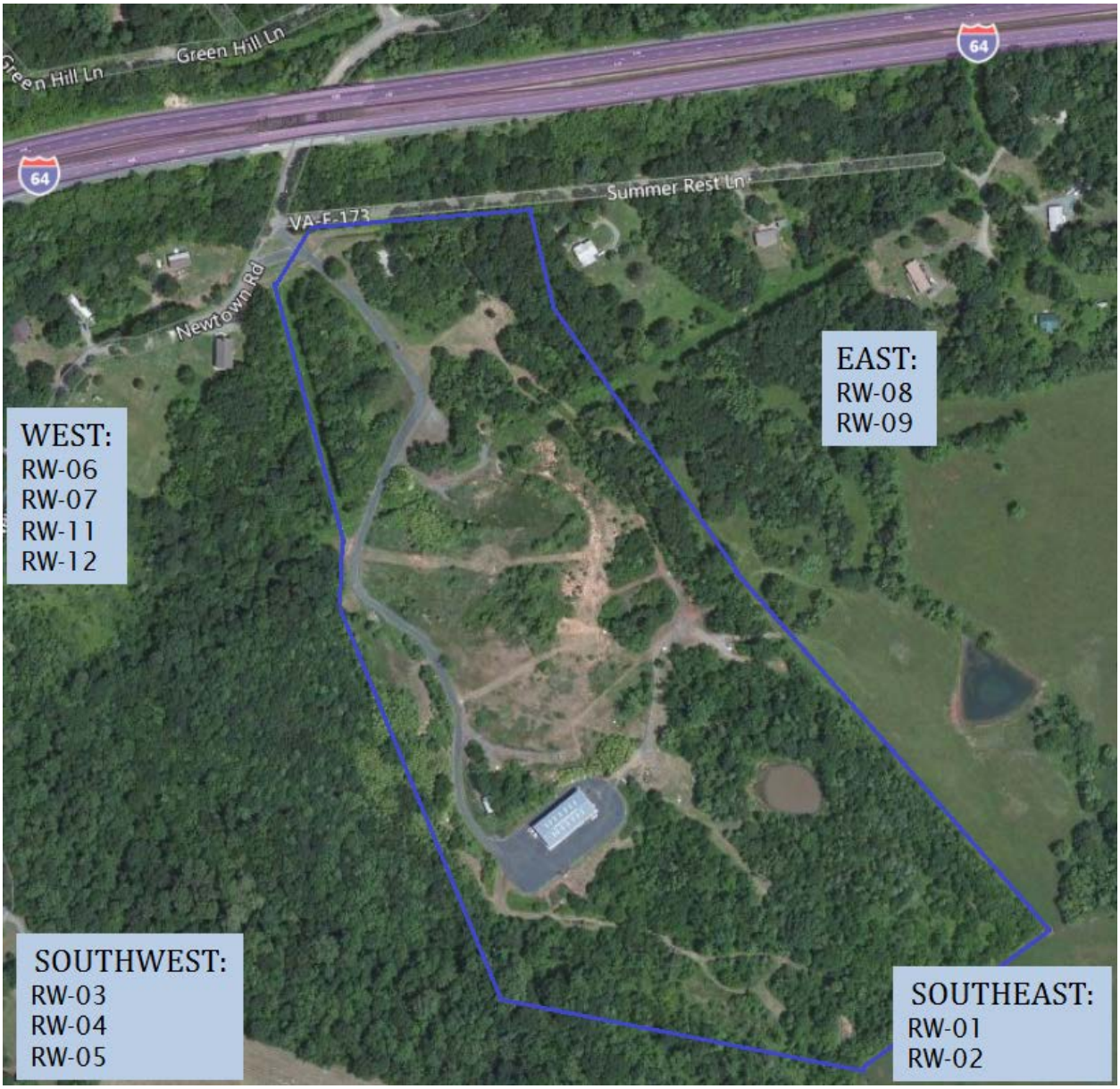
Source: Fourth Five-year Review Report for Greenwood Chemical Superfund Site.

APPENDIX B: MAP OF SITE FOLLOWING EPA ACTION



Source: Annual Operation & Maintenance (O&M) and Monitoring Report January 2016 through December 2016.

