Health Consultation

Public Health Evaluation of Environmental Data (Air, Groundwater, and Surface Water)
Collected in the Vicinity of the Carter Impoundment

Mt. Pleasant Township, Washington County, Pennsylvania

JULY 30, 2015

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: http://www.atsdr.cdc.gov

HEALTH CONSULTATION

Public Health Evaluation of Environmental Data (Air, Groundwater, and Surface Water) Collected in the Vicinity of the Carter Impoundment

Mt. Pleasant Township, Washington County, Pennsylvania

Prepared By:

Eastern Branch
Division of Community Health Investigations
Agency for Toxic Substances and Disease Registry

Summary

Introduction

The goal of the Agency for Toxic Substances and Disease Registry (ATSDR) is to work with communities to prevent toxic chemical exposures. ATSDR does this by investigating chemical exposures, recommending actions to protect people, educating the public, and conducting research to protect public health. The Carter Impoundment is a manmade 13.5 million gallon-capacity pond for holding and recycling flowback fluids from hydraulic fracturing operations in the area. There are other natural gas related operations in the area including the MarkWest cryogenic gas plant, gas production wells, condensate tanks, natural gas collection lines, glycol dehydrators, pig launchers, compressor stations and associated truck traffic. Several homes are within a quarter mile of the impoundment, with the nearest home less than 800 feet away. Nearby homeowners petitioned ATSDR to evaluate whether exposure to chemicals detected in the air, groundwater and surface water could affect their health. Residents are concerned about potential exposures to contaminants in both air and water.

The purpose of this health consultation is to evaluate the available environmental sampling data to determine if harmful exposures are occurring. If data are not sufficient, ATSDR recommends additional environmental sampling to fill data gaps. The site is located in an agriculturally zoned area where other industrial activities (beyond upstream natural gas operations) were not observed during an ATSDR site visit in May 2013.

Conclusions

ATSDR reached four important conclusions in this health consultation:

Conclusion 1

Not enough data are available to determine whether breathing contaminants in air in the area around the Carter Impoundment could harm nearby residents' health.

Basis for Conclusion

Available air sampling was limited in location, duration and frequency and was not collected during odor events. Also, the laboratory analytical techniques used did not test for several substances reasonably expected to be present (either used in the hydraulic fracturing water or known to be associated with wastewater impoundments). While the air sampling data are limited, the chemicals detected were generally below the levels that would be expected to harm health.

Next Steps

More representative air sampling could help ATSDR make firmer conclusions about the community public health impacts of the impoundment. We recommend air sampling:

- include offsite sampling collected both specifically during an odor event and collected over time to characterize typical impoundment operations (covering different seasons, scheduled releases, and maintenance activities); and
- be collected and analyzed for a wide range of compounds, for example aldehydes, carbonyls, and other volatile substances involved in the extraction, processing, and transport of natural gas, as well as low molecular weight sulfur compounds known to be released from wastewater impoundments.

Conclusion 2	**Chemicals found in drinking water samples collected in 2011 and 2012 from two private wells and one spring near the Carter Impoundment are generally below the levels that would be expected to harm health. More recent sampling data would be needed to evaluate current exposures to groundwater in the area.**
Basis for Conclusion	Private water sampling results represented general water quality and other parameters that could be potentially affected by the impoundment, though they were limited in location and number of samples. Of three private drinking water sources with data available, one had high concentrations of manganese detected (not seen in the baseline water samples collected before the use of the impoundment). However, this water was treated before use and the home is now connected to a public water source for drinking water. Available well or spring water data from the other two private sources did not show any levels above health-based screening values.
Next Steps	As a prudent public health measure, ATSDR recommends that all homeowners who use water from private wells, and in particular those in areas near gas drilling activity, have their wells routinely tested. The Penn State Extension Program provides low cost well testing and offers a specific gas/oil water testing package. Please see page 13 of this report for links to further information on the private water well testing program and specific analytes appropriate to include in drinking water testing in the area.
Conclusion 3	**Chemicals found in surface water near the Carter Impoundment are not expected to harm people's health. More recent sampling data would be needed to evaluate current exposures to surface water in the area.**
Basis for Conclusion	The intermittent creek that flows off the Carter Impoundment property onto a residential property is not used for drinking water. Two samples from the creek did not show any chemicals detected at levels above screening values for drinking water.

Next Steps	The reported levels of chemicals in surface water do not require a response. However, the limited number and locations of the sampling add uncertainty regarding current exposures and new industry infrastructure in the area may have changed surface water quality and flow patterns.
Conclusion 4	**Not enough water sampling data are available to determine whether drinking private well or spring water, or coming in contact with surface water, in the future will harm people's health.**
Basis for Conclusion	Sampling data on private water sources and surface water included only a few locations and time points. The impacts of impoundment operations on local groundwater and surface water quality have not been adequately characterized.
Next Steps	ATSDR recommends that regulatory authorities consider additional monitoring of groundwater and surface water around the impoundment.
For More Information	For further information about this health consultation, please call ATSDR at 1-800-CDC-INFO and ask for information about the "Carter Impoundment Site". If you have concerns about your health, contact your health care provider.

Background and Statement of Issues

The Carter Impoundment is a 13.5 million gallon-capacity water impoundment constructed in late 2009 and completed in January 2010. The impoundment holds water for use in hydraulic fracturing and serves as a collection and recycling point for flowback water from several area gas wells. Flowback water is water containing hydraulic fracturing chemicals, salts, and other minerals that returns through the well from underground formations after hydraulic fracturing. Several residential properties are located adjacent to and very near the impoundment property and associated wells, with homes less than 800 feet from the impoundment. Residents are concerned about health impacts of releases of chemicals from the operations into the environment.

The Agency for Toxic Substances and Disease Registry (ATSDR) evaluates and makes recommendations to prevent community exposures to hazardous substances in the environment. In March 2013, a group of residents near the Carter Impoundment petitioned ATSDR to evaluate whether exposures to chemicals in air or water from the impoundment or associated operations could affect the health of people living nearby.

ATSDR determined that the available air sampling data are not sufficient to fully evaluate exposures to chemicals potentially released into the air by the impoundment. This is because only a few ambient air samples were collected, the samples were not collected during odor events reported by residents, and collection and analysis of the samples did not include the full range of chemicals that might be released by this type of facility. In this document, ATSDR evaluates the compounds that were assessed in the limited air sampling data to determine whether people could be harmed by breathing those chemicals.[1] Also, ATSDR describes the type of air sampling data that would better represent exposures of potential concern, allowing residents' health concerns to be more fully evaluated.

ATSDR examined sampling data on private wells and springs used by nearby residents. The quantity of samples and number of sampling locations were limited, but the analytical results sufficiently reflect water quality parameters that could potentially be affected by natural gas operations (including hydraulic fracturing and wastewater impoundments). Results for one of the private wells had results for a wider range of potentially affected parameters.[2] In this document, ATSDR evaluates the results of private water and surface water sampling to determine whether people were or are being exposed to harmful levels of chemicals through water.

