ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

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SRP/Tech

LPC No. 0990555005

Black Brothers Company

MEMORANDUM

Date: October 2, 2018

To: Cleanup Objectives Review and Evaluation Group (CORE)

From: Jeff Guy, Voluntary Site Remediation Unit
Neelu Lowder, Manager, Voluntary Site Remediation Unit

Subject: 0990555005/LaSalle County
Mendota/Black Brothers Company
Site Remediation Program/Technical Reports

Recommendations Requested from CORE

The attached memorandum is presented to CORE to request concurrence with a Tier 3 evaluation developed in general accordance with 35 Illinois Administrative Code (35 IAC) Section 742.935 to support development of Tier 3 remediation objectives for groundwater and soil gas. The objective of this Tier 3 evaluation is to negate the requirement for an institutional control with respect to existing/future building construction at the Site – as related to the indoor inhalation exposure route.

Background Information

This Tier 3 evaluation was performed using an alternative vapor transport model and proposes the use of a mass flux vapor transport model proposed by Little, Daisey, and Nazaroff (LDN). The mathematical and technical information for the proposed model are provided as part of this Tier 3 evaluation. The calculated Tier 3 objectives are independent of building slab or basement structures. The calculations utilize conservative assumptions and default input values that are consistent with the most recent USEPA RSL values and TACO residential scenario assumptions.

Tier 3 soil gas and groundwater objectives were calculated for the volatile chemicals listed in TACO (Appendix A, Table J) that are identified as site contaminants of concern (COCs). The information is provided in the June 2018 *Revised Site Investigation Report/Remediation Objectives Report/Remedial Action Plan* (received August 7, 2018/Log No. 18-67167).

The calculated Tier 3 soil gas and groundwater remediation objectives proposed in the above-referenced document are summarized on Table P-1 attached. It should be noted that the U.S. EPA J&E model was recently updated to include a dirt floor scenario. As a result, the Illinois EPA calculated different results for most of the COCs (see Table P-1), which are the proposed Tier 3 objectives. For soil gas, 'depth to source' (D_{soucre}) is 4.5 feet. For groundwater D_{soucre} is 6 feet.

Site Description

The former manufactured gas plant (MGP) is in the City of Mendota, LaSalle County, Illinois, located at the southeast corner of 5th Street and 9th Avenue. The former MGP was constructed in 1875 and operated until 1941. Coal carbonization was the only process known to have been used at the MGP and reported production levels reportedly ranged from 3,200,000 cubic feet per year to more than 22,000,000 cubic feet per year. None of the former MGP buildings or above-grade structures currently remain, but the exact date of demolition of those structures is unknown. The site consists of the former MGP property (approximately 0.65 area), a portion of the adjacent BBC property and adjacent City of Mendota property – for a total of 1.3 acres.

The site is currently covered by an asphalt parking lot, as well as a small one-story brick building which is currently used as a parking garage for Black Brothers Company (BBC) vehicles. Landscaping and grassy areas are present along portions of the north and west boundaries of the site. In 1966, BBC purchased the former MGP property from Northern Illinois Gas. BBC produces equipment associated with laminating and roll coating. The property surrounding the former MGP to the east and south has always been zoned for industrial uses and over time has all been purchased by BBC.

The former MGP is bound to the north by City-owned parkway with Mendota Creek, then 5th Street, and then residential properties alongside a service business district, successively to the north of the former MGP property. To the south is BBC property consisting of the continuation of the asphalt parking lot, as well as BBC's two-story brick office and manufacturing building, with the BNSF Railway Company tracks, successively to the south. To the east is BBC property consisting of the continuation of the asphalt parking lot, with BBC buildings currently used as a warehouse and for manufacturing located immediately east of the asphalt lot. Beyond the BBC property to the east is the Buckman Iron & Metal Company, Inc., which is a metal recycling center. The area immediately west of the former MGP is City-owned parkway, 9th Avenue, then residential properties and a small asphalt parking lot located to the southwest.

RECs

Major features historically located on the site included the following: retorts and purifiers, two (2) gas holders, two (2) crude oil tanks, coal piles, a tar well, and other MGP apparatus such as the tar/oil separator and miscellaneous small buildings.

Investigation Summary

Site investigations were conducted in three phases from 2011 through 2013. Prior to remediation, investigation activities included excavation of nine (9) test pits, advancement of 31 soil borings and 196 soil probes, as well as the installation of four (4) shallow groundwater monitoring wells, seven (7) soil gas probes and two (2) sub-slab soil gas probes. A total of 247 soil samples, seven (7) groundwater samples, seven (7) soil gas samples and two (2) sub-slab soil gas samples were collected and submitted for chemical analyses. Four (4) quarters of groundwater sampling, which included the collection of 16 groundwater samples, were conducted.

Soil and groundwater samples were analyzed for the focused list of MGP constituents, total petroleum hydrocarbons (TPH), pH, and/or fraction of organic carbon (f_{oc}). In addition to environmental samples, 10 soil samples were collected for geotechnical testing.

Soil borings and soil probes were advanced at depths ranging from 3 feet bgs to 70 feet below ground surface (bgs). Soil samples were collected both inside and outside historic structures and historical features. In addition, a grid-based, random sampling scheme was generated for soil sampling. Regarding the groundwater investigation, the well screen intervals were approximately 5-15 feet bgs. Soil gas sampling was also performed at from depths between 3-5 feet bgs at seven (7) locations.

Proposed Remediation

Excavation of contaminated soil is proposed throughout the entire site to a maximum depth of 28 feet bgs. Confirmation groundwater and/or soil gas samples will be collected upon completion of remedial activities to demonstrate compliance with the proposed Tier 3 remediation objectives to evaluate the indoor inhalation exposure route.

Summary

The documentation provided in this memorandum includes a Tier 3 evaluation using the LDN model including supporting information. Post-remediation groundwater and/or soil gas data will be compared to the proposed Tier 3 objectives to evaluate the indoor inhalation exposure route.

