Using Monitored Natural Attenuation (MNA) as a Remedial Option

Brian Waite

Linda Stanek

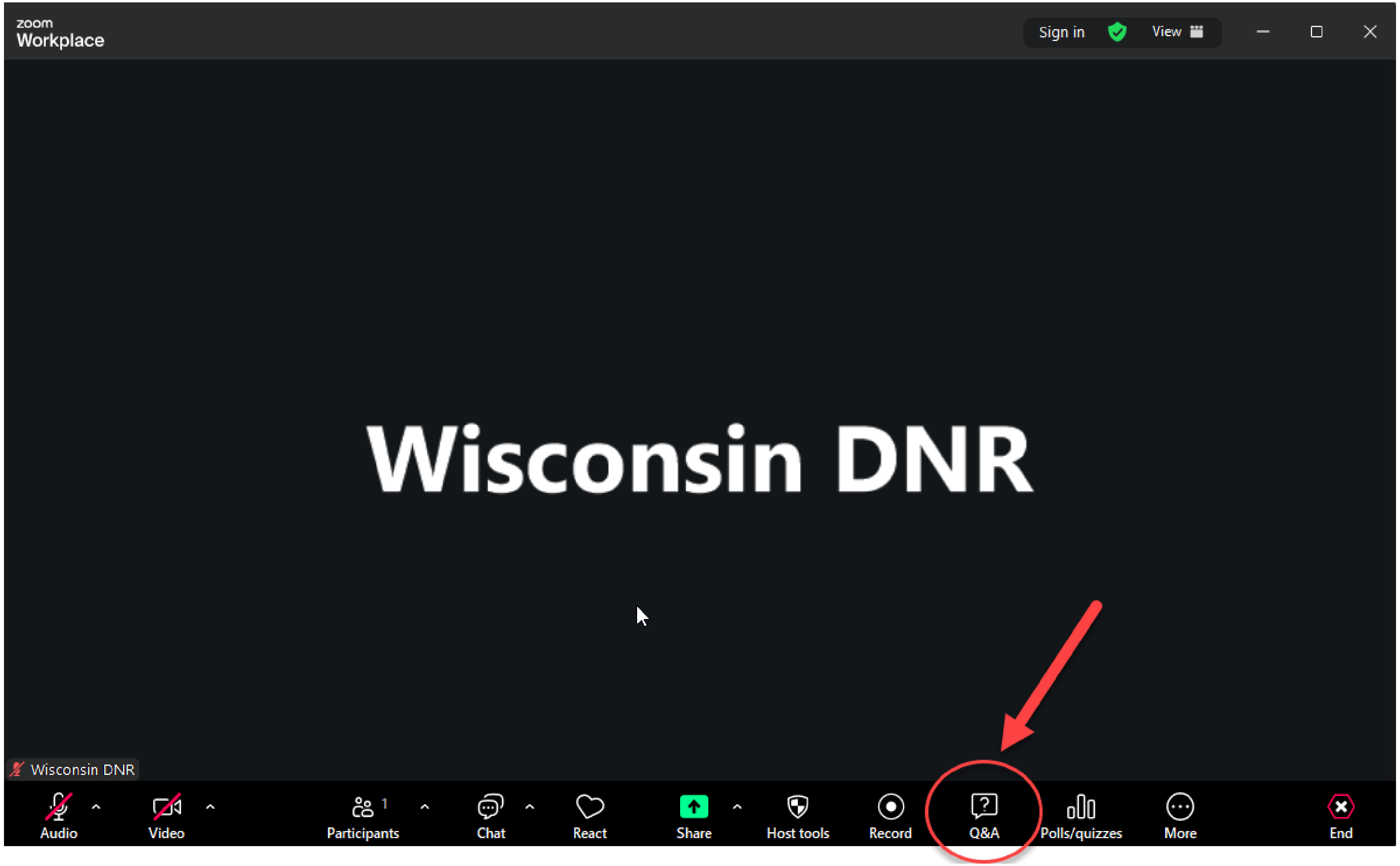
DNR Remediation and Redevelopment Program

2026 Issues & Trends Schedule

July 16, 2026	September 17, 2026
• Deep Dive into Vapor Intrusion: Application of RR-800	• Conduit Vapor Intrusion: Application of RR-649 and RR-800

Recorded sessions available at dnr.wi.gov, search “RR Training Library”

Asking Questions – Use Q & A



Objectives

Know what monitored natural attenuation (MNA) is

Understand how MNA can be used **as a remedial alternative**

Know where to find information and guidance

Using Monitored Natural Attenuation (MNA) as a Remedial Option

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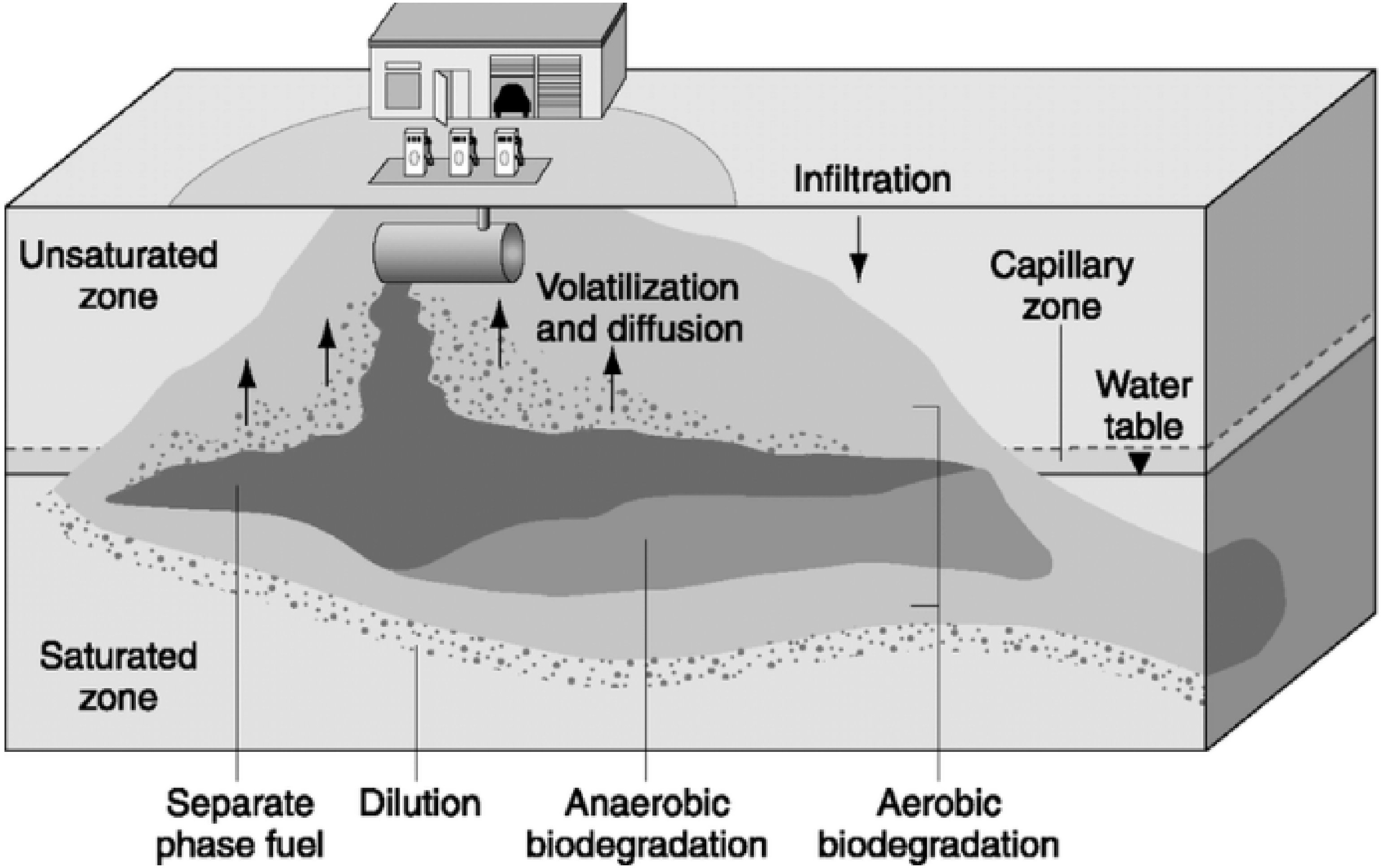
Agenda

Part 1:
Monitored Natural Attenuation Processes and Data Collection

Part 2:
Review of Guidance

Part 3:
Application and Discussion

Part 1: Natural Attenuation Processes and Data Collection



Natural Attenuation and Monitored Natural Attenuation

Natural Attenuation

- Reduction in concentrations and mass of a substance and its breakdown products in groundwater
- Caused by naturally occurring physical, chemical, and biological processes

Monitored Natural Attenuation

- Requires collection and monitoring of data
- Data must show that concentrations are decreasing due to **natural attenuation**

Using MNA in Remedial Actions

Consider:

- Target compounds
- Identified process of natural attenuation
- Site conditions
- Potential receptors
- Restoration timeframe

- Most often used for petroleum and chlorinated volatile organic compounds
- May be used for some semi-volatile organic compounds and inorganics may be supported under certain circumstances and site-specific condition

When MNA is Not Appropriate

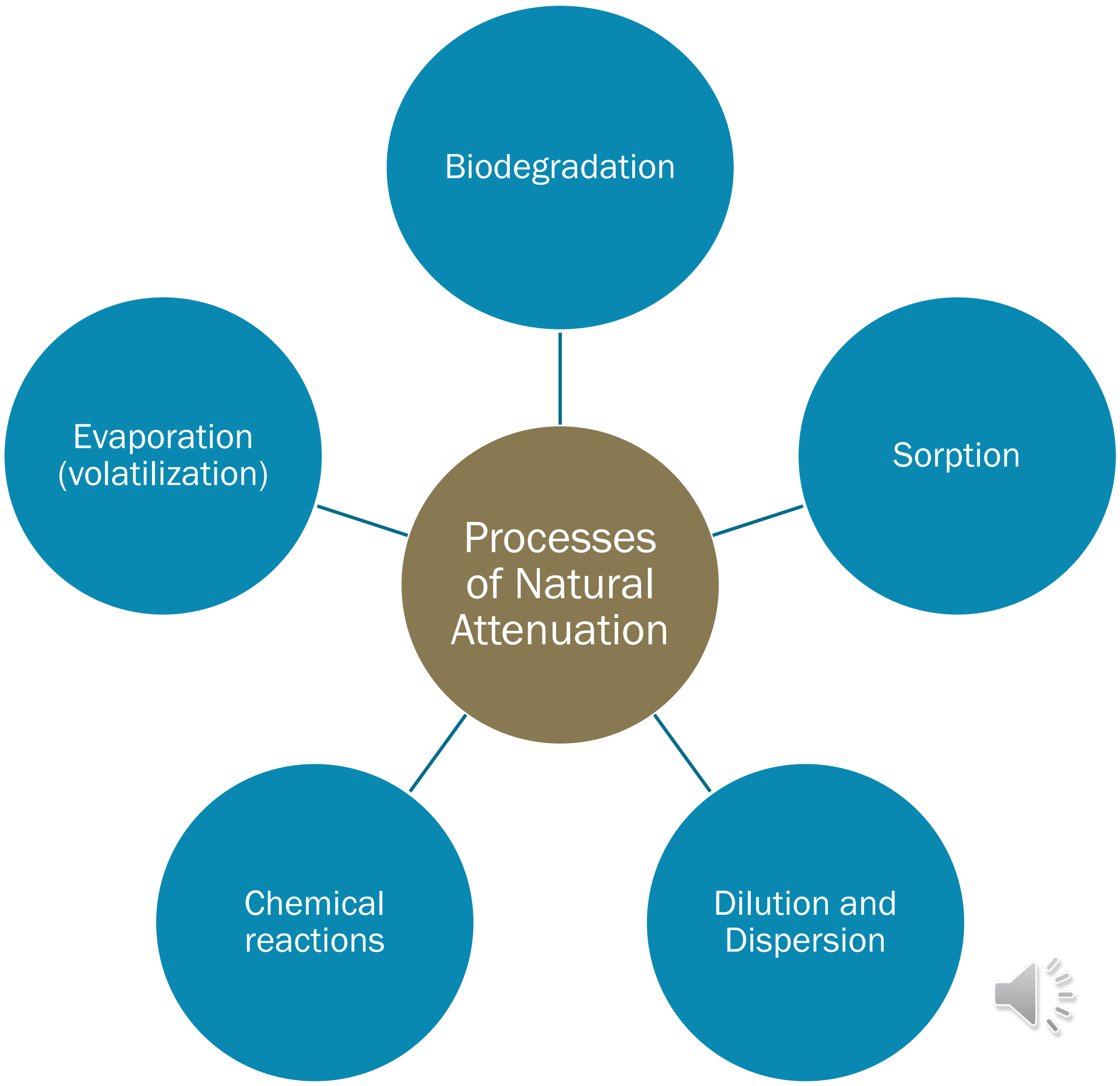
Contaminant mass or plume is expanding over time

No clear geochemical evidence that degradation is occurring

Unacceptable risk to receptors remains without active control

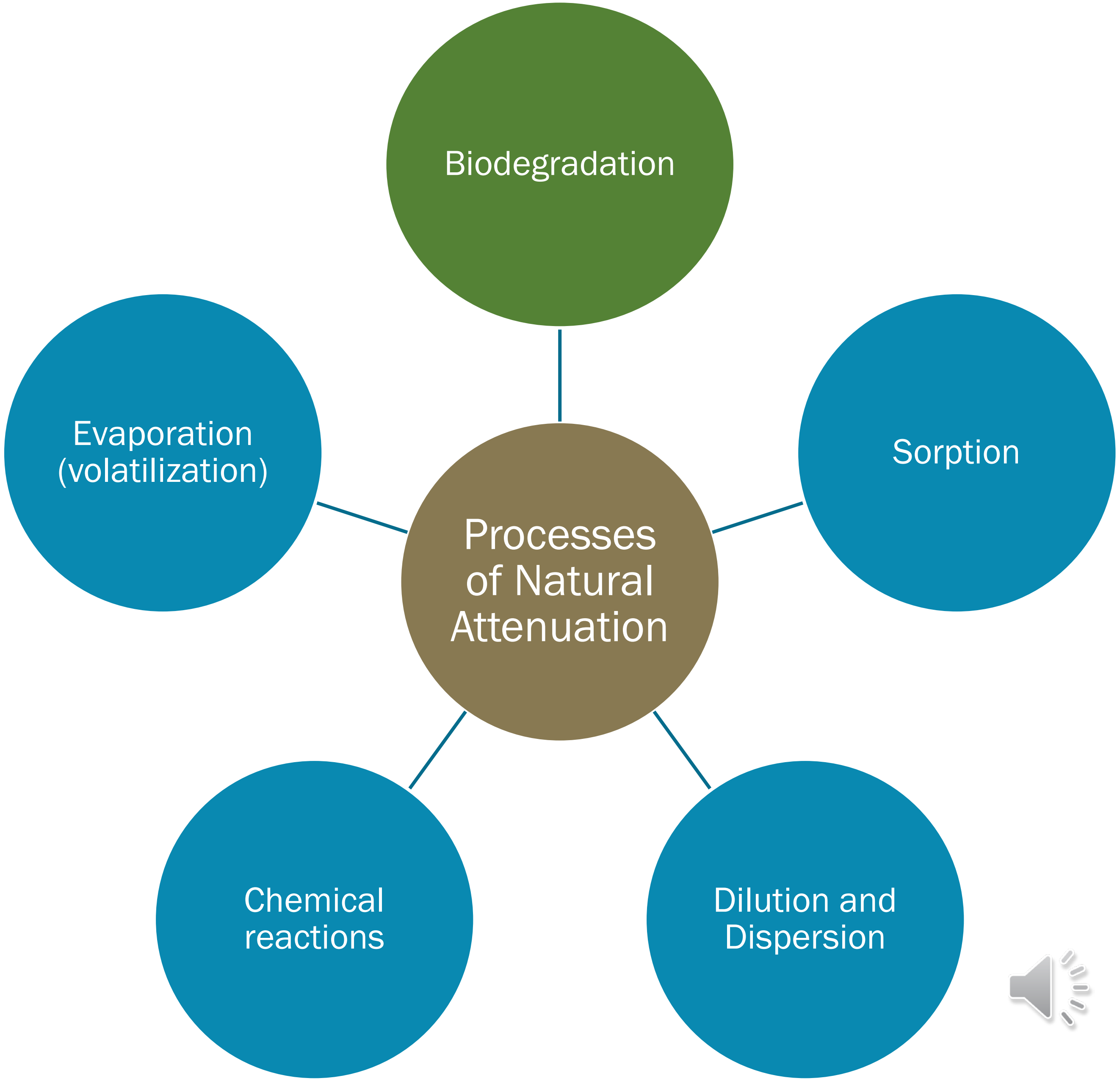
Time needed to reach groundwater standards cannot be estimated

