MICHIGAN DEPARTMENT OF
ENVIRONMENT, GREAT LAKES, AND ENERGY

Tier 2 MIRBCA Example Site

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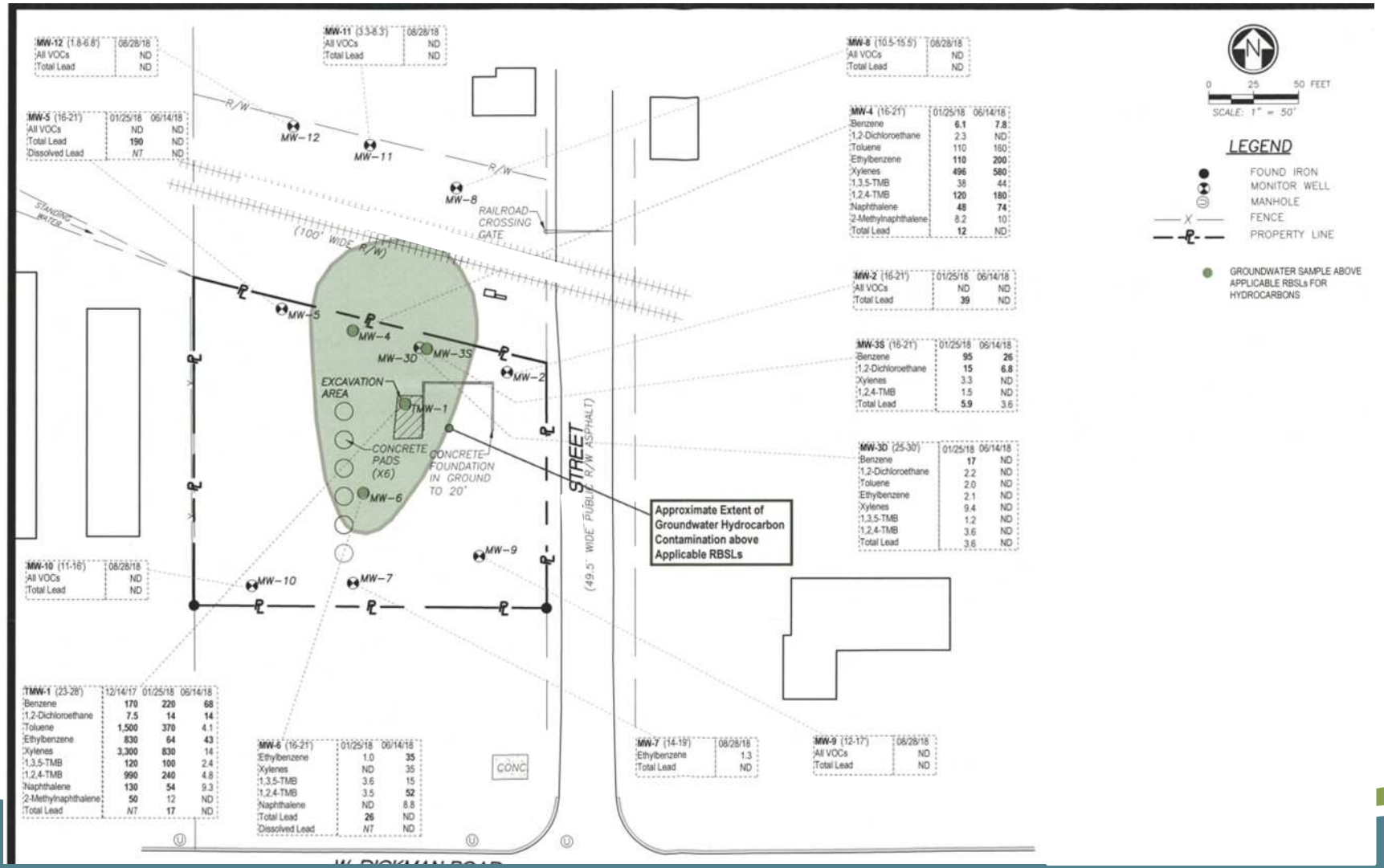
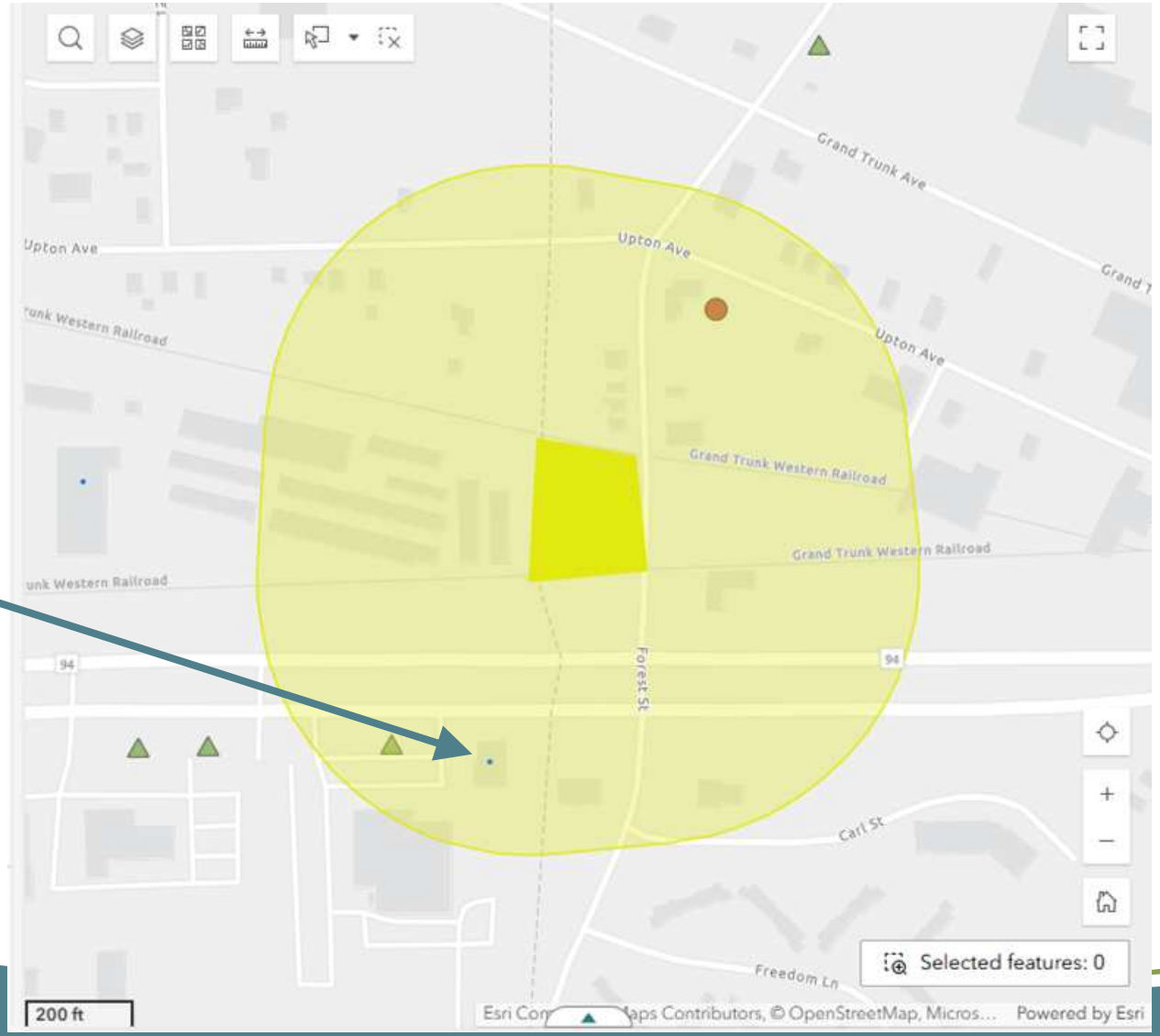
Example Site



500’ Well Survey

Water supply well



Current Use

- Is there a water supply well onsite?
  - No
- Is there a potentially impacted offsite supply well?
  - There is one supply well, 320’ upgradient from property boundary
  - No supply wells are potentially impacted (professional judgment)
- The groundwater protection pathway is not complete for current use

MIRBCA Form 13(1) – Onsite

MIRBCA REPORT — **FORM NO. 13(1)**

Facility ID number:	**Date(s) confirmed release(s) discovered:**
Date form completed:	**Form completed by:**

GROUNDWATER PROTECTION - CURRENT USE (ONSITE AND OFFSITE)

ONSITE: Determine if the pathway is complete for current use onsite

1. Is there a water supply well onsite? ☐ Yes ☑ No

   If the answer is "Yes", provide the total depth of the well (ft bgs):

   The onsite supply well(s) is the point of exposure (POE) for current use and must be sampled. If there is no onsite well, then the pathway is not complete for current use.

2. Is the current land use nonresidential? ☑ Yes ☐ No

Based on the above considerations, is the GW protection pathway complete for:

Onsite residential current use	☐ **Yes** ☑ **No**
Onsite nonresidential current use	☐ **Yes** ☑ **No**

EGLE

MIRBCA Form 13(1) – Offsite

OFFSITE: Determine if the pathway is complete for current use offsite

1. Are there any water supply wells within 500 ft of the site property boundary? ☑ Yes ☐ No

If the answer is "Yes", provide the following information for each well:

Well ID	Distance from Site Property to Well (ft)	Direction	Screen Interval (ft bgs)	Water Use	Land Use R	Land Use NR
X12345Y	*320*	*South*	*70-90*	*Potable*	☑	☐
					☐	☐
					☐	☐
					☐	☐
					☐	☐

Any potentially impacted supply wells are points of exposure (POEs) for current use and must be sampled. If there are no potentially impacted supply wells, then the pathway is not complete for current use.

Based on the above considerations, is the GW protection pathway complete for:

Offsite residential current use	☐ **Yes**	☑ **No**
Offsite nonresidential current use	☐ **Yes**	☑ **No**

EGLE

MIRBCA Form 13(2) – Onsite Future Use

GWNIAA

GW in a shallow, unusable aquifer

MIRBCA REPORT — **FORM NO. 13(2)**

Facility ID number:	**Date(s) confirmed release(s) discovered:**
Date form completed:	**Form completed by:**

GROUNDWATER PROTECTION - FUTURE USE (ONSITE)

ONSITE: Determine if the pathway is complete for future use onsite	**Yes**	**No**
1. Is there a land use or groundwater resource use restriction onsite?	☐	☑
2a. **Groundwater quantity**. Does the formation yield sufficient water? *(Refer to Appendix B.2 and justify below, if the answer is "No")*	☑	☐
2b. **Hydraulic communication**. Is the impacted formation likely to transport COCs to an aquifer? *(Refer to Appendix B.2 and justify below, if the answer is "No")*	☑	☐
3a. Is the depth to the bottom of the aquifer >15 feet? *(Refer to Appendix B.3 and justify below, if the answer is "No")*	☑	☐
3b. Is the impacted formation likely to transport COCs to a useable aquifer? *(Refer to Appendix B.3 and justify below, if the answer is "No")*	☑	☐
3c. Are there any water supply wells within 300 feet of the site property? *(Refer to Appendix B.3 and provide justification below)*	☐	☑

If either: (i) 2a and 2b are checked "No", or (ii) 3a, 3b, and 3c are checked "No", the pathway is not complete for future use. If the pathway is complete for future use, the POE is any point in the affected aquifer and is evaluated in Tier 1 by the recent maximum concentration of each COC on each impacted property.

Based on the above considerations, is the GW protection pathway complete for:

Onsite residential future use	☑ **Yes**	☐ **No**
Onsite nonresidential future use	☐ **Yes**	☑ **No**

MIRBCA Form 13(2) – Offsite Future Use

MIRBCA REPORT **FORM NO. 13(3)**

Facility ID number:	Date(s) confirmed release(s) discovered:
Date form completed:	Form completed by:

GROUNDWATER PROTECTION - FUTURE USE (OFFSITE)

OFFSITE: Determine if the pathway is complete for future use offsite	Yes	No
1. Is there a land use or groundwater resource use restriction onsite?	☐	☑
2a. **Groundwater quantity**. Does the formation yield sufficient water? (*Refer to Appendix B.2 and justify below, if the answer is "No"*)	☑	☐
2b. **Hydraulic communication**. Is the impacted formation likely to transport COCs to an aquifer? (*Refer to Appendix B.2 and justify below, if the answer is "No"*)	☑	☐
3a. Is the depth to the bottom of the aquifer >15 feet? (*Refer to Appendix B.3 and justify below, if the answer is "No"*)	☑	☐
3b. Is the impacted formation likely to transport COCs to a useable aquifer? (*Refer to Appendix B.3 and justify below, if the answer is "No"*)	☑	☐
3c. Are there any water supply wells within 300 feet of the site property? (*Refer to Appendix B.3 and provide justification below*)	☐	☑

If either: (i) 2a and 2b are checked "No", or (ii) 3a, 3b, and 3c are checked "No", the pathway is not complete for future use. If the pathway is complete for future use, the POE is any point in the affected aquifer and is evaluated in Tier 1 by the recent maximum concentration of each COC on each impacted property.