Attachments:

Supporting information from June 2018 *Revised Site Investigation Report/Remediation Objectives Report/Remedial Action Plan* (received August 7, 2018/Log No. 18-67167)

0990555005/LaSalle County
Mendota/Black Brothers Company
Site Remediation Program/Technical Reports

Recommendation:
The Remediation Applicant (RA) is requesting approval of Tier 3 soil gas and groundwater remediation objectives to evaluate the indoor inhalation exposure route at the Black Brothers Company. The indoor inhalation exposure route was evaluated using the Little, Daisey, and Nazaroff (LDN) model (Tier 3 alternate model); post-remediation groundwater and/or soil gas data will be compared to the proposed Tier 3 objectives.

☒ Concur with action or resolution proposed by the project manager

☐ Concur with action or resolution proposed by the project manager with the following conditions:

☐ Reject action or resolution proposed by the project manager

☐ Request the following information before issuing a final CORE recommendation:

Section Manager _____ Date 10/15/18

Unit Manager _____ Date 10/15/18

Project Manager _____ Date 10/15/18

Notes:

9.3.1 Development of Tier 3 Remediation Objectives

The objective of this Tier 3 evaluation is to develop remediation objectives for groundwater and soil gas for the indoor inhalation exposure route that do not require the implementation of an institutional control. The Little, Daisey, and Nazaroff (1992) model for vapor intrusion was used to calculate Tier 3 remediation objectives for groundwater and soil gas. This is a mass flux vapor model that conservatively assumes that no concrete slab or basement floor and walls are present to inhibit the advection of soil gas into the building. A detailed presentation of the model selection, transport mechanisms and calculations of Tier 3 remediation objectives is presented in Appendix P. Tier 3 indoor inhalation remediation objectives for residential receptors in buildings constructed with no concrete slab (i.e., earthen floor) were developed for each of the focused list of MGP compounds and analytes that appear on the TACO indoor inhalation volatiles list (TACO, Appendix A, Table J): benzene, ethylbenzene, styrene, toluene, xylenes, 2-methylphenol, 2-methylnaphthalene, naphthalene, phenol and mercury.

As outlined in the TACO Tier 3 requirements (35 IAC 742.935 (c) and (e)), the following site-specific information is presented to support development of Tier 3 remediation objectives for groundwater and soil gas.

Scaled map of the area, showing all buildings and man-made pathways (current and planned)

The layout of the Site is depicted on Figure 2. Currently, the Site has a one-story brick garage building and other BBC buildings are adjacent to the Site. Potential manmade preferential pathways currently include buried utility trenches and remnants of below ground structures related to the former MGP operations. Remedial actions will include excavation of soil to depths ranging from three feet bgs to 28 feet bgs, to meet unrestricted residential remediation objectives. In the process of excavation, these manmade preferential pathways will be removed, with the exception of several utilities in the western parkway and the storm sewer that runs along BBC buildings.

Current extent and modeled migration of contamination

The extent of COCs in soil is well-defined and is described in this Revised SI/ROR/RAP. To meet the soil remediation objectives, remedial action (consisting of soil removal) is planned. The extent of COCs in groundwater is also well-defined and is described in this Revised SI/ROR/RAP for the Site. The soil remedial actions proposed for the Site are expected to result in reduced constituent concentrations in the upper water-bearing unit.

Geology, including soil types and parameters and the thickness of the capillary fringe

Section 3 presents an evaluation of the geology of the Site based on soil probes and soil borings advanced during investigations. In summary, the geologic materials generally present on the Site are: fill; silty clay; silty sand; clay till; and sand. The Tier 3 indoor inhalation remediation objectives were calculated using TACO default soil and capillary fringe parameters (TACO, Appendix C, Table M) that were used by Illinois EPA to develop Tier 1 indoor inhalation remediation objectives. These values are appropriate and conservative for each soil type present at the Site.

Depth to groundwater (including seasonal variation) and flow direction

Section 3 presents an overview of the hydrogeologic conditions at the Site. The upper water-bearing unit flow in general is to the north toward the Mendota Creek. Some seasonal and year-to-year variation in depth to groundwater has been observed. The shallowest depth to water measured at the Site was 5.17 feet bgs in the round of water table sampling in November 2011. The Tier 3 indoor inhalation exposure route groundwater remediation objectives with a water table at 5 feet bgs will be used for the Site.

Location of soil gas sampling points and discussion of soil gas sampling procedures

As discussed, for current site use seven soil gas locations were installed between 3 to 5 feet bgs beneath the one-story brick building and adjacent to current BBC office and manufacturing buildings. The soil gas locations are presented in Figure 10. The soil gas probes were sampled for chemical analysis which included; benzene, 2-methylnaphthalene, naphthalene and mercury.

Results and locations of groundwater sampling events

Water table samples were collected from the seven locations positioned across the Site. Two sampling locations were located inside and beneath the one-story brick building in the northwest corner of the former MGP, and five sampling locations were located outside and adjacent to the BBC buildings. These water table locations are shown in Figure 9. In addition, groundwater samples from the Site were also collected from the four shallow monitoring wells that were all screened at the water table and their locations are presented in Figure 8.

Mathematical and technical justification for the model proposed, and demonstration that the model was correctly applied

Appendix P presents the mathematical and technical justification for use of the Little, Daisey, and Nazaroff (1992) model. It also presents rationale for the model selected and the inputs used, and addresses the transport mechanisms included in the model.

9.3.2 Application of Tier 3 Indoor Inhalation Remediation Objectives

Based on the evaluation of the site-specific conditions, the Tier 3 indoor inhalation residential groundwater and soil gas remediation objectives were calculated in Appendix P and are acceptable for use at the Site. These Tier 3 remediation objectives are appropriate for evaluation of a potential future building with an earthen crawl space or earthen floor. Post-remediation samples of groundwater and/or soil gas will be collected for evaluating the indoor inhalation exposure route, as further described in Section 12. Post-remediation samples will be analyzed for all the focused list of MGP constituents that are volatile and screened using the established Tier 3 indoor inhalation remediation objectives.