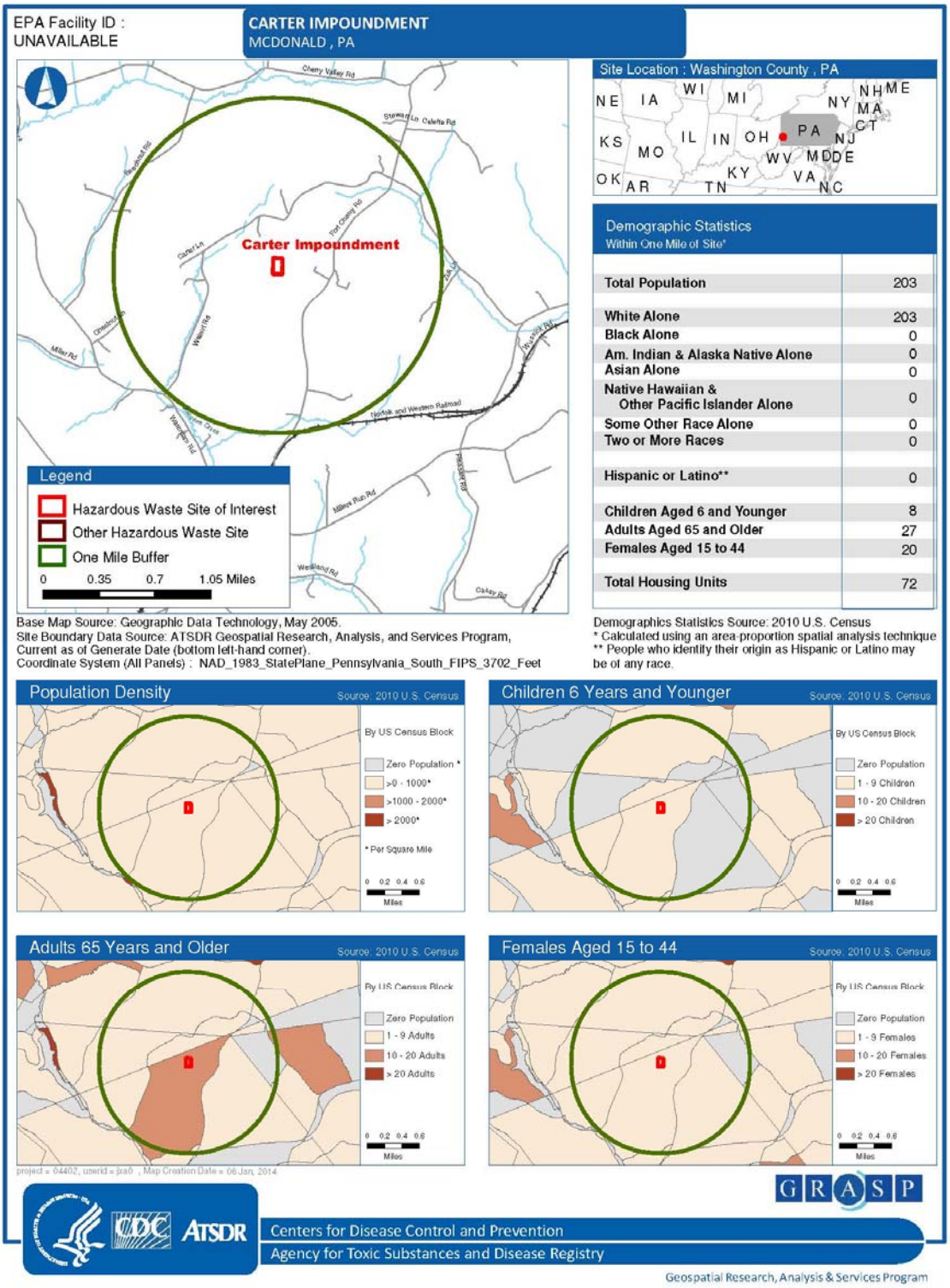
ATSDR's evaluation is based on the limited environmental sampling data that were available as of October 2013. Conclusions could change if new information becomes available in the future.

Description of the Site

Figure 1 shows the general location of the site and information about the demographic makeup of the surrounding population. The Carter Impoundment is in rural southwestern Pennsylvania, between Fort Cherry Road and Walnut Road southwest of McDonald, Washington County, PA.

[1] Appendix A includes the evaluation of exposure to the compounds detected in the limited air sampling.
[2] Appendix B details sampling and analytical parameters in the available private well and spring sampling.

Figure 1. Location and Demographic Information for the Carter Impoundment, McDonald, PA



The area surrounding the site is rural, with just over 200 people living within a one-mile radius from the site. The population includes groups potentially more sensitive to environmental contaminant exposures, including children, women of childbearing age, and the elderly.

This area is under the jurisdiction of Mount Pleasant Township in Washington County. The impoundment was constructed beginning in 2009 to serve at least partially as freshwater[3] storage for use in hydraulic fracturing of Marcellus Shale at two locations, the Drummond Well Pad and Cowden Wolfe Well Pad. These wells were completed in late 2011 or early 2012, but the impoundment continues to be used as a centralized treatment and recycling impoundment for flowback water from many other gas wells in the surrounding area. In 2013, the operator drained the impoundment for maintenance and repair of the material lining the basin. The drained water was taken to other impoundments. No groundwater monitoring wells or secondary liner are in place at this impoundment. The impoundment is still operating as of May 2015.

Community Concerns

Nearby residents have reported intermittent, but strong and irritating, odors during both normal operation and draining of the impoundment. The odors were reported to occur more often at night (between about 9:00 pm and 7:30 am) and were reported to be so strong that residents were unable to spend time outdoors during the events. Residents are concerned about chemical exposures from breathing air near the impoundment during odor events and at other times.

Nearby residents are also concerned about potential contamination from the impoundment affecting private wells or springs used for drinking water. Limited data are available on private water quality before and after construction of the impoundment. In 2012, several homes along Fort Cherry Road near the impoundment were connected to municipal water by the impoundment operator. Other homes in the same area continue to use private wells and springs for drinking water and other uses.

In addition to chemical exposure concerns, residents are concerned about noise and nuisance issues related to the large number of trucks entering and exiting the impoundment property and permitting issues related to the operation of the impoundment.

Mount Pleasant Township supervisors and a State representative sent emails supporting ATSDR's acceptance of the petition and evaluation of air and water data. The Township Zoning Board has conducted and continues to conduct appeal hearings (as of October 2013) regarding the Board's June 13, 2012, ruling that continued operation of the impoundment violates zoning ordinances.

Exposure Pathways and ATSDR's Evaluation Process

ATSDR evaluates whether people may have come into contact with chemicals from a site by examining *exposure pathways*. Exposure pathways consist of five elements: a contamination *source*; *transport* of the contaminant through an environmental medium like air, soil, or water; an *exposure point* where people can come in contact with the contaminant; an *exposure route* whereby the contaminant can be taken into the body; and an *exposed population* of people actually coming in contact with site contaminants [1].

[3] Freshwater in hydraulic fracturing generally refers to water with low dissolved solids content (less than 10,000 milligrams per liter), as opposed to flowback water which contains higher dissolved solids.