Based on the above considerations, is the GW protection pathway complete for:

Offsite residential future use	☑ **Yes**	☐ **No**
Offsite nonresidential future use	☐ **Yes**	☑ **No**

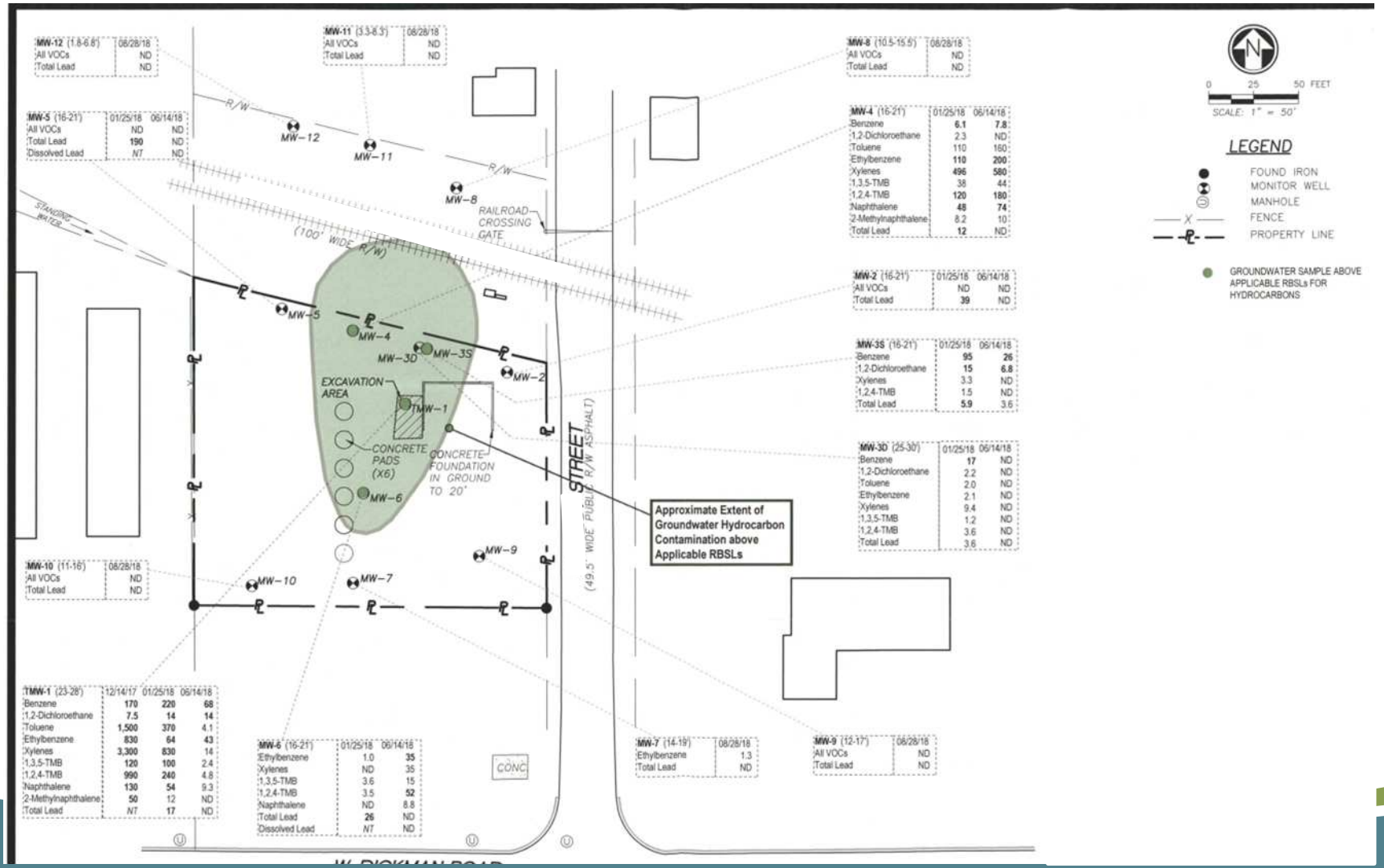
Summary of Tier 1 Exposure Model

MIRBCA REPORT								FORM NO. 15(5) - SUMMARY OF EM
Facility ID number:			Date(s) confirmed release(s) discovered:					
Date form completed:			Form completed by:					
SUMMARY OF EXPOSURE MODEL (COMPLETE ROUTES OF EXPOSURE HIGHLIGHTED)								
ROUTES OF EXPOSURE	ONSITE RECEPTOR				OFFSITE RECEPTOR			
	CURRENT USE		FUTURE USE		CURRENT USE		FUTURE USE	
	Residential	Nonresidential	Residential	Nonresidential	Residential	Nonresidential	Residential	Nonresidential
VADOSE ZONE SOIL								
Volatilization to indoor air								
Groundwater protection	NC	NC	C	NC	NC	NC	C	NC
Surface water protection								
GROUNDWATER								
Groundwater protection	NC	NC	C	NC	NC	NC	C	NC
Surface water protection								
Volatilization to indoor air								

Representative Concentrations

- Tier 1 – Recent Maximum for each COC
  - Onsite – Determine recent maximum for each COC
  - Offsite – Determine recent maximum for each COC
  - Maximum can be from different wells

Representative Concentrations



Representative Concentrations

- Benzene – 220 ug/L
- Toluene – 1,500 ug/L
- Ethylbenzene – 830 ug/L
- Xylenes – 3,300 ug/L
- (for demonstration only)

Onsite Current Use Evaluation

MIRBCA REPORT										FORM NO. 16(2CG) - ONSITE NONRESIDENTIAL CURRENT USE					
Facility ID number:				**Date(s) confirmed release(s) discovered:**											
Date form completed:				**Form completed by:**											
COMPARISON OF TIER 1 RBSLs WITH REPRESENTATIVE CONCENTRATIONS - ONSITE NONRESIDENTIAL CURRENT USE (SURFICIAL SOIL AND GW PROTECTION)															
CHEMICALS OF CONCERN	**SURFICIAL SOIL**									**VADOSE ZONE SOIL**			**GROUNDWATER**		
	Direct contact (dermal contact and ingestion)			Ambient air inhalation (vapors)			Ambient air inhalation (particulates)			Groundwater protection		**NC**	Groundwater protection		**NC**
	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. POE [µg/kg]	RBSLs POE [µg/kg]	**E/NE**	Rep. Conc. POE [µg/L]	RBSLs POE [µg/L]	**E/NE**
Benzene															
Toluene															
Ethylbenzene															
Total xylenes															
1,2,4-Trimethylbenzene															
1,3,5-Trimethylbenzene															

Future Use Onsite Evaluation

MIRBCA REPORT												FORM NO. 16(1FG) - ONSITE RESIDENTIAL FUTURE USE					
Facility ID number:				**Date(s) confirmed release(s) discovered:**													
Date form completed:				**Form completed by:**													
COMPARISON OF TIER 1 RBSLs WITH REPRESENTATIVE CONCENTRATIONS - ONSITE RESIDENTIAL FUTURE USE (SURFICIAL SOIL AND GW PROTECTION)																	
CHEMICALS OF CONCERN	**SURFICIAL SOIL**									**VADOSE ZONE SOIL**			**GROUNDWATER**		
	Direct contact (dermal contact and ingestion)			Ambient air inhalation (vapors)			Ambient air inhalation (particulates)			Groundwater protection		**C**	Groundwater protection		**C**
	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. POE [µg/kg]	RBSLs POE [µg/kg]	**E/NE**	Rep. Conc. POE [µg/L]	RBSLs POE [µg/L]	**E/NE**
Benzene													*2.20E+02*	5.00E+00	**E**
Toluene													*1.50E+03*	7.90E+02	**E**
Ethylbenzene													*8.30E+02*	7.40E+01	**E**
Total xylenes													*3.30E+03*	2.80E+02	**E**

MIRBCA REPORT													FORM NO. 16(3FG) - OFFSITE RESIDENTIAL FUTURE USE		
Facility ID number:				**Date(s) confirmed release(s) discovered:**											
Date form completed:				**Form completed by:**											
COMPARISON OF TIER 1 RBSLs WITH REPRESENTATIVE CONCENTRATIONS - OFFSITE RESIDENTIAL FUTURE USE (SURFICIAL SOIL AND GW PROTECTION)															
CHEMICALS OF CONCERN	**SURFICIAL SOIL**									**VADOSE ZONE SOIL**			**GROUNDWATER**		
	Direct contact (dermal contact and ingestion)			Ambient air inhalation (vapors)			Ambient air inhalation (particulates)			Groundwater protection		**C**	Groundwater protection		**C**
	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. [µg/kg]	RBSLs [µg/kg]	**E/NE**	Rep. Conc. POE [µg/kg]	RBSLs POE [µg/kg]	**E/NE**	Rep. Conc. POE [µg/L]	RBSLs POE [µg/L]	**E/NE**
Benzene													*5.00E-01*	5.00E+00	**NE**
Toluene													*1.00E+01*	7.90E+02	**NE**
Ethylbenzene													*1.00E+01*	7.40E+01	**NE**
Total xylenes													*1.00E+01*	2.80E+02	**NE**
1,2,4-Trimethylbenzene															

Replace ND values with <detection limit
(values in slide are for demonstration purposes only)

Summary of Exceedances

MIRBCA REPORT						FORM NO. 16(6) - SUMMARY OF EXCEEDANCES			
Facility ID number:		**Date(s) confirmed release(s) discovered:**							
Date form completed:		**Form completed by:**							
SUMMARY OF EXCEEDANCES (EXCEEDANCES FOR COMPLETE ROUTES OF EXPOSURE HIGHLIGHTED)									
ROUTES OF EXPOSURE	**CURRENT USE**		**FUTURE USE**		**CURRENT USE**		**FUTURE USE**		
	Residential	**Nonresidential**	**Residential**	**Nonresidential**	**Residential**	**Nonresidential**	**Residential**	**Nonresidential**	
SURFICIAL SOIL									
Direct contact (dermal contact and ingestion)									
Ambient air inhalation (vapors)									
Ambient air inhalation (particulates)									
VADOSE ZONE SOIL									
Groundwater protection									
Surface water protection (POE at GSI)									
Surface water protection (POE at Storm sewer outfall)									
Volatilization to indoor air (Building 1)									
Volatilization to indoor air (Building 2)									
GROUNDWATER									
Groundwater protection			E				NE		
Surface water protection (POE at GSI)									

Recommendations Based on Tier 1 Evaluation

MIRBCA REPORT **FORM NO. 17(1)**

Facility ID number:	Date(s) confirmed release(s) discovered:
Date form completed:	Form completed by:

CONCLUSION AND RECOMMENDATION BASED ON TIER 1 EVALUATON (ONSITE RECEPTORS)

Instructions: *Based on the results of the Tier 1 Evaluation, (refer to Form 16(6)), discuss each medium, pathway and receptor combination that exceeds the Tier 1 RBSLs. For each exceedance, propose actions to manage the unacceptable risk. Actions can include (i) Tier 2 evaluation, (ii) institutional controls, notices, and restrictions to eliminate the pathway, (iii) Monitoring, (iv) others including active remediation, Tier 3 etc. or (v) a combination of these.*

Current/Future Use	Medium	Receptor	Complete Exposure Pathway for Which Representative Concentration Exceeds RBSL	Proposed Management Strategy
Future Use	*Groundwater*	*Residential*	*Groundwater protection*	☑ Tier 2 Evaluation ☐ Institutional controls ☐ Monitoring ☐ Other (active remediation, Tier 3 etc. (provide details below)
				☐ Tier 2 Evaluation ☐ Institutional controls ☐ Monitoring ☐ Other (active remediation, Tier 3 etc. (provide details below)

Exposure Model for Tier 2 Evaluation

MIRBCA REPORT			FORM NO. 18(1)
Facility ID number:			Date(s) confirmed release(s) discovered:
Date form completed:			Form completed by:
EXPOSURE MODEL FOR TIER 2 EVALUATION BASED ON TIER 1 RESULTS (ONSITE RECEPTORS)			
Current/Future Use	**Medium**	**Receptor**	**Complete Exposure Pathway for Which Representative Concentration Exceeds RBSL**
Future Use	Groundwater	Residential	Groundwater protection

