Health Consultation

Vapor Intrusion

KROUTS CREEK SITE

AUBURN AND VINSON ROADS

HUNTINGTON, WAYNE COUNTY, WEST VIRGINIA

JUNE 14, 2007

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR 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 which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HUNTINGTON, WAYNE COUNTY, WEST VIRGINIA

Prepared By:

West Virginia Department of Health and Human Resources
Under a Cooperative Agreement with
The U.S. Department of health and Human Services
Agency for Toxic Substances and Disease Registry
Atlanta, Georgia

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Foreword

This document summarizes public health concerns related to vapor intrusion at the Krouts Creek site. This document assesses the potential for adverse human health effects from exposure to chemical vapors accumulating inside homes above the contaminated groundwater plume at this site.

The steps taken were as follows:

Evaluating exposure: The West Virginia Department of Health and Human Resources – Agency for Toxic Substances and Disease Registry (ATSDR) Cooperative Partners Program (WVDHHR) started by reviewing information about environmental conditions at the site. The first task is determining how much contamination is present, where it is on the site, and how people might be exposed. WVDHHR typically does not collect environmental samples. WVDHHR relies on information provided by the West Virginia Department of Environmental Protection (WVDEP), the US Environmental Protection Agency (EPA), and other governmental agencies, businesses, and other respected sources of information.

Evaluating health effects: If evidence indicates people are or could be exposed, to hazardous substances, WVDHHR scientists will take steps to evaluate whether exposure could be harmful to human health. This evaluation, the health consultation, is based on existing scientific information. The health consultation focuses on the health impact on the community as a whole.

Developing recommendations: WVDHHR outlines its conclusions regarding any potential health threat posed by a site and offers recommendations for reducing or eliminating human exposure to contaminants. The role of WVDHHR at a site is primarily advisory. Therefore, the health consultation recommends actions to be taken by other agencies, including WVDEP and EPA.

Soliciting community input: The evaluation process is interactive. WVDHHR starts by soliciting and evaluating information from various governmental agencies, the organizations responsible for environmental cleanup, and the community surrounding the site. Conclusions are shared with the communities and organizations providing the information.

If you have questions or comments about this report, we encourage you to write:

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Summary and statement of issues

The West Virginia Department of Environmental Protection (WVDEP) requested an evaluation of potential public health impacts from the vapor intrusion pathway at the Krouts Creek site (site). Some of the volatile chemicals found at this site are associated with the 2004 TechSol coal tar light oil (CTLO) spill.

Groundwater and soil containing volatile chemicals (chemicals that easily become a gas) release vapors into the soil. This gas moves within the spaces between soil particles. Vapors can move from soil gas under buildings into indoor air where people can inhale them. This process is called vapor intrusion. A vapor intrusion assessment determines if people living where vapors might accumulate would be exposed to sufficient chemicals to cause adverse health effects.

WVDHHR concluded exposure to chemicals at this site from the CTLO spill through vapor intrusion poses “no apparent public health hazard” for the present and the future. The conclusion is based on an analysis using very conservative assumptions due to data limitations and uncertainties. Many factors may reduce exposure to these chemicals in the future. Surface water, soil, and sediment contaminated by the CTLO spill have been removed. The contaminated groundwater is moving toward the northeast, toward the Ohio River. Soil microorganisms may be converting the benzene to less toxic chemicals. Active remediation of the benzene-contaminated groundwater may occur.

Additional chemicals not associated with the CTLO spill with potential to accumulate vapors inside buildings were detected at this site. Although existing data indicates no apparent public health hazard, the extent and source of the plume is unknown. No predictions can be made about future levels of these chemicals in the groundwater and soil gas. For these reasons, the public health hazard category for exposures to these chemicals is an “indeterminate public health hazard.”

The West Virginia Department of Health and Human Resources (WVDHHR) prepared this health consultation under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR).

Background

Site description and history

The Krouts Creek site, in the Westmoreland area of Huntington, West Virginia, is a 150-home neighborhood. The nearest intersection to the soil gas samples is Auburn and Vinson Roads. The site boundaries are Waverly Road (US Rt. 60) (south), the Ohio River floodwall (west and north), and Burlington Road (east).