APPENDIX P

Calculation of Tier 3 Soil Gas and Groundwater Remediation Objectives for the Indoor Inhalation Exposure Pathway

1.0 INTRODUCTION

The Tier 1 remediation objectives (ROs) for the indoor inhalation exposure route presented in TACO, Appendix B, Tables H and I (35 IAC 742) were developed using the Johnson and Ettinger (1991) model (J&E) for subsurface vapor intrusion into buildings. This model includes analytical solutions for phase partitioning and attenuation of constituent vapor concentrations based on physical processes, including diffusion through subsurface soil and advection of soil gas into indoor air.

The TACO Tier 1 default model parameters used for calculation of soil gas and groundwater ROs assume that current or future buildings have a full concrete slab-on-grade that is a minimum of 10 centimeters thick, or have full concrete basement floor and walls. Consequently, TACO specifies that use of the Tier 1 ROs for the indoor inhalation exposure route requires the implementation of an institutional control that ensures current or future buildings on the subject property will be constructed to meet these assumed criteria. Additionally, TACO presents Tier 1 remediation objectives for "diffusion only" and "diffusion and advection" scenarios. The "diffusion only" scenario is less conservative, and requires implementation of an additional institutional control requiring any current or future building to be greater than 5 feet vertically and horizontally from contamination.

The objective of this Tier 3 evaluation is to develop ROs for soil gas and groundwater for the indoor inhalation exposure route that do not require the implementation of an institutional control. A mass flux vapor model was used to simulate conditions where the full concrete slab-on-grade or the full concrete basement floor and walls specified in Tier 1 TACO assumptions are absent. Furthermore, this Tier 3 evaluation uses the more conservative "diffusion and advection" scenario. Therefore, the resultant Tier 3 ROs developed do not require the building to be greater than 5 feet away from the contaminants, and they allow the Site to be evaluated using either soil gas or groundwater sample analytical results. As shown in Table P-1, Tier 3 ROs for residential receptors in buildings constructed with no concrete slab (i.e., earthen floor) were calculated for soil gas and for two groundwater scenarios.

2.0 MODEL SELECTION

Three mass flux transport models were outlined in a paper by Little, Daisey, and Nazaroff (1992). One of these models (hereafter referred to as the LDN Model), which describes transport from a planar source and, like the J&E Model, includes diffusion and advection transport mechanisms, was selected to calculate the Tier 3 ROs. Unlike the J&E model, which assumes there is attenuation of soil gas constituent concentrations across a building concrete slab or basement floor and walls, the LDN model

conservatively assumes that the entire flux of constituents arriving at the zone near the building is transported into the building. Therefore, the LDN Model, as described in the 1992 paper, is appropriate to evaluate the scenario where no concrete slab or no basement with concrete floor and walls are present to limit vapor transport into the building (e.g. an earthen floor). The LDN Model is also appropriate for evaluation of other building foundation construction types that may provide little resistance to vapor transport like stone foundations, partial concrete floors, or crawl spaces.

3.0 TRANSPORT MECHANISMS: DIFFUSION AND ADVECTION

As required in 35 IAC 742.935(c), this Tier 3 evaluation using the LDN Model accounts for diffusive transport from the contaminant source to areas near the building (i.e., the zone of building pressure influence), and then advective transport from the zone of advective influence into indoor air, as summarized below:

- *Diffusive transport through soils (i.e., total effective diffusion coefficient, D_T^{eff}):* The LDN Model accounts for diffusive transport using the same relationship for diffusion through soils that is used in published mass flux models and by the United States Environmental Protection Agency (USEPA) and Illinois EPA to assess diffusive transport through soils. This relationship for calculation of D_T^{eff}, is consistent with TACO Equations J&E9a and J&E11. The diffusion-related input assumptions used in the TACO Tier 1 default model have been used as input assumptions in the LDN Model.

- *Advective transport*: The LDN Model accounts for advective transport by conservatively assuming that constituents in soil gas are "swept into the building as fast as they arrive at the zone of influence" rather than by using a specific input value for the advective flow rate of soil gas into the building (Little, Daisey, and Nazaroff 1992). This assumption is equivalent to assuming a high soil gas advection rate from soil into the building (i.e., assuming an infinite value for the volumetric flow rate of soil gas into the enclosed space [Q_{soil}]).

  The Tier 3 ROs are more conservative than the Tier 1 "diffusion and advection" ROs because the assumption for advective transport that all constituents in soil gas are swept into the building is more conservative than the Tier 1 assumption of an empirically established advective flow rate (Q_{soil} = 83.33 cm^3/sec). The Tier 3 ROs should not be compared to the Tier 1 "diffusion only" ROs, which assume that constituents only enter the building by diffusing across the slab and no advective migration occurs at all (Q_{soil} = 0 cm^3/sec).

Because the LDN Model assumes that there are no transport limitations due to the presence of a concrete slab, and instead all subsurface constituents in soil gas are swept into the building, the overall rate of movement of soil gas to indoor air is limited by the rate of diffusion in soil (i.e., diffusion-limited conditions for constituent transport).

4.0 INPUT VALUES

As shown in Table P-2, the input parameters to the LDN Model were based on TACO default physical setting input values for Tier 1 ROs for parameters that are not related to the slab; however, the following parameters are not included in the LDN Model because no slab is present:

- Area of total cracks (A_{crack});
- Slab thickness (L_{crack});
- Air-filled porosity for soil in cracks ($\theta_{a,crack}$);
- Total porosity for soil in cracks ($\theta_{T,crack}$);
- Water-filled porosity for soil in cracks ($\theta_{w,crack}$); and
- Floor-wall seam gap (w).

Additionally, as previously discussed, no value was needed for the volumetric flow rate of soil gas into the enclosed space (Q_{soil}), because the LDN Model assumes that all constituents in soil gas beneath the building floor are swept into the building. This is similar to assuming an infinite value for Q_{soil}.

Tier 3 ROs for residential receptors were calculated for soil gas and for two groundwater scenarios. For calculation of the Tier 3 soil gas ROs, the TACO default distance from ground surface to top of contamination (D_{source}) of 5 feet was used. Two sets of groundwater ROs were calculated. One set used the TACO default D_{source} value of 10 feet, and to maintain conservatism for sites with water tables less than 10 feet bgs, a second set of Tier 3 groundwater ROs was calculated using a D_{source} value of 5 feet.