Tier 2 Future Use POE

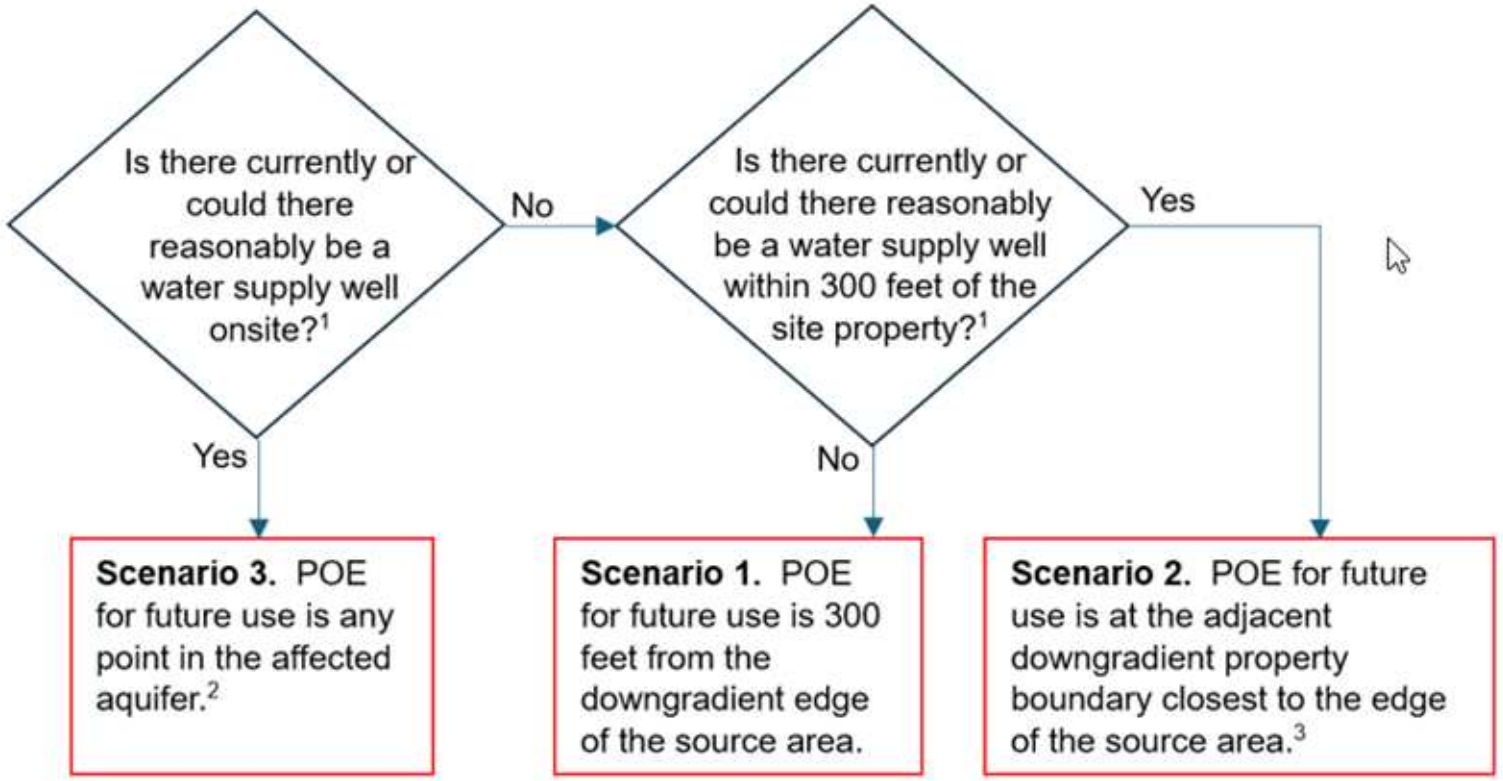


Figure 5-13. Determining a Tier 2 POE for the groundwater protection pathway

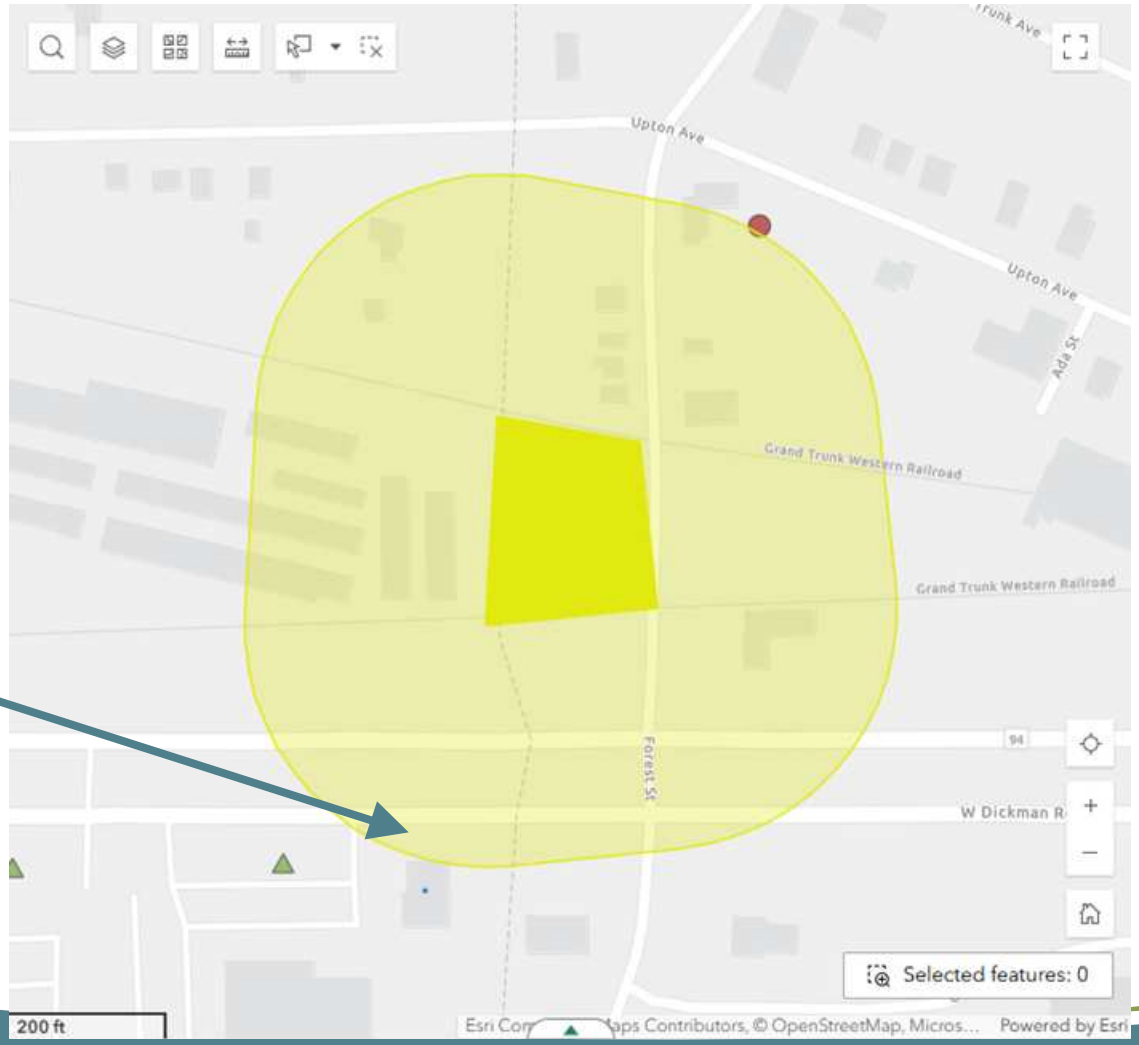
[1]Refer to the three bullet points listed in Scenario 1 to determine if a future water supply well could reasonably be installed. [2]Excluding restricted areas and ROWs. [3]The POE is located in the affected aquifer, at a point closest to the source area on the adjacent property boundary, excluding restricted areas and ROWs. Refer to the discussion in Scenario 2, below.

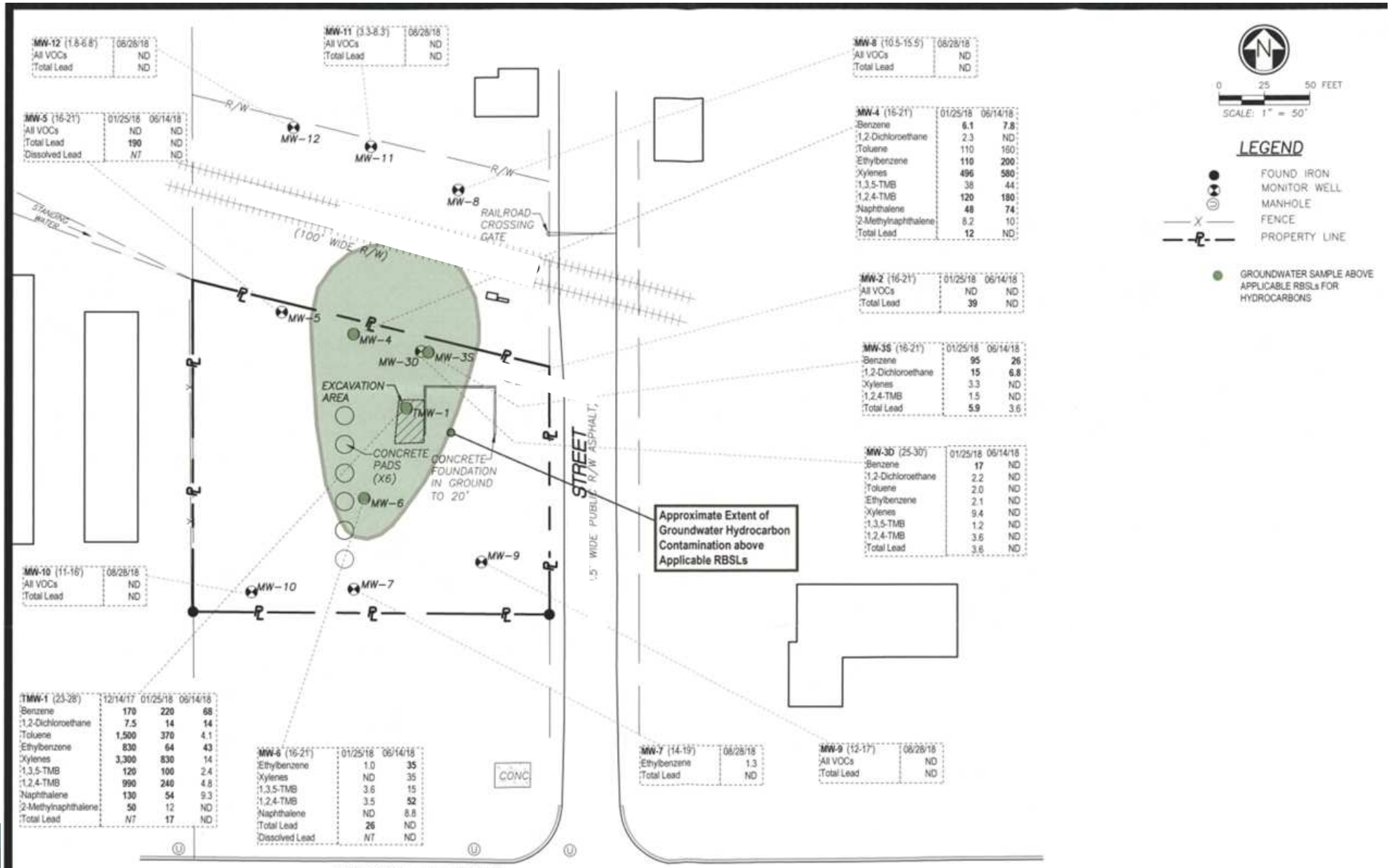
A well cannot reasonably be installed if…

- Property is connected to municipal water
- Municipal water is available and there is an ordinance that either requires hookup or prohibits future wells
- Groundwater use on the property is reliably restricted pursuant to Section 21310a of the NREPA

300’ Buffer from Property Boundary

Property boundary of property with supply well is within 300’ of site property boundary




MW-12 (1.8-6.8') 08/28/18
All VOCs ND
Total Lead ND
MW-11 (3.3-8.3') 08/28/18
All VOCs ND
Total Lead ND
MW-8 (10.5-15.5') 08/28/18
All VOCs ND
Total Lead ND
MW-5 (16-21') 01/25/18 06/14/18
All VOCs ND ND
Total Lead 190 ND
Dissolved Lead NT ND
MW-4 (16-21') 01/25/18 06/14/18
Benzene 6.1 7.8
1,2-Dichloroethane 2.3 ND
Toluene 110 160
Ethylbenzene 110 200
Xylenes 496 580
1,3,5-TMB 38 44
1,2,4-TMB 120 180
Naphthalene 48 74
2-Methylnaphthalene 8.2 10
Total Lead 12 ND
MW-2 (16-21') 01/25/18 06/14/18
All VOCs ND ND
Total Lead 39 ND
MW-3S (16-21') 01/25/18 06/14/18
Benzene 95 26
1,2-Dichloroethane 15 6.8
Xylenes 3.3 ND
1,2,4-TMB 1.5 ND
Total Lead 5.9 3.6
MW-3D (25-30') 01/25/18 06/14/18
Benzene 17 ND
1,2-Dichloroethane 2.2 ND
Toluene 2.0 ND
Ethylbenzene 2.1 ND
Xylenes 9.4 ND
1,3,5-TMB 1.2 ND
1,2,4-TMB 3.6 ND
Total Lead 3.6 ND
MW-10 (11-16') 08/28/18
All VOCs ND
Total Lead ND
TMW-1 (23-28') 12/14/17 01/25/18 06/14/18
Benzene 170 220 68
1,2-Dichloroethane 7.5 14 14
Toluene 1,500 370 4.1
Ethylbenzene 830 64 43
Xylenes 3,300 830 14
1,3,5-TMB 120 100 2.4
1,2,4-TMB 990 240 4.8
Naphthalene 130 54 9.3
2-Methylnaphthalene 50 12 ND
Total Lead NT 17 ND
MW-6 (16-21') 01/25/18 06/14/18
Ethylbenzene 1.0 35
Xylenes ND 35
1,3,5-TMB 3.6 15
1,2,4-TMB 3.5 52
Naphthalene ND 8.8
Total Lead 26 ND
Dissolved Lead NT ND
MW-7 (14-19') 08/28/18
Ethylbenzene 1.3
Total Lead ND
MW-9 (12-17') 08/28/18
All VOCs ND
Total Lead ND
R/W
MW-12
MW-11
MW-8
RAILROAD CROSSING GATE
STANDING WATER
(100' WIDE R/W)
MW-5
MW-4
MW-3D
MW-3S
EXCAVATION AREA
TMW-1
CONCRETE PADS (X6)
CONCRETE FOUNDATION IN GROUND TO 20'
MW-6
MW-9
MW-10
MW-7
STREET
(66' WIDE PUBLIC R/W ASPHALT)
Approximate Extent of Groundwater Hydrocarbon Contamination above Applicable RBSLs
CONC
W. DICKMAN ROAD
N
0 25 50 FEET
SCALE: 1" = 50'
LEGEND
FOUND IRON
MONITOR WELL
MANHOLE
FENCE
PROPERTY LINE
GROUNDWATER SAMPLE ABOVE APPLICABLE RBSLs FOR HYDROCARBONS