Processes of Natural Attenuation



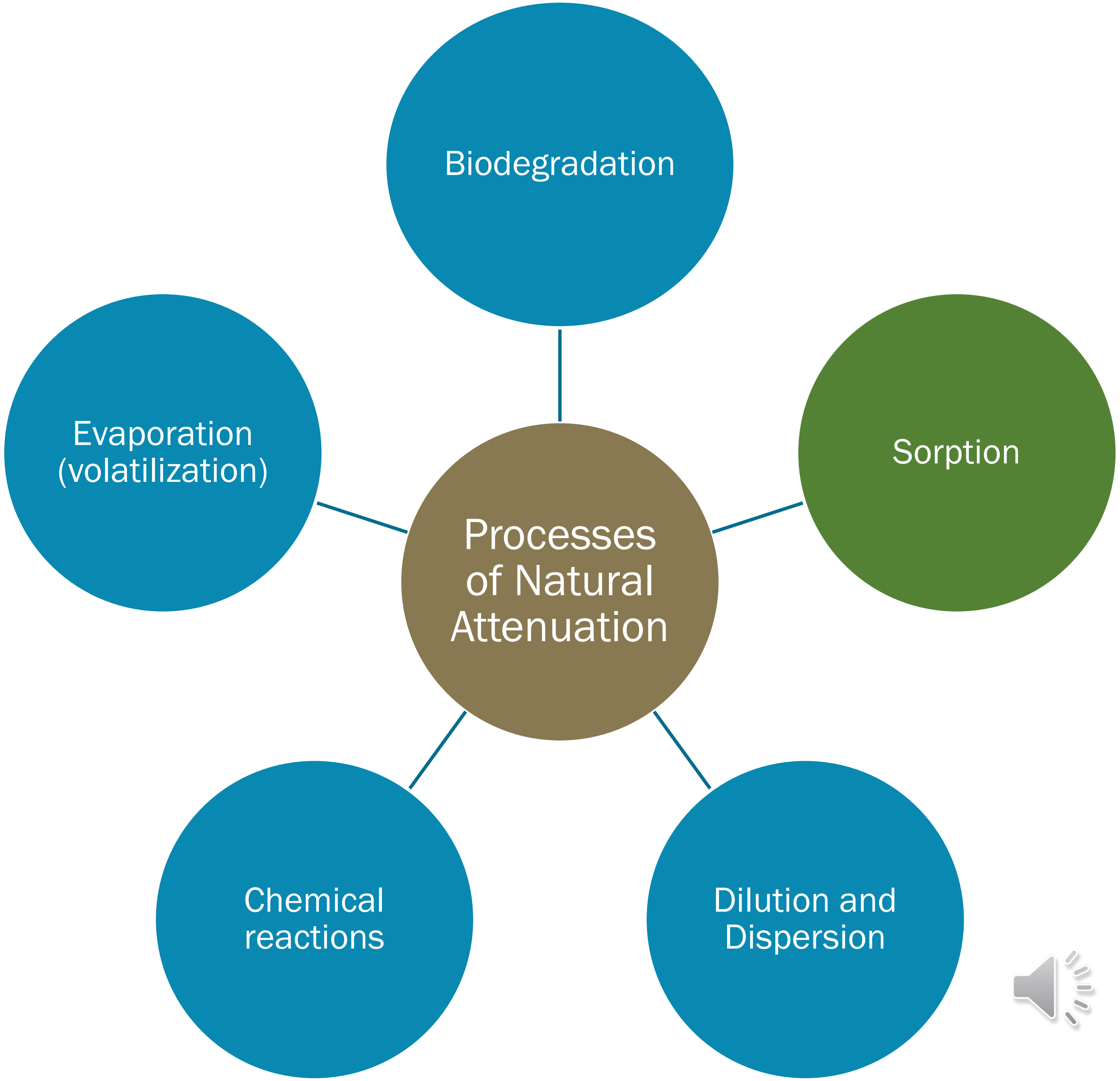
Biodegradation

Contaminants in soil and groundwater are transformed into harmless substances by living organisms called microbes.



Sorption

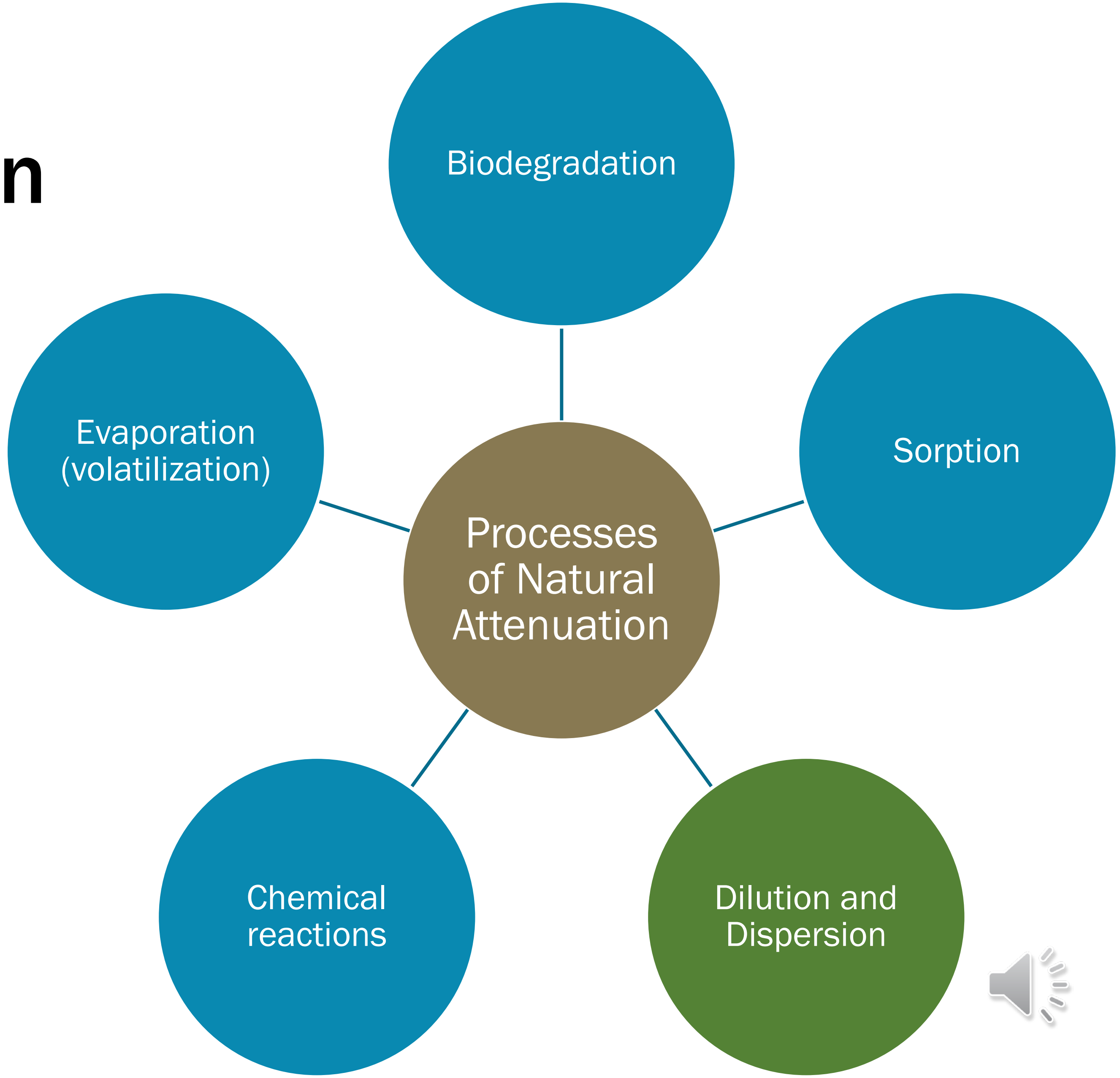
Reduces dissolved concentrations and can limit plume length by binding the petroleum and chlorinated hydrocarbons to soil particles, minerals or organic matter. The binding makes the sorbed fraction immobile.



Dispersion and Dilution

Dispersion: spreading and mixing of the contaminant plume as it moves through an aquifer due to variations in groundwater flow and velocity.

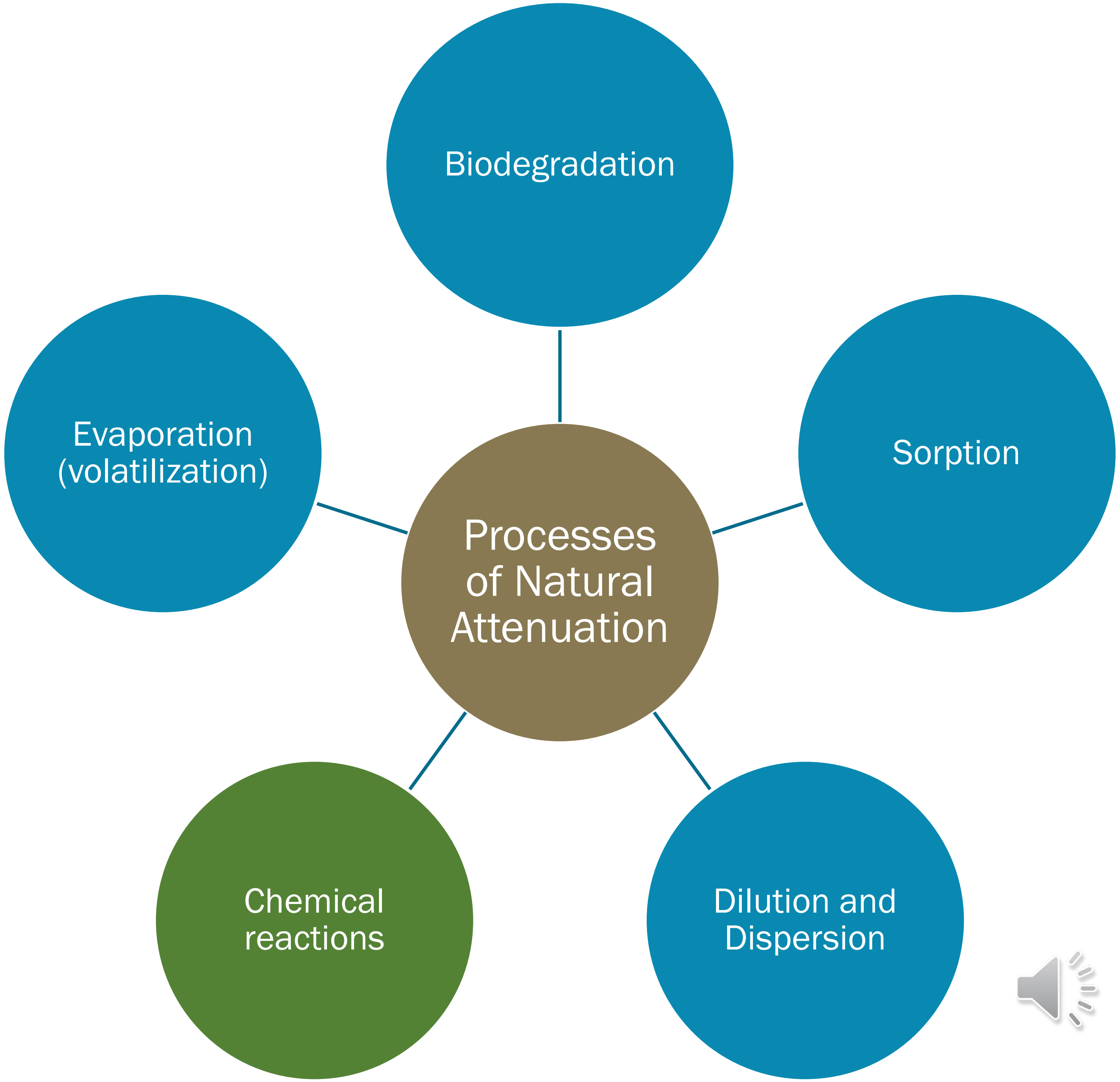
Dilution: decrease in contaminant concentrations resulting from mixing with uncontaminated water.



Chemical Reactions

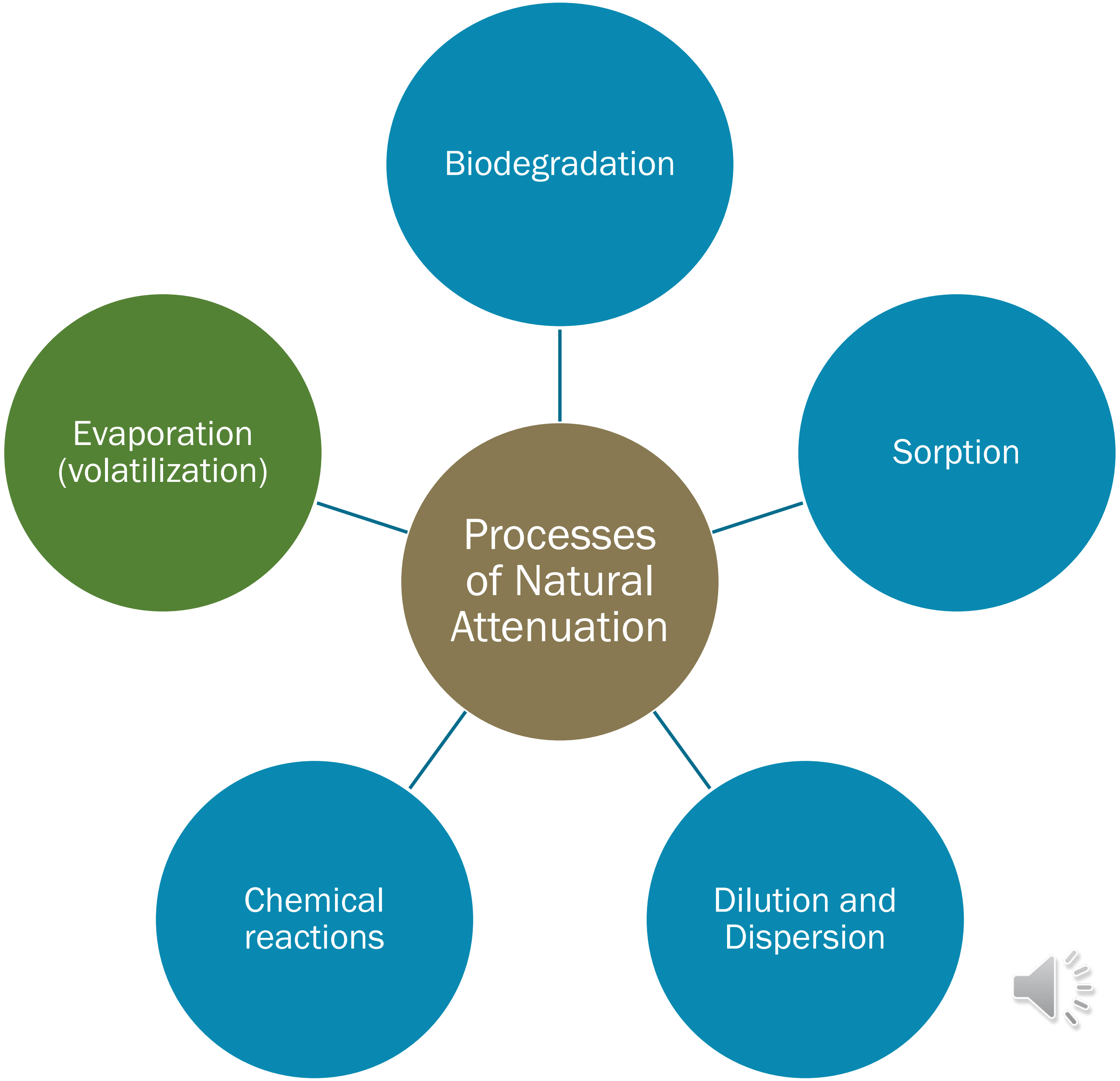
Most common chemical reactions that degrade **chlorinated compounds** without microbial activity:

- Hydrolysis
- Dehydrohalogenation
- Reactions with reducing metals such as iron



Volatilization

Reduces concentration of petroleum and chlorinated hydrocarbons through evaporation and dispersion in the atmosphere.