Completed exposure pathways are those for which all five pathway elements are evident. If one or more elements is missing or has been stopped (for example, by preventing transport of the chemical from the source to the exposure point), the pathway is *incomplete*. Exposure cannot occur for incomplete exposure pathways. For *potential* exposure pathways, exposure appears possible, but one or more of the elements is not clearly defined.

The air, drinking water, and surface water pathways near Carter Impoundment evaluated in this document are considered potential exposure pathways. This is primarily because the exact releases from the impoundment (the source) and transport through the environment have not been well characterized. People living in nearby homes could be exposed to contaminants by breathing air, drinking from wells, or contacting surface water affected by the impoundment operations. The drinking water pathway is eliminated for those homes that have been connected to the municipal system and are no longer using groundwater or spring water for drinking or other purposes that may bring residents in contact with the water or contaminating chemicals released into the air.

A completed exposure pathway does not necessarily mean that harmful health effects will occur. A chemical's ability to harm health depends on many factors, including how much of the chemical is present, how long and how often a person is exposed to the chemical, and how toxic the chemical is. Further evaluation of the specific exposure occurring is needed to determine whether the exposure could cause harmful effects.

The process by which ATSDR evaluates the potential for adverse health effects to result from exposure to contaminants is described briefly below, focusing on the air and water pathways of concern to the community around Carter Impoundment.

- ATSDR first screens air or water sampling results against chemical-specific comparison values (CVs). CVs are concentrations of chemicals in air or drinking water below which no harmful health effects are expected to occur, even with continual exposure. If a chemical is present at a level higher than the corresponding CV, it does not mean that harmful health effects will occur, but the chemical is evaluated further. CVs may include values derived by ATSDR and values developed by other state, federal, or international organizations.
- For chemicals in air that exceed CVs, ATSDR compares the air concentrations with known health effect levels identified in ATSDR's toxicological profiles, The U.S. Environmental Protection Agency's (EPA's) Integrated Risk Information System, or other scientific literature. For cancer-causing substances, an estimate of the increased risk of developing cancer from the exposure is calculated by multiplying the air concentration by an appropriate inhalation unit risk.
- For chemicals in drinking water that exceed CVs, ATSDR calculates exposure doses—estimated amounts of a chemical that people could take up into their bodies, on an equivalent body weight basis. The estimated dose is compared to a corresponding health guideline representing a dose below which no harmful non-cancer health effects would be expected. The potential for doses that exceed health guidelines to cause harmful effects is determined by comparing the dose to known health effect levels identified in ATSDR's toxicological profiles, EPA's Integrated Risk Information System, or other scientific literature. For cancer-causing substances, an estimate of

the increased risk of developing cancer from the exposure is calculated by multiplying the dose by an appropriate cancer slope factor.

Air Sampling Data Evaluation

Residents provided ATSDR with limited air sampling data collected by the residents near the Carter Impoundment. The samples were collected in certified clean SUMMA canisters and analyzed by nationally certified laboratories. Sampling equipment, coordination, and analysis was sponsored by a non-profit advocacy group. ATSDR reviewed these sampling results. Although the data were collected and analyzed using standard methods, they don't provide all the information ATSDR would need to fully evaluate nearby residents' exposures to air contaminants from the impoundment. Details of our assessment of the sampling data are listed below.

- Five air samples were collected in 2012 and 2013. Three were collected in afternoon hours during the spring or fall, and two were collected before dawn during the winter. These limited samples could easily have missed odor events described by residents as intermittent and strongest during nighttime hours.
- Evidence for possible higher levels of chemicals during odor events includes data from a resident-owned photoionization detector (PID), which showed intermittent detections of volatile organic compounds up to 600 parts per billion during a 4-day period in March 2011. This is much higher than any detections in the air sampling data provided, and certain compounds could be of health concern at concentrations below levels monitored with a PID.
- Only two of the air sample results packages included quality assurance/ quality control (QA/QC) information and chain of custody forms. Results summaries alone were available for the other three samples. The available air samples were analyzed for volatile organic compounds and (in one sample) methane. Although no serious QA/QC problems were identified with the provided information, ATSDR could not assess the quality of all of the data. Also, the methods selected do not assess several chemicals that could be a source of exposures of health concern, such as low molecular weight sulfur compounds known to be produced as wastewater degrades or aldehydes used as hydraulic fracturing water additives.

Using the Agency's standard procedures, ATSDR evaluated whether the compounds analyzed and detected in the air samples could be harmful to people breathing the air. Details of the evaluation are presented in Appendix A. The chemicals detected were generally below the levels that would be expected to harm health. *However, ATSDR reiterates that the sampling does not fully represent potential exposures.* The analysis did not include a number of chemicals that could be used in the hydraulic fracturing process or that are known to be associated with wastewater impoundments. The samples were also limited in number and location, were not collected during odor events, and had incomplete documentation of QA/QC and sampling methods and details.

To make a conclusion about the community public health impacts of air emissions from the impoundment, ATSDR would need sufficient and representative data. A more comprehensive assessment would include offsite sampling collected both specifically during odor events and collected over time to characterize typical impoundment operations (covering different seasons, scheduled

releases, upwind and downwind locations, and maintenance activities). All samples would be analyzed for a wide range of compounds, including aldehydes and other volatile substances used in the hydraulic fracturing process and low molecular weight sulfur compounds known to be released from wastewater impoundments.

Private Well Data Evaluation

Until recently, all homes near the Carter Impoundment used private wells or springs for drinking water and other household use. Several homes along Fort Cherry Road were added to a public water source in the first half of 2012 by the company that owns and operates the Carter Impoundment. Homes along Walnut Road and at least one home on Fort Cherry Road still use wells and/or springs, though some of these residents choose to purchase water for drinking.

ATSDR received drinking water data from 3 homes near the impoundment. "Baseline" data collected before construction of the impoundment and nearby gas wells were available from 3 homes (labeled A, B, and C for privacy). Homes A and C had at least one sample collected after completion of the impoundment in January 2010. The information provided was limited; most samples did not include details on QA/QC, chain of custody forms, or sampling procedures. All the drinking water samples appear to be of untreated water. The analyses were performed by laboratories operated or certified by the State of Pennsylvania or EPA, and included analyses for general water quality parameters, metals, volatile and semi-volatile organic compounds, petroleum hydrocarbons, and others. More information about the sampling and analyses is presented in Appendix B. Although the samples are limited in number and locations, the analyses included general water quality and other parameters that could be potentially affected by the impoundment.

According to anecdotal information provided to ATSDR, residents at Home A used water from their private well for drinking and other household purposes before 2012, when their home was added to the public water line. The private well at Home A is still used for non-household uses. Water from the private well at Home A was and is still chlorinated, softened, and filtered before use. Homes B and C are not on public water currently. Residents at Home B use water from a private well that is not treated; the residents reported that they buy drinking water but may occasionally drink water from their private water well. Residents at Home C use spring water and reportedly treat it with a water softener and UV light before using.

Only a few sample results are available for these three private drinking water sources, and these results only cover the years 2009-2012. The results only represent the condition of the water at the time of sampling and may not be representative of water quality in the past or in the future. In addition, the water in the private well at Home A was and is treated before use, so the untreated water results do not necessarily reflect actual exposure that would occur to people drinking the treated water. However, in this health consultation ATSDR discusses these water quality results as if the water were used directly for drinking.