Twenty-two thousand (22,000) gallons of CTLO spilled from a railroad car on October 28, 2004 at the TechSol Chemical Company, 4711 Piedmont Road, Huntington, West Virginia. The firm had no containment structures. The CLTO entered the storm drains as well as Krouts Creek. The CTLO contained 68% benzene, 24% toluene, 7% xylene, and 1% other chemicals. The named chemicals in the “other” category were ethylbenzene, trimethylbenzene, styrene, and naphthalene [1].

Numerous state and local agencies as well as Marathon Ashland Petroleum LLC, now Marathon Petroleum Company LLC (MPC), were involved in the spill response and cleanup. WVDEP requested MPC's involvement due to TechSol's limited ability to respond [2]. MPC was the intended recipient of the CTLO.

Quick and effective action by these entities kept the CTLO from reaching the Ohio River. The product entered Krouts Creek about 3,000 feet upstream from the creek's discharge into the Ohio River. An emergency dam constructed across Krouts Creek contained the CTLO. Some product seeped into stream sediment before the contaminated surface water was removed. Brown material seeped from parts of the stream bank during a period of high water along Krouts Creek [2]. Krouts Creek restoration was completed October 2005, after 3,000 tons of contaminated sediment were removed [3]. The removal limited, but apparently did not eliminate, local groundwater contamination.

About 500 people in a 2-mile radius of the spill were evacuated. The evacuation area involved portions of Wayne and Cabell counties and affected approximately 200 homes, an elementary school, and several businesses [2]. Most residents returned in a few days after CTLO was cleared from the storm sewers and risk of explosion was eliminated. However, residents living close to Krouts Creek were not allowed to return to their homes until November 5, 2004.

Residents were allowed to return when benzene in air outdoors and inside homes was determined to be below levels of health concern. This occurred when more than 90% of outside air samples were below 0.1 parts per million (ppm) benzene (the detection limit) and few detections exceeded 1.0 ppm benzene [4]. All readings inside homes were below the detection limit except one where the levels found were 0.4 ppm or less.

Volatile chemicals were found in groundwater at this site. Other sources of volatile chemicals in addition to the CTLO spill are in the area, such as, the TechSol facility, gasoline stations, automobile repair garages, and railroad and automobile emissions.

Public water supplied to people at the site is not affected by the chemicals found in the groundwater. Direct chemical exposures from household water are not possible because no one is using private well water. However, exposures through vapor intrusion are possible due to the nature of the chemicals found in the groundwater.

The community is concerned that exposure to the chemicals from the CTLO spill may affect their health.

Discussion

Data review

A 3-13 foot layer of silty-clay overlays sand in this area. It has been found in every drilled well except for MW#17 at the western side of the plume along Auburn Road (Figure 1). This layer appears to be a barrier to vapor migration.

The data reviewed were collected by Arcadis G&M Inc (Arcadis) for MPC to determine groundwater quality and movement. Data were collected and analyzed following EPA-approved sampling and analytical methods. The data has not been validated.

Groundwater

Groundwater samples from June through November 2006 indicate the benzene is concentrated in the area near Krouts Creek and the emergency dam. This indicates the benzene is associated with the CTLO spill. The highest benzene concentration was found in groundwater in the area bound by Auburn Rd, Vinson Rd, the alley between Auburn and Magazine Roads, and Blair Road. The contamination appears to be moving toward the northeast.

Benzene evaporates from the surface of the groundwater, so the concentrations in the upper layers were considered most important. Maximum benzene readings from monitoring wells of note are: MW#9, 164,000 ppb; MW#15, 95,000 ppb; MW#5, 89,000 ppb; MW#13, 82,000 ppb; MW#19, 75,000 ppb; MW#16, 58,000 ppb; MW#18, 58,000 ppb). Benzene in groundwater from MW#17 is much less than from those further east, ranging from non-detectible (<1.0 parts per billion [ppb]) to 23 ppb (Figure 1).