Collecting Data: Multiple Lines of Evidence

First Line of Evidence: Plume Stability

↓

Second Line of Evidence: Geochemical

↓

Third Line of Evidence: Lab or field studies

First Line of Evidence – Plume Stability

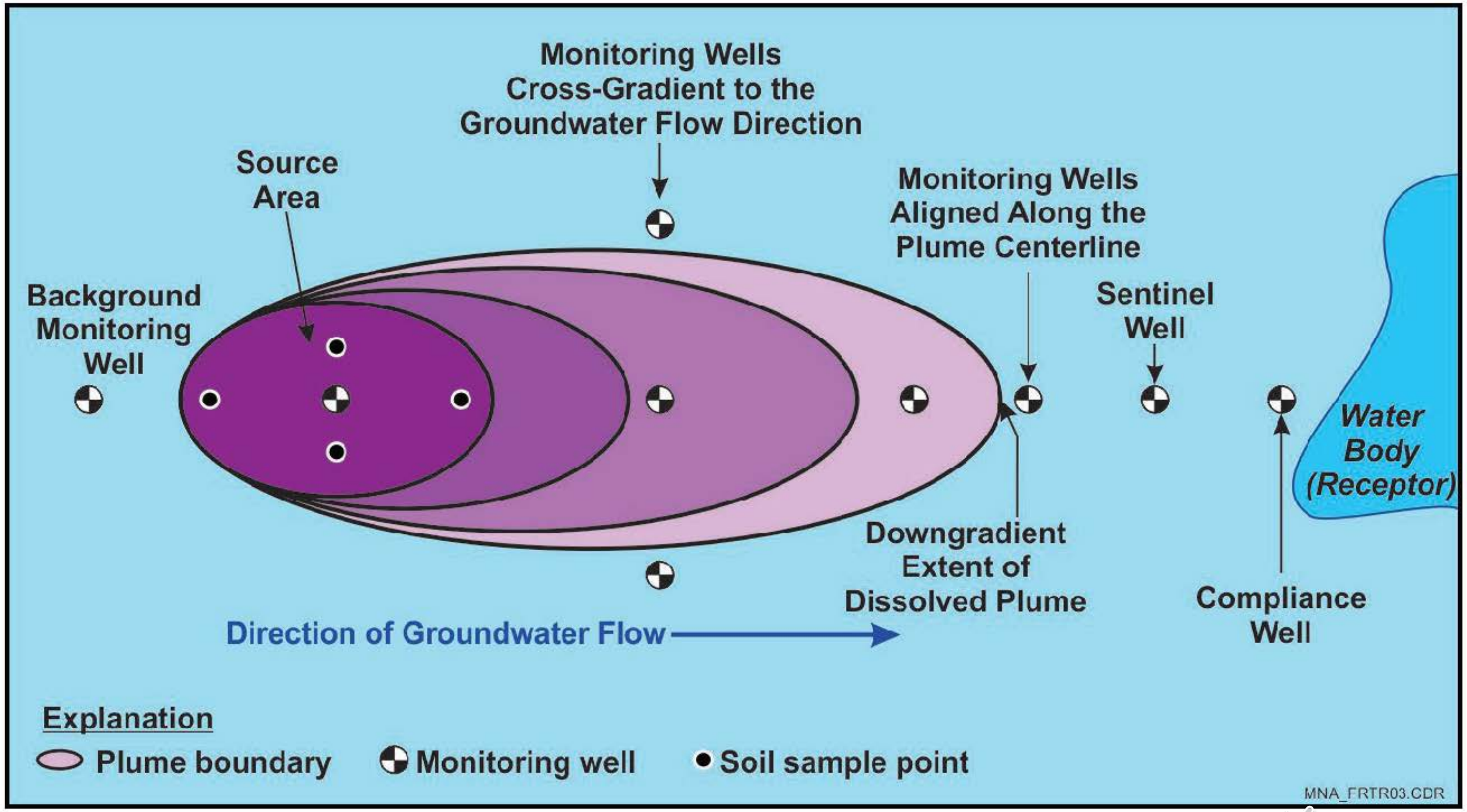
Determine the areal extent of plume to determine if MNA is appropriate (**plume is stable or receding**)

Use statically significant trends of decreasing or stable contaminant mass or concentration

Use multiple monitoring events (minimum of four, sampled at least quarterly)

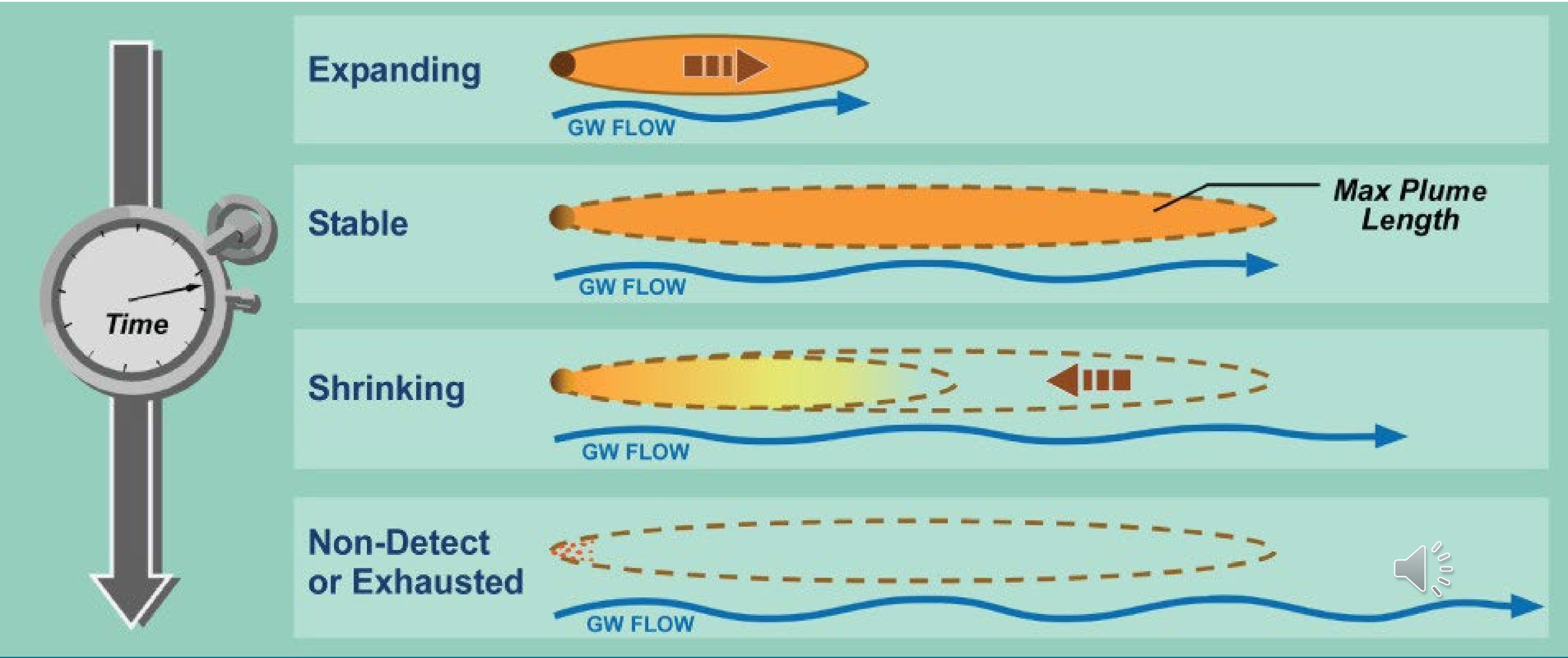
MNA Monitoring Well Network Design and Timeline

- Bracket the plume and include:
  - Background Wells
  - Source Area Wells
  - Centerline Wells
  - Cross-Gradient Wells
  - Downgradient Wells
- Reflects site hydrogeology and contaminant properties
- Timeline shows MNA as effective remedy

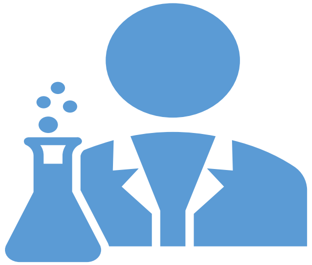


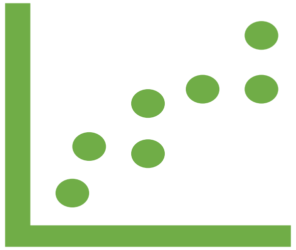
Evaluation of Contaminant Plume Characteristics

Groundwater, Volume: 53, Issue: 2, Pages: 195-206, First published: 12 July 2014, DOI: (10.1111/gwat.12233)



Second Line of Evidence – Geochemical





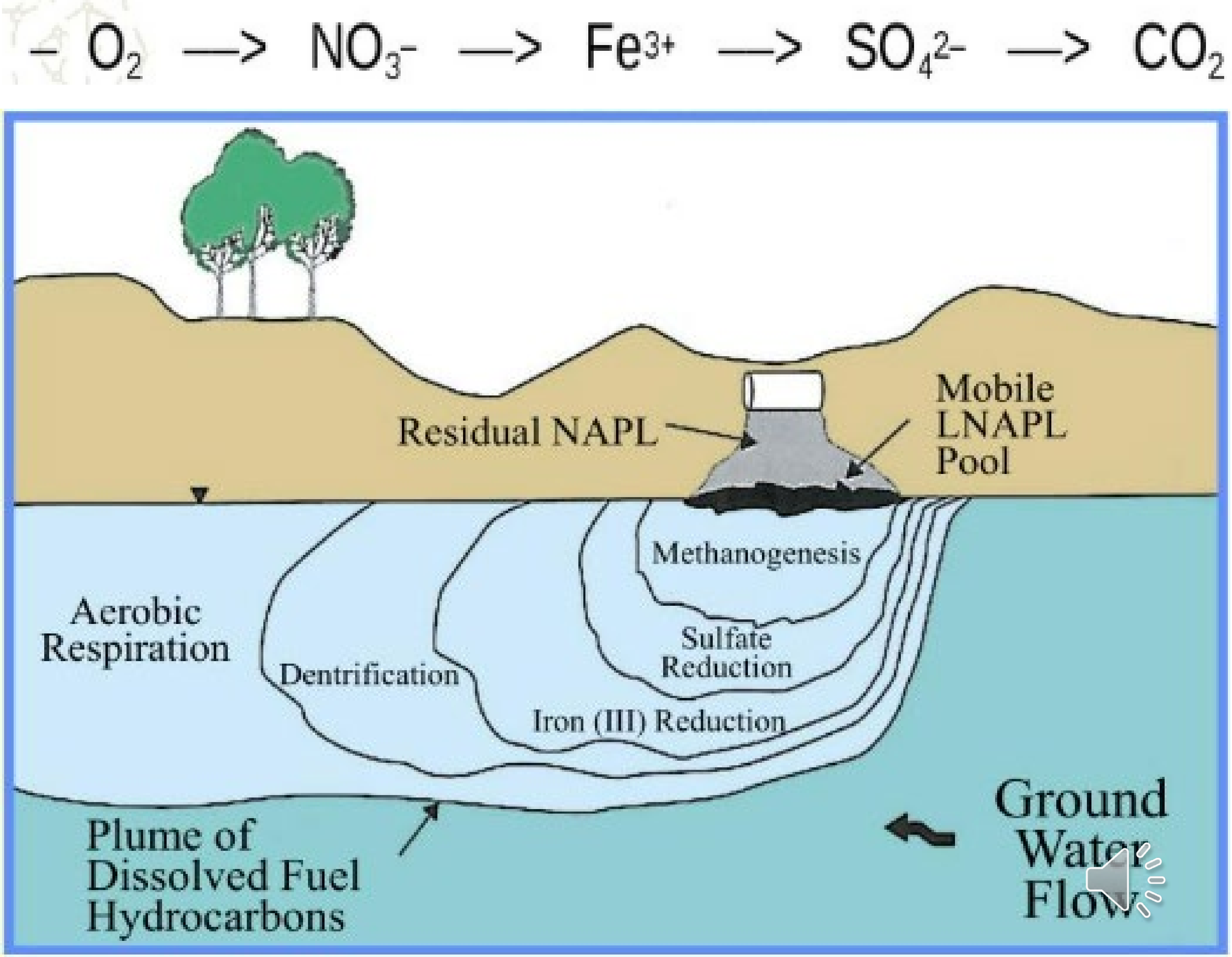
Determine relevant geochemical parameters

- Initial site characterization
- Investigation

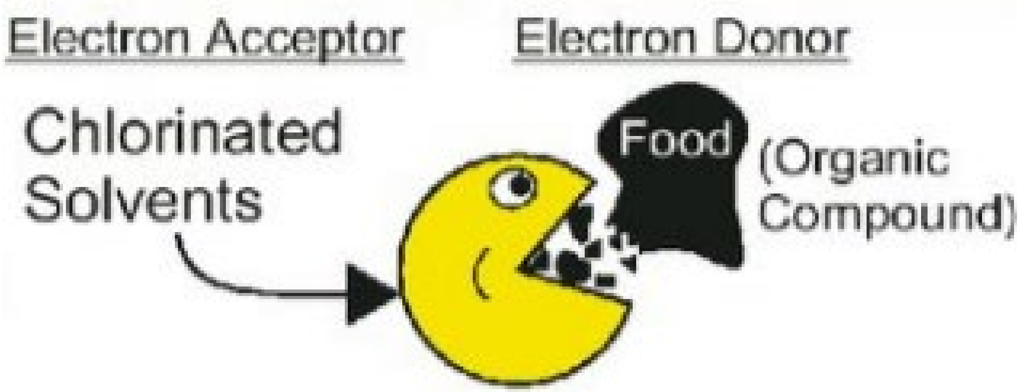
Patterns in the collected data can:

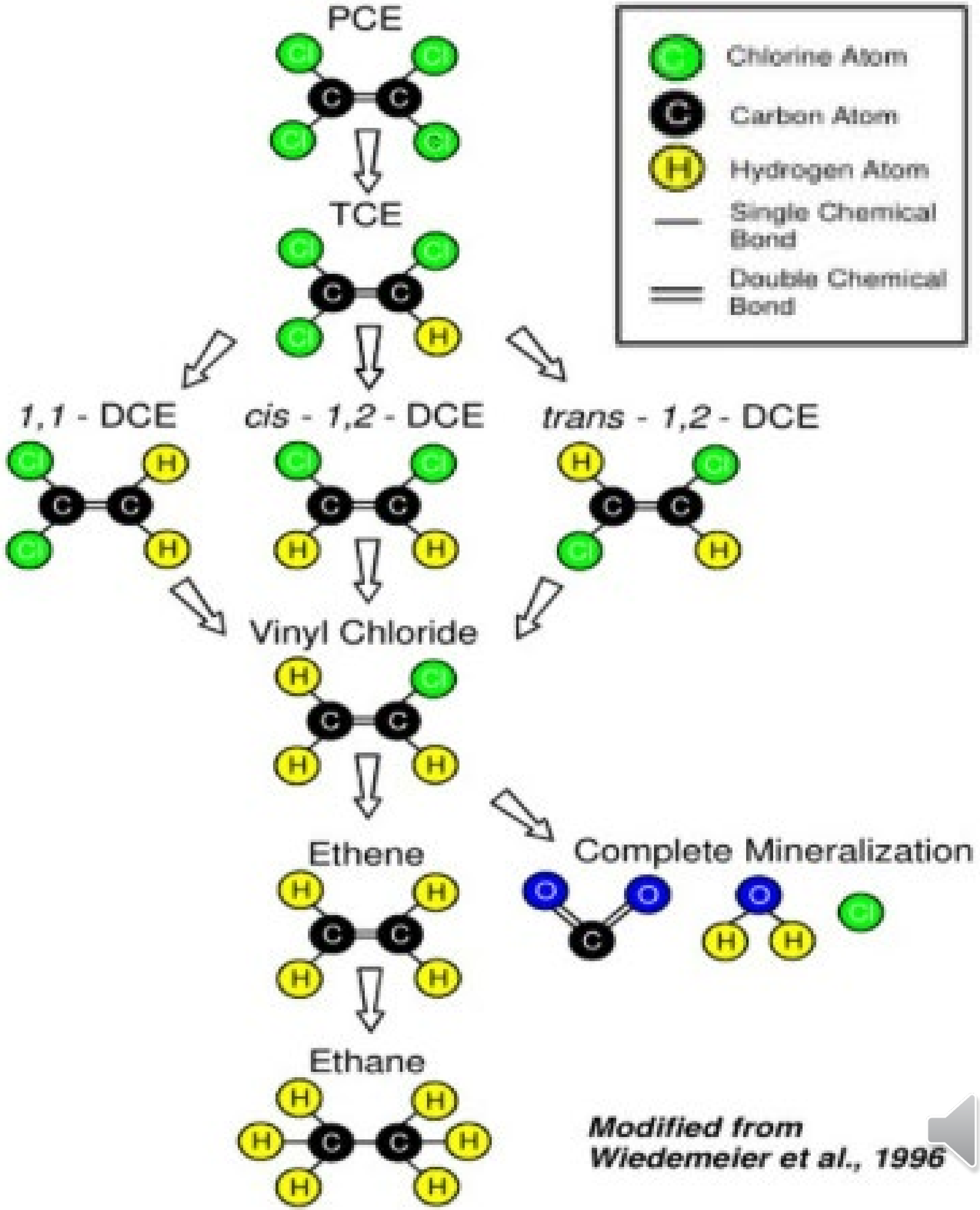
- Delineate the plume boundaries
- Identify likely microbial processes occurring in the plume