Table 3 summarizes the contaminants detected in these samples. Many of the compounds analyzed were not detected. For simplicity, only those compounds detected in at least one well or spring sample are included in the table. Not every compound was analyzed in each sample. The results are compared with health-based CVs below which health effects are unlikely.

Table 3. Parameters Detected in Domestic Water Supplies Near the Carter Impoundment, McDonald, PA

Parameter	Maximum Concentration Detected in Home's Water, µg/L			Comparison Value and Source, µg/L
	Home A	Home B	Home C	
Ammonia	200	-	-	30,000 – Lifetime Health Advisory [16]
Arsenic	2.3	-	ND	3 – EMEG
Barium	800	78	167	2,000 – EMEG
Bromide	1,800	-	-	2,000 –Drinking Water Concentration for Acceptable Daily Intake [17]
Calcium	98,000	114,741	83,600	1,250,000 – Upper Limit [18]
Carbon tetrachloride	0.5	-	-	70 – RMEG 0.5 – CREG
Chloride	28,000	5,100	9,100	250,000 – Secondary MCL [19]
Chromium	ND	-	5	9 – EMEG for hexavalent chromium
Copper	60	-	ND	100 - iEMEG
Diesel Range Organics	34.6	-	-	47 – Maryland cleanup standard [20]
Dissolved Methane	30.4	ND	-	10,000 – DOI Screening Level 28,0000 – DOI Immediate Action Level [21]
Fluoride	200	-	-	4,000 - MCL [22]
Iron	3,040	23	50	11,000 – Regional Screening Level [23] 300 – Secondary MCL [15]
Lead	ND	ND	5	15 – EPA Action Level [22] There is no safe lead level.
Magnesium	18,000	9,250	13,000	65,000 – Tolerable Upper Intake [18]
Manganese	**1,090**	ND	ND	300 – Lifetime Health Advisory [16] 50 – Secondary MCL [19]
Nickel	0.7	-	-	100 – Lifetime Health Advisory [16]
Nitrate + Nitrite	800	-	900	10,000 – MCL [22]
Phosphorus	30	-	-	1,500,000 – Tolerable Upper Intake [18]
Potassium	2,019	1,247	-	Essential element; water would supply less than 1% of adequate intake level [24,25]
Silicon	11,000	-	-	No evidence substance causes harm [28]
Sodium	**20,400**	15,023	-	20,000 – EPA Drinking Water Advisory [16]
Strontium	1,790	499	-	4,000 – Lifetime Health Advisory [16]
Sulfate	28,000	68,000	-	250,000 – Secondary MCL [19]
Sulfur	8,220	-	-	250,000 – Secondary MCL [19]
Titanium	2	-	-	Within normal range for municipal water [29]
Toluene	0.8	-	-	200 µg/L - iEMEG
Zinc	20	-	-	3000 µg/L - EMEG

Shaded Cells are above CV and discussed further.
µg/L = micrograms per liter ND = not detected '-" = not reported
DOI = Department of Interior
EMEG = Environmental Media Evaluation Guide derived from ATSDR Minimal Risk Level (chronic, 1 year or more)
iEMEG = EMEG based on intermediate exposure duration (2 weeks up to 1 year)
RMEG = Remedial Media Evaluation Guide derived from EPA Reference Dose
MCL = EPA Maximum Contaminant Level
CREG = Cancer Risk Evaluation Guide derived from cancer slope factor

Most substances detected were below CVs, and no adverse health effects would be expected from exposure to these levels. Home A's water had the only detection above a screening CV. The well at Home A had manganese and sodium concentrations above CVs and will be discussed further in the following section.

Manganese

Manganese is an essential mineral, but regularly breathing in high concentrations of manganese is known to cause irreversible neurological effects similar to Parkinson's disease. Studies have suggested the potential for similar toxicity through drinking water exposure. Concentrations of manganese in groundwater vary depending on the local geology and other issues. The United States Geological Survey reported manganese concentrations ranging from less than 0.13 µg/L to 1,710 µg/L in a survey of 20 domestic wells in Sullivan County, Pennsylvania [25]. Similarly, Chester County, Pennsylvania reports manganese concentrations in 360 wells ranging from less than 1 µg/L to 3,200 µg/L [26]. EPA has developed a lifetime health advisory for manganese in drinking water of 300 µg/L [16,30].

The lifetime health advisory is based on an EPA reference dose of 0.14 milligrams of manganese per kilogram body weight per day (mg/kg/day) with modifying factors to account for uncertainties about effects of manganese in water versus food and to account for intake from food and drinking water. The reference dose was developed from population dietary data and represents a general intake that is not likely to result in any adverse effects. For most people, the greatest exposure to manganese is from food [30].

EPA also developed a short term (10 days or less) health advisory value for manganese in drinking water of 1,000 µg/L. However, EPA recommended the lower advisory of 300 µg/L be used for infants under 6 months, since studies suggest developing children might be more susceptible to manganese toxicity and one study suggested toxic effects from manganese concentrations at only about twice the short term health advisory concentration [30].

A sample collected from the well at Home A in May 2010 had a manganese concentration of 10 µg/L. Subsequent samples collected in July 2011 and March 2012, however, showed manganese concentrations of 1,060 µg/L and 1,090 µg/L, respectively. These concentrations are higher than both the lifetime and the short-term health advisories for manganese in drinking water.

The concentrations of manganese recently detected in Home A's well would also give drinking water an unpleasant taste and appearance, and could cause black staining of household fixtures [19]. EPA's secondary drinking water standard for manganese was set at 50 µg/L to avoid these taste and staining problems. The water from this well may not be palatable. If the water were drunk regularly for a long time, this chronic exposure could increase the risk of health problems such as neurological effects, especially in young children.

Reportedly, the water from the well at Home A is and was treated with chlorination, water softening, and filtration before use. This treatment should reduce manganese levels in the water, so it is unlikely the users of this well water were ever exposed to harmful levels of manganese. As of 2012, the home served by this well has been connected to a public water supply, and therefore *drinking water exposure to this private well water is no longer occurring*.

Sodium

Sodium is an essential element used in the body for proper muscle and nerve function. High sodium intake can affect blood pressure, and some people with high blood pressure or kidney problems may be on sodium-restricted diets. EPA has a drinking water advisory of 20,000 µg/L for people on a sodium-restricted diet [16]. The tolerable upper intake level for sodium, the highest level of sodium that can be consumed daily that is unlikely to be harmful for healthy people, ranges from 1,500 milligrams per day (mg/day) for children to 2,300 mg/day for adults [24].

A sample collected from the well at Home A in May 2010 had a sodium concentration of 20,400 µg/L, slightly above EPA's drinking water advisory for people on sodium-restricted diets. Drinking two liters of water with this concentration of sodium each day would result in an intake of less than 3% of the tolerable upper intake for sodium. The home served by this well is now connected to a public supply well, so *drinking water exposures to this water is no longer occurring*.