Soil gas

Arcadis collected soil gas samples using temporary soil vapor probes. The probes were inserted near existing monitoring wells and are designated using the monitoring well numbers (Figure 1). The sample sites were selected in the area where the most concentrated benzene was detected in groundwater, locations to the north and northeast of this area, as well as near MW#17 where the apparent barrier to soil gas movement, the silty-clay layer, was not detected.

Soil vapor from SV#5 (near MW#5) was collected, June 27, 2006, at 11, 16, and 20 feet-below-soil surface. Soil vapor from SV#12 was collected, June 26, 2006, at 5, 8, and 15 feet-below-soil surface. Samples collected May 2, 2007 were between 5 and 7 feet-below-soil surface from SV# 15, 17, 18, 20 and 21.

Measurement of soil gas is subject to considerable uncertainty as it can be affected by many factors such as:

- water and air movement through soil,
- soil and groundwater temperature variations,
- the amount of rainfall (United States Geological Survey wells, along the Ohio River about 2 miles away, indicated little change in groundwater levels in June 2006 when these samples were taken),
- the presence of soil bacteria digesting the chemical (biodegradation),
- air pressure,
- building structures,
- pressure differences between the inside and outside of buildings, and
- the amount of soil gas accumulating under a building.

Tests on soil gas samples detected 36 chemicals. Six of these chemicals, 4-ethyltoluene, n-heptane, cyclohexane, propylene, 2-propanol, tetrahydrofuran, are not considered a potential public health hazard through the vapor intrusion pathway. These chemicals do not readily evaporate (low volatility) or exposures to substantial amounts of vapors would not likely cause adverse health effects (low toxicity).[1]

Of the remaining 30 chemicals, 21 are not associated with the CTLO spill. The source of these chemicals and the extent of the plume are unknown. Table 1 lists the chemicals associated, and not associated, with the CTLO spill.

The maximum detected soil gas concentration was compared to appropriate environmental comparison values to determine which of these chemicals needed further review for potential adverse health effects. To be sure that all chemicals needing further review were selected, we assumed that the maximum soil gas detected would be the amount of chemical people would inhale inside buildings. Benzene was the only chemical associated with CTLO needing further review. Six chemicals not associated with CTLO were selected for further review. They are 1,3-butadiene, methylene chloride, chloroform, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and propylbenzene (Table 1).

No adverse health effects are likely from exposures to chemicals whose concentrations fall below the environmental comparison value. Exposures to chemicals found to be greater than the environmental comparison values, or for which no comparison value is found, need additional review to determine if adverse health effects are likely.

Human exposure pathway analysis

The vapor intrusion pathway is a *complete* pathway at this site because there is

1. a source(s) of contamination, volatile chemicals in the groundwater,
2. movement of the volatile chemicals from the groundwater through the soil as soil gas (vapors),
3. buildings where vapors might accumulate,
4. a way for humans to be exposed to chemical vapors by breathing air inside these buildings, and
5. people who may be breathing the vapors.

A completed pathway means people have been exposed to chemicals. However, a completed pathway *does not necessarily mean a public heath hazard* existed in the past, exists currently, or is likely to exist in the future. The amount and length of exposure must be evaluated to determine if there is a public health hazard.

As noted previously, the ingestion pathway was eliminated because no one is using groundwater for household use and a public water supply exists.

Exposure analysis

Gas vapor movement through soil and into buildings is complex. Estimation of indoor air concentrations involves significant uncertainties. Some experts say the uncertainty may reach two orders of magnitude (±100%). Estimates of indoor air concentrations and a determination of

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1 Chemicals whose vapor concentration on the pure component poses an incremental lifetime cancer risk less than 1 in a million or a non-cancer hazard index less than 1 (insufficiently toxic) or whose Henry's Law Constant is less than $1x10^{-5}$ atm-m^3/mol (insufficiently volatile).

a potential for an unacceptable health risk from vapor intrusion into buildings at this site were calculated using two methods.

Some scientists believe that vapor intrusion is highly unlikely if there is two to five feet of uncontaminated soil between the building and contaminated groundwater, as exists at this site [5]. Also the walk-out basements, prevalent along Auburn Road, may reduce the potential for vapor accumulation due to increased air flow.