Idealized Sequence of Terminal Electron Acceptors For Biodegradation



Reductive Dechlorination Pathway





Third Line of Evidence – Laboratory or Field Studies

Compound-Specific Isotope Analysis

Molecular Biological Tools (e.g., DNA, RNA, protein)

Microcosm Studies

Key Takeaways

MNA projects must:

- ✓ Meet regulatory performance standards
- ✓ Be prepared for active intervention if conditions change

Successful use of MNA requires:

- ✓ Rigorous site data
- ✓ Detailed periodic monitoring
- ✓ Robust reporting
- ✓ Adaptive site management

Part 2: Review of Guidance

Wisconsin DNR

WISCONSIN DEPT. OF NATURAL RESOURCES

Remediation and Redevelopment **December 2025**

Monitored Natural Attenuation Guidance (RR-0156)

Wis. Stat. ch. 292, Wis. Admin. Code chs. NR 700-799

Purpose

This guidance is for persons who investigate, remediate and mitigate contaminated sites under Wisconsin Statute (Wis. Stat.) ch. 292 and Wisconsin Administrative (Wis. Admin.) Code chs. NR 700 - 799. It provides guidance for characterization, assessment and monitoring of sites where natural attenuation is being considered as a remedial option for petroleum or chlorinated hydrocarbon contamination. It focuses on the practical application and includes quick lookup tables to facilitate evaluation of site data, attenuation processes, geochemical indicators and contaminant trends. The information in this guidance may be used to support informed decisions using the regulatory framework, site investigation components, lines of evidence that support monitored natural attenuation as a remedy and monitoring recommendations to verify remedy effectiveness.

Guidance is Available

RR-0156	RR-614	RR-671	RR-699
"Front door" to MNA decision-making	Petroleum specific information	Explain to property owners	Chlorinated specific information
December 2025	January 2014	May 2026	October 2014

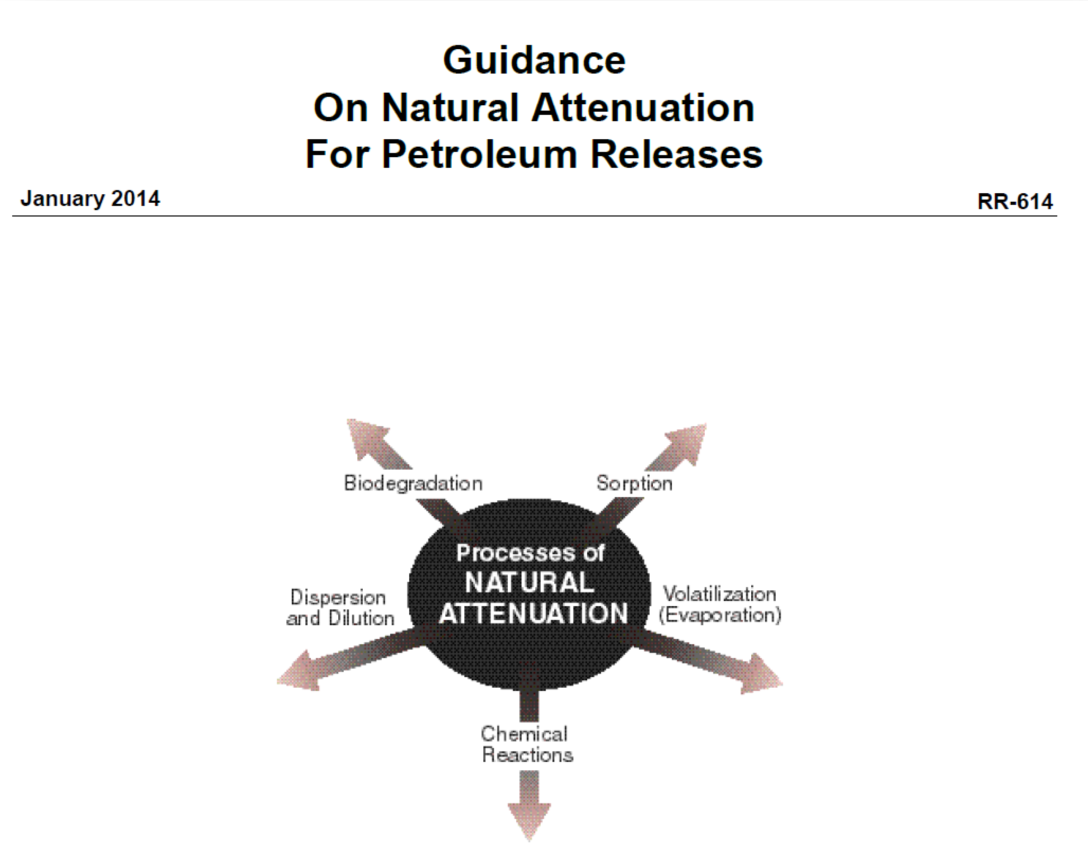
New! MNA Guidance (RR-0156)

Introduces detailed site characterization protocol to prove attenuation

Targets sites where active remediation may be impractical

Integrates with other guidance (RR-614 and RR-699)

Update in Process! Guidance on Monitored Natural Attenuation of Petroleum Hydrocarbons (RR-614)


Guidance
On Natural Attenuation
For Petroleum Releases

January 2014 RR-614

Updates likely to reflect current natural attenuation practice and regulatory expectations, including stronger emphasis on site conceptual models, source control, plume trend analysis, and geochemical lines of evidence.

Public comment period anticipated soon

Update! What Landowners Should Know About Using Natural attenuation to Clean Up Contaminated Groundwater (RR-671)

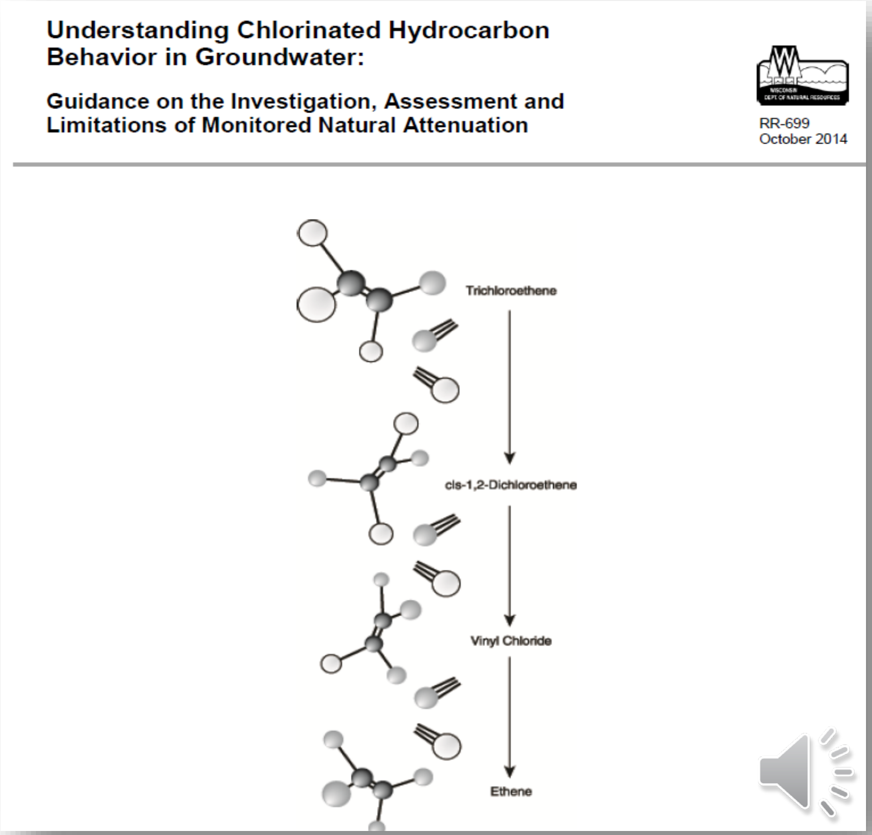
Helps property owners understand natural attenuation and how it can ensure long-term protectiveness needed to close a case

Informs landowners about the basics when contamination remains, including the need to manage for any restrictions or requirements on the property over time.

Update in Process! Guidance on Monitored Natural Attenuation of Chlorinated Hydrocarbons (RR-699)

The update will add modern science-based tools for evaluating MNA, including mass flux, isotope analysis, and microbial indicators.

The update will require multiple lines of evidence, and it will require clear contingency actions if performance criteria are not met.


Understanding Chlorinated Hydrocarbon Behavior in Groundwater:

Guidance on the Investigation, Assessment and Limitations of Monitored Natural Attenuation

RR-699
October 2014

Optional Tool: MNA Checklist

Purpose:

- Help step through considerations
- Foster consistency in applying guidance

Requires:

- Knowledge of administrative code
- Professional judgement

MNA REVIEW CHECKLIST

General Purpose and Applicability of this Checklist

- Support consistent evaluations of monitored natural attenuation (MNA) submittals using RR-0156, RR-614, and RR-699.
- It is a tool, not a rule, and should be adapted to site specific conditions.
- RR Program specialists are available to discuss results of the MNA review.

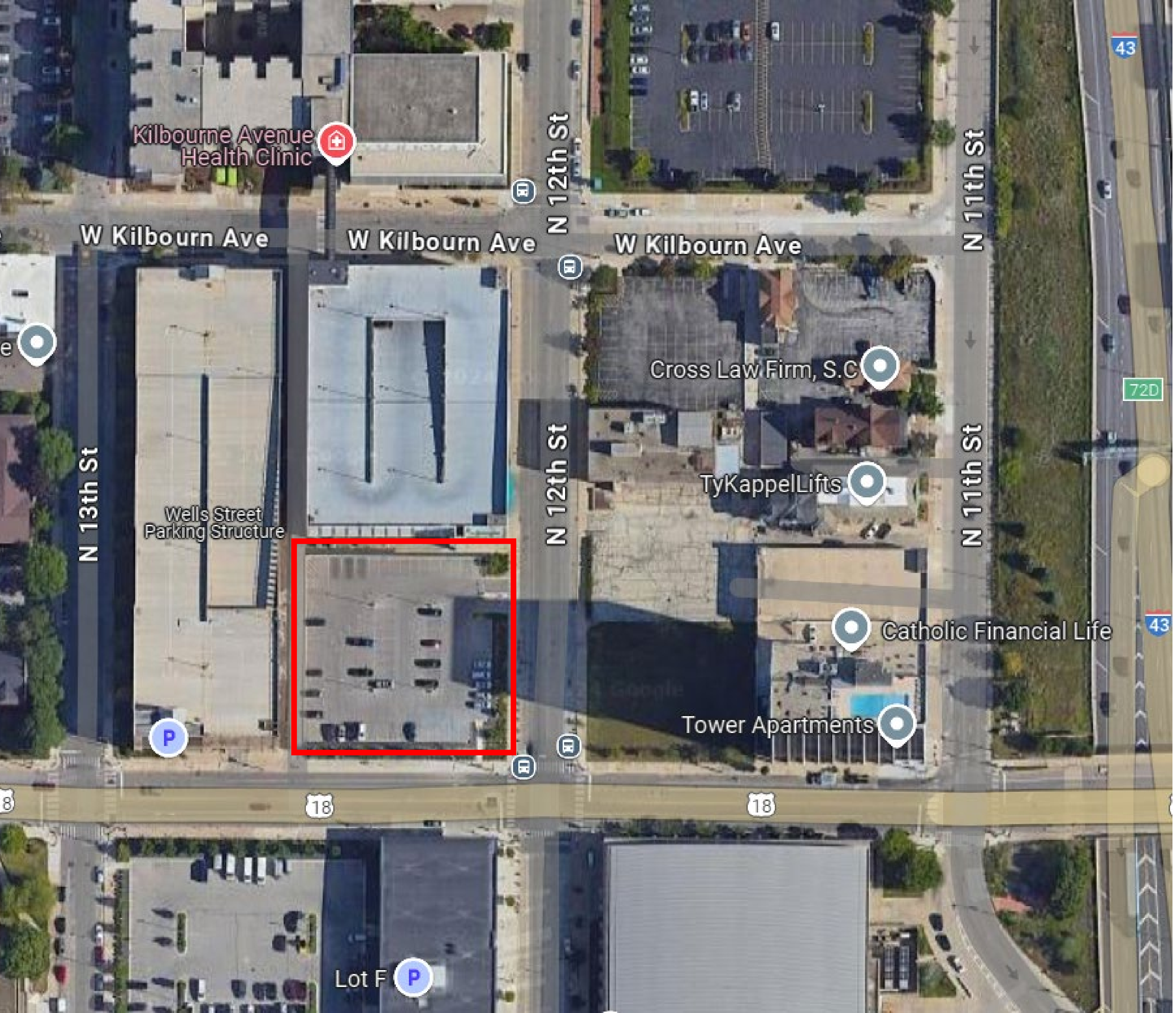
Site Specific Information

SITE NAME:	
BRRTS ID:	
REVIEWER:	
DATE:	

Section 1		Administrative and Regulatory Basics	Comments
	☐	Site name, location, BRRTS ID, and RP/Consultant information clearly identified.	
	☐	Applicable enforcement standards (ESs) and preventative action levels (PALs) cited in the submittal.	
	☐	Site documents indicate that MNA is not being used as a default or presumed "walk away" remedy, but chosen after evaluating other options.	
	☐	Remedy selection clearly documents why MNA is appropriate compared to active remedies , referencing effectiveness, implementability, cost, and timeframe. Refer to the list of evaluation criteria in NR 722.07(4).	
	☐	Site documents clearly state remedial objectives, performance standards, and points of compliance for groundwater. Reminder that the PALs are applicable to restore groundwater quality, as in NR 140.02(3).	
Section 2		**Conceptual Site Model**	**Comments**
	☐	Sources (tanks, piping, discharge areas, historical operations) are identified and described.	
	☐	Hydrogeologic conditions are summarized (aquifer type, hydraulic conductivity, gradient, stratigraphy, confining units, bedrock).	
	☐	CSM clearly identifies natural attenuation processes expected to operate (e.g., dispersion, sorption, biodegradation , etc.) and where they act in the flow system.	
	☐	CSM discusses key uncertainties (e.g., preferential pathways, heterogeneity, fracture zones) and their implications for MNA reliability.	