Private Well Testing Information

As a prudent public health measure, ATSDR recommends that all homeowners who use water from private wells, and in particular those in areas near gas drilling activity, have their wells routinely tested. The Penn State Extension Program provides low cost well testing and offers a specific gas/oil water testing package. Further information on the private water well testing program can be obtained from the Washington County Penn State Extension Office (724-228-6881) or the Penn State Extension Lab Testing website (http://agsci.psu.edu/aasl/water-testing). Penn State has also developed a fact sheet with discussion of specific recommendations for analytes appropriate to include in drinking water testing; the fact sheet can be found at: http://extension.psu.edu/natural-resources/water/marcellus-shale/drinking-water/testing-drinking-water-supplies-near-gas-drilling-activity/extension_publication_file.

Surface Water Data Evaluation

Two surface water samples were collected in 2011 and 2012 from a small intermittent creek that flows off the Carter Impoundment property and is about 1,000 feet from the Carter Impoundment. Limited information on sampling, QA/QC, and chain of custody was available for these samples. The chemicals detected in these samples are shown in Table 4 below. This surface water has never been used for drinking water. For perspective, however, the corresponding drinking water CV for each chemical is presented. None of the contaminants in surface water samples exceeded health-based CVs for drinking water.

Table 4. Parameters Detected in Surface Water Samples Collected Near the Carter Impoundment, McDonald, PA

Parameter	Concentration Detected in Surface Water, µg/L		Drinking Water Comparison Value and Source, µg/L
	July 2011	March 2012	
Arsenic	ND	0.91	3 – EMEG
Barium	155	140	2,000 – EMEG
Bromide	480	660	2,000 –Drinking Water Concentration for Acceptable Daily Intake [17]
Calcium	103,000	99,200	1,250,000 – Upper Limit [18]
Chloride	60,400	41,900	250,000 – Secondary MCL [19]
Chromium	ND	0.7	9 – EMEG for hexavalent chromium
Diesel Range Organics	28.7	29	47 – Maryland cleanup standard [20]
Fluoride	140	130	4,000 - MCL [22]
Iron	699	679	11,000 – Regional Screening Level [23] 300 – Secondary MCL [15]
Lead	ND	0.9	15 – EPA Action Level [22] There is no safe lead level.
Magnesium	10,400	8,940	65,000 – Tolerable Upper Intake [18]
Manganese	100	70	300 – Lifetime Health Advisory [16] 50 – Secondary MCL [19]
Nickel	ND	0.8	100 – Lifetime Health Advisory [16]
Nitrate + Nitrite	400	1300	10,000 – MCL [22]
Phosphorus	40	50	1,500,000 – Tolerable Upper Intake [18]
Potassium	1,800	1,440	Essential element; water would supply less than 1% of adequate intake level [24,25]
Silicon	7,770	6,560	No evidence substance causes harm [28]
Sodium	2,110	1,730	20,000 – EPA Drinking Water Advisory [16]
Strontium	402	599	4,000 – Lifetime Health Advisory [16]
Sulfate	43,600	40,500	250,000 – Secondary MCL [19]
Sulfur	1,320	13,000	250,000 – Secondary MCL [19]
Titanium	28	30	Within normal range for municipal water [29]
Zinc	20	ND	3000 µg/L - EMEG

NOTE: Comparison values are for perspective; the surface water is not used for drinking water purposes.
µg/L = micrograms per liter ND = not detected
EMEG = Environmental Media Evaluation Guide derived from ATSDR Minimal Risk Level (chronic, 1 year or more)
iEMEG = EMEG based on intermediate exposure duration (2 weeks up to 1 year)
RMEG = Remedial Media Evaluation Guide derived from EPA Reference Dose
MCL = EPA Maximum Contaminant Level
CREG = Cancer Risk Evaluation Guide derived from cancer slope factor

Conclusions

ATSDR reached four important conclusions in this health consultation.

Conclusion 1. Not enough data are available to determine whether breathing contaminants in air in the area around the Carter Impoundment could harm nearby residents' health. This conclusion is based on the following:

- Available air sampling was limited in location, duration and frequency and was not collected during odor events. Also, the laboratory analytical techniques used did not test for several substances reasonably expected to be present (either used in the hydraulic fracturing water or known to be associated with wastewater impoundments). While the air sampling data are limited, the chemicals detected were generally below the levels that would be expected to harm health.

Conclusion 2. Chemicals found in drinking water samples collected in 2011 and 2012 from two private wells and one spring near the Carter Impoundment are generally below levels that would be expected to harm people's health. More recent sampling data would be needed to evaluate current groundwater contamination in the area. This conclusion is based on the following:

- Private water data results represented general water quality and other parameters that could be potentially affected by the impoundment, though they were limited in location and number of samples. Of three private drinking water sources with data available, one had high concentrations of manganese detected (not seen in the baseline water samples collected before the use of the impoundment). However, this water was treated before use and the home is now connected to a public water source for drinking water. Available well or spring water data from the other two private sources did not show any levels above health-based screening values.

Conclusion 3. Chemicals found in surface water near the Carter Impoundment are not expected to harm people's health. More recent sampling data would be needed to evaluate current exposures to surface water in the area. This conclusion is based on the following:

- The intermittent creek that flows off the Carter Impoundment property onto a residential property is not used for drinking water. Two samples from the creek did not show any chemicals detected at levels above screening values for drinking water.

Conclusion 4. Not enough data are available to determine whether drinking private well or spring water, or coming in contact with surface water, in the future will harm people's health. This conclusion is based on the following:

- Data on private water sources and surface water included only a few locations and time points. The impacts of impoundment operations on local groundwater and surface water quality have not been adequately characterized.

Recommendations

- More representative air sampling could help ATSDR make firmer conclusions about the community public health impacts of the impoundment. We recommend air sampling:
    - include offsite sampling collected both specifically during odor events and collected over time to characterize typical impoundment operations (covering different seasons, scheduled releases, and maintenance activities); and
    - be collected and analyzed for a wide range of compounds, for example aldehydes, carbonyls, and other volatile substances involved in the extraction, processing, and transport of natural gas, as well as low molecular weight sulfur compounds known to be released from wastewater impoundments.

- As a prudent public health measure, ATSDR recommends that all homeowners who use water from private wells, and in particular those in areas near gas drilling activity, have their wells routinely tested. The Penn State Extension Program provides low cost well testing and offers a specific gas/oil water testing package. Please see page 13 of this report for links to further information on the private water well testing program and specific analytes appropriate to include in drinking water testing in the area.

- The reported levels of chemicals in surface water do not require a response. However, the limited number and locations of the sampling add uncertainty regarding current exposures and new industry infrastructure in the area may have changed surface water quality and flow patterns.

- ATSDR recommends that regulatory authorities consider additional monitoring of groundwater and surface water around this impoundment during and following operations.

Public Health Action Plan

ATSDR will make this health consultation available to interested community members and agency representatives.

ATSDR will remain available to discuss any public health questions or concerns related to the site with community members and local, state, and federal authorities.

ATSDR will evaluate the need for additional community based air sampling at this location, and consider reviewing any additional environmental sampling data or relevant public health information collected at the site.

Site Team

Division of Community Health Investigations, Eastern Branch

Jill Dyken, Ph.D., P.E.
Environmental Health Scientist

Robert H. Helverson
Environmental Health Scientist

Karl Markiewicz, Ph.D.
Senior Toxicologist

Lora Siegmann Werner, MPH
Regional Director, Region 3

References

1. Agency for Toxic Substances and Disease Registry. Toxicological profile for benzene (updated). Atlanta: US Department of Health and Human Services; August 2007.