These are some of the factors that make estimates of exposure uncertain.

- Soil gas concentrations may vary throughout the year.
- The soil gas plume may not have been adequately characterized.
- Soil gas under homes may be different from that detected in the samples.
- More or less vapors may accumulate inside homes than assumed, due to local soil conditions or an unrecognized way for vapors to enter the home.
- Home construction may have disturbed the silty-clay layer in the soil, a likely barrier to vapor migration, and vapors may have a preferential pathway into homes.
- Water pulled by a sump pump may contain volatile chemicals which evaporate into inside air.

Estimate of risk assuming all soil gas enters buildings

The first method used a very conservative assumption that the indoor air concentration is the same as found in the soil gas, i.e. that buildings are not a barrier to the soil vapors and 100% of the soil gas enters homes. In reality, people are exposed to a small portion of vapors in soil because buildings are major, but incomplete, barriers to soil gas vapors. A building restricts entry of a significant amount (at least 99%) of soil gas unless a home has major cracks in the foundation or has water seeps in the home or a sump pump. This method does not take into account many factors used in the Johnson Ettinger model, such as the chemical's properties affecting vapor intrusion. The method also assumed daily exposures to these chemicals over a lifetime. This method was used because of the uncertainty of soil gas data and the limited data set.

Estimate of risk using the Johnson & Ettinger Model

The second method uses the Johnson & Ettinger vapor intrusion model from the EPA [6]. The Johnson & Ettinger model uses many assumptions and factors to estimate the indoor air concentration based on soil gas measurements, chemical properties affecting soil gas movement, and site specific data. Tables 2 and 3 list the assumptions and site-specific data used in the model. The model assumes that not all soil gas will enter the building.

Health risk analysis

Seven chemicals were selected for further health risk analysis (Table 1). Benzene was the only chemical associated with the CTLO spill needing further analysis. None of the exposure estimates were likely to cause adverse non-carcinogenic health effects, based on the Johnson & Ettinger model. Therefore, no further review was needed for exposures to 1,3-dichlorobenzene, 1,4-dichlorobenzene and propylbenzene.

Estimates of estimated air concentrations and excess cancer risk estimated for benzene, 1,3-butadiene, methylene chloride, and chloroform are listed in Table 4. Method 1 assumes all soil gas enters the building. Method 2 uses the Johnson & Ettinger model to estimate excess cancer risk. The EPA inhalation unit risk was used to estimate excess cancer risk for Method 1 (indoor air concentration divided by the inhalation unit risk) and the indoor air concentration for Method 2 (excess cancer risk times the inhalation unit risk).

It is important to recognize that there are other sources of these chemicals in air inside homes. Indoor air concentration estimates are unlikely to raise indoor air concentrations significantly above background levels as noted in Table 4.

A chemical that causes cancer is called a carcinogen. Excess cancer risk is an estimate of the additional cancers that might occur because of exposure to a particular chemical. Excess cancer risk calculations assume no safe exposure levels to a chemical that causes cancer.. In addition, the method uses an assumption of risk that captures 95% of the data (the 95% upper bound for risk) rather than the average of risk data. The use of these and other conservative assumptions means that there is a very good chance that the actual cancer risk is lower than estimated, perhaps by several orders of magnitude.[2] The true risk is unknown and could be as low as zero.

All calculations of excess cancer risk indicated a low to very low excess cancer risk, even with the very conservative assumptions used. The excess cancer risk from daily exposures to 1,3-butadiene at the maximum amount detected is 2 in 10,000. All other estimates are well below 1 in 10,000, a very low excess cancer risk.

Child health considerations

The differences between children and adults demand special consideration. Children can be at greater risk than adults from certain exposures to hazardous substances. Children play outdoors and often use hand-to-mouth behaviors, increasing their exposure potential. Children breathe dust, soil, and vapors that are close to the ground because they are shorter than adults. Children receive a higher dose of a substance per unit of body weight than adults due to their size. Young children may be more susceptible to inhaled chemicals because they breathe more air per body weight than adults and may absorb more of the inhaled chemicals. If toxic exposure levels are high enough during critical growth stages, children's developing body systems can be permanently damaged. Finally, children are dependent on adults for housing access, medical care, and risk identification.