MIRBCA REPORT	FORM NO. 2-3
Facility ID number:	**Date(s) confirmed release(s) discovered:**
Date form completed:	**Form completed by:**

TIER 2 DETERMINING GROUNDWATER PROTECTION POE FOR FUTURE USE

1. Is there a water supply well onsite or could a well reasonably be installed onsite? ☐ Yes ☑ No

   (Refer to MIRBCA Section 5.4)

   *If the answer is "Yes", omit Questions 2 to 7 and complete the bottom part of the form. The POE for future use is any point in the affected aquifer (**Scenario 3**) and is evaluated by the maximum of the recent average (refer to MIRBCA Section 5.4) on each impacted property. If "No", continue with the form.*

2. List source dimensions (ft): Length (W) **25** Width (Y) **25** *(Refer to MIRBCA Section 7.2.2)*

3. List the predominant groundwater flow direction: **NNE**

4. Are there any existing water supply wells or could a future water supply well reasonably be installed within 300 ft of the site property boundary? ☑ Yes ☐ No

   *If "No", the POE for future use is 300 ft downgradient from the edge of the source (**Scenario 1**). Provide documentation of no current wells within 300 ft of property boundary and documentation that a well could not reasonably be installed (e.g., documentation that all properties within 300 feet are connected to municipal water or documentation of an ordinance that requires connection to municipal water or prohibits future wells). If "Yes", complete the information below.*

MIRBCA REPORT | **FORM NO. 2-3**

Facility ID number:	Date(s) confirmed release(s) discovered:
Date form completed:	Form completed by:

TIER 2 DETERMINING GROUNDWATER PROTECTION POE FOR FUTURE USE

Offsite Property Address	Distance From Source to Property With Current or Reasonable Future Well (ft)	Direction
123 Main St.	**290 feet**	*South*

5. List distance and direction from edge of source to nearest downgradient property boundary — Distance(ft) ***150*** Direction ***NNE***

6. Is a distance listed in #4 less than the distance listed in #5 ☐ Yes ☑ No

If "Yes", the distance and direction in #4 must also be evaluated as a POE:

Distance(ft) _____ Direction _____ (Additional POE for **Scenario 2**)

7. Does an additional POE other than #5 require evaluation because of uncertainty or variability in groundwater flow direction? ☐ Yes ☑ No

If "Yes", list distance from source to nearest property boundary and list direction.

Distance(ft) _____ Direction _____ (Additional POE for **Scenario 2**)

Conclusions (Check All That Apply):

☐ Scenario 1: POE is **300 ft** downgradient from edge of source area — Direction _____

☑ Scenario 2: POE is nearest downgradient property boundary — Distance(ft) ***150*** Direction ***NNE***

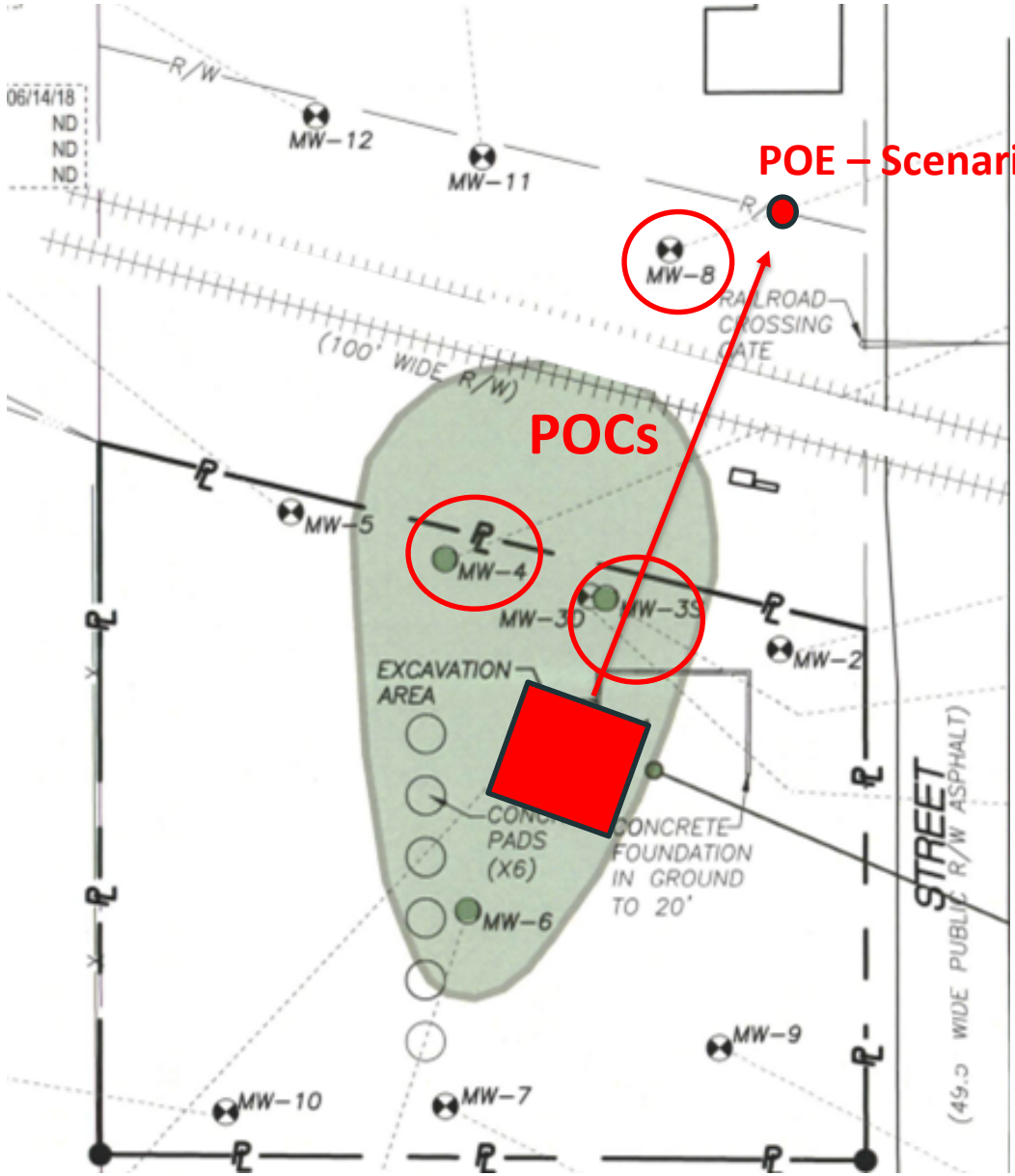
☐ Scenario 2: Additional POE(s) — Distance(ft) _____ Direction _____

☐ Scenario 3: POE is any point in the affected aquifer

List POC Wells (Scenario 2 and 3 Only):

POC#	Well ID	Distance from Source (ft)	Direction from Source
1	*MW-3s*	*40*	*NW*
2	*MW-4*	*50*	*NNE*
3	*MW-8*	*130*	*NNE*

EGLE

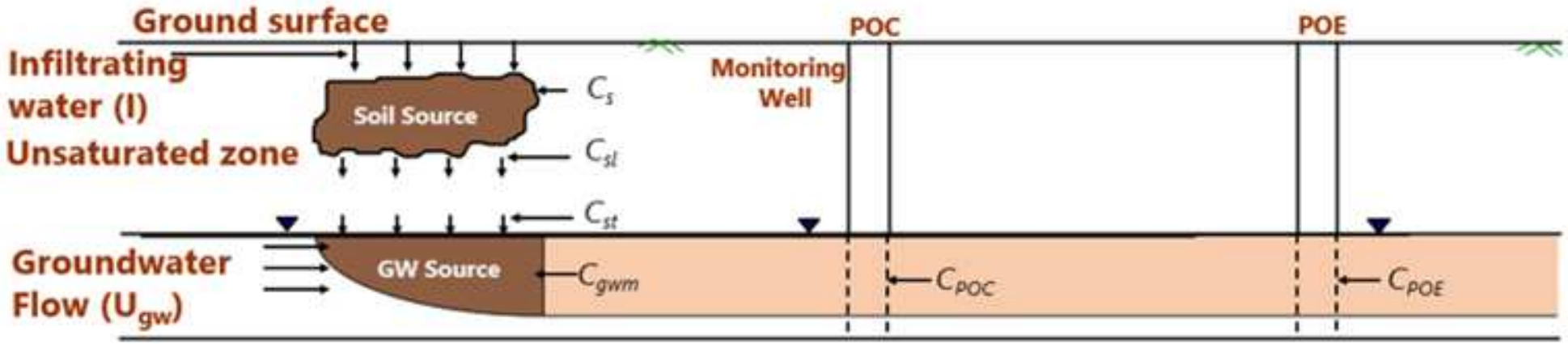

POE – Scenario 2
POCs
06/14/18
ND
ND
ND
MW–12
MW–11
MW–8
R/W
RAILROAD CROSSING GATE
(100' WIDE R/W)
MW–5
MW–4
MW–3D
MW–3S
MW–2
EXCAVATION AREA
CONC PADS (X6)
CONCRETE FOUNDATION IN GROUND TO 20'
MW–6
MW–9
MW–10
MW–7
STREET
(49.5 WIDE PUBLIC R/W ASPHALT)

Tier 2 Inputs

- Precipitation is 30”/year; assume infiltration is 10%
- Depth to GW is 16’
- Aquifer is silty sand, assume 35,000 cm/year (~1150 ft/year)
- Gradient is 1.5’ per 150’ = 0.01
- Mixing zone thickness 7’ estimated
- Source dimensions = 25’ by 25’

Dilution Attenuation Factors

- DAF-vadose zone = 1
- DAF-mixing zone = 13.86
- DAF-saturated zone = 10.97
- DAF-POC1 = 1.40
- DAF-POC2 = 1.79
- DAF-POC3 = 8.40



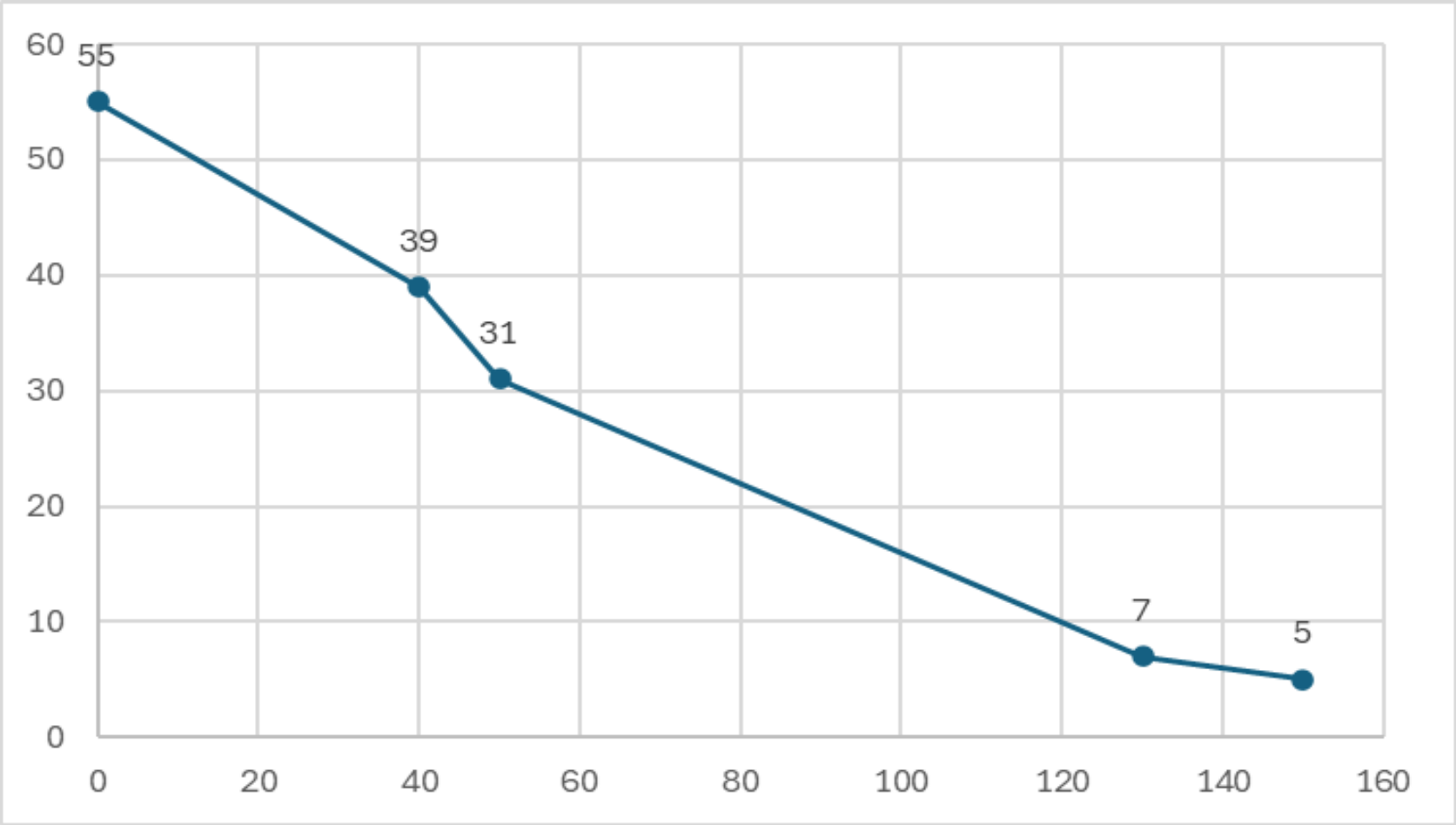
Tier 2 SSTLs

	SSTL(soil source)	SSTL(GWsource)	SSTL(POC1)	SSTL(POC2)	SSTL(POC3)	RBTL(POE)
Benzene	390	55	39	31	7	5
Toluene	83248	8688	6184	4859	1034	790
Ethylbenzene	12635	814	579	455	97	74
Xylenes	42223	3079	2192	1722	366	280