Part 3:

Application and Discussion



MNA Case Study

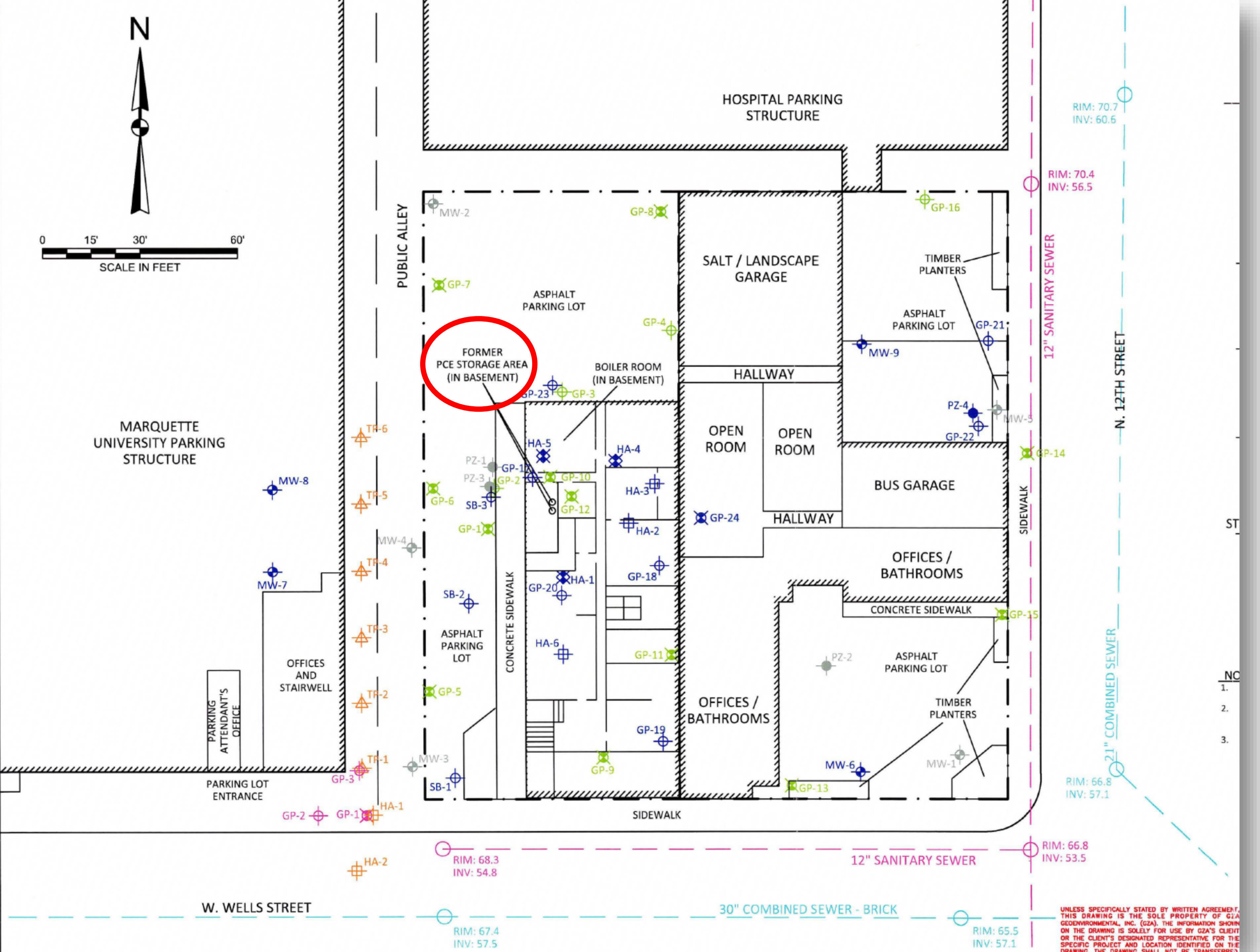
TAXMAN INVESTMENTS CO (FMR)
1214 WEST WELLS STREET,
MILWAUKEE, WISCONSIN

BRRTS NO. 02-41-152248

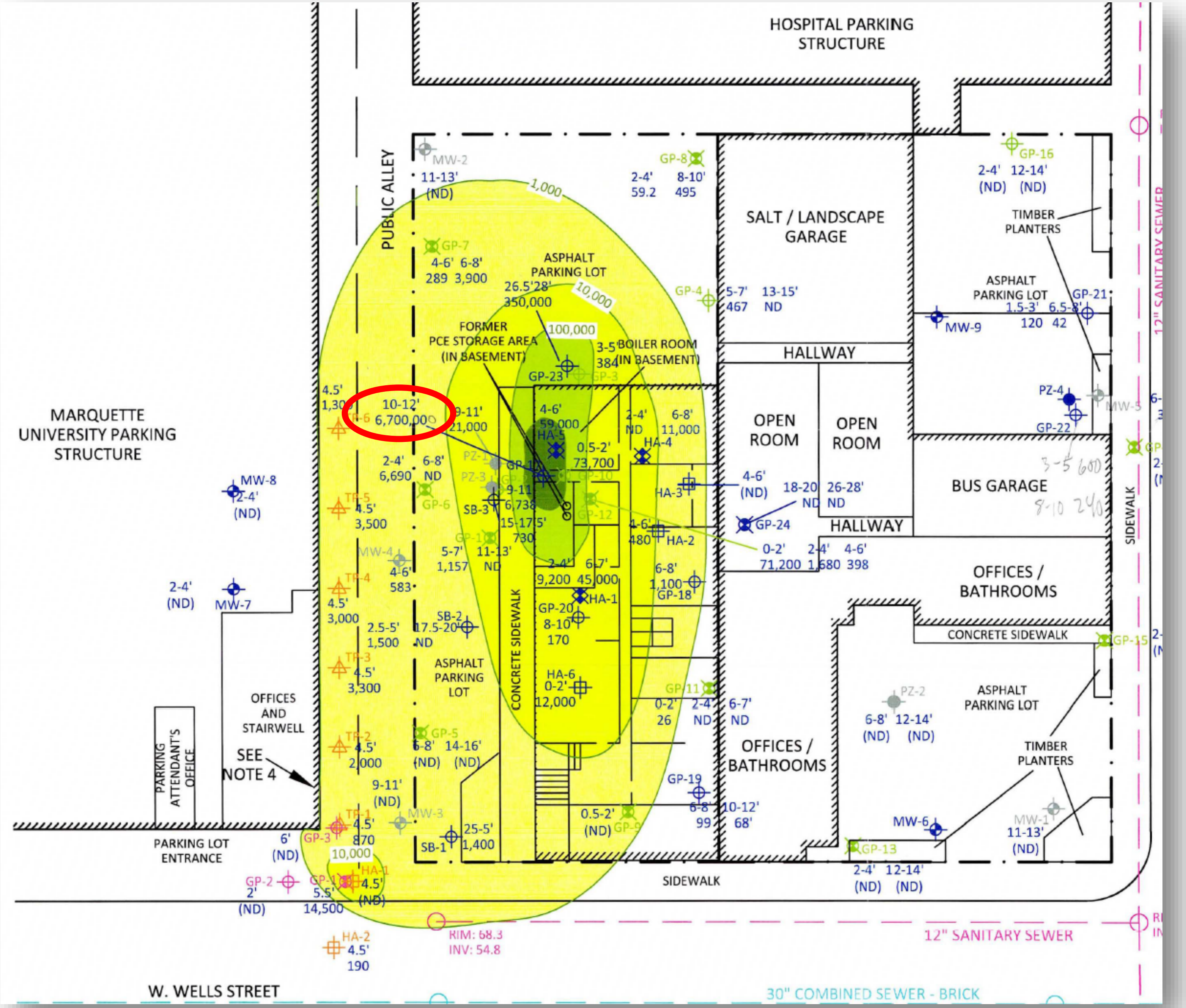
Site status:

- Not ready for closure
- Still in the investigation stage

* Figures and data tables from submitted reports and other information sources may have been marked up for presentation purposes.