This health consultation considered potential health effects to children to assist adults making decisions regarding their children's health. Studies have not shown children to be more susceptible to benzene, 1,3-butadiene, methylene chloride, chloroform, and dichlorobenzenes than other age groups [7-11].

Conclusions

The five public health hazard categories used by ATSDR are; (1) no public health hazard, (2) no apparent public health hazard, (3) indeterminate public health hazard, (4) public health hazard, and (5) urgent public health hazard.

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2 One order of magnitude is 10 times greater or lower than the original number. Similarly, two orders of magnitude are 100 times, and three orders of magnitude are 1,000 times greater or lower than the original number.

WVDHHR concluded exposure to chemicals at this site from the CTLO spill through vapor intrusion poses “no apparent public health hazard” for the present and the future. The conclusion is based on an analysis using very conservative assumptions due to data limitations and uncertainties. Many factors may reduce exposure to these chemicals in the future. Surface water, soil, and sediment contaminated by the CTLO spill have been removed. The contaminated groundwater is moving toward the northeast, toward the Ohio River. Soil microorganisms may be converting the benzene to less toxic chemicals. Active remediation of the benzene-contaminated groundwater may occur.

Additional chemicals not associated with the CTLO spill with potential to accumulate vapors inside buildings were detected at this site. Although existing data indicates no apparent public health hazard, the extent and source of the plume is unknown. No predictions can be made about future levels of these chemicals in the groundwater and soil gas. For these reasons, the public health hazard category for exposures to these chemicals is an “indeterminate public health hazard.”

Recommendations

WVDHHR makes no recommendations to avoid exposures from vapor intrusion at this site. Existing soil gas data show exposures to vapors inside homes to chemicals associated with the CTLO spill pose “no apparent public health hazard” for the present.

WVDHHR recommends WVDEP characterize the chemical plume for those chemicals not associated with the CTLO spill in groundwater and soil gas.

WVDHHR will review additional data and reassess these conclusions and recommendations if needed to protect the public health.

Public health action plan

A fact sheet co-authored with the Wayne and Cabell health departments will be distributed to residents in this area.

WVDHHR will provide appropriate health education based on community need and requests.

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Certification

This health consultation for the Krouts Creek site was prepared by West Virginia Department of Health and Human Resources (WVDHHR) under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodologies and procedures existing at the time the health consultation was initiated. Editorial review was completed by the Cooperative Agreement partner.

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The Division of Health Assessment and Consultation of ATSDR has reviewed this health consultation and concurred with its findings.

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Appendix. Tables and Figure

Table 1. Soil gas detections compared to environmental comparison values			
Chemical	Maximum soil gas detected (ppbv*)	Environmental Comparison Value	Does this chemical need further review?
Chemicals associated with coal tar light oil (CTLO)			
Benzene	2.3	CREG: 0.03 ppbv	YES
Toluene	51	chronic EMEG/MRL: 80 ppbv	NO
Ethylbenzene	2.8	RfC: 200 ppbv	NO
Xylenes (m-& p- and o-xylenes)	9.7	chronic EMEG/MRL: 50 ppbv	NO
Styrene	4.2	chronic EMEG/MRL: 60 ppbv	NO
1,3,5-Trimethylbenzene	1.1	REL: 25,000 ppbv	NO
1,2,4-Trimethylbenzene	4.6	REL: 25,000 ppbv	NO
Chemicals not associated with coal tar light oil (CTLO)			
1,3-Butadiene	2.6	CREG: 0.01 ppbv	YES
Methylene chloride	5.3	CREG: 0.9 ppbv	YES
Chloroform	0.5	CREG: 0.008 ppbv	YES
1,3-Dichlorobenzene	1.5	RBC: 1.8 ppbv	YES
1,4-Dichlorobenzene	23	chronic EMEG/MRL: 10 ppbv	YES
Propylbenzene	0.21	no environmental CV found	YES
Freon 12	0.49	RBC: 364 ppbv	NO
n-Hexane	5.1	chronic EMEG/MRL: 600 ppbv	NO
Acetone	140	chronic EMEG/MRL: 13,000 ppbv	NO
2-Butanone	9.1	RfC: 2,000 ppbv	NO
Methyl isobutyl ketone	9.2	RfC: 700 ppbv	NO
Ethanol	120	REL: 1,000,000 ppbv	NO
Ethyl acetate	4.4	RBC: 916 ppbv	NO
Chloromethane	0.61	RBC: 46 ppbv	NO
Chlorobenzene	0.63	RBC: 11 ppbv	NO
Isopropylbenzene	0.98	RfC: 80 ppb	NO
1,1,1-Trichloroethane	6.3	RBC: 183 ppbv	NO
Tetrachloroethene	1.1	chronic EMEG/MRL: 40 ppbv	NO
Freon 11	0.58	RBC: 130 ppbv	NO
Freon 113	1.6	RBC: 4,046 ppbv	NO
Carbon disulfide	1.7	RBC: 235 ppbv	NO