- DAF-vadose zone = 1
- DAF-mixing zone = 13.86
- DAF-saturated zone = 10.97
- DAF-POC1 = 1.40
- DAF-POC2 = 1.79
- DAF-POC3 = 8.40

$$C_{POC} = C_{POE} \times \frac{DAF_{POE}}{DAF_{POC}}$$

Tier 2 Benzene SSTLs



Width of groundwater source (Y)

- Estimate based on soil borings, plume width, size of release
- Can conservatively estimate large size
- Smaller width requires more justification

- 50’ = 5.78 DAF; 29 ppb benzene
- 25’ = 10.97 DAF; 55 ppb benzene
- 10’ = 27.09 DAF; 135 ppb benzene

$$\frac{1}{DAF} = \frac{C(x)}{C_o} = erf\left[\frac{Y}{4\sqrt{\alpha_y x}}\right] \times erf\left[\frac{\delta_{gw}}{2\sqrt{\alpha_z x}}\right]$$

Dispersivity

- Longitudinal dispersivity (alpha-x)
  - 10% of distance to POC
- Lateral dispersivity (alpha-y)
  - 33% of longitudinal dispersivity
- Vertical dispersivity (alpha-z)
  - 5% of longitudinal dispersivity

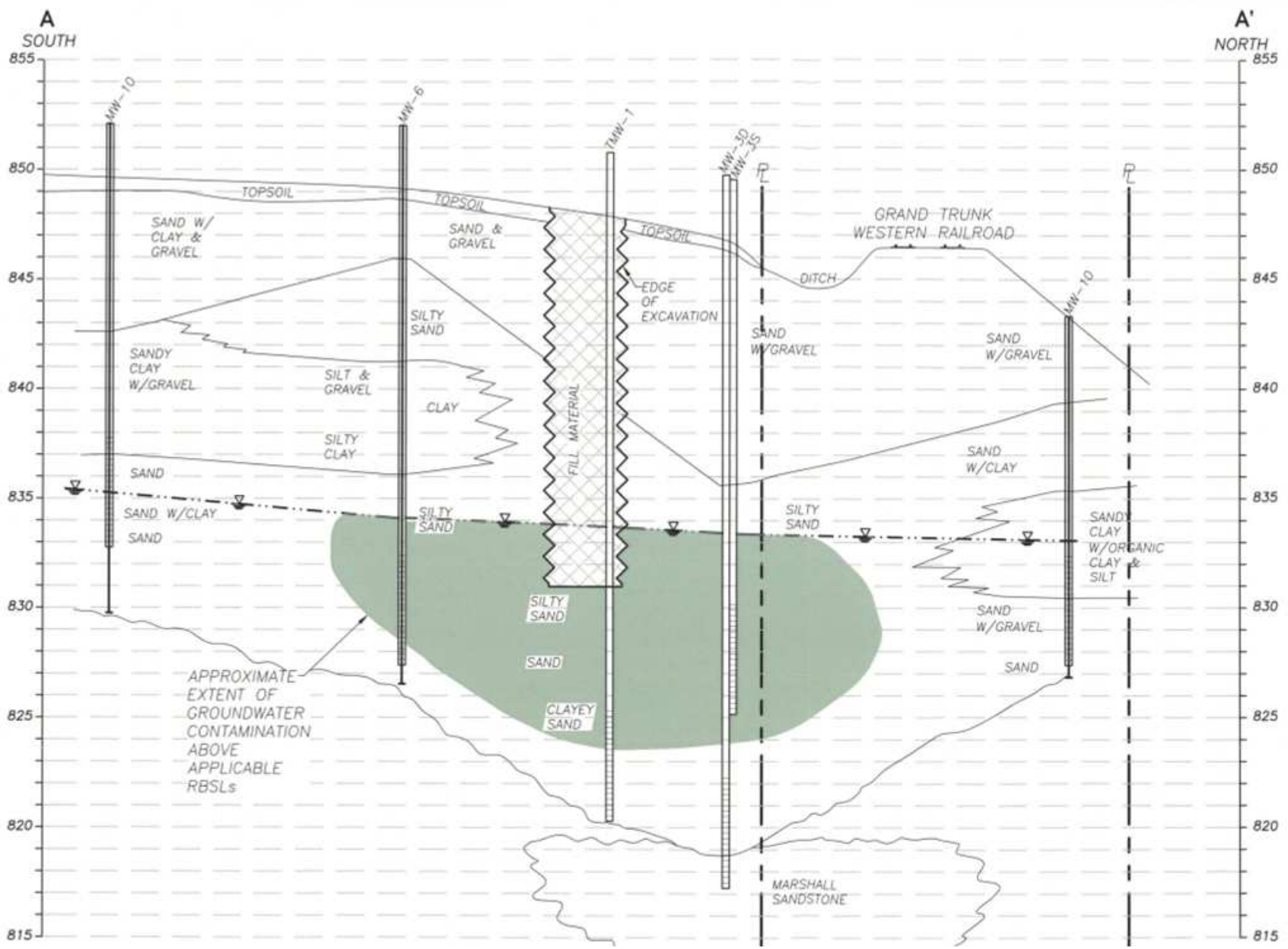
$$\frac{1}{DAF} = \frac{C(x)}{C_o} = erf\left[\frac{Y}{4\sqrt{\alpha_y x}}\right] \times erf\left[\frac{\delta_{gw}}{2\sqrt{\alpha_z x}}\right]$$

Mixing zone thickness

- Estimate based on soil borings, plume thickness – preferred
- Can be calculated

$$\delta_{gw} = (0.0112 \times W^2)^{0.5} + d_a \left\{1 - exp\left[\frac{-WI}{Kid_a} \times 365\right]\right\}$$

  - GW source parallel to flow (W)
  - Aquifer thickness (da)
  - Infiltration rate (I)
  - Hydraulic conductivity (K)
  - Hydraulic gradient (i)


A
SOUTH
A'
NORTH
855
850
845
840
835
830
825
820
815
MW-10
MW-6
TMW-1
MW-30
MW-35
PL
PL
MW-10
TOPSOIL
TOPSOIL
TOPSOIL
SAND W/ CLAY & GRAVEL
SAND & GRAVEL
GRAND TRUNK WESTERN RAILROAD
DITCH
EDGE OF EXCAVATION
SILTY SAND
SANDY CLAY W/GRAVEL
SILT & GRAVEL
CLAY
FILL MATERIAL
SAND W/GRAVEL
SAND W/GRAVEL
SILTY CLAY
SAND
SAND W/CLAY
SAND
SILTY SAND
SILTY SAND
SAND W/CLAY
SANDY CLAY W/ORGANIC CLAY & SILT
SILTY SAND
SAND W/GRAVEL
SAND
SAND
CLAYEY SAND
APPROXIMATE EXTENT OF GROUNDWATER CONTAMINATION ABOVE APPLICABLE RBSLs
MARSHALL SANDSTONE

Mixing zone thickness

- 2’ = DAF 37.24; 186 ppb benzene
- 7’ = DAF 10.97; 55 ppb benzene
- 12’ = DAF 6.86; 34 ppb benzene

GW SSTLs are a function of:

- Width of groundwater source
- Mixing zone thickness
- The smaller the value, the more critical it is to ask:
  - Is the value reasonable?
  - Is the value supported by site data?
  - Is the value protective of the POE?

Range of SSTLs for POE at 150’

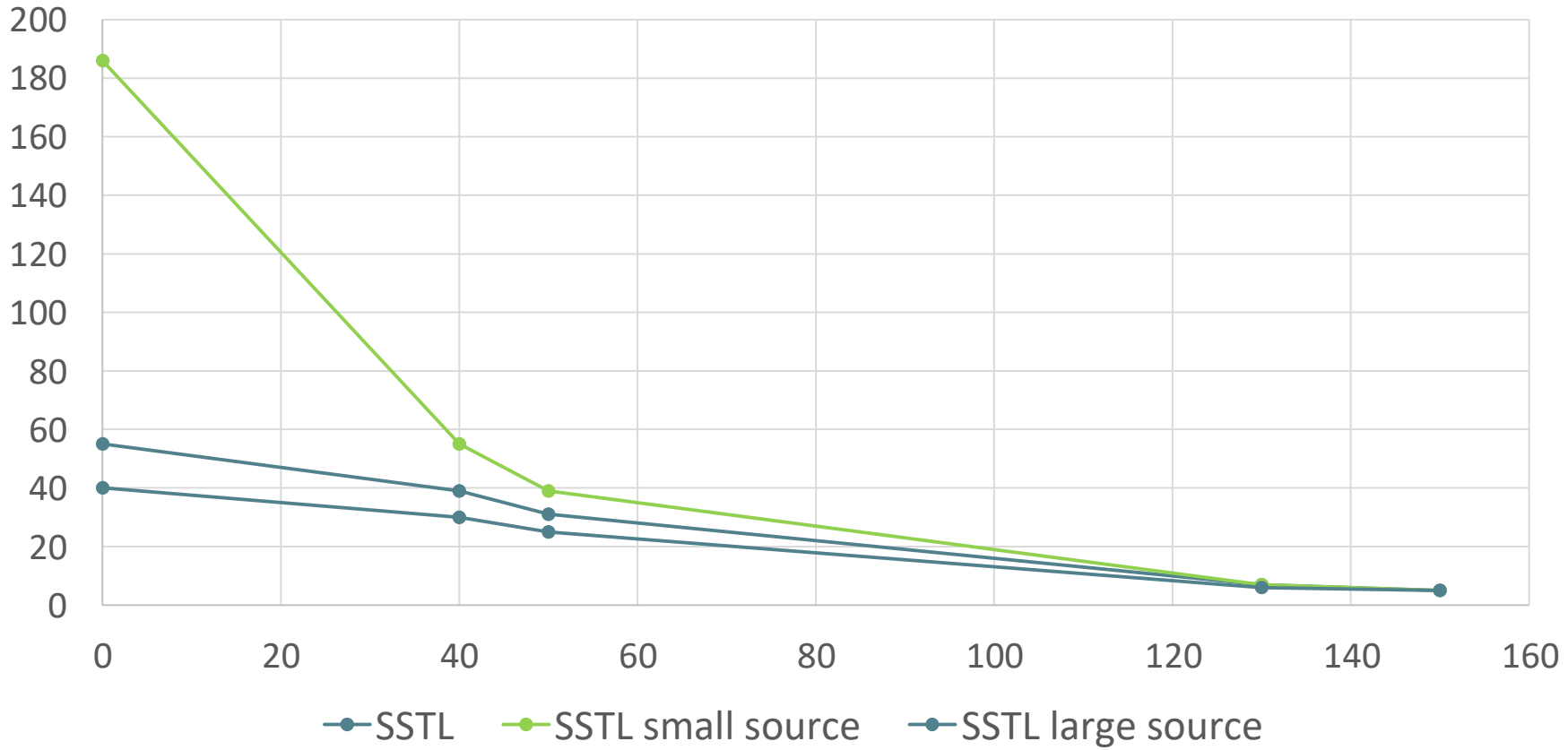
- Source width = 10’; thickness = 2’

	SSTL(GWsource)	SSTL(POC1)	SSTL(POC2)	SSTL(POC3)	
Benzene	186	55	39	7	5
Toluene	29425	8719	6101	1045	790
Ethylbenzene	2756	817	572	98	74
Xylenes	10429	3090	2163	370	280

- Source width = 50’; thickness = 10’

	SSTL(GWsource)	SSTL(POC1)	SSTL(POC2)	SSTL(POC3)	
Benzene	40	30	25	6	5
Toluene	6305	4819	4015	1022	790
Ethylbenzene	591	451	376	96	74
Xylenes	2235	1708	1423	362	280

Range of Benzene SSTLs for POE at 150’