APPENDIX C: RESIDENTIAL WELL DISTRIBUTION



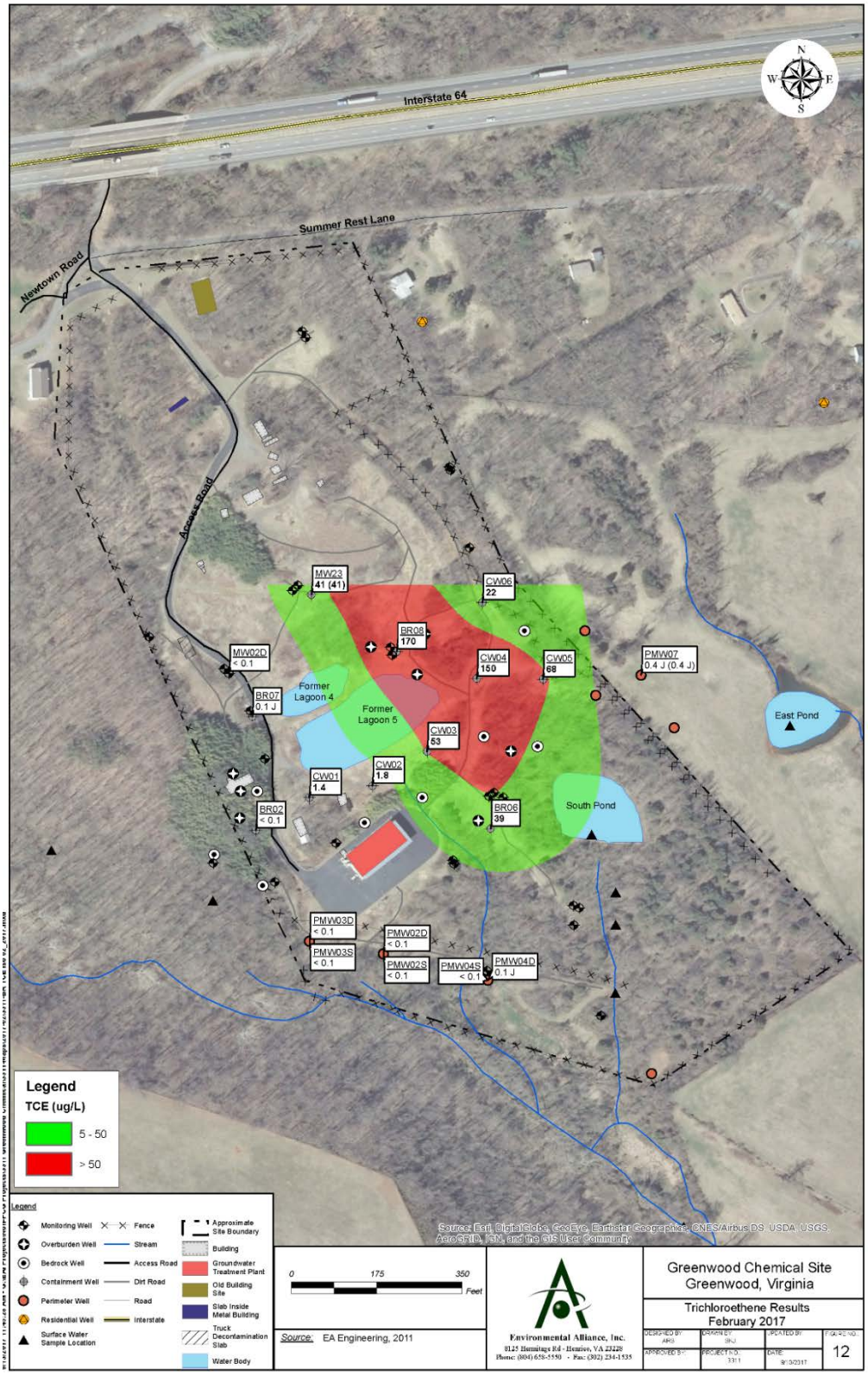
Source: www.mapquest.com, accessed January 19, 2017.