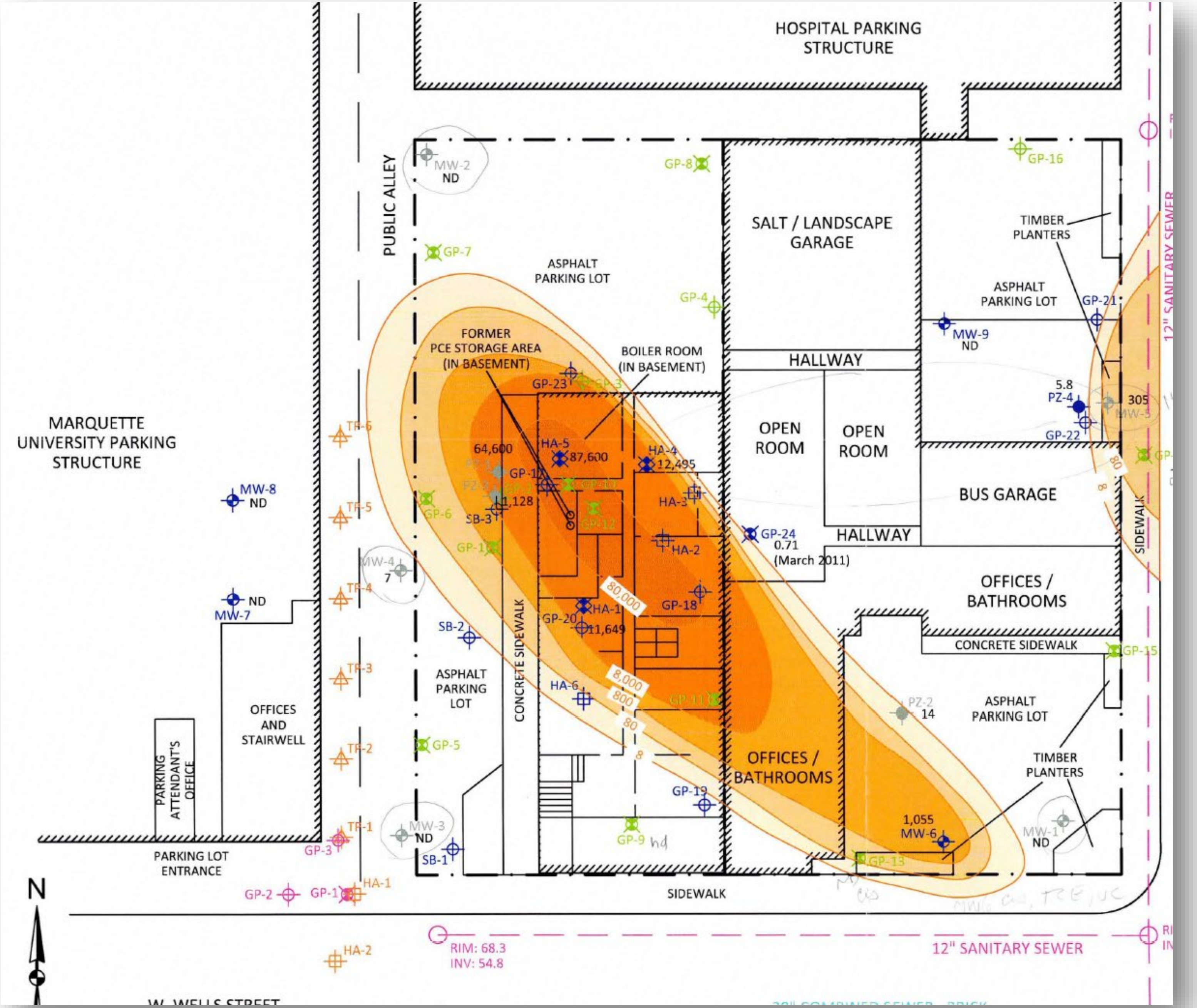


Former Site Layout

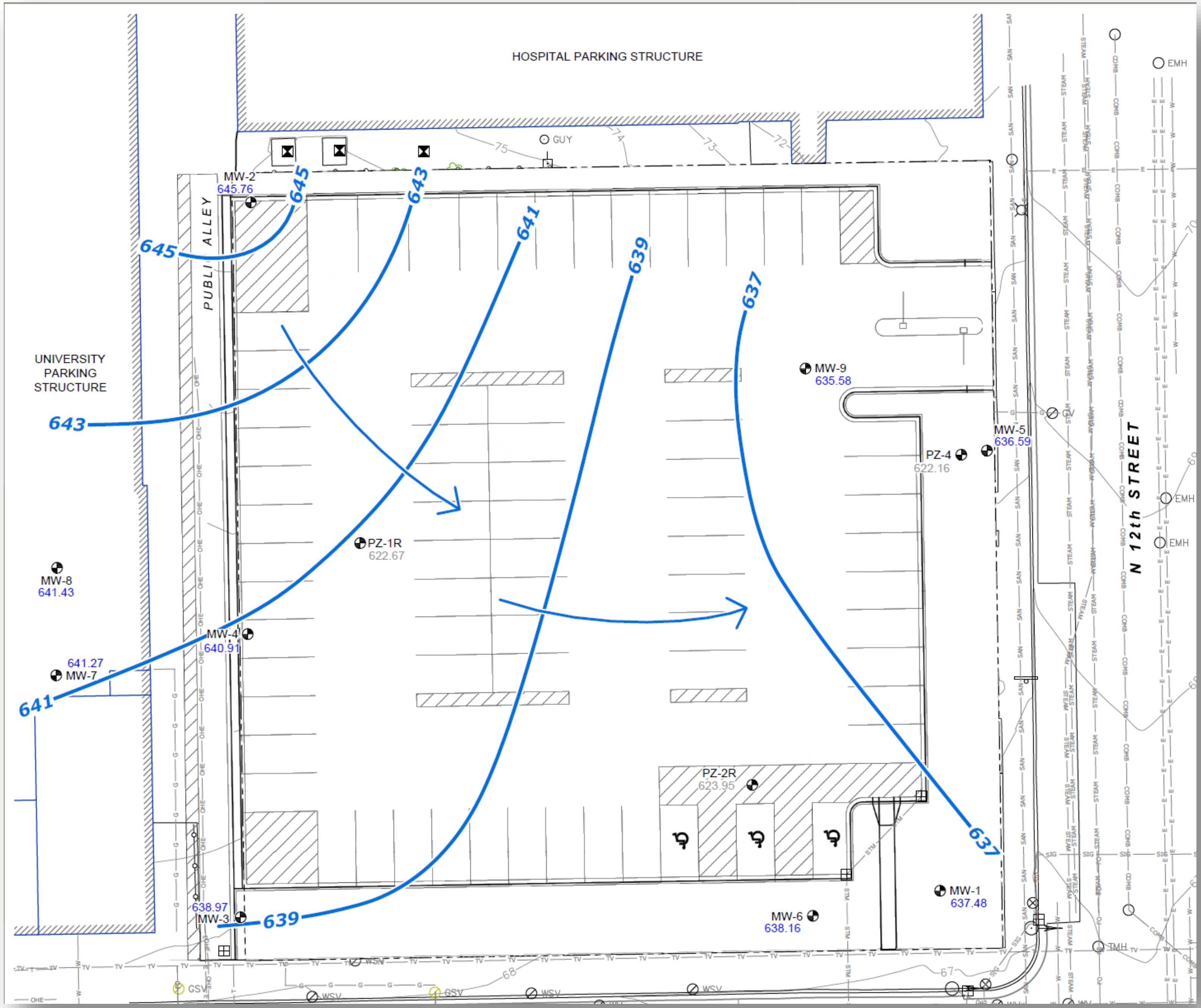


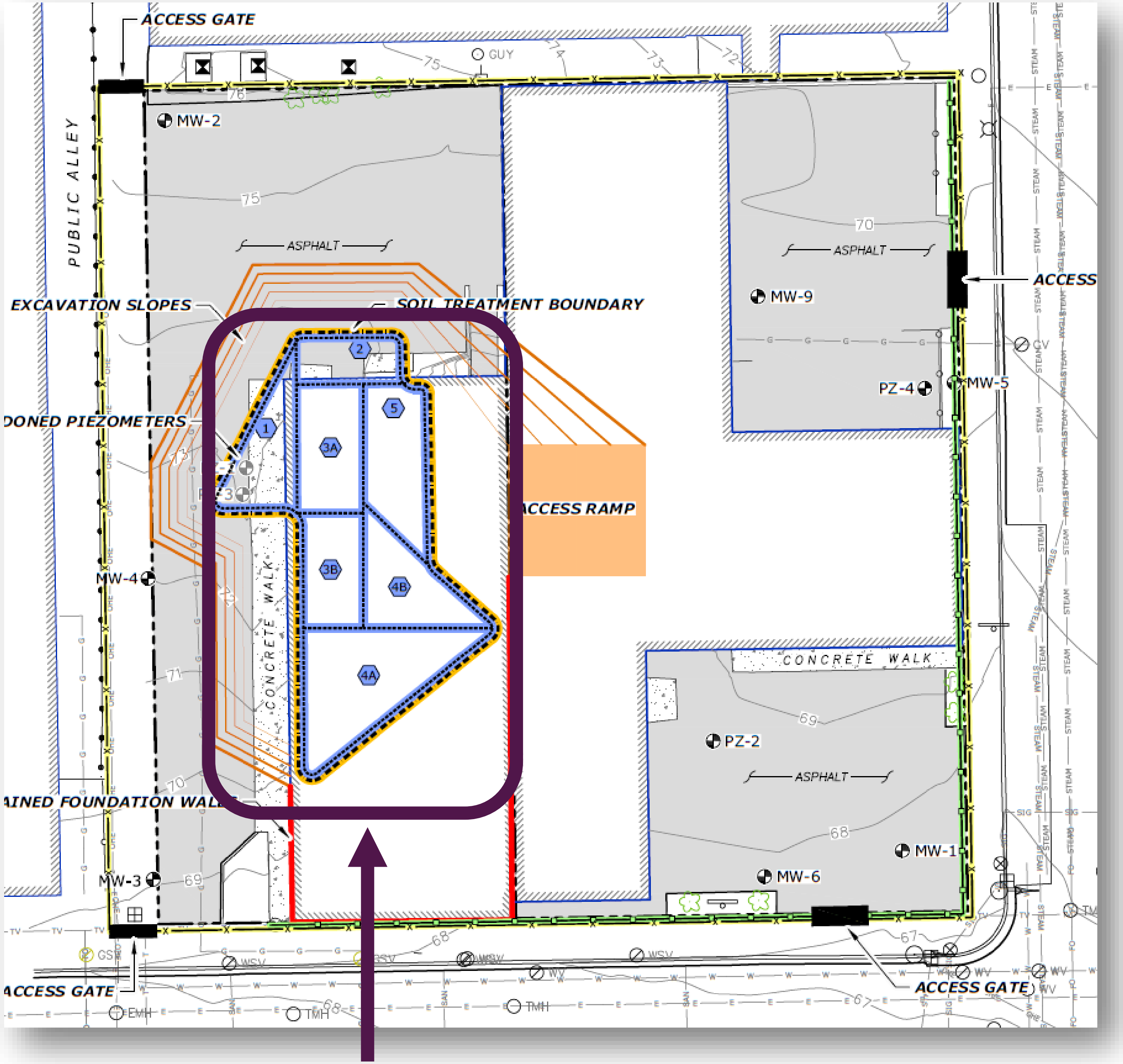
PCE Soil Isoconcentration Map

Former PCE Storage Location
6,700,000 ug/kg at 10 – 12 feet


HOSPITAL PARKING STRUCTURE
SALT / LANDSCAPE GARAGE
PUBLIC ALLEY
ASPHALT PARKING LOT
FORMER PCE STORAGE AREA (IN BASEMENT)
BOILER ROOM (IN BASEMENT)
HALLWAY
OPEN ROOM
OPEN ROOM
BUS GARAGE
HALLWAY
OFFICES / BATHROOMS
CONCRETE SIDEWALK
ASPHALT PARKING LOT
TIMBER PLANTERS
OFFICES / BATHROOMS
MARQUETTE UNIVERSITY PARKING STRUCTURE
OFFICES AND STAIRWELL
PARKING ATTENDANT'S OFFICE
PARKING LOT ENTRANCE
CONCRETE SIDEWALK
ASPHALT PARKING LOT
SIDEWALK
12" SANITARY SEWER
RIM: 68.3
INV: 54.8
N
MW-2 ND
MW-9 ND
MW-8 ND
MW-7 ND
MW-4 7
MW-3 ND
MW-1 ND
1,055 MW-6
PZ-2 14
5.8 PZ-4
305
GP-24 0.71 (March 2011)
64,600
HA-5 87,600
HA-4 12,495
1,128
11,649
80,000
8,000
800
80
8

Groundwater Flow Direction





Soil Blending Treatment Areas

Remedial actions

2018

- Demolition of buildings and paved areas, utilities disconnected
- Soil Blending and Treatment and Zero Valent Iron and ABC Carbon amendment ~2000CY are treated

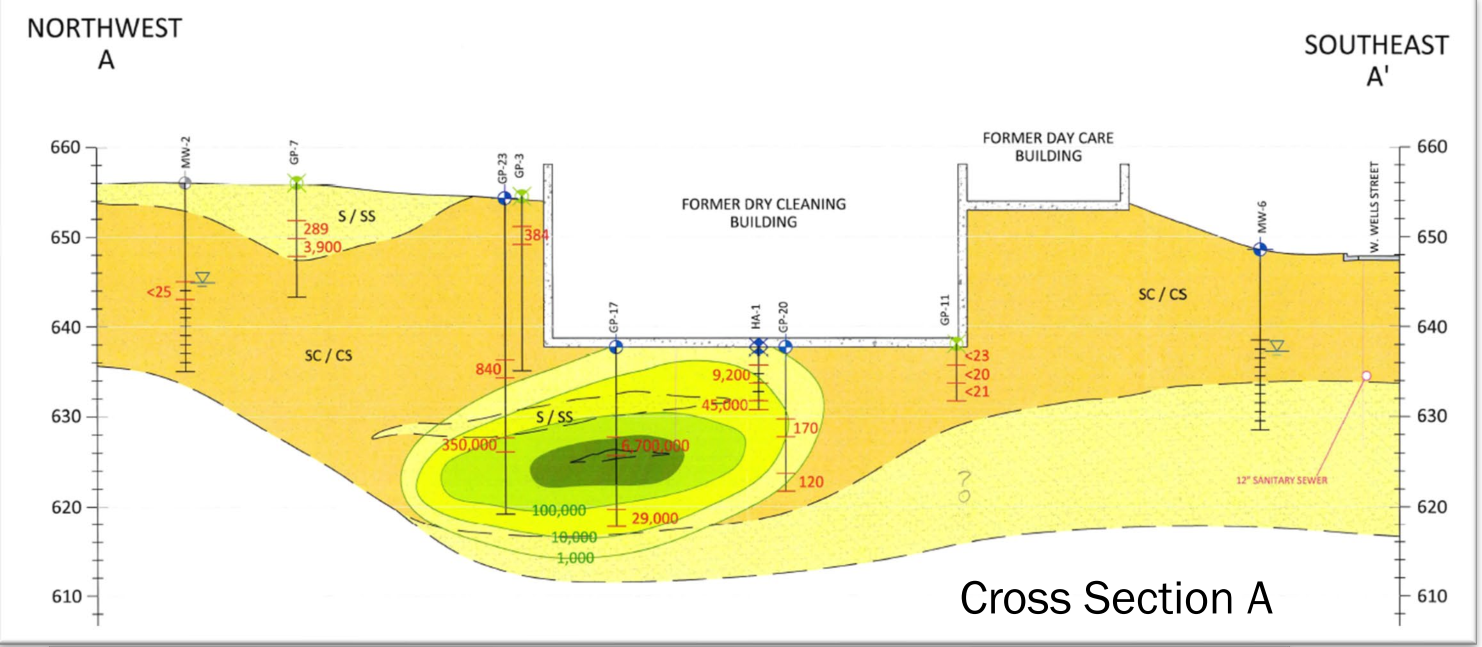
Sept. 2020, April 2021 and Oct. 2022

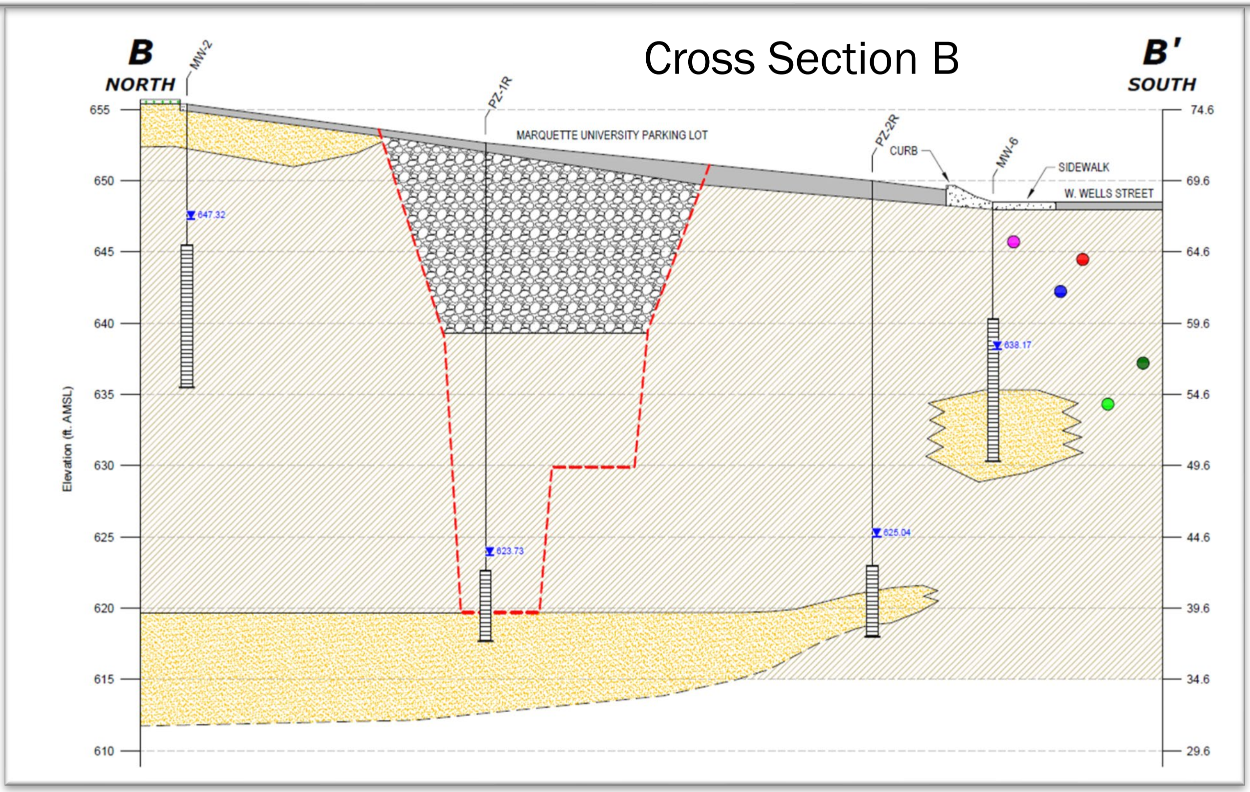
- In-situ enhanced reductive **dechlorinization** (ERD) injections

After 2022

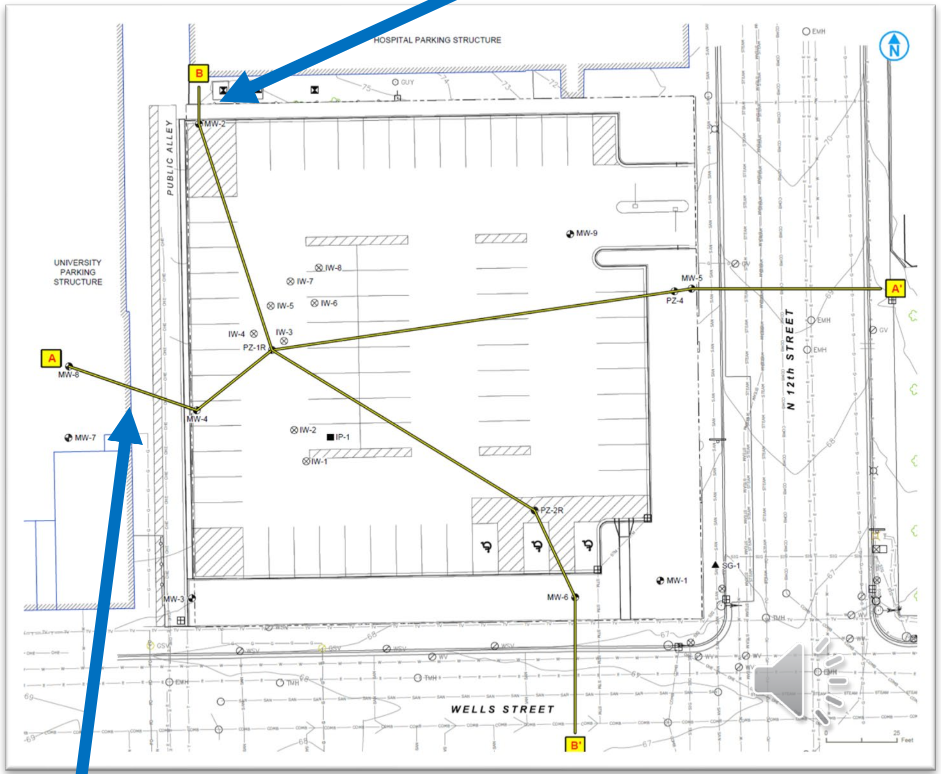
- Post-remediation monitoring
- Site redevelopment
- Soil confirmation sampling
- Soil vapor sampling
- Groundwater monitoring