As recommended by Illinois EPA, the chemical-specific physical parameters and toxicity parameters used for the calculations were the values in the USEPA *Regional Screening Levels (RSLs) – Generic Tables* (June 2017).

5.0 CALCULATED TIER 3 REMEDIATION OBJECTIVES

As listed in Table P-1, ROs were calculated for constituents that are listed on the focused list of MGP compounds and analytes that appears onthe TACO Indoor Inhalation Volatile Chemicals List (35 IAC 742, Appendix A, Table J). Risk-based carcinogenic or non-carcinogenic indoor air target concentrations (or both) were calculated as appropriate based on the toxicological effects of each chemical, using the same equations and exposure scenario input values as specified in TACO for Tier 1 and Tier 2 applications. For chemicals exhibiting both carcinogenic and non-carcinogenic effects, the minimum of the carcinogenic and non-carcinogenic target concentrations was selected as the target concentration in indoor air, $RO_{indoor\ air}$.

Using the input parameters presented in Table P-2, the LDN Model was used to calculate the vapor intrusion attenuation factors, α, for soil gas and groundwater source scenarios. Because the attenuation factor is the ratio of the concentration in indoor air to the concentration in soil gas, the attenuation factors

were then used to calculate residential and industrial/commercial remediation objectives for soil gas as follows:

$$RO_{soil\ gas} = \frac{RO_{indoor\ air}}{\alpha}$$

The attenuation factors were used similarly to calculate groundwater remediation objectives, with the additional use of the Henry's Law equilibrium constant at the system temperature (H'_{TS}) and a unit conversion from liters (L) to cubic meters (m^3) to calculate partitioning between the groundwater phase and the soil gas phase:

$$RO_{gw} = \frac{RO_{indoor\ air}}{\alpha \times H'_{TS} \times 1000 \frac{L}{m^3}}$$

Table P-3 present the calculations for soil gas ROs. Table P-4 present the calculations for groundwater ROs using a D_{source} input value of 5 feet; these remediation objectives are applicable for sites at which the water table is equal to or greater than 5 feet but less than 10 feet bgs. Table P-5 present the calculations for groundwater remediation objectives using a D_{source} input value of 10 feet; these remediation objectives are applicable for sites at which the water table is equal to or greater than 10 feet bgs. Table P-1 summarizes the Tier 3 ROs that were calculated for soil gas and groundwater.

6.0 CONCLUSIONS

The LDN Model was used to develop Tier 3 ROs for soil gas and groundwater for the indoor inhalation exposure route for buildings without a concrete slab on grade or full concrete basement floor and walls (i.e. an earthen floor). The resultant Tier 3 ROs facilitate closure of a site without the use of institutional controls.

7.0 REFERENCES

Illinois Administrative Code (IAC), 2004. Title 35: Environmental Protection, Subtitle G: Waste Disposal, Chapter I: Pollution Control Board, Subchapter f: Risk Based Cleanup Objectives, Part 740, Site Remediation Program.

IAC, 2013. Title 35: Environmental Protection, Subtitle G: Waste Disposal, Chapter I: Pollution Control Board, Subchapter f: Risk Based Cleanup Objectives, Part 742, Tiered Approach to Corrective Action Objectives.

Johnson, P.C. and Ettinger, R.A., 1991. Heuristic model for predicting the intrusion rate of contaminant vapors in buildings. *Environmental Science and Technology* vol. 25, pages 1445-1452.

Little, J.C.; Daisey, J.M.; and Nazaroff, W.W., 1992. Transport of subsurface contaminants into buildings: an exposure pathway for volatile organics. *Environmental Science and Technology* vol. 26, pages 2058-2066.

USEPA, 2004. *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings.*

USEPA, 2016. Risk Assessment » Regional Screening Levels (RSLs) - Generic Tables (June 2017), Internet Address: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017 Accessed June 2017.
Files Accessed: (1) Summary Table, Excel format, (2) Chemical Specific Parameters, Excel format, and (3) User's Guide, HTML format.

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EPA results

Table P-1
Summary of Residential Remediation Objectives
Tier 3 Indoor Inhalation Exposure Route

Compound/Analyte	Tier 3 Soil Gas ROs (D_{source} = 5 feet) Residential (mg/m^3)		Tier 3 Groundwater ROs Water Table at 5 feet bgs (D_{source} = 5 feet) Residential (mg/L)		Tier 3 Groundwater ROs Water Table at 10 feet bgs (D_{source} = 10 feet) Residential (mg/L)
Volatile Organic Compounds (VOCs)					
Benzene	0.23	0.057	0.10	0.097	0.103
Ethylbenzene	0.93	0.21	0.36	0.34	0.37
Styrene	960	230	✓ *310*	310	*310*
Toluene	4,400	960	✓ *530*	530	*530*
Xylenes, Total	100	23	30	26	30
Semivolatile Organic Compounds (SVOCs)					
2-Methylnaphthalene	*410*	530	✓ *25*	25	*25*
2-Methylphenol	310	81	11,900	9,400	26,000
Phenol	49	14	5,600	4,700	14,000
Naphthalene	0.077	0.019	✓ 0.055	0.056	0.065
Mercury					
Mercury	0.67	0.07	*0.060*	0.047	*0.060*

Notes:

1) bgs - below ground surface; mg/m^3 - milligrams per cubic meter; mg/L - milligrams per liter

2) ROs shown in *italics* are based on the solubility limit of the chemical because no inhalation toxicity criteria were available.

Table P-2
Input Values for Residential Calculations
Tier 3 Indoor Inhalation Exposure Route

Symbol	Parameter	Units	Residential Tier 3 Input Values	
			Equation/Reference	Input Value
		Building-Related Parameters		
A_B	Surface area of enclosed space at or below grade	cm^2	$A_B = (L_B \times W_B)$ (same as TACO Equation J&E12a)	1.000×10^6
ER	Air exchange rate	exchanges per hour	TACO Appendix C, Table M	0.53
H_B	Height of building	cm	TACO Appendix C, Table M	244
L_B	Length of building	cm	TACO Appendix C, Table M	1,000
L_F	Distance from ground surface to bottom of floor	cm	TACO Appendix C, Table M	10*
Q_{bldg}	Building ventilation rate	cm^3/s	$Q_{bldg} = \left(\frac{L_B \times W_B \times H_B \times ER}{3600 \frac{sec}{hr}} \right)$ (same as TACO Equation J&E13)	3.59×10^4
W_B	Width of building	cm	TACO Appendix C, Table M	1,000

Note:
1) * - Although the Tier 3 model assumes no slab is present, setting L_F = 10 cm is conservative (shortens the diffusion path length) and results in the appropriate value for L_T to maintain consistency with Tier 1 for non-building-related parameters (see page 2 of this table).