2. Agency for Toxic Substances and Disease Registry. Toxicological profile for carbon tetrachloride (updated). Atlanta: US Department of Health and Human Services; August 2005.

3. Agency for Toxic Substances and Disease Registry. Public Health Assessment Guidance Manual (Update). Atlanta, GA: Department of Health and Human Services; January 2005.

4. U.S. Environmental Protection Agency. Integrated Risk Information System. Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. Available from URL: http://www.epa.gov/iris Accessed September 5, 2013.

5. National Cancer Institute. SEER cancer statistics review 1975-2006, Table 1.14, lifetime risk of being diagnosed with cancer by site and race/ethnicity, 2004-2006.

6. National Toxicology Program. Report on carcinogens, twelfth edition. Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program. 2011.

7. American College of Toxicology, Cosmetic Ingredient Review Expert Panel. Final Report on the Safety Assessment of Benzaldehyde. International Journal of Toxicology, 25 (Suppl. 1):11-27, 2006. DOI: 10.1080/10915810600716612.

8. Ruth JH. Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review. Am Ind Hyg Assoc J (47):A142-A151. March 1986.

9. Occupational Safety and Health Administration. Chemical Sampling Information. Accessed on September 5, 2013 at: https://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html.

10. Code of Federal Regulations. 21 CFR 184.1165. n-Butane and Iso-Butane. 48 FR 57270, Dec. 29, 1983, as amended at 73 FR 8607, Feb. 14, 2008.

11. National Institute of Occupational Safety and Health. NIOSH Pocket Guide to Chemical Hazards. Accessed on September 5, 2013 at: http://www.cdc.gov/niosh/npg/.

12. American Conference of Governmental Industrial Hygienists. 2013 TLVs® and BEIs®. Cincinnati: ACGIH, 2013.

13. Code of Federal Regulations, Title 21, Subpart F, Section 172.515. Synthetic flavoring substances and adjuvants. Accessed on September 6, 2013 at: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/cfrsearch.cfm?cfrpart=172&showfr=1.

14. National Library of Medicine. Hazardous Substance Data Bank. Accessed on September 6, 2013 at: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

15. American Industrial Hygiene Association Guideline Foundation. 2013 ERPG/WEEL Handbook. Accessed on September 6, 2013 at: http://www.aiha.org/get-involved/AIHAGuidelineFoundation/WEELs/Documents/2011WEELValues.pdf

16. U.S. Environmental Protection Agency. 2012 Edition of the Drinking Water Standards and Advisories. Washington, DC: U.S. Environmental Protection Agency, Office of Water. EPA-822-S-12-001. April 2012.

17. World Health Organization. Bromide in Drinking-water, Background Document for Development of WHO Guidelines for Drinking-water Quality. WHO/HSE/WSH/09.01/6. 2009.

18. Institute of Medicine. Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. Washington, DC: National Academies Press. 1997.

19. U.S. Environmental Protection Agency. National Secondary Drinking Water Regulations. Accessed on September 9, 2013 at: http://water.epa.gov/drink/contaminants/index.cfm#Secondary.

20. State of Maryland. Cleanup Standards for Soil and Groundwater. Interim Final Guidance, Update No. 2.1. Annapolis, MD: Maryland Department of the Environment. June 2008.

21. U.S. Department of the Interior. Technical Measures for the Investigation and Mitigation of Fugitive Methane Hazards in Areas of Coal Mining. Pittsburgh, PA: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement. September 2001.

22. U.S. Environmental Protection Agency. National Primary Drinking Water Regulations. Accessed on September 9, 2013 at: http://water.epa.gov/drink/contaminants/index.cfm#Primary.

23. U.S. Environmental Protection Agency. Regional Screening Table website. Accessed in September 2013 at: http://epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm.

24. Institute of Medicine. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. Washington, DC: National Academies Press. 2004.

25. Sloto, R.A., 2013, Baseline groundwater quality from 20 domestic wells in Sullivan County, Pennsylvania, 2012: U.S. Geological Survey Scientific Investigations Report 2013–5085, 27 p., http://pubs.usgs.gov/sir/2013/5085/.

26. Ludlow RA and Loper CA. Chester County ground-water atlas, Chester County, Pennsylvania. U.S. Department of the Interior and U.S. Geological Survey. Open-File Report 03-442.

27. World Health Organization. Guidelines for Drinking-water Quality, Fourth Edition. Geneva: 2001.

28. Institute of Medicine. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC: National Academies Press. 2000.

29. World Health Organization. Environmental Health Criteria Monograph 24, Titanium. Geneva, Switzerland: World Health Organization, International Programme on Chemical Safety. 1982. Accessed on September 9, 2013 at: http://www.inchem.org/documents/ehc/ehc/ehc24.htm.

30. U.S. Environmental Protection Agency. Drinking Water Health Advisory for Manganese. Washington, DC: U.S. Environmental Protection Agency, Office of Water. EPA-822-R-04-003. January 2004.

Appendix A. Air Sampling Data Evaluation

As described in the body of this report, ATSDR found that the available air sampling did not include analysis for a number of substances that could potentially be associated with the impoundment operations, and the sampling was not conducted during odor events when a greater number or concentration of chemicals might be present. Therefore, the data do not allow a full evaluation of potential exposures. However, the limited results do give some information about potential exposures, so ATSDR applied its standard evaluation process to determine whether exposures to the chemicals analyzed and detected in the available sampling could affect health.

In this appendix, ATSDR presents the results for compounds analyzed and detected in the air samples provided to ATSDR by residents near the Carter Impoundment and evaluates whether those compounds could be harmful to people breathing the air. Samples were collected from two homes (labeled A and B for privacy) and from offsite on private property east and south of the impoundment. The exact air sampling locations were not provided to ATSDR. Table 1 presents volatile compounds detected in the air sampling, and Table 2 presents additional tentatively identified compounds in analysis of the air samples from east and south of the impoundment.

Most of the chemicals detected were below health-based CVs, and no adverse health effects would be expected from breathing those chemicals at the levels detected. Benzene and carbon tetrachloride were detected above cancer CVs in air samples near the homes, and several tentatively identified compounds with no CVs available were listed for the air samples collected east or south of the impoundment. These detections will be discussed further in the ensuing sections.

Further Evaluation of Benzene and Carbon Tetrachloride

Benzene and carbon tetrachloride exceeded their respective cancer CVs in air samples from outside two homes. All measured concentrations were well below noncancer CVs, so noncancer health effects are not expected. The maximum concentrations of both benzene and carbon tetrachloride were consistent with ambient air concentrations measured in rural and urban areas throughout the United States [1,2].