Physical Site Parameters



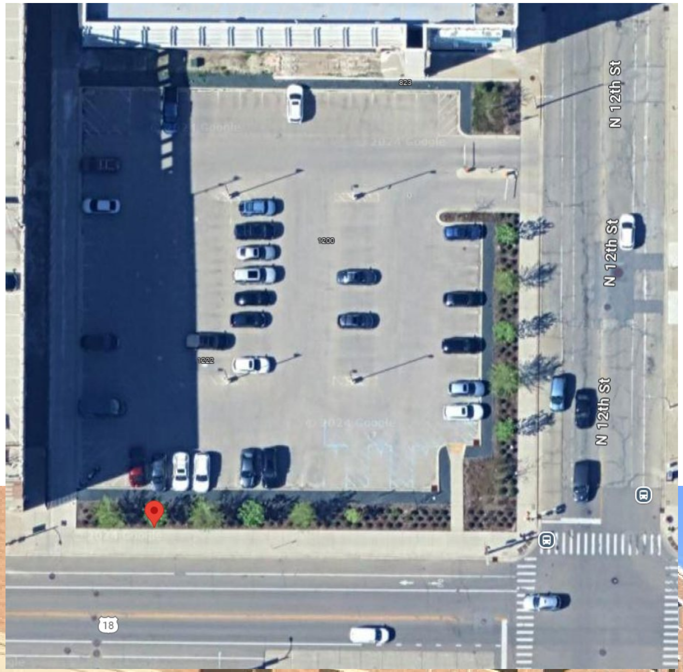


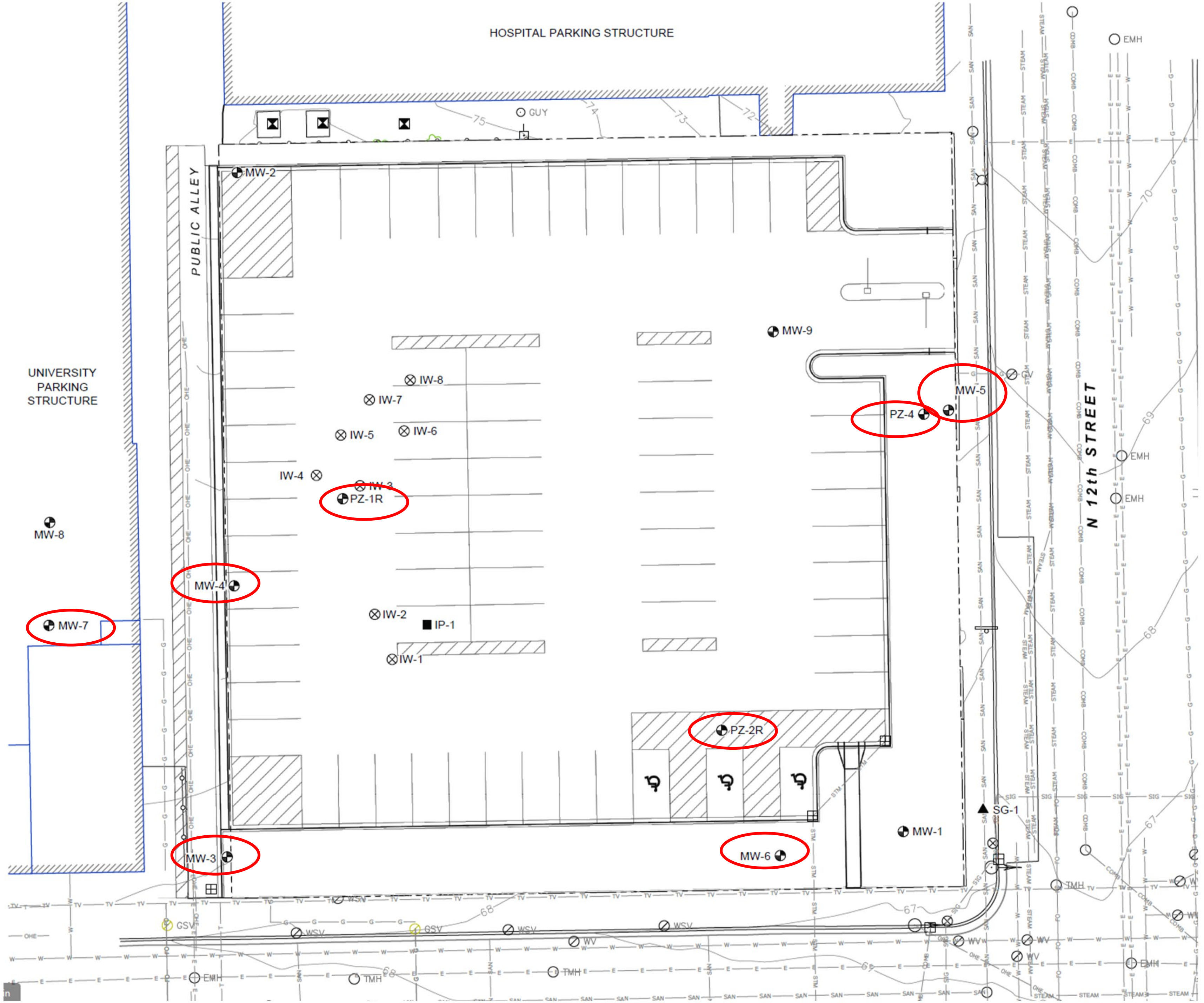
Cross Section Transect Lines B



Cross Section Transect Lines A

Current Site Layout





Monitored Wells

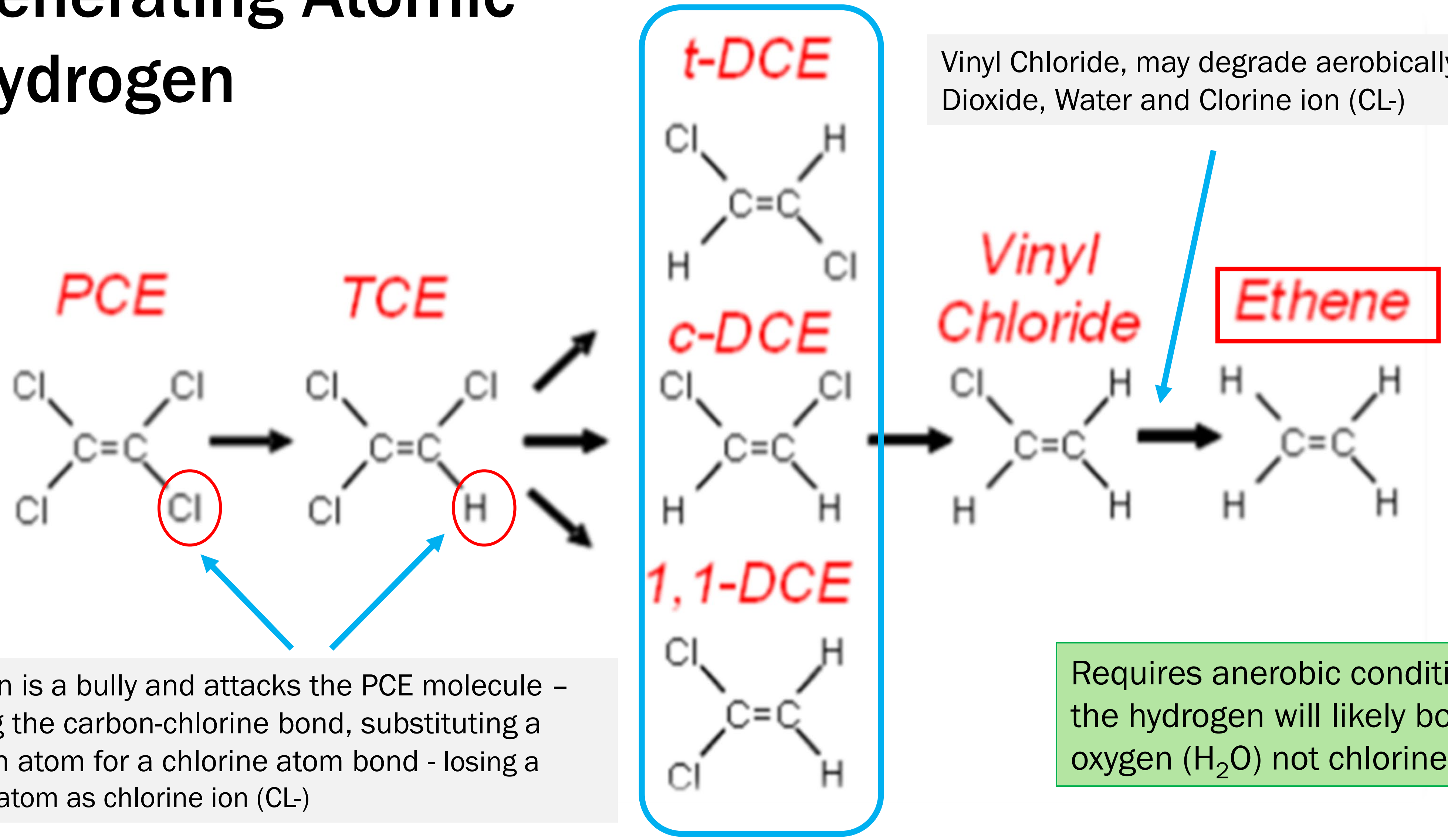
3 Piezometers

PZ-1 – Source Well

5 Monitoring Wells

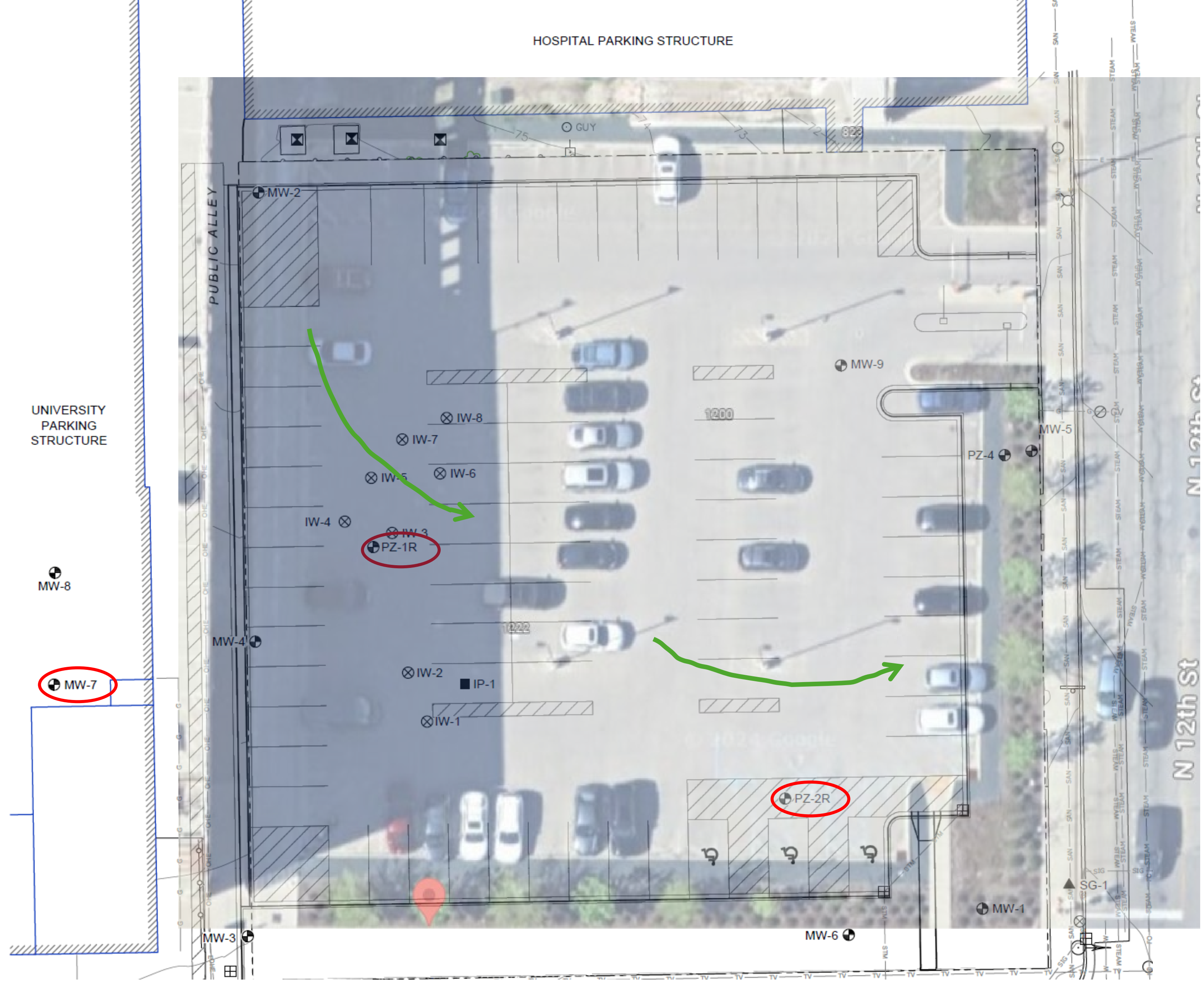
Generating Atomic Hydrogen

Vinyl Chloride, may degrade aerobically. Carbon Dioxide, Water and Clorine ion (CL-)



Hydrogen is a bully and attacks the PCE molecule – breaking the carbon-chlorine bond, substituting a hydrogen atom for a chlorine atom bond - losing a chlorine atom as chlorine ion (CL-)

Requires anerobic conditions or the hydrogen will likely bond with oxygen (H_2O) not chlorine.

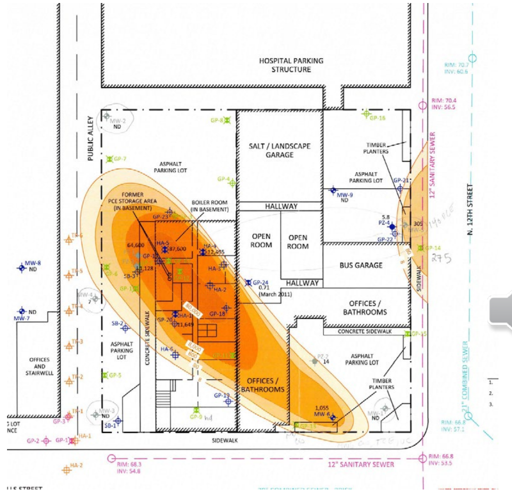


MNA Monitoring Wells

Source Area: PZ-1R

Up gradient/Background: MW-7

Down Gradient PZ-2R



First Step

Data Trends - Source Well

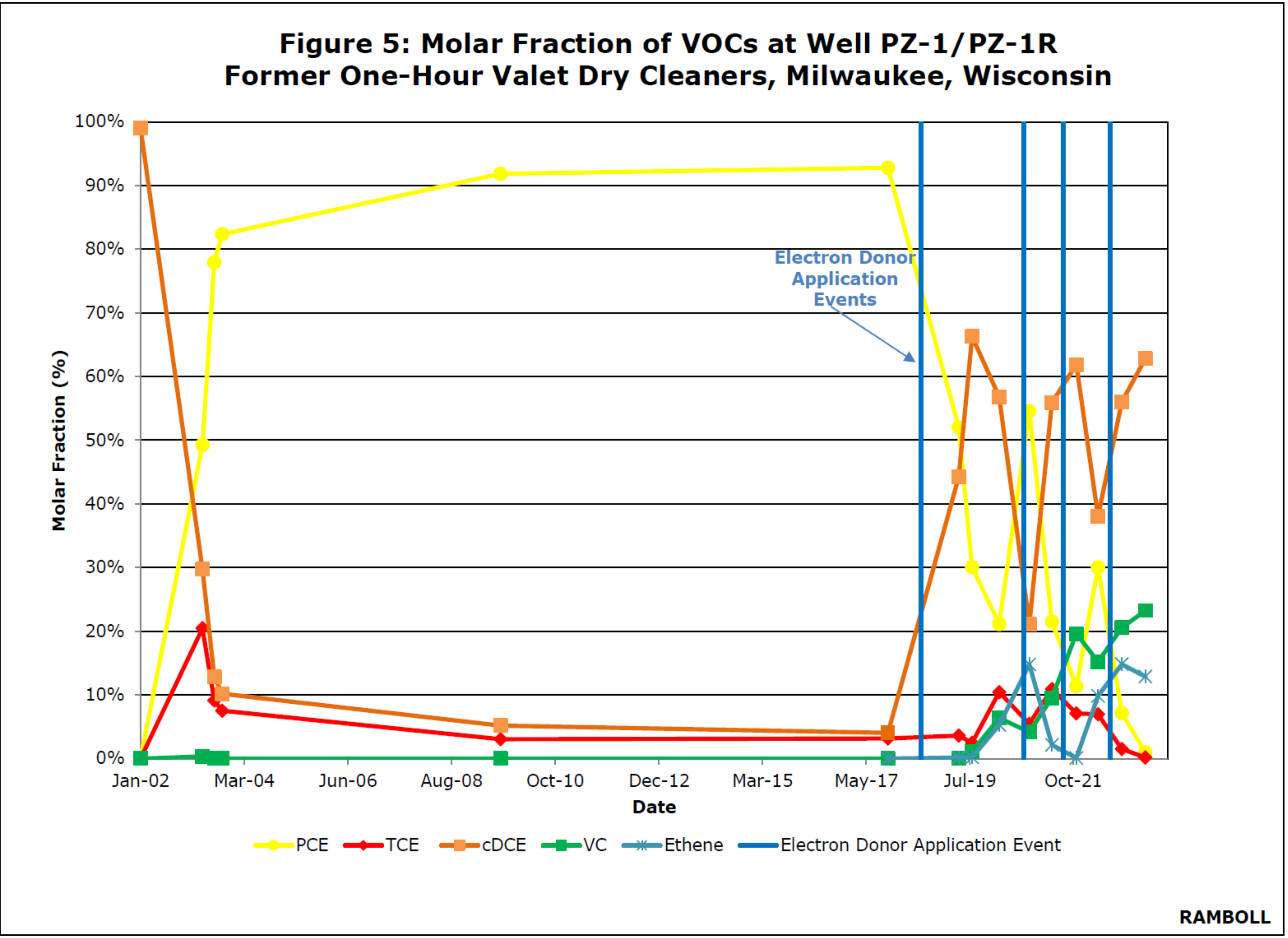
3. Cis -1, 2

1. PCE

2. TCE

4. VC

Analyte[1,2]		Benzene	Chloroform	1,1-Dichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Ethylbenzene	Methylene chloride	Tetrachloroethene	Toluene	Trichloroethene	1,2,4-Trimethylbenzene[3]	Vinyl chloride	Xylenes, total[4]
CAS		71-43-2	67-66-3	75-35-4	156-59-2	156-60-5	100-41-4	75-09-2	127-18-4	108-88-3	79-01-6	95-63-6	75-01-4	1330-20-7
Units		ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
NR 140 ES		5	6	7	70	100	700	5	5	800	5	480	0.2	2000
NR 140 PAL		0.5	0.6	0.7	7	20	140	0.5	0.5	160	0.5	96	0.02	400
PZ-1R Source Well	5/2/2019	<123	<637	<122	**30,000**	<545	<109	<290	**60,300 M1**	<86.1	**3,310**	<420	<87.3	<750
	8/14/2019	<123	<637	**140 J**	**108,000**	<545	<109	<290	**83,700**	<86.1	**5,450**	<420	**1,110**	<750
	3/10/2020	<123	<637	<122	**36,400**	<545	<159	<290	**23,200**	<135	**9,060**	<420	**2,630**	<750
	10/28/2020	<123	<637	<122	**6,500**	<232	<159	<290	**28,800**	<135	**2,280**	<420	**822**	<750
	4/21/2021	<148	<591	<291	**98,200**	<264	<163	<160	**64,500**	<144	**26,000**	<224	**10,800**	<524
	10/27/2021	<148	<591	<291	**69,500**	<264	<163	<160	**21,800**	<144	**10,800**	<224	**14,200**	<524
	4/13/2022	<148	<591	<291	**47,800**	<264	<163	<160	**64,600**	<144	**11,800**	<224	**12,300**	<524
	10/12/2022	<148	<591	<291	**92,600**	<264	<163	<160	**20,200**	<144	**3,350**	<224	**21,900**	<524
	4/12/2023	<148	<252	<291	**72,100**	<264	<163	<160	**1,890**	<144	**240 J**	<224	**17,200**	<524
	10/31/2023	<148	<252	<291	**66,100**	<264	<163	<160	**1,660**	<144	**289 J**	<224	**16,500**	<524
	4/10/2024	<148	<252	<291	**66,300**	<264	<163	<160	**460 J**	<144	<160	<224	**19,700**	<524
	10/25/2024	<148	<252	<291	**71,100**	<264	<163	<160	<204	<144	<160	<224	**22,400**	<524
	4/21/2025	<148	<252	<291	**104,000**	<264	<163	<160	<204	<144	<160	<224	**17,300**	<524