Table P-2 (Continued)
Input Values for Residential Calculations
Tier 3 Indoor Inhalation Exposure Route

Symbol	Parameter	Units	Residential Tier 3 Input Values	
			Equation/Reference	Input Value
		Exposure Parameters		
AT_c	Averaging time for carcinogens	year	TACO Appendix C, Table M	70
AT_{nc}	Averaging time for noncarcinogens	year	TACO Appendix C, Table M	30
ED	Exposure duration	year	TACO Appendix C, Table M	30
EF	Exposure frequency	day/year	TACO Appendix C, Table M	350
RfC	Reference concentration	µg/m^3	USEPA RSL Tables[1]	Chemical Specific
$RO_{indoor\ air}^{carc}$	Indoor Air Target Concentration for carcinogenic chemicals	mg/m^3	$RO_{indoor\ air} = \frac{TR \times AT_c \times 365\frac{days}{yr}}{ED \times EF \times URF \times 1000\frac{\mu g}{mg}}$ (same as TACO Equation J&E1)	Calculated value
$RO_{indoor\ air}^{nc}$	Indoor Air Target Concentration for non-carcinogenic chemicals	mg/m^3	$RO_{indoor\ air} = \frac{THQ \times AT_{nc} \times 365\frac{days}{yr} \times RfC}{ED \times EF}$ (same as TACO Equation J&E2)	Calculated value
$RO_{gw\text{-}calc}$	Groundwater remediation objective	mg/L	$RO_{gw} = \frac{RO_{indoor\ air}}{\alpha \times H'_{TS} \times 1000\frac{L}{m^3}}$ (derived from TACO Equations J&E4 and J&E6)	Calculated value
$RO_{sg\text{-}calc}$	Soil gas remediation objective	mg/m^3	$RO_{soil\ gas} = \frac{RO_{indoor\ air}}{\alpha}$ (same as TACO Equation J&E4)	Calculated value
THQ	Target hazard quotient	unitless	TACO Appendix C, Table M	1
TR	Target risk	unitless	TACO Appendix C, Table M	1×10^{-6}
URF	Unit risk factor	$(\mu g/m^3)^{-1}$	USEPA RSL Tables[1]	Chemical Specific

Note:
(1) "USEPA RSL Tables" refers to *Regional Screening Level (RSL) Chemical-specific Parameters Supporting Table June 2017* and *Regional Screening Level Summary Table June 2017* published by USEPA, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017

Table P-2 (Continued)
Input Values for Residential Calculations
Tier 3 Indoor Inhalation Exposure Route

Symbol	Parameter	Units	Residential Tier 3	
			Equation/Reference	Input Value
Attenuation and Partitioning Parameters				
D_i	Diffusivity in air	cm^2/s	USEPA RSL Tables[1]	Chemical Specific
D_{soil}^{eff}	Effective diffusion coefficient for the soil layer	cm^2/s	$D_i^{eff} = D_i\left(\frac{\theta_{a,i}^{3.33}}{\theta_{T,i}^2}\right) + \left(\frac{D_w}{H'_{TS}}\right)\left(\frac{\theta_{w,i}^{3.33}}{\theta_{T,i}^2}\right)$ (same as TACO Equation J&E11)	Calculated Value
D_{capp}^{eff}	Effective diffusion coefficient for the capillary fringe	cm^2/s	$D_i^{eff} = D_i\left(\frac{\theta_{a,i}^{3.33}}{\theta_{T,i}^2}\right) + \left(\frac{D_w}{H'_{TS}}\right)\left(\frac{\theta_{w,i}^{3.33}}{\theta_{T,i}^2}\right)$ (same as TACO Equation J&E11)	Calculated Value
D_{source}	Distance from ground surface to top of contamination	cm	Site Specific Value	Soil Gas Model: 152.4 Groundwater Model (5ft): 152.4 Groundwater Model (10ft): 304.8
D_T^{eff}	Total overall effective diffusion coefficient	cm^2/s	$D_T^{eff} = \frac{L_T}{\sum_{i=1}^{n} L_i / D_i^{eff}}$ (same as TACO Equation J&E9a)	Calculated Value
D_w	Diffusivity in water	cm^2/s	USEPA RSL Tables[1]	Chemical Specific
H'_{TS}	Dimensionless Henry's law constant at 13°C	unitless	TACO Appendix C Table E	Chemical Specific

Note:
(1) "USEPA RSL Tables" refers to *Regional Screening Level (RSL) Chemical-specific Parameters Supporting Table June 2017* and *Regional Screening Level Summary Table June 2017* published by USEPA, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017

Table P-2 (Continued)
Input Values for Residential Calculations
Tier 3 Indoor Inhalation Exposure Route