Calculate soil SSTLs

Leachate concentration

Assume 1

- GW source width
- Mixing zone thickness

$$C_{sl} = DAF_{unsat} \times DAF_{mix} \times DAF_{sat} \times C_{POE}$$

$$C_s = C_{sl} \times ECF$$

5 ppb benzene

Converts leachate concentration to soil concentration

DAF-mixing zone

GW concentration at top of water table in source area

GW Darcy velocity

Mixing zone thickness

$$DAF_{mix} = \frac{C_{st}}{C_{gwm}} = 1 + \frac{U_{gw}\delta_{gw}}{IW}$$

GW source SSTL

Infiltration rate

Source parallel to GW flow

Hydraulic conductivity

$$U_{gw} = i \times \frac{K}{365}$$

Hydraulic gradient

DAF-mixing zone

- Higher DAF-mixing zone when
  - High values for:
    - Hydraulic conductivity
    - Hydraulic gradient
  - Small values for:
    - Infiltration rate
    - GW source dimension parallel to flow direction
- More critical to look at values when DAF is a large number

$$DAF_{mix} = \frac{C_{st}}{C_{gwm}} = 1 + \frac{U_{gw}\delta_{gw}}{IW}$$

$$U_{gw} = i \times \frac{K}{365}$$

Hydraulic conductivity

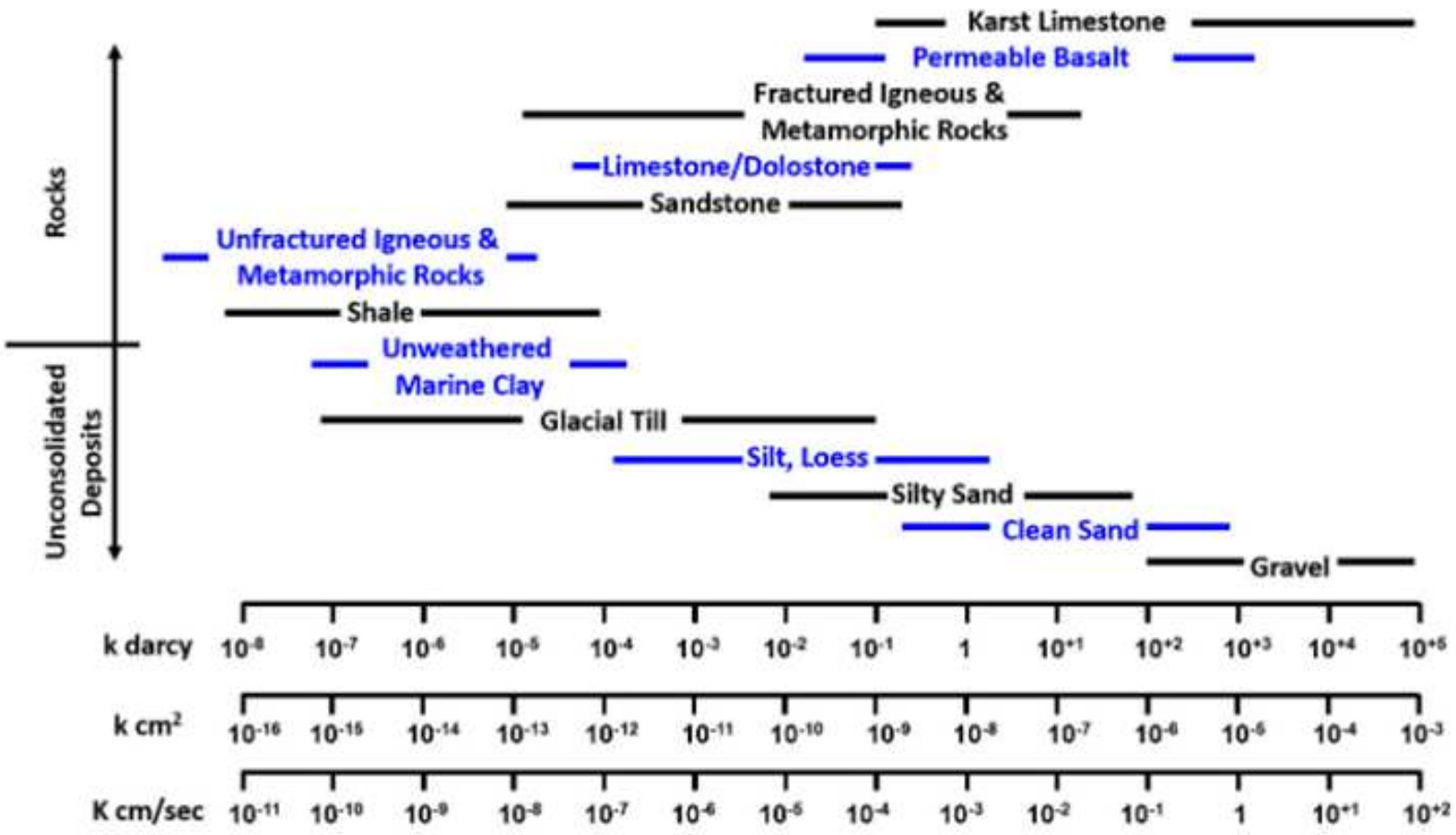


Figure 32 – Ranges of intrinsic permeability, k, and hydraulic conductivity, K, values. The alternating colors are used to make the chart easier to read. For conversion purposes, 1 cm/s = 1.02×10^{-5} cm^2 and 1.04×10^3 darcy (after Freeze and Cherry, 1979).

Infiltration rate

- Annual precipitation
  - Assume 10% of precipitation if site is unpaved
  - Assume 1% of precipitation if site is paved

Sensitivity Analysis

- Infiltration
  - Variability in annual precipitation has little effect on SSTL
  - 10% vs 1% of precipitation
  - Affects soil SSTL by ~10x
- Hydraulic conductivity
  - Range of several orders of magnitude
  - A change in 10x affects soil SSTL by ~10x

Soil SSTLs

- Infiltration of 30”/year x 10% (no pavement)
- Hydraulic conductivity of 35,000 cm/y (silty sand)
- Source parallel to flow of 25’
- Hydraulic gradient of 0.01
- Mixing zone thickness of 7’

- DAF-mixing zone = 13.86
  - A 13x dilution from leachate to GW at edge of source area
  - Need to convert leachate concentration to soil concentration

Equilibrium Conversion Factor (ECF)

Volumetric water/air content

Soil-water partition coefficient

$$ECF = \frac{[\theta_{wv} + (K_d \times \rho_{bv}) + (H'_{ST} \times \theta_{av})]}{\rho_{bv}}$$

Henry's Law constant (chemical-specific)

Dry soil bulk density

Fraction of organic carbon

$$K_d = K_{oc} \times f_{ocv}$$

Organic carbon partition coefficient (chemical-specific)

Soil SSTL Calculation

$$C_{sl} = DAF_{unsat} \times DAF_{mix} \times DAF_{sat} \times C_{POE}$$

$$\frac{1}{DAF} = \frac{C(x)}{C_o} = erf\left[\frac{Y}{4\sqrt{\alpha_y x}}\right] \times erf\left[\frac{\delta_{gw}}{2\sqrt{\alpha_z x}}\right]$$

$$C_s = C_{sl} \times ECF$$

$$ECF = \frac{[\theta_{wv} + (K_d \times \rho_{bv}) + (H'_{ST} \times \theta_{av})]}{\rho_{bv}}$$

$$DAF_{mix} = \frac{C_{st}}{C_{gwm}} = 1 + \frac{U_{gw}\delta_{gw}}{IW}$$

$$K_d = K_{oc} \times f_{ocv}$$

$$U_{gw} = i \times \frac{K}{365}$$

Takeaway

Soil concentrations in the source area are a **poor indicator** of groundwater concentrations at the POE

Sensitivity Analysis

Infiltration rate at 10%,
K = 35,000 cm/y
Foc = 0.002

	SSTL(soil source)
Benzene	390
Toluene	83248
Ethylbenzene	12635
Xylenes	42223

Infiltration rate at 10%,
K = 35,000 cm/y
Foc = 0.02

SSTL(soil source)
2390
590231
103208
336380

Infiltration rate at 1%,
K = 350,000 cm/y
Foc = 0.002

SSTL(soil source)
36182
7730219
1173215
3920700

Representative Concentrations

- Recent average – GW source

TMW-1	Concentration 1	Concentration 2	Concentration 3	Recent Average
Benzene	170	220	68	**153**
Toluene	1500	370	4.1	**625**
Ethylbenzene	830	64	43	**312**
Xylenes	3300	830	14	**1381**