Impact of Soil Blending and in-situ Injections

Second Step

Data Trends - Down Gradient : Time & Distance

3. Cis -1, 2

1. PCE

2. TCE

4. VC

Analyte[1,2]		Benzene	Chloroform	1,1-Dichloroethene	cis-1,2-Dichloroethene	trans-1,2-Dichloroethene	Ethylbenzene	Methylene chloride	Tetrachloroethene	Toluene	Trichloroethene	1,2,4-Trimethylbenzene[3]	Vinyl chloride	Xylenes, total[4]
CAS		71-43-2	67-66-3	75-35-4	156-59-2	156-60-5	100-41-4	75-09-2	127-18-4	108-88-3	79-01-6	95-63-6	75-01-4	1330-20-7
Units		ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
NR 140 ES		5	6	7	70	100	700	5	5	800	5	480	0.2	2000
NR 140 PAL		0.5	0.6	0.7	7	20	140	0.5	0.5	160	0.5	96	0.02	400
PZ-1R	5/2/2019	<123	<637	<122	**30,000**	<545	<109	<290	**60,300** M1	<86.1	**3,310**	<420	<87.3	<750
	8/14/2019	<123	<637	**140** J	**108,000**	<545	<109	<290	**83,700**	<86.1	**5,450**	<420	**1,110**	<750
	3/10/2020	<123	<637	<122	**36,400**	<545	<159	<290	**23,200**	<135	**9,060**	<420	**2,630**	<750
	10/28/2020	<123	<637	<122	**6,500**	<232	<159	<290	**28,800**	<135	**2,280**	<420	**822**	<750
	4/21/2021	<148	<591	<291	**98,200**	<264	<163	<160	**64,500**	<144	**26,000**	<224	**10,800**	<524
	10/27/2021	<148	<591	<291	**69,500**	<264	<163	<160	**21,800**	<144	**10,800**	<224	**14,200**	<524
	4/13/2022	<148	<591	<291	**47,800**	<264	<163	<160	**64,600**	<144	**11,800**	<224	**12,300**	<524
	10/12/2022	<148	<591	<291	**92,600**	<264	<163	<160	**20,200**	<144	**3,350**	<224	**21,900**	<524
	4/12/2023	<148	<252	<291	**72,100**	<264	<163	<160	**1,890**	<144	**240** J	<224	**17,200**	<524
	10/31/2023	<148	<252	<291	**66,100**	<264	<163	<160	**1,660**	<144	**289** J	<224	**16,500**	<524
	4/10/2024	<148	<252	<291	**66,300**	<264	<163	<160	**460** J	<144	<160	<224	**19,700**	<524
	10/25/2024	<148	<252	<291	**71,100**	<264	<163	<160	<204	<144	<160	<224	**22,400**	<524
	4/21/2025	<148	<252	<291	**104,000**	<264	<163	<160	<204	<144	<160	<224	**17,300**	<524
PZ-2R Down Gradient Well	8/14/2019	<0.25	<1.3	<0.24	*26.9*	<1.1	<0.22	<0.58	**12.7**	<0.17	0.39 J	<0.84	**15.5**	<1.5
	3/10/2020	<0.25	<1.3	<0.24	*33.9*	<1.1	<0.32	<0.58	<0.33	<0.27	<0.26	<0.84	**11.3**	<1.5
	10/28/2020	<0.25	<1.3	<0.24	**90.2**	1.1 J	<0.32	<0.58	<0.33	<0.27	<0.26	<0.84	**10.8**	<1.5
	4/21/2021	<0.30	<1.2	<0.58	**109**	1.5	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**14.1**	<1.0
	10/27/2021	<0.30	<1.2	<0.58	**104**	1.3	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**12.6**	<1.0
	4/13/2022	<0.30	<1.2	<0.58	**91.5**	1.4	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**11.1**	<1.0
	10/12/2022	<0.30	<1.2	<0.58	**121**	1.7	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**11.1**	<1.0
	4/12/2023	<0.30	<0.50	<0.58	**89.9**	1.5	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**11.8**	<1.0
	10/31/2023	<0.30	<0.50	<0.58	**113**	1.7	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**11.6**	<1.0
	4/10/2024	<0.30	<0.50	<0.58	**111**	1.7	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**12.8**	<1.0
	10/24/2024	<0.30	<0.50	<0.58	**105**	1.8	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**13.4**	<1.0
	4/21/2025	<0.30	<0.50	<0.58	**109**	1.9	<0.33	<0.32	<0.41	<0.29	<0.32	<0.45	**15.6** v1	<1.0

Well ID	Sample Date	Dissolved Oxygen (mg/L)	Ethane (µg/L)	Ethene (µg/L)	pH	Iron, Ferrous (mg/L)	Methane (µg/L)	Nitrogen, NO_2 plus NO_3 (mg/L)	ORP (mV)	Sulfate (mg/L)	Total Organic Carbon (mg/L)
PZ-1	1/15/2002	0.66	NA	NA	NR	NA	NA	NA	-65.3	NA	NA
	5/8/2003	1.31	NA	NA	NR	NA	NA	NA	-18.3	NA	NA
	8/8/2003	0.12	NA	NA	NR	NA	NA	NA	-93.7	NA	NA
	10/7/2003	0.09	1.7	0.48	NR	NA	7	NA	-97.1	NA	NA
	8/25/2009	0.83	<10	<10	NR	NA	<10	NA	-73.0	NA	2.04
	11/2/2017	0.64	<0.58	<0.52	8.14	0.060 H	<1.4	0.33	38.5	155	0.50 J
	PZ-1 abandoned on 1/11/2018. PZ-1R installed on 4/18/2019.										
PZ-1R	5/2/2019	1.01	337	32.4	7.05	5.8 H	23.1	<0.095	-102.6	101	124 J D3
	8/14/2019	0.21	3,060	87.2	6.97	6.5 H	129	<0.095	-138.4	93.1	184
	3/10/2020	0.00	2,130	974	7.58	5.1 H	162	<0.059	-270.1	85.9	115
	10/28/2020	0.21	1,560	1,320	6.47	168 H	1510	NA	-126.9	4.9 J, D3	2,440
	4/21/2021	0.19	1,540	1,090	7.35	19.7 H	2,680	NA	-487.7	<2.2 D3	499
	10/27/2021	0.18	2.7 J	21.9	6.43	19.0 H	1,820	NA	-58.6	<2.2 D3	959
	4/13/2022	0.36	683	3,570	6.62	3.9 H, M	5,650	NA	-244.8	66.2	240
	10/12/2022	0.48	1,040 J	7,090	6.47	7.2 H	13,900	NA	-312.7	<2.2 D3	241
	4/12/2023	0.12	135	4,270	6.16	12 H	13,300	NA	-243.9	<0.44 M	177
	10/31/2023	0.04	299	6,570	6.32	10 H	17,100	NA	-430.3	<22.2 D3	204 1q
	4/10/2024	0.08	283	3,720	6.51	13.9 H, M	9,410	NA	-155.7	<2.2	171
	10/25/2024	0.08	162	3,210	6.63	12.2 H, M	9,040	NA	-64.1	<4.4	33.3
	4/21/2025	0.17	126	2,160	6.63	6.9 H, M	6,560	NA	-240.3	<0.89 D3	113
PZ-2	8/8/2003	0.19	NA	NA	NR	NA	NA	NA	-41.3	NA	NA
	10/6/2003	0.15	1.3	0.79	NR	NA	60	NA	-35.1	NA	NA
	8/27/2009	0.78	NA	NA	NR	NA	NA	NA	-16.0	NA	NA
	11/1/2017[1]	2.67	<0.58	<0.52	7.64	3.1 H	23.1	<0.095	-100.3	178	<0.25
	5/2/2019[4]	NS	NS	NS		NS	NS	NS	NS	NS	NS
	PZ-2 abandoned on 7/19/2019. PZ-2R installed on 7/19/2019.										
PZ-2R	8/14/2019	0.13	0.82 J	<0.52	7.15	3.6 H	22	<0.095	-36.8	164	0.40 J
	3/10/2020	0.10	<1.2	<1.2	7.29	2.9 H, M	10.3	<0.059	-68.3	140	0.36 J M
	10/28/2020	0.35	NA	NA	6.99	NA	NA	NA	-80.6	NA	NA
	4/21/2021	0.47	NA	NA	7.65	NA	NA	NA	-81.7	NA	NA
	10/27/2021	0.38	NA	NA	7.19	NA	NA	NA	-45.8	NA	NA
	4/13/2022	0.57	NA	NA	7.11	NA	NA	NA	-40.0	NA	NA
	10/12/2022	0.81	NA	NA	6.90	NA	NA	NA	-65.8	NA	NA
	4/12/2023	0.37	NA	NA	7.00	NA	NA	NA	-162.9	NA	NA
	10/31/2023	0.30	NA	NA	7.20	NA	NA	NA	-183.6	NA	NA
	4/10/2024	0.13	NA	NA	7.22	NA	NA	NA	-94.9	NA	NA
	10/24/2024	0.26	NA	NA	7.17	NA	NA	NA	-37.9	NA	NA
	4/21/2025	0.15	NA	NA	7.16	NA	NA	NA	-197.7	NA	NA
PZ-3	8/25/2009	0.72	NA	NA	NR	NA	NA	NA	-53.0	NA	NA
	11/2/2017	1.34	NA	NA	7.98	NA	NA	NA	-103.8	NA	NA
	PZ-3 abandoned on 1/11/2018										
PZ-4	8/25/2009	0.72	NA	NA	NR	NA	NA	NA	-55.0	NA	NA
	11/2/2017	1.47	NA	NA	7.76	NA	NA	NA	-111.8	NA	NA
	5/2/2019	2.99	NA	NA	7.02	NA	NA	NA	48.2	NA	NA
	8/14/2019	0.24	NA	NA	6.95	NA	NA	NA	-40.0	NA	NA
	3/10/2020	0.24	NA	NA	6.98	NA	NA	NA	-61.7	NA	NA
	10/28/2020	7.72	NA	NA	8.77	NA	NA	NA	12.4	NA	NA
	4/21/2021	0.54	NA	NA	7.44	NA	NA	NA	-88.1	NA	NA
	10/27/2021	0.31	NA	NA	7.09	NA	NA	NA	-36.9	NA	NA
MW-7	8/26/2009	NA	NA	NA	NR	NA	NA	NA	NA	NA	NA
	11/9/2017[2]	7.49	NA	NA	7.72	NA	NA	NA	-50.7	NA	NA
	10/31/2023	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4/10/2024	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	10/24/2024	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4/21/2025	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Third Step
MNA Parameters

Field Parameters

Geochemical Parameters

Source Well

Down Gradient Well

Up-Gradient/ Background Well

Groundwater *Field* Parameters at PZ-1R (April 2025)

Bare minimum data required to begin MNA evaluation

Type	Analyte	Concentration in Source Zone or Change from Background
Contaminants of Concern	VOCs (PCE, TCE, cis 1,2-DCE, VC)	See Common Degradation Pathways attachment for likely parent/daughter compounds.
Field Parameters - All Wells	Specific Conductivity	Increase over background
	pH	5 < pH > 9
	Oxidation Reduction Potential (ORP)	<-100 mV
	Dissolved Oxygen (D.O.)	< 0.5 mg/l

Table - DRAFT 2023.10.09 Job Aid for Monitored Natural Attenuation (MNA) of Groundwater

Well ID	Sample Date	Dissolved Oxygen (mg/L)	Ethane (µg/L)	Ethene (µg/L)	pH	Iron, Ferrous (mg/L)	Methane (µg/L)	Nitrogen, NO_2 plus NO_3 (mg/L)	ORP (mV)	Sulfate (mg/L)	Total Organic Carbon (mg/L)
PZ-1R	5/2/2019	1.01	337	32.4	7.05	5.8 H	23.1	<0.095	-102.6	101	124 J D3
	8/14/2019	0.21	3,060	87.2	6.97	6.5 H	129	<0.095	-138.4	93.1	184
	3/10/2020	0,00	2,130	974	7,58	5,1 H	162	<0,059	-270,1	85,9	115
	10/28/2020	0,21	1,560	1,320	6,47	168 H	1510	NA	-126,9	4,9 J, D3	2,440
	4/21/2021	0,19	1,540	1,090	7,35	19,7 H	2,680	NA	-487,7	<2,2 D3	499
	10/27/2021	0,18	2,7 J	21,9	6,43	19,0 H	1,820	NA	-58,6	<2,2 D3	959
	4/13/2022	0,36	683	3,570	6,62	3,9 H, M	5,650	NA	-244,8	66,2	240
	10/12/2022	0.48	1,040 J	7,090	6.47	7,2 H	13,900	NA	-312,7	<2.2 D3	241
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	4/21/2025	0.17	126	2,160	6.63	6.9 H, M	6,560	NA	-240.3	<0.89 D3	113

pH values

Favorable for anaerobic dechlorination

ORP measurements

Negative ORP values indicate reducing conditions

DO levels

Indicate anaerobic conditions

Groundwater *Geochemical* Parameters at PZ-1R

Dissolved Gasses - PZ-1R	Ethene	Present
	Ethane	Present
	Methane	Increase over background
Anions/ Inorganics (Select for appropriateness of MNA strategy) - PZ-1R	Nitrite (NO−2)/Nitrate (NO−3)	< 1 mg/l
	Manganese (Mn2+)	Increase over groundwater along flow path
	Ferrous Iron (Fe2+) dissolved & total (Fe3+)	Increase over groundwater along flow path
	Sulfate (SO_4^{-2})	Decrease compared to background
	Sulfide (S^{2-})	Increase over background
	Chloride (Cl)	> 2x background
	Total Organic Carbon (TOC)	> 20 mg/l
	Alkalinity	> 2x background

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Ethene (C_2H_4) and ethane (C_2H_6)

Indicates **complete** reductive dechlorination of PCE

Methane

Indicates favorable reducing conditions for continued anaerobic dechlorination of CVOCs

Ferrous iron

Indicates continued iron-reducing conditions necessary for anaerobic dechlorination

Detectable sulfate

Indicates sulfate-reducing conditions favorable for continued reductive dechlorination of CVOCs.

TOC

Desirable within an anaerobic treatment zone

Key Criteria: Determining MNA suitability

Site Characterization

- Favorable hydrogeologic and geochemical conditions including plume delineation
- Groundwater flow direction
- Sufficient monitoring points and data to track trends.

Contaminant Behavior

- No current receptors or expanding plumes

Protective Conditions

- Source control to the maximum extent practicable is essential
- Attenuation rates must outpace plume migration to meet cleanup goals in reasonable timeframe

Monitoring Feasibility

- Multiple lines of evidence are needed
- Specific processes like reductive dechlorination or aerobic biodegradation must be demonstrated.

MNA Checklist

Consultants

Walks you through considerations

- Prior to implementing MNA
- During the MNA process
- Evaluating effectiveness of MNA

Supports consistent evaluations

Helps with documentation

DNR

Follows administrative code/guidance

Supports a consistent review

Helps with documentation

MNA REVIEW CHECKLIST

General Purpose and Applicability of this Checklist

stent evaluations of monitored natural attenuation (MNA) submittals using RR-0156, RR-614, and RR-699.

t a rule, and should be adapted to site specific conditions.

specialists are available to discuss results of the MNA review.

Site Specific Information

AME:	Taxman Investments Co (FMR)
'S ID:	02-41-152248
VER:	
)ATE:	

ion 1		Administrative and Regulatory Basics	Comme
	☐	Site name, location, BRRTS ID, and RP/Consultant information clearly identified.	☑
	☐	Applicable enforcement standards (ESs) and preventative action levels (PALs) cited in the submittal.	☑
	☐	Site documents indicate that MNA is not being used as a default or presumed "walk away" remedy, but chosen after evaluating other options.	Has graphs, field ar geochemical data, evaluation and disc
	☐	Remedy selection clearly documents why MNA is appropriate compared to active remedies , referencing effectiveness, implementability, cost, and timeframe. Refer to the list of evaluation criteria in NR 722.07(4).	
	☐	Site documents clearly state remedial objectives, performance standards, and points of compliance for groundwater. Reminder that the PALs are applicable to restore groundwater quality, as in NR 140.02(3).	
ion 2		**Conceptual Site Model**	**Comme**
	☐	Sources (tanks, piping, discharge areas, historical operations) are identified and described.	Dry Cleaner
	☐	Hydrogeologic conditions are summarized (aquifer type, hydraulic conductivity, gradient, stratigraphy, confining units, bedrock).	
	☐	CSM clearly identifies natural attenuation processes expected to operate (e.g., dispersion, sorption, biodegradation , etc.) and where they act in the flow system.	
	☐	CSM discusses key uncertainties (e.g., preferential pathways, heterogeneity, fracture zones) and their implications for MNA reliability.	
	☐	CSM links plume behavior to geochemical controls (e.g., redox fronts, pH zones, mineral phases).