Symbol	Parameter	Units	Residential Tier 3	
			Equation/Reference	Input Value
Attenuation and Partitioning Parameters (Continued)				
L_{capp}	Thickness of capillary fringe	cm	TACO Appendix C, Table M	Soil Gas Model: NA Groundwater Models: 37.5
L_{soil}	Thickness of vadose zone soil	cm	$L_{soil} + L_{capp} = L_T$ therefore $L_{soil} = L_T - L_{capp}$ (based on TACO Equation J&E9b: $\sum_{i=1}^{n} L_i = L_T$)	Soil Gas Model: NA Groundwater Model (5ft): 104.9 Groundwater Model (10ft): 257.3
L_T	Distance from bottom of floor to top of contamination	cm	$L_T = D_{source} - L_F$ (same as TACO Equation J&E10)	Soil Gas Model: 142.4 Groundwater Model (5ft): 142.4 Groundwater Model (10ft): 294.8
n	Total number of layers of different types of soil vapors migrate through from source to building	unitless	TACO Appendix C, Table M	Soil Gas Model: 1 Groundwater Models: 2 (vadose zone and capillary fringe)
S	Solubility in water	mg/L	USEPA RSL Tables(1)	Chemical Specific
α	Attenuation factor	unitless	$\alpha = \frac{A_{bldg} \times D_T^{eff}}{Q_{bldg} \times L_T}$ Little, Daisey, and Nazaroff (1992): equation 5, steady state form	Calculated Value
$\theta_{a,soil}$	Air-filled soil porosity	cm^3/cm^3	TACO Appendix C, Table M	0.28
$\theta_{a,capp}$	Air-filled porosity of capillary fringe	cm^3/cm^3	TACO Appendix C, Table M (Capillary Fringe = 0.1 x $\theta_{T,i}$)	0.043
$\theta_{T,i}$	Total porosity of soil layer i	cm^3/cm^3	TACO Appendix C, Table M	0.43
$\theta_{w,soil}$	Water-filled soil porosity	cm^3/cm^3	TACO Appendix C, Table M	0.15
$\theta_{w,capp}$	Water-filled porosity of capillary fringe	cm^3/cm^3	TACO Appendix C, Table M (Capillary Fringe = 0.9 x $\theta_{T,i}$)	0.387

Note:
(1) "USEPA RSL Tables" refers to *Regional Screening Level (RSL) Chemical-specific Parameters Supporting Table June 2017* and *Regional Screening Level Summary Table June 2017* published by USEPA, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017

Table P-2 (Continued)
Input Values for Residential Calculations
Tier 3 Indoor Inhalation Exposure Route

Symbol	Parameter	Units	Residential Tier 3	
			Equation/Reference	Input Value
		Vapor Saturation Paremeters		
C_v^{sat}	Vapor saturation limit	mg/m^3	$C_v^{sat} = \frac{P \times MW}{R \times T} \times 10^6$ (same as TACO Equation J&E5)	Calculated Value
VP	Vapor pressure	atm	USEPA RSL Tables[1] (with unit conversion from mm Hg to atm)	Chemical Specific
MW	Molecular Weight	g/mol	USEPA RSL Tables[1]	Chemical Specific
R	Ideal gas constant	L-atm/K-mol	TACO Appendix C, Table M	0.08206
T	Temperature	K	USEPA RSL Tables[1]	298

Note:
(1) "USEPA RSL Tables" refers to *Regional Screening Level (RSL) Chemical-specific Parameters Supporting Table June 2017* and *Regional Screening Level Summary Table June 2017* published by USEPA, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017

Table P-5
Calculation of Residential Groundwater Remediation Objectives
Water Table at 10 feet bgs (D_{source} = 10 feet)
Tier 3 Indoor Inhalation Exposure Route

Compound/Analyte	Chemical-Specific Parameters					Little, Daisey, & Nazaroff (1992) Model Calculations				Calculation of Indoor Air Target Concentrations			Calculated Tier 3 RO	Solubility Limit	Selected Tier 3 RO
	D_i (cm^2/sec)	D_w (cm^2/sec)	H'_{TS} (unitless)	URF ($\mu g/m^3$)	RfC (mg/m^3)	D_{eff}^{eff} (cm^2/sec)	D_{capp}^{eff} (cm^2/sec)	D_T^{eff} (cm^2/sec)	α (unitless)	$RO_{indoor\ air}^{carc}$ (mg/m^3)	$RO_{indoor\ air}^{nc}$ (mg/m^3)	$RO_{indoor\ air}$ (mg/m^3)	$RO_{gw-calc}$ (mg/L)	S (mg/L)	$RO_{groundwater}$ (mg/L)
Volatile Organic Compounds (VOCs)															
Benzene	9.0E-02	1.0E-05	1.34E-01	7.8E-06	3.0E-02	7.0E-03	3.1E-05	2.4E-04	2.3E-05	3.1E-04	3.1E-02	3.1E-04	0.103	1.8E+03	0.103
Ethylbenzene	6.8E-02	8.5E-06	1.64E-01	2.5E-06	1.0E+00	5.3E-03	2.2E-05	1.7E-04	1.6E-05	9.7E-04	1.0E+00	9.7E-04	0.37	1.7E+02	0.37
Styrene	7.1E-02	8.8E-06	5.43E-03	NA	1.0E+00	5.6E-03	3.8E-04	2.0E-03	1.9E-04	NC	1.0E+00	1.0E+00	1,000	3.1E+02	*310*
Toluene	7.8E-02	9.2E-06	1.49E-01	NA	5.0E+00	6.1E-03	2.6E-05	2.0E-04	1.9E-05	NC	5.2E+00	5.2E+00	1,900	5.3E+02	*530*
Xylenes, Total	6.9E-02	8.5E-06	2.71E-01	NA	1.0E-01	5.3E-03	1.8E-05	1.4E-04	1.3E-05	NC	1.0E-01	1.0E-01	30	1.1E+02	30
Semivolatile Organic Compounds (SVOCs)															
2-Methylnaphthalene	5.2E-02	7.8E-06	6.95E-03	NA	NA	4.1E-03	2.6E-04	1.4E-03	1.4E-04	NC	NC	NC	NC	2.5E+01	*25*
2-Methylphenol	7.3E-02	9.3E-06	2.00E-05	NA	6.0E-01	1.0E-02	1.1E-01	1.2E-02	1.1E-03	NC	6.3E-01	6.3E-01	29,000	2.6E+04	26,000
Phenol	8.3E-02	1.0E-05	6.67E-06	NA	2.0E-01	2.2E-02	3.5E-01	2.5E-02	2.3E-03	NC	2.1E-01	2.1E-01	14,000	8.3E+04	14,000
Naphthalene	6.0E-02	8.4E-06	8.29E-03	3.4E-05	3.0E-03	4.7E-03	2.4E-04	1.4E-03	1.3E-04	7.2E-05	3.1E-03	7.2E-05	0.065	3.1E+01	0.065
Mercury															
Mercury	3.1E-02	6.3E-06	1.56E-01	NA	3.0E-04	2.4E-03	1.4E-05	1.0E-04	9.8E-06	NC	3.1E-04	3.1E-04	0.200	6.0E-02	*0.060*