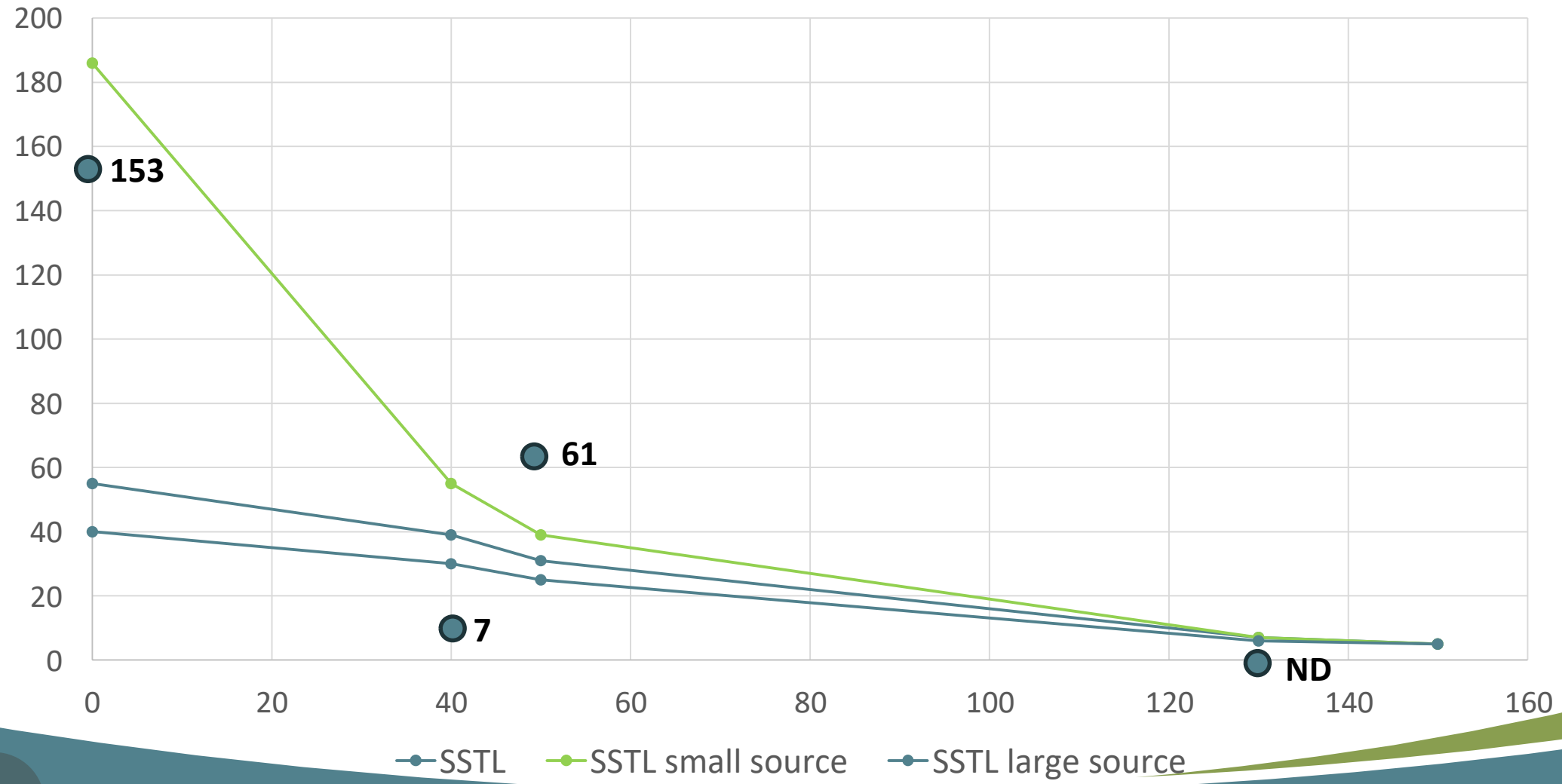
Representative Concentrations

- Recent average – POC1, POC2

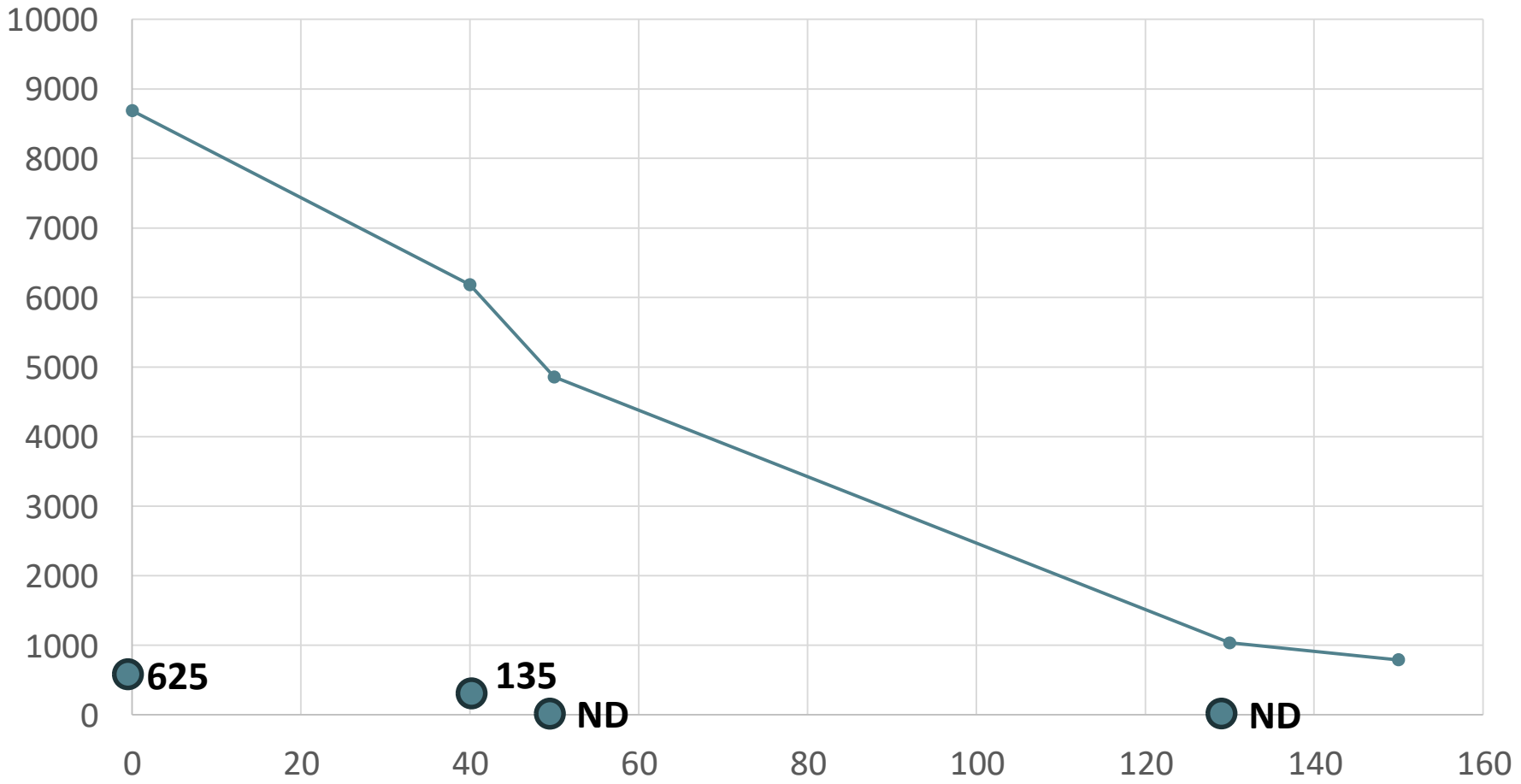
MW-4	Conc 1	Conc 2	Average
Benzene	6.1	7.8	**7.0**
Toluene	110	160	**135**
Ethylbenzene	110	200	**155**
Xylenes	496	580	**538**

MW-3s	Conc 1	Conc 2	Average
Benzene	95	26	**60.5**
Toluene	1	1	**1**
Ethylbenzene	1	1	**1**
Xylenes	1	1	**1**

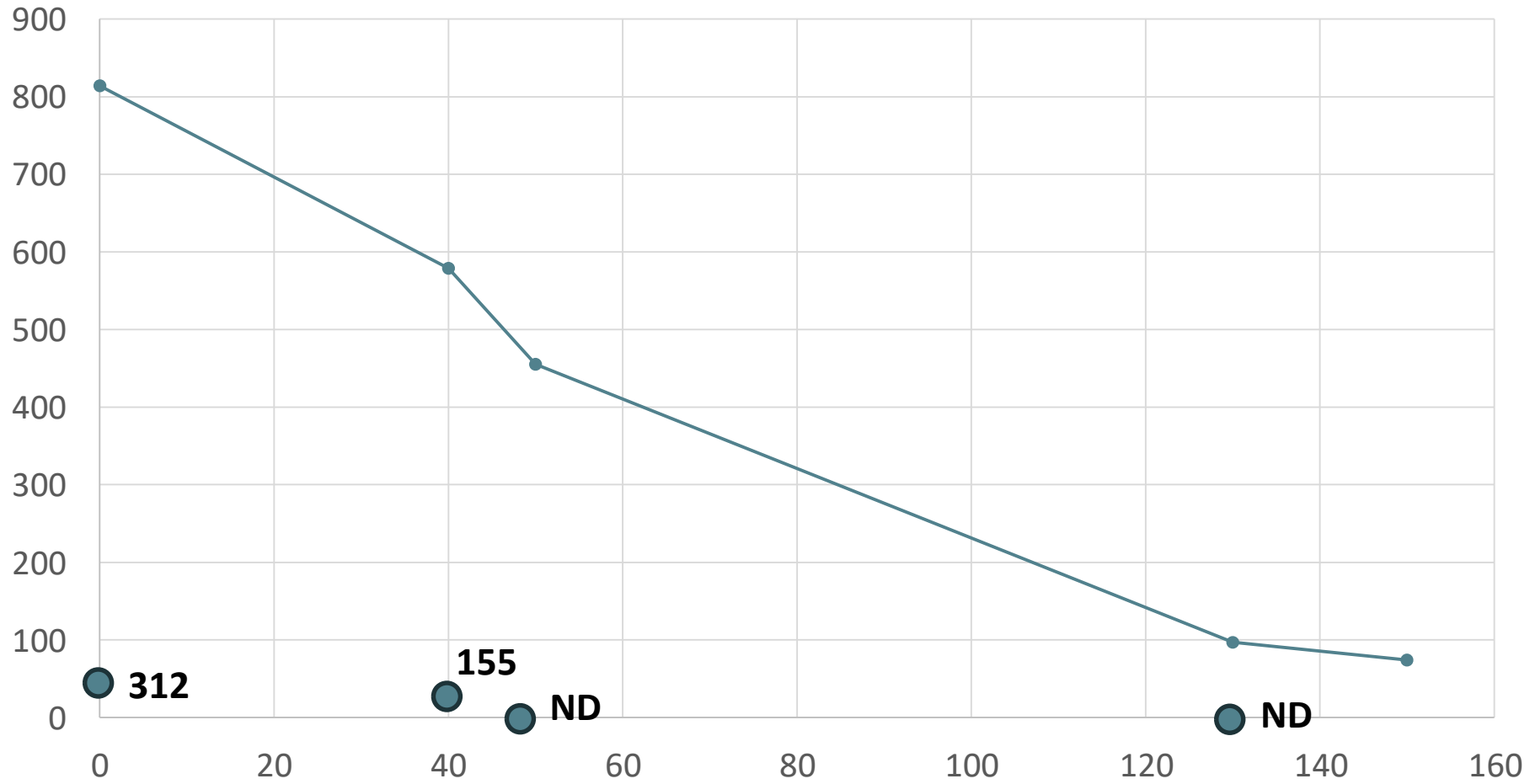
Benzene SSTLs and Representative Concentrations



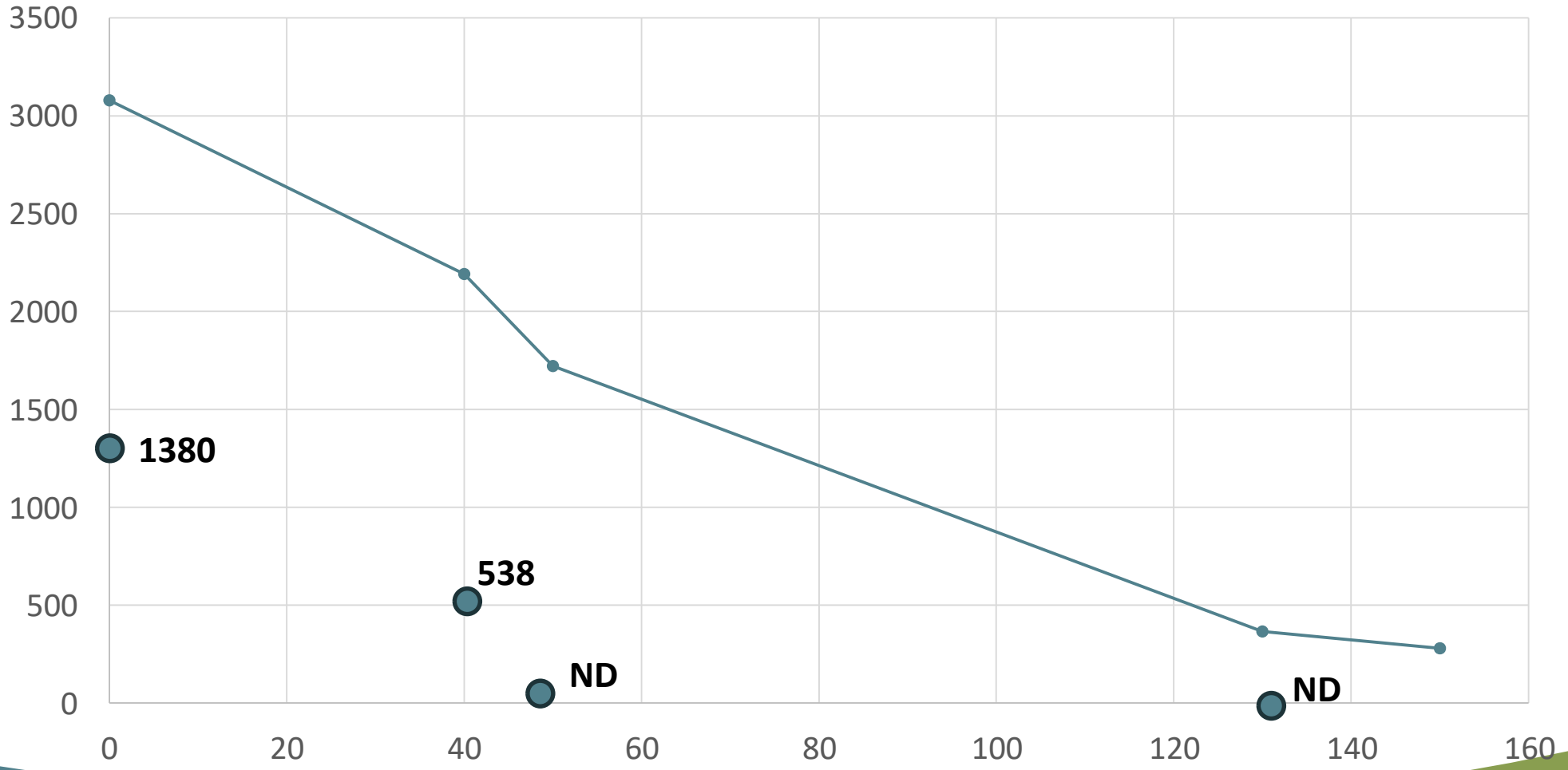
Toluene SSTLs and Representative Concentrations



Ethylbenzene SSTLs and Representative Concentrations



Xylenes SSTLs and Representative Concentrations



Tier 2 Risk Evaluation – Without Biodegradation

MIRBCA REPORT																FORM NO. 2-7(5FG
Facility ID number:				Date(s) confirmed release(s) discovered:												
Date form completed:				Form completed by:												
COMPARISON OF TIER 2 SSTLs WITH REPRESENTATIVE CONCENTRATIONS - RESIDENTIAL FUTURE USE (GROUNDWATER PROTECTION)																
CHEMICALS OF CONCERN	SOIL SOURCE			GROUNDWATER SOURCE			GROUNDWATER POCs									
	Groundwater protection		C/NC C	Groundwater protection		C/NC C	Groundwater protection (POC 1)		C/NC C	Groundwater protection (POC 2)		C/NC C	Groundwater protection (POC 3)		C/NC C	
	Rep. Conc. [µg/kg]	SSTLs [µg/kg]	E/NE	Rep. Conc. [µg/L]	SSTLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTLs [µg/L]	E/NE	Rep. Conc. [µg/L]	SSTLs [µg/L]	E/NE	
DISTANCE FROM SOURCE TO POE AND POC (ft)	150						40			50			130			
POC WELL ID							MW-3s			MW-4			MW-8			
Benzene		3.30E+02		1.53E+02	5.50E+01	E	7.00E+00	3.90E+01	NE	6.05E+01	3.10E+01	E	1.00E+00	7.00E+00	NE	
Toluene		8.32E+04		6.25E+02	8.69E+03	NE	1.35E+02	6.18E+03	NE	1.00E+00	4.86E+03	NE	1.00E+00	1.03E+03	NE	
Ethylbenzene		1.26E+04		3.12E+02	8.14E+02	NE	1.55E+02	5.79E+02	NE	1.00E+00	4.55E+02	NE	1.00E+00	9.70E+01	NE	
Total xylenes		4.22E+04		1.38E+03	3.08E+03	NE	5.38E+02	2.13E+03	NE	1.00E+00	1.72E+03	NE	1.00E+00	3.66E+02	NE	
1,2,4-Trimethylbenzene																

Groundwater Protection SSTLs with Biodegradation

Steve Beukema, Ph.D.