**ppbv = parts per billion volume*
CREG: cancer risk evaluation guide
chronic EMEG/MRL = ATSDR Environmental Media Evaluation Guide for exposures lasting longer than 365 days/Minimal Risk Level
RfC = EPA Reference Concentration
REL = Recommended Exposure Limit from National Institute for Occupational Safety and Health
RBC = EPA Region III Risk Based Concentration

Table 2. Default assumptions used in the Johnson & Ettinger model		
Vapor entry through floor-wall seam gap.	0.1 cm	Floor-wall crack width is 0.1 centimeters (cm). All vapors originating from below the building could enter the building. Vapors enter the structure primarily through cracks and openings in the walls and foundation.
Convective transport		Convective transport occurs primarily within the building zone of influence. Vapor speed (velocities) decrease rapidly with increasing distance from the structure.
Diffusion		Diffusion dominates vapor transport between the source of contamination and the building zone of influence.
Pressure differential	4 Pa	4 Pascals (Pa) = 40 gram per centimeter squared (g/cm-s^2) is the pressure differential between the soil and buildings.
Distribution		The contaminant is evenly distributed in the contaminated area.
Extent of contamination		The area of contamination is greater than the floor area in contact with the soil.
Transport		Vapors move in the soil without the influence of water column evaporation and infiltration and no mechanical means of dispersion is occurring.
Transformation		No biodegradation, hydrolysis, or other change in the chemical is occurring.
Permeability		The soil layer in contact with the structure floor and walls is identical in all directions with respect to permeability.
Ventilation rate		Both the building ventilation rate and the difference in dynamic pressure between the interior of the structure and the soil surface are constant values.
Depth below grade to bottom of enclosed space	200 cm or 15 cm	Basement 200 cm (6.7 feet). Slab-on-grade 15 cm. The slab thickness is 10 cm of impermeable concrete.
Building mixing height	3.66 m or 2.44 m	Basement 3.66 meters (m). Slab-on-grade 2.44 m
Indoor air exchange rate	0.25 hr	Inside air is exchanged in 0.25 hours.
Building area	10m x 10m	Building "footprint" is 10m by 10m corresponding to the 10^{th} percentile floor space area for residential single-family dwellings.
Exposure duration	30 years	30 years - length of time at one residence.
Averaging time	70 years	70 year – years in a lifetime
Exposure frequency	350days/yr	Number of days at home in a year.
Soil properties		Soil properties in any horizontal plane are uniform

Table 2. Default assumptions used in the Johnson & Ettinger model		
Soil-organic carbon fraction	0.002	
Soil gas flow rate	5 L /min	5 liters per minute