Notes:
1) Chemical-specific parameters are from the USEPA Regional Screening Levels (RSLs) Summary Table, revised June 2017.
2) Dimensionless Henry's Law Constants (H'_{TS}) are the values contained in TACO Appendix C, Table E for a system temperature (TS) of 13°C.
3) Chemicals shown are the SRP target compounds and analytes that appear on the TACO indoor inhalation volatile chemicals list (TACO, Appendix A, Table J).
4) NA - Toxicity information is not available for this chemical for the inhalation route of exposure.
5) carc - carcinogenic
6) nc - non-carcinogenic
7) NC - Not calculated because toxicity information is not available for the inhalation route of exposure.
8) $RO_{indoor\ air}$ is the lesser of the calculated carcinogenic and non-carcinogenic ROs for indoor air.
9) Solubility limits are from the USEPA RSLs Summary Table, revised June 2017.
10) Selected Tier 3 RO is the lesser of the calculated Tier 3 RO and the solubility limit. If no toxicity criteria were available for the inhalation route of exposure, the solubility limit was selected as the Tier 3 RO, in the same manner as used in Tier 1 (TACO, Appendix B, Table H, Footnote f). ROs based on the solubility limit are shown in *italics*.
11) * - Although a URF is provided in the USEPA RSLs Summary Table, chemical does not meet the statutory definition of a carcinogen as specified in the Illinois Environmental Protection Act (Chapter 415 of the Illinois Compiled Statutes (415 ILCS 5/58.2)).

Table P-3
Calculation of Residential Soil Gas Remediation Objectives
D_{source} = 5 feet
Tier 3 Indoor Inhalation Exposure Route

Compound/Analyte	Chemical-Specific Parameters							Little, Daisey, & Nazaroff (1992) Model Calculations			Calculation of Indoor Air Target Concentrations			Calculated Tier 3 RO	Vapor Saturation Limit	Selected Tier 3 RO
	D_i (cm^2/sec)	D_w (cm^2/sec)	H'_{TS} (unitless)	MW (g/mole)	VP (mm Hg)	URF ($\mu g/m^3$)$^{-1}$	RfC (mg/m^3)	D_{ed}^{eff} (cm^2/sec)	D_T^{eff} (cm^2/sec)	α (unitless)	$RO_{indoor\ air}^{carc}$ (mg/m^3)	$RO_{indoor\ air}^{nc}$ (mg/m^3)	$RO_{indoor\ air}$ (mg/m^3)	$RO_{sg\text{-}calc}$ (mg/m^3)	C_v^{sat} (mg/m^3)	$RO_{soil\ gas}$ (mg/m^3)
Volatile Organic Compounds (VOCs)																
Benzene	9.0E-02	1.0E-05	1.34E-01	7.8E+01	9.5E+01	7.8E-06	3.0E-02	7.0E-03	7.0E-03	1.4E-03	3.1E-04	3.1E-02	3.1E-04	0.23 *	4.0E+05	0.23
Ethylbenzene	8.5E-02	8.5E-06	1.64E-01	1.1E+02	9.6E+00	2.5E-06	1.0E+00	5.3E-03	5.3E-03	1.0E-03	9.7E-04	1.0E+00	9.7E-04	0.93	5.7E+04	0.93
Styrene	7.1E-02	8.8E-06	5.48E-03	1.0E+02	6.4E+00	NA	1.0E+00	5.6E-03	5.6E-03	1.1E-03	NC	1.0E+00	1.0E+00	960	3.4E+04	960
Toluene	7.8E-02	9.2E-06	1.49E-01	9.2E+01	2.8E+01	NA	5.0E+00	6.1E-03	6.1E-03	1.2E-03	NC	5.2E+00	5.2E+00	4,400	1.4E+05	4,400
Xylenes, Total	8.9E-02	8.5E-06	2.71E-01	1.1E+02	8.0E+00	NA	1.0E-01	5.3E-03	5.3E-03	1.0E-03	NC	1.0E-01	1.0E-01	100	4.7E+04	100
Semivolatile Organic Compounds (SVOCs)																
2-Methylnaphthalene	5.2E-02	7.8E-06	6.95E-03	1.4E+02	5.5E-02	NA	NA	4.1E-03	4.1E-03	8.0E-04	NC	NC	NC	NC	4.1E+02	*410*
2-Methylphenol	7.3E-02	9.3E-06	2.00E-05	1.1E+02	3.0E-01	NA	6.0E-01	1.0E-02	1.0E-02	2.0E-03	NC	6.3E-01	6.3E-01	310	1.8E+03	310
Phenol	8.3E-02	1.0E-05	6.67E-06	9.4E+01	3.5E-01	NA	2.0E-01	2.2E-02	2.2E-02	4.2E-03	NC	2.1E-01	2.1E-01	49	1.8E+03	49
Naphthalene	6.0E-02	8.4E-06	8.29E-03	1.3E+02	8.5E-02	3.4E-05	3.0E-03	4.7E-03	4.7E-03	9.3E-04	7.2E-05	3.1E-03	7.2E-05	0.077	5.9E+02	0.077
Mercury																
Mercury	3.1E-02	6.3E-06	1.59E-01	2.0E+02	2.0E-03	NA	3.0E-04	2.4E-03	2.4E-03	4.7E-04	NC	3.1E-04	3.1E-04	0.67	2.2E+01	0.67