Although the concentrations of benzene and carbon tetrachloride are consistent with typical ambient levels, they could contribute to the risk of cancer. EPA has developed inhalation unit risks for cancer-causing compounds which can be used to estimate the increased risk of cancer from breathing the compounds [4]. The inhalation unit risk for benzene is 7.8×10^{-6} $(\mu g/m^3)^{-1}$, and for carbon tetrachloride is 6×10^{-6} $(\mu g/m^3)^{-1}$ [4]. Conservatively assuming a resident's continuous lifetime exposure to the highest concentration measured of each of these compounds, the total theoretical increased risk of cancer is calculated as the sum of each maximum detected value times the corresponding inhalation unit risk, as shown in the following calculation:

$$0.89\,\frac{\mu g\ benzene}{m^3} \times 7.8 \times 10^{-6}\ \left(\frac{\mu g}{m^3}\right)^{-1} + 0.71\,\frac{\mu g\ carbon\ tet}{m^3} \times 6 \times 10^{-6}\ \left(\frac{\mu g}{m^3}\right)^{-1}$$

$$= 1.1\times 10^{-5}, \text{ or about 1 in 100,000.}$$

Table 1. Parameters Detected in Air Samples Collected Near the Carter Impoundment, McDonald, PA

Compound	Concentration Detected in Air Sample, µg/m^3					Comparison Value and Source, µg/m^3
	Home A 10/11/11 3:03 pm	Home A 5/3/12 6:20 pm	Home B 6/15/13 12:15 pm	East of Impoundment 1/3/13 5:25 am	South of Impoundment 1/3/13 5:15 am	
1,1,2-Trichloro-1,2,2-trifluoroethane	0.64	0.63	0.63	ND	ND	31,000 – RSL
1,2,4-Trimethylbenzene	0.38		-	ND	ND	7.3 – RSL
1,4-Dichlorobenzene	ND	ND	ND	ND	1	60 – MRL
2-Butanone (Methyl ethyl ketone)	-	1.7	1.3	ND	ND	5,000 – RfC
Acetone		9.3	7.8	ND	ND	31,000 – MRL
Benzene	0.89	ND	0.45	ND	ND	9.6 – MRL 0.13 – CREG
Carbon Tetrachloride	0.57	0.71	0.56	ND	ND	190 – MRL 0.17 – CREG
Chloromethane	1	1.2	0.98	ND	ND	100 – MRL
Dichlorodifluoromethane (CFC-12)	2.6		-	2.8	2.8	100 – RSL
Ethylbenzene	0.34	ND	ND	ND	ND	260 – MRL
m&p-Xylene	0.92	ND	ND	ND	ND	100 – RfC for total xylenes
Methylene chloride	2	ND	ND	ND	ND	1,000 – MRL 100 – CREG
n-Hexane	-	-	-	ND	0.99	700 – RfC
n-Pentane		-	-	ND	3.5	1,000 – RSL
o-Xylene	0.39	ND	ND	ND	ND	100 – RfC for total xylenes
Tetrachloroethene (PCE)	0.56	ND	ND	ND	ND	270 – MRL 3.8 - CREG
Toluene	2	0.68	1	ND	ND	300 - MRL
Trichloroethene (TCE)	ND	ND	0.09	ND	ND	2.1 – MRL 0.24 - CREG
Trichlorofluoromethane (CFC-11)	1.8	1.5	1.4	1.4	1.4	730 – RSL

Shaded cells indicate detections above the lowest CV. These are discussed further in the text. µg/m^3 = micrograms per cubic meter
RSL = EPA Regional Screening Level for Resident Air MRL = ATSDR Minimal Risk Level RfC = EPA Reference Concentration
CREG = Cancer Risk Evaluation Guide ND = Not Detected "-" = Not Reported

This calculation results in an estimated lifetime increased cancer risk that falls within EPA's target risk range for Superfund of between 1 in 1,000,000 and 1 in 10,000. Out of 100,000 people exposed continuously for an entire lifetime, approximately one additional case of cancer might occur due to the exposure. For perspective, based on U.S. cancer rates, the lifetime risk of cancer in the general population is about 1 in 2.5, or about 40,000 out of every 100,000 people [5].

Again, this evaluation only includes the compounds detected above CVs in limited sampling. More representative sampling and analysis might identify other compounds, or higher concentrations of these compounds, that could also contribute to the non-cancer and cancer risk from exposure.

Table 2. Tentatively Identified Compounds With No CVs Detected in Air Samples Collected Near the Carter Impoundment, McDonald, PA

Tentatively Identified Compound	Concentration Detected in Air Sample, µg/m^3				
	Home A 10/11/11 3:03 pm	Home A 5/3/12 6:20 pm	Home B 6/15/13 12:15 pm	East of Impoundment 1/3/13 5:25 am	South of Impoundment 1/3/13 5:15 am
Benzaldehyde	-	-	-	4.8	-
Hexamethylcyclotrisiloxane (D3)	-	-	-	-	5
Isobutane	-	-	-	-	4
Isopentane	-	-	-	-	3.6
n-Butane	-	-	-	-	7.1
n-Nonanol	-	-	-	-	2.9
Propane	-	-	-	-	7.2
Unidentified Compound	-	-	-	-	4.4

Shaded cells indicate detections of compounds with no CV available. These are discussed further in the text. µg/m^3 = micrograms per cubic meter
"-" = Not Reported

Further Evaluation of Compounds With No CV Available

In the testing performed in January 2013, several tentatively identified compounds without health-based CVs were detected. These were listed in Table 2 and will be discussed in the following section.

Benzaldehyde is an aromatic compound with an almond-like scent. It is a "generally recognized as safe" food additive in the United States and has been accepted as a flavoring substance in the European Union [7]. Benzaldehyde occurs naturally in bitter almond oil, other plants, and insects. The odor threshold is reported to be between 0.8 and 184.9 µg/m^3 [8]. Inhalation of very high concentrations of benzaldehyde (several thousand µg/m^3 or more) could result in respiratory irritation [7]. However, the concentration of benzaldehyde tentatively identified in air sampling near the Carter Impoundment, 4.8 µg/m^3, is thousands of times lower than levels that would cause irritation and is at expected background or consumer use levels. Breathing in this level of benzaldehyde would not be expected to result in any harmful effects. Benzaldehyde is not known to be used as a direct additive in the hydraulic fracturing process.

Hexamethylcyclotrisiloxane, also known as D3, is a raw material for silicone products and is widely used in a number of industrial, military, and medical applications. Limited toxicological studies have been performed on this substance. No federal exposure limits exist for D3, but the Occupational Health and Safety Administration (OSHA) states that a no-effect level for systemic toxicity in rats inhaling D3 for 6 hours a day for up to 39 days appears to be 100 ppm (or 909,000 $\mu g/m^3$) [9]. The concentration of D3 tentatively identified in air sampling for this site, 5 $\mu g/m^3$, is hundreds of thousands of times smaller than this value. Breathing in this level of D3 would not be expected to result in any harmful effects. D3 is not known to be used as an additive in the hydraulic fracturing process, though it might be present in materials used in well development activities.