Table 3. Site specific data used in the Johnson & Ettinger model		
Groundwater temperature	14.5ºC	USGS data for wells in Cabell and Wayne counties average 14.5ºC (58.1ºF).
Soil type vadose zone	SIC	SIC = silty clay Maximum concentration from MW#12 collected at 152 cm (5 feet) below ground surface. Silty clay is from 3 to 13 feet thick above a 3-7 feet layer of sand and silt.
Soil type vadose zone	S	S = sand Maximum concentration from MW#5 collected at 610 cm (20 feet) below ground surface. Silty clay is from 3 to 13 feet thick above a 3-7 feet layer of sand and silt.
Soil dry bulk density	SIC soil	1.38 [ρ_b^A (g/cm^3)
	S soil	1.66 [ρ_b^A (g/cm^3)
Soil total porosity	SIC soil	0.481 [n^v (cm^3/cm^3)
	S soil	0.375 [n^v (cm^3/cm^3)
Soil water-filled porosity	SIC soil	0.216 [$\theta_w{}^v$ (cm^3/cm^3)
	S soil	0.054 [$\theta_w{}^v$ (cm^3/cm^3)
Benzene		1.9 ppbv sampled in MW#5 20 feet below ground surface in sand
		2.0 ppbv sampled in MW#12 5 feet below ground surface in silty clay
1,3-butadiene		2.6 ppbv sampled in MW#5 20 feet below ground surface in sand
		2.0 ppbv sampled in MW#12 5 feet below ground surface in silty clay

Table 4. Estimates of indoor air concentration, excess cancer risk, and information about background concentrations in homes.

	Method 1*	Method 2**	Background amounts found in homes
Chemical associated with coal tar light oil (CTLO)			
BENZENE: EPA inhalation unit risk for a 1 in 10,000 risk level– (4.07 ppbv)$^{-1}$			
Estimated air concentration	2.3 ppbv	0.004 ppbv	The background level of benzene in homes can range from 0.4 to 1.8 ppbv. The amount can vary widely depending on people's habits, hobbies, and whether a garage is attached to the house. Benzene is in gasoline and automobile exhaust. Benzene is found in glue, paint, furniture wax, detergent, and tobacco smoke. [12]
Number of excess cancers in 10,000 people due to exposures (estimated)	0.6	0.001	
Chemicals not associated with coal tar light oil (CTLO)			
1,3-BUTADIENE: EPA inhalation unit risk for a 1 in 10,000 risk level – (1.36 ppbv)$^{-1}$			
Estimated air concentration	2.6 ppbv	0.003 ppbv	1,3-Butadiene in homes is estimated to be about 0.3 ppbv: 1,3-butadiene is widely found in air from various sources including rubber and plastic production, auto exhaust, gasoline stations, and smoke from wood fires, cigarettes, and open barrel burning. [13]
Number of excess cancers in 10,000 people due to exposures (estimated)	2	0.002	
METHYLENE CHLORIDE: EPA inhalation unit risk for a 1 in 10,000 risk level – (58 ppbv)$^{-1}$			
Estimated air concentration	5.3 ppbv	0.58 ppbv	Methylene chloride is found in homes from 0.11 to 1.8 ppbv: Methylene chloride is found in paint strippers and some products packaged in aerosol cans. [12]
Number of excess cancers in 10,000 people due to exposures (estimated)	0.1	less than 0.001	
CHLOROFORM: EPA inhalation unit risk for a 1 in 10,000 risk level- (0.82 ppbv)$^{-1}$			
Estimated air concentration	0.5 ppbv	0.007 ppbv	<0.05 – 0.9 ppbv: Chloroform in air may come from evaporation from the small amounts found in most drinking water supplies and beverages made from chloroform-containing water. [12]
Number of excess cancers in 10,000 people due to exposures (estimated)	0.6	0.008	
*Method: 1 assumed indoor air concentration is equal to soil gas vapor			
** Method: 2 estimated indoor air concentration and excess cancer risk using the Johnson & Ettinger model			
ppbv = parts per billion volume			