APPENDIX D: VOLATILE AND SEMIVOLATILE CHEMICALS ASSESSED IN RESIDENTIAL SAMPLING

Acenaphthene
Acenaphthylene
Acetone
Acetophenone
Anthracene
Atrazine
Benzaldehyde
Benzene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
1,1'-Biphenyl
Bis(2-chloroethoxy)methane
Bis(2-chloroethyl)ether
Bis(2-ethylhexyl)phthalate
Bromochloromethane
Bromodichloromethane
Bromoform
Bromomethane
4-Bromophenyl-phenylether
2-Butanone
Butylbenzylphthalate
Caprolactam
Carbazole
Carbon disulfide
Carbon tetrachloride
4-Chloroaniline
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
4-Chloro-3-methylphenol
2-Chloronaphthalene
2-Chlorophenol
4-Chlorophenyl-phenylether
Chrysene
Cyclohexane
Dibenz(a,h)anthracene
Dibenzofuran
1,2-Dibromo-3-chloropropane
Dibromochloromethane
1,2-Dibromoethane
Di-n-butylphthalate
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
3,3'-Dichlorobenzidine
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
2,4-Dichlorophenol
1,2-Dichloropropane
cis-1,3-Dichloropropene
trans-1,3-Dichloropropene
Diethylphthalate
2,4-Dimethylphenol
Dimethylphthalate
4,6-Dinitro-2-methylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Di-n-octylphthalate
Ethylbenzene
Fluoranthene
Fluorene
Freon
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
2-Hexanone
Indeno(1,2,3-cd)pyrene
Isophorone
Isopropylbenzene
Methyl acetate
Methyl *tert*-butyl ether
4-Methyl-2-pentanone
Methylcyclohexane
Methylene chloride
2-Methylnaphthalene
2-Methylphenol
4-Methylphenol
Naphthalene
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
Nitrobenzene
2-Nitrophenol
4-Nitrophenol
N-Nitroso-di-n-propylamine
N-Nitrosodiphenylamine
2,2'-Oxybis(1-chloropropane)
Pentachlorophenol
Phenanthrene
Phenol
Pyrene
Styrene
1,2,4,5-Tetrachlorobenzene
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
2,3,4,6-Tetrachlorophenol
Toluene
1,2,3-Trichlorobenzene
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichlorofluoromethane
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
Vinyl chloride
m+*p*-Xylene
o-Xylene

Compounds in **bold** are included on the list of COCs.

APPENDIX E: TCE PLUME MODELING, FEBRUARY 2017



Source: Annual Operation & Maintenance (O&M) and Monitoring Report January 2017 through August 2017.