Notes:
1) Chemical-specific parameters are from the USEPA Regional Screening Levels (RSLs) Summary Table, revised June 2017.
2) Dimensionless Henry's Law Constants (H'_{TS}) are the values contained in TACO Appendix C, Table E for a system temperature (TS) of 13°C.
3) Chemicals shown are the SRP target compounds and analytes that appear on the TACO indoor inhalation volatile chemicals list (TACO, Appendix A, Table J).
4) NA - Toxicity information is not available for this chemical for the inhalation route of exposure.
5) For the soil gas model, $D_T^{eff} = D_{ed}^{eff}$ because only one layer is modeled in the system.
6) carc - carcinogenic
7) nc - non-carcinogenic
8) NC - Not calculated because toxicity information is not available for the inhalation route of exposure.
9) $RO_{indoor\ air}$ is the lesser of the calculated carcinogenic and non-carcinogenic ROs for indoor air.
10) Vapor saturation limits are calculated as described in Table P-2.
11) Selected Tier 3 RO is the lesser of the calculated Tier 3 RO and the vapor saturation limit. If no toxicity criteria were available for the inhalation route of exposure, the vapor saturation limit was selected as the Tier 3 RO, in the same manner as used in Tier 1 (TACO, Appendix B, Table H, Footnote f). ROs based on the vapor saturation limit are shown in *italics*.
12) * - Although a URF is provided in the USEPA RSLs Summary Table, chemical does not meet the statutory definition of a carcinogen as specified in the Illinois Environmental Protection Act (Chapter 415 of the Illinois Compiled Statutes [415 ILCS 5/58.2]).

Table P-4
Calculation of Residential Groundwater Remediation Objectives
Water Table at 5 feet bgs (D_{source} = 5 feet)
Tier 3 Indoor Inhalation Exposure Route

Compound/Analyte	Chemical-Specific Parameters					Little, Daisey, & Nazaroff (1992) Model Calculations				Calculation of Indoor Air Target Concentrations			Calculated Tier 3 RO	Solubility Limit	Selected Tier 3 RO
	D_i (cm^2/sec)	D_w (cm^2/sec)	H'_{TS} (unitless)	URF ($\mu g/m^3$)	RfC (mg/m^3)	D_{soil}^{eff} (cm^2/sec)	D_{crack}^{eff} (cm^2/sec)	D_T^{eff} (cm^2/sec)	α (unitless)	$RO_{indoor\ air}^{carc}$ (mg/m^3)	$RO_{indoor\ air}^{nc}$ (mg/m^3)	$RO_{indoor\ air}$ (mg/m^3)	$RO_{gw-calc}$ (mg/L)	S (mg/L)	$RO_{groundwater}$ (mg/L)
Volatile Organic Compounds (VOCs)															
Benzene	9.0E-02	1.0E-05	1.34E-01	7.8E-06	3.0E-02	7.0E-03	3.1E-05	1.2E-04	2.3E-05	3.1E-04	3.1E-02	3.1E-04	0.102	1.8E+03	0.10
Ethylbenzene	6.8E-02	8.5E-06	1.64E-01	2.5E-06	1.0E+00	5.3E-03	2.2E-05	8.3E-05	1.6E-05	9.7E-04	1.0E+00	9.7E-04	0.38	1.7E+02	0.38
Styrene	7.1E-02	8.8E-06	5.48E-03	NA	1.0E+00	5.6E-03	3.8E-04	1.2E-03	2.4E-04	NC	1.0E+00	1.0E+00	810	3.1E+02	*310*
Toluene	7.8E-02	9.2E-06	1.49E-01	NA	5.0E+00	6.1E-03	2.6E-05	9.8E-05	1.9E-05	NC	5.2E+00	5.2E+00	1,600	5.3E+02	*530*
Xylenes, Total**	6.9E-02	8.5E-06	2.71E-01	NA	1.0E-01	5.3E-03	1.8E-05	6.6E-05	1.3E-05	NC	1.0E-01	1.0E-01	30	1.1E+02	30
Semivolatile Organic Compounds (SVOCs)															
2-Methylnaphthalene	5.2E-02	7.8E-06	6.95E-03	NA	NA	4.1E-03	2.6E-04	8.5E-04	1.7E-04	NC	NC	NC	NC	2.5E+01	*25*
2-Methylphenol	7.3E-02	9.3E-06	2.00E-05	NA	6.0E-01	1.0E-02	1.1E-01	1.3E-02	2.6E-03	NC	6.3E-01	6.3E-01	11,900	2.6E+04	11,900
Phenol	8.3E-02	1.0E-05	6.67E-06	NA	2.0E-01	2.2E-02	3.5E-01	2.9E-02	5.6E-03	NC	2.1E-01	2.1E-01	5,600	8.3E+04	5,600
Naphthalene	6.0E-02	8.4E-06	8.29E-03	3.4E-05	3.0E-03	4.7E-03	2.4E-04	8.0E-04	1.6E-04	7.2E-05	3.1E-03	7.2E-05	0.055	3.1E+01	0.055
Mercury															
Mercury	3.1E-02	6.3E-06	1.59E-01	NA	3.0E-04	2.4E-03	1.4E-05	5.1E-05	1.0E-05	NC	3.1E-04	3.1E-04	0.20	6.0E-02	*0.060*

Notes:

1) Chemical-specific parameters are from the USEPA Regional Screening Levels (RSLs) Summary Table, revised June 2017.
2) Dimensionless Henry's Law Constants (H'_{TS}) are the values contained in TACO Appendix C, Table E for a system temperature (TS) of 13°C.
3) Chemicals shown are the focused list of MGP compounds and analytes that appear on the TACO indoor inhalation volatile chemicals list (TACO, Appendix A, Table J).
4) NA - Toxicity information is not available for this chemical for the inhalation route of exposure.
5) carc - carcinogenic
6) nc - non-carcinogenic
7) NC - Not calculated because toxicity information is not available for the inhalation route of exposure.
8) $RO_{indoor\ air}$ is the lesser of the calculated carcinogenic and non-carcinogenic ROs for indoor air.
9) Solubility limits are from the USEPA RSLs Summary Table, revised June 2017.
10) Selected Tier 3 RO is the lesser of the calculated Tier 3 RO and the solubility limit. If no toxicity criteria were available for the inhalation route of exposure, the solubility limit was selected as the Tier 3 RO, in the same manner as used in Tier 1 (TACO, Appendix B, Table H, Footnote f). ROs based on the solubility limit are shown in *italics*.
11) ** - No Dimensionless Henry's law constant (H'_{TS}) is provided within TACO for Total Xylenes at 13°C. The value used for the Dimensionless Henry's Law Constant (HTS) is the value contained in TACO for total xylenes at 25°C, which results in a more conservative groundwater remediation objective for the indoor inhalation exposure route.