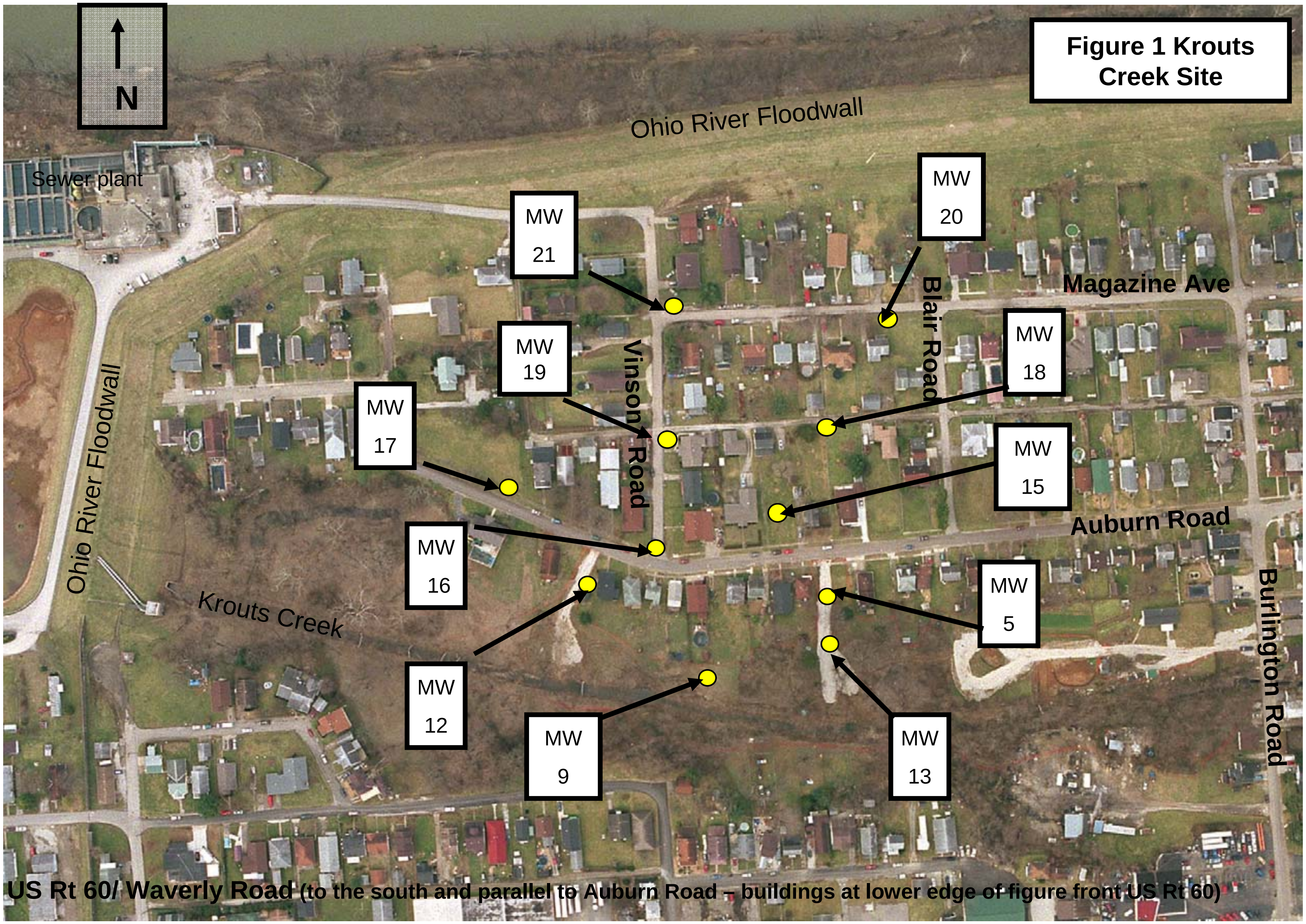
Figure 1 Krouts Creek Site
N
Ohio River Floodwall
Sewer plant
MW 21
MW 20
Magazine Ave
Blair Road
MW 19
Vinson Road
MW 18
MW 17
MW 15
Auburn Road
MW 16
MW 5
Ohio River Floodwall
Krouts Creek
MW 12
Burlington Road
MW 9
MW 13
US Rt 60/ Waverly Road (to the south and parallel to Auburn Road – buildings at lower edge of figure front US Rt 60)