APPENDIX F: SITE PERIMETER GROUNDWATER MONITORING WELL DETECTIONS OUTSIDE THE CAPTURE ZONE, 2012 THROUGH 2016*

Monitoring Wells 13, 21D, and 21D2

	Concentration (µg/L)																
	MW-13					MW-21D					MW-21D2						
Contaminant	**2012**	**2013**	**2014**	**2015**	**2016**	**2012**	**2013**	**2014**	**2015**	**2016**	**2012**	**2013**	**2014**	**2015**	**2016**	**CREG**	**GPS†**
Benzene	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.44	ND
Carbon tetrachloride	<0.1	<0.1	<0.1	<0.1	<0.1	*0.2*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.35	4.0
Chloro-benzene	*0.35*	*0.3*	*0.3*	*0.3*	*0.2*	*0.44*	*0.5*	*0.4*	<0.1	*0.3*	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
Chloroform	<0.1	<0.1	<0.1	<0.1	<0.1	*0.3*	*0.1*	*0.1*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
1,2-Dichloro-benzene	*0.47*	*0.4*	*0.4*	*0.3*	*0.2*	*0.29*	*0.1*	*0.1*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
1,2-Dichloro-ethane	*0.1*	*0.1*	*0.2*	*0.2*	*0.1*	*0.32*	*0.4*	*0.3*	*0.2*	*0.2*	<0.1	<0.1	<0.1	<0.1	<0.1	0.27	5.0
Methylene chloride	0.37‡	<0.2	<0.2	<0.2	<0.2	0.23‡	<0.2	<0.2	<0.2	<0.2	0.26‡	<0.2	<0.2	<0.2	<0.2	6.1	ND
Tetrachloro-ethylene	*0.4*	*0.3*	*0.4*	*0.3*	*0.1*	0.63‡	*0.3*	*0.3*	*0.2*	*0.3*	<0.1	<0.1	<0.1	<0.1	<0.1	12	0.8
Toluene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.1*	<0.1	<0.1	<0.1	<0.1		ND
Trichloro-ethylene	**1.4**	**1.5**	**1.5**	**1.1**	**0.9**	**1.3**	**1.6**	**1.6**	**0.9**	**1.1**	<0.1	<0.1	<0.1	<0.1	<0.1	0.43	1.0
Vinyl chloride	***0.2***	***0.2***	***0.1***	***0.1***	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0086	0.5
Bis(2-chloro-ethyl) ether	**0.067**	**0.057**	**0.071**	**0.057**	<0.01	**0.13**	**0.26**	**0.17**	**0.21**	**0.18**	*0.039*	<0.01	<0.01	<0.01	<0.01	0.022	0.5
Bis(2-ethyl-hexyl phthalate	<2	<2	<2	*3*	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	1.7	ND
Naphthalene	0.7	<0.1	<0.1	<0.1	*0.2*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND

* When multiple measurements are available for a year, the highest detectable is given.
† Groundwater Performance Standard (risk-based site-specific standard).
‡ Not detected substantially above the level reported for field blanks.
Concentration estimated for values in italics.
Results in bold font exceed the CREG.
Shaded columns are 2016 results.
All values were below non-cancer health effects CVs.

Monitoring Well 22 and Perimeter Monitoring Wells 1D and 4D

	Concentration (µg/L)																
	MW-22					**PMW-1D**					**PMW-4D**						
Contaminant	**2012**	**2013**	**2014**	**2015**	**2016**	**2012**	**2013**	**2014**	**2015**	**2016**	**2012**	**2013**	**2014**	**2015**	**2016**	**CREG**	**GPS†**
Benzene	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	<0.1	<0.1	<0.1	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	0.44	ND
Carbon tetrachloride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.35	4.0
Chloro-benzene	0.7	1.7	*0.5*	0.5	0.7	0.52	<0.1	*0.1*	*0.3*	*0.4*	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
Chloroform	<0.1	<0.1	<0.1	<0.1	<0.1	*0.1*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
1,2-Dichloro-benzene	*0.23*	*0.4*	*0.2*	*0.2*	*0.2*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
1,2-Dichloro-ethane	**0.8**	**1.7**	***0.5***	*0.1*	**0.7**	**3.20**	0.2	**1.5**	*0.2*	**1.3**	*0.3*	*0.2*	*0.2*	*0.1*	<0.1	0.27	5.0
Methylene chloride	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	6.1	ND
Tetrachloro-ethylene	**0.9**	0.7	0.6	*0.2*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.3*	<0.1	<0.1	*0.1*	*0.1*	12	0.8
Toluene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.3*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND
Trichloro-ethylene	**2**	**2.3**	**0.9**	**0.6**	*0.1*	***0.5***	*0.3*	*0.2*	*0.1*	*0.1*	*0.5*	*0.4*	*0.4*	*0.2*	*0.3*	0.43	1.0
Vinyl chloride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.2*	<0.1	<0.1	<0.1	<0.1	0.0086	0.5
Bis(2-chloro-ethyl) ether	***0.03***	**0.7**	**0.17**	**0.15**	**0.22**	**0.96**	**0.16**	***0.6***	***0.043***	**0.56**	**0.063**	***0.049***	<0.5	***0.044***	***0.049***	0.022	0.5
Bis(2-ethyl-hexyl phthalate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	1.7	ND
Naphthalene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	—	ND

* When multiple measurements are available for a year, the highest detectable is given.
† Groundwater Performance Standard (risk-based site-specific standard).
‡ Not detected substantially above the level reported for field blanks.
Concentration estimated for values in italics.
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