Isobutane (2-methylpropane) is a colorless gas with a gasoline-like or natural gas odor [11]. Isobutane is "generally recognized as safe" as a direct human food ingredient for use as a propellant or aerating agent [9,10]. There is no OSHA regulatory exposure limit for isobutane, but the National Institute of Occupational Safety and Health (NIOSH) recommends an 8-hour workday time-weighted average exposure level of 800 ppm (or 1,900,000 $\mu g/m^3$) for isobutane [11]. Community exposure scenarios may involve more continuous or longer exposures and include sensitive populations not considered in worker scenarios, so limits developed for workers are not typically considered protective for communities. However, the concentration of isobutane tentatively identified in air sampling for this site, 4 $\mu g/m^3$, is hundreds of thousands of times lower than the recommended occupational limit. Breathing in this level of isobutane would not be expected to result in any harmful effects. Isobutane is in the liquids associated with the natural gas obtained from the Marcellus Shale and is likely released through well development activities.

Isopentane (2-methylbutane) is a volatile, colorless liquid with a gasoline-like odor [11]. There are no federal exposure limits specifically for isopentane [9]. The American Conference of Governmental Industrial Hygienists (ACGIH), a professional society advancing worker health protection, has developed an 8-hour workday time-weighted average threshold limit value (TLV) for pentane, all isomers, of 600 ppm (or 1,770,000 $\mu g/m^3$); in 2013, ACGIH gave notice that it intends to change this TLV to 1000 ppm (or 2,950,000 $\mu g/m^3$) [12]. The TLV guideline represents a scientific opinion by ACGIH of a level of exposure that nearly all workers may be repeatedly exposed to without adverse health effects [12]. Community exposure scenarios may involve more continuous or longer exposures and include sensitive populations not considered in worker scenarios, so guidelines developed for workers do not generally apply. However, the concentration of isopentane tentatively identified in air sampling for this site, 3.6 $\mu g/m^3$, is hundreds of thousands of times lower that the TLV. Breathing in this level of isopentane would not be expected to result in any harmful effects. Isopentane is in the liquids associated with the natural gas obtained from the Marcellus Shale and is likely released through well development activities.

n-Butane is a colorless gas with a gasoline-like or natural gas odor [11]. n-Butane is "generally recognized as safe" as a direct human food ingredient for use as a propellant or aerating agent [9,10]. There is no OSHA regulatory exposure limit for n-butane, but NIOSH recommends an 8-hour workday time-weighted average exposure level of 800 ppm (or 1,900,000 $\mu g/m^3$) for n-butane. Community exposure scenarios may involve more continuous or longer exposures and

include sensitive populations not considered in worker scenarios, so limits developed for workers are not typically considered protective for communities. However, the concentration of n-butane tentatively identified in air sampling for this site, 7.1 µg/m^3, is hundreds of thousands of times lower that the recommended occupational limit. Breathing in this level of n-butane would not be expected to result in any harmful effects. N-butane is in the liquids associated with the natural gas obtained from the Marcellus Shale and is likely released through well development activities.

n-Nonanol is a fatty alcohol compound with a citrus odor similar to citronella oil. It is listed by the Food and Drug Administration (FDA) with synthetic flavoring substances and adjuvants that may be safely used in food in the minimum amount needed to impart their intended effect [13]. No federal limits or other guidelines could be found for n-nonanol. The National Library of Medicine's Hazardous Substances Data Bank, in its summary on higher alcohols, states, "Higher alcohols are of a low order of toxicity in an industrial setting. As the carbon chain lengthens, the toxicity decreases. They are not able to penetrate skin as readily as smaller molecular weight alcohols and are less likely to be absorbed by inhalation. The exact mechanism is unknown [14]." With this in mind, data for the alcohol n-octanol (with 8 carbon atoms instead of n-nonanol's 9) should be conservatively applicable to n-nonanol. The American Industrial Hygiene Association (AIHA) develops guidelines similar to ACGIH's TLVs called workplace environmental exposure levels (WEELs). The 8-hour time-weighted WEEL for n-octanol is 50 ppm (or 266,000 µg/m^3) [15]. Community exposure scenarios may involve more continuous or longer exposures and include sensitive populations not considered in worker scenarios, so limits developed for workers are not typically considered protective for communities. However, the WEEL value is hundreds of thousands of times higher than the concentration (2.9 µg/m^3) of n-nonanol tentatively identified at the site. Breathing in this level of n-nonanol would not be expected to result in any harmful effects. N-nonanol is not known to be used as an additive in the hydraulic fracturing process.

Propane is a colorless, odorless gas [11]. (Propane fuel often has a foul-smelling odorant added so consumers can identify leaks.) OSHA has set a regulatory 8-hour workday time-weighted average permissible exposure limit for propane of 1,000 ppm (or 1,800,000 µg/m^3) [9]. Community exposure scenarios may involve more continuous or longer exposures and include sensitive populations not considered in worker scenarios, so limits developed for workers are not typically considered protective for communities. However, the concentration of propane tentatively identified in air sampling for this site, 7.2 µg/m^3, is hundreds of thousands of times lower that the occupational limit. Breathing in this level of propane would not be expected to result in any harmful effects. Propane is in the liquids associated with the natural gas obtained from the Marcellus Shale and is likely released through well development activities.

One unidentified compound was detected at 4.4 µg/m^3. This concentration is similar to the other tentatively identified compounds.

Appendix B. Details of Well and Spring Sampling and Analysis

Private well or spring sampling data were available for 3 nearby homes, labeled A, B, and C for privacy. The below text summarizes the number and dates of sampling for each home and the analyses that were performed for each sample.

Home A – 5 samples collected from 2009-2012

- July 2009 and Nov 2010 – Analyzed by PA DEP certified laboratory for nitrate/nitrite, lead, copper, iron, calcium, magnesium, hardness, pH, conductivity, total coliform, E. coli, BTEX, 17 VOCs, and barium.
- May 2010 – Analyzed by a PA DEP laboratory for chloride, hardness, magnesium, strontium, barium, potassium, iron, manganese, pH, sodium, calcium, alkalinity, and total dissolved solids.
- July 2011 and Nov 2012 – Analyzed by the U.S. EPA (using thorough data validation because was part of highly influential hydraulic fracturing research study) for general chemistry (pH, chloride, bromide, fluoride, sulfate, hydrogen sulfide, nitrate/nitrite, ammonia, iron, carbon, alkalinity, etc.), 38 VOCs, 84 SVOCs, 4 dissolved gases (methane, ethane, propane and butane), 4 glycols (e.g. 2-butoxyethanol), 6 low molecular weight acids (e.g. acetate, butyrate), petroleum hydrocarbons, 32 metals (dissolved and total), isotopes, and radiologicals.

Home B – 1 sample in 2009, before the drilling

- Sept. 2009 – Analyzed by a PA DEP certified laboratory for nitrate/nitrite, lead, copper, iron, calcium, magnesium, hardness, pH, conductivity, total coliform, E. coli, BTEX, 17 VOCs, and barium.

Home C – 2 samples collected in 2009-2010

- July 2009 – Analyzed by a PA DEP certified laboratory for nitrate/nitrite, lead, copper, iron, calcium, magnesium, hardness, pH, conductivity, total coliform, E. coli, BTEX, 17 VOCs, and barium.
- Nov 2010 – Analyzed by a PA DEP certified laboratory for all the above parameters plus arsenic, chromium, cadmium, manganese.

Many of the results were non-detect for the analyzed parameter. The tables in the text of this document only list compounds detected above ATSDR comparison values or suggested ranges for non-chemical parameters.