Part 213 Program Coordinator

269.547.0125 | beukemas@michigan.gov

Biodegradation

$$\frac{C(x)}{C_o} = exp\left[\frac{x}{2\alpha_x}\left[1 - \sqrt{1 + \frac{4\lambda\alpha_x}{v}}\right]\right] \times erf\left[\frac{Y}{4\sqrt{\alpha_y x}}\right] \times erf\left[\frac{\delta_{gw}}{2\sqrt{\alpha_z x}}\right]$$

$$v = (K\ i)/(R_s\ \theta_{ts})$$

where:

K	=	Hydraulic conductivity [cm/year]
i	=	Hydraulic gradient [--]
θ_{ts}	=	Total porosity in the saturated zone [cm^3/cm^3-soil]
R_s	=	Retardation factor in the saturated zone [--]

$$R_s = 1 + \frac{\rho_{bs} K_d}{\theta_{TS}}$$

$$K_d = K_{oc} \times f_{ocs}$$

EGLE

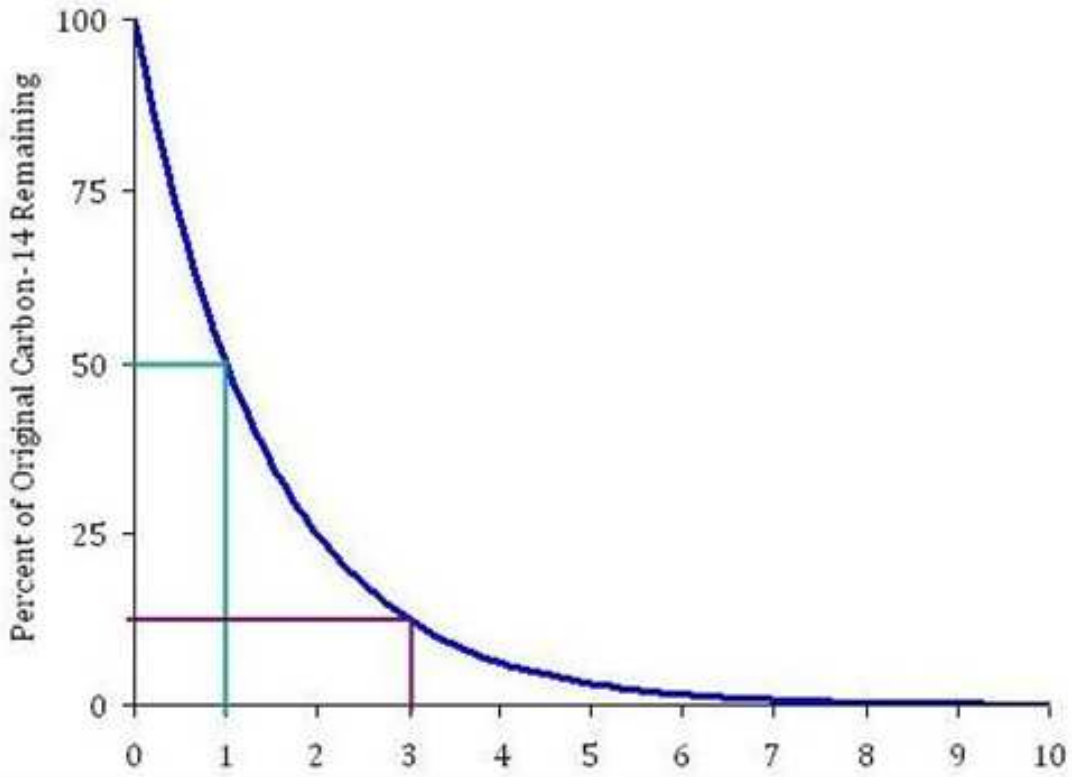
Half-life

$$t_{1/2} = \frac{0.693}{\lambda}$$

- Benzene – default half-life of 5 years
- Can calculate site-specific half-life (Appendix C)

What does half-life signify?

- Radioactive isotopes (e.g. C14)
  - The time for 50% of isotope to decay
  - C14 half-life is 5,730 years



What does half-life signify?

- Source concentrations vs. time
- **Concentration vs. distance**
- Concentration of benzene is related to:
  - Time (half-life)
  - Velocity
    - Hydraulic conductivity
    - Hydraulic gradient
    - Retardation factor (Koc, Foc)
    - Porosity

What does half-life signify?

- The time (and distance) for the concentration to decrease by 50%
- In our example
  - K = 35,000 cm/year
  - V = 403 cm/year = 13 ft/year
- Assume benzene half-life = 5 years
  - 13 ft x 5 years = 65 feet

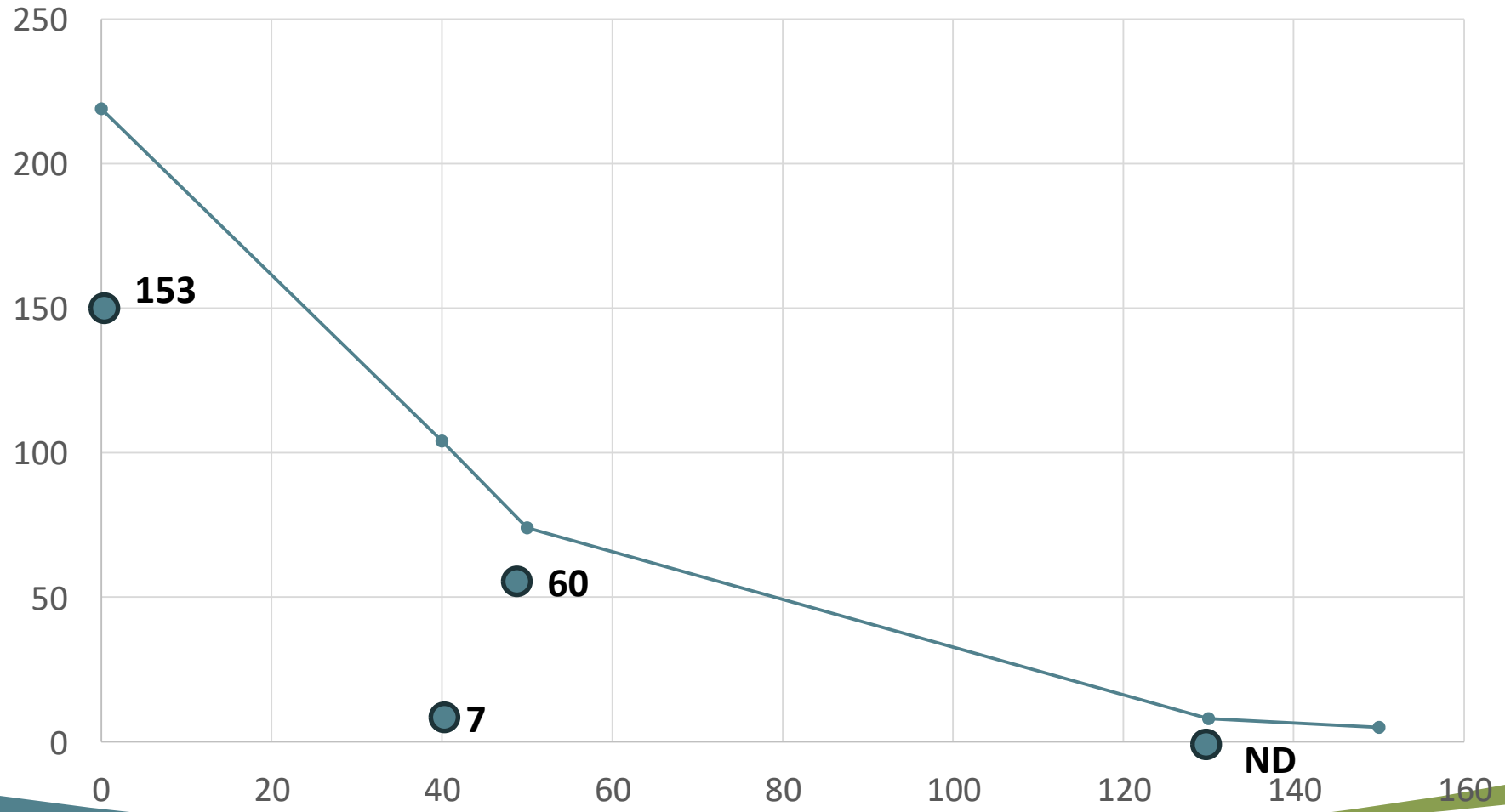
Biodegradation

- At 65’ = 50% concentration — 1 half-life
- At 130’ = 25% concentration — 2 half-lives
- At 195’ = 12.5% concentration — 3 half-lives
- At 260’ = 6.25% concentration — 4 half-lives
- At 325’ = 3.13% concentration — 5 half-lives

Benzene SSTLs with 5-year half-life

	GW source	POC1	POC2	POC3	POE
Benzene (5-yr half-life)	219	104	74	8	5
Benzene (no degradation)	55	39	31	7	5
Representative concentration	153	7	60	1	

Benzene SSTLs with 5-year half-life



Site-specific half-life

- Identify wells along plume centerline
- Calculate natural log of concentrations
- Calculate slope: LN(concentration) vs. distance
- Test if null hypothesis can be rejected at 0.05 level of significance
  - Null hypothesis: slope of regression line is zero (no relationship between LN(concentration) and distance
- Estimate seepage velocity and longitudinal dispersivity

Site-specific half-life

- Multiple slope by seepage velocity to estimate k
- Estimate biodegradation rate (λ)

$$\lambda = \frac{v}{4\alpha_x}\left\{\left[1 + 2\alpha_x\left(\frac{k}{v}\right)\right]^2 - 1\right\}$$

Site-specific inputs

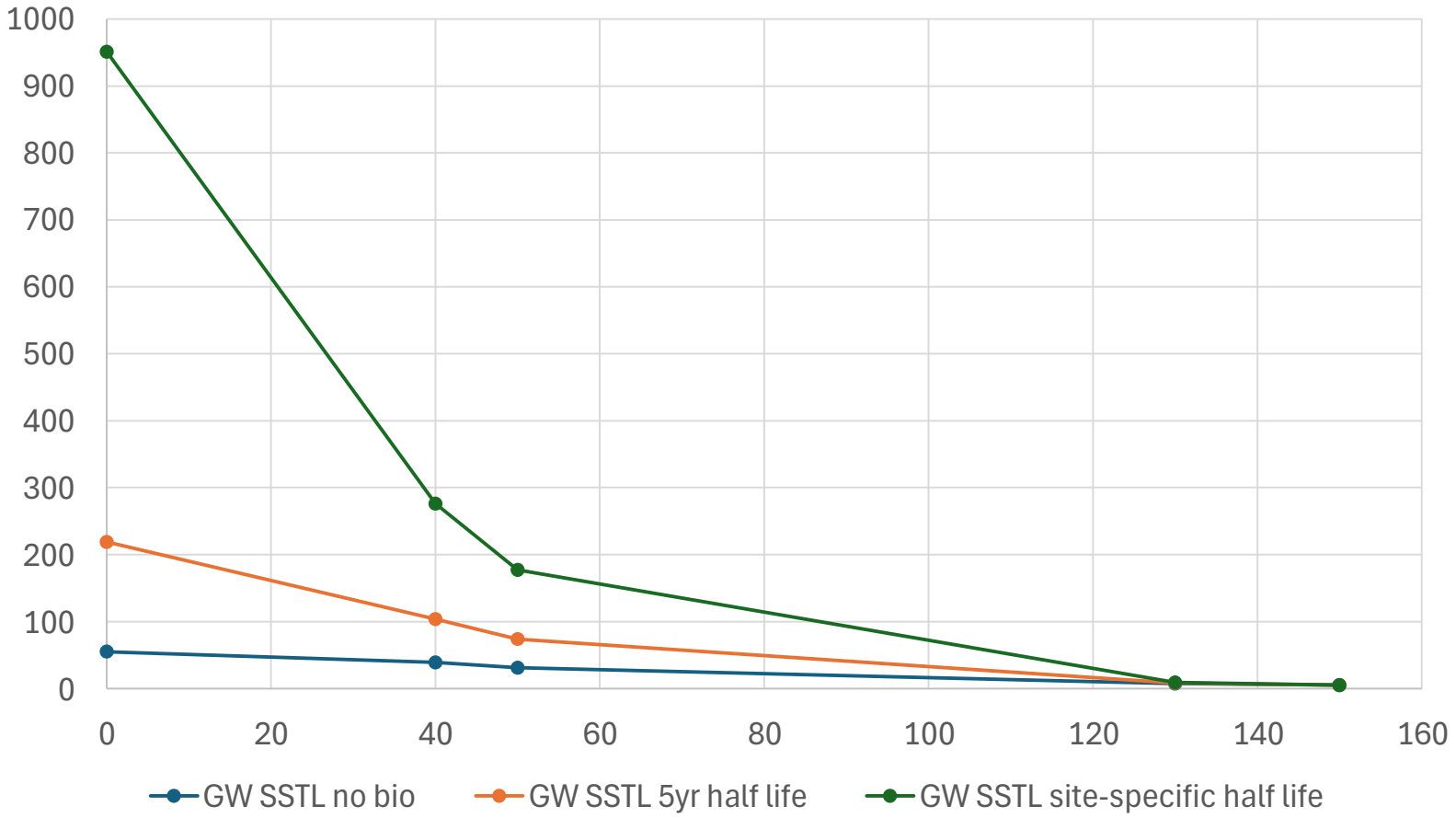
	GW source	POC1
Distance	0	50
Concentration (event 1)	220	95
Concentration (event 2)	68	26

Half-life (event 1)	2.30
Half-life (event 2)	2.00
Half-life (average)	2.14

SSTLs with site-specific half-life

	GW source	POC1	POC2	POC3	POE
Benzene (half-life 2.3 years)	810	249	162	9	5
Benzene (half-life 2.0 years)	1141	310	196	9	5
Benzene (half-life 2.14 years)	951	276	177	9	5
Benzene (5-yr half-life)	219	104	74	8	5
Benzene (no degradation)	55	39	31	7	5
Representative concentration	153	7	60	1	

SSTL comparison



Sensitivity Analysis – hydraulic conductivity

- Half-life = 5 years
- K = 35,000 cm/year
- V = 13 ft/year
- SSTLsource = 219 ppb
- K = 350,000 cm/year
- V = 132 ft/year
- SSTLsource = 64 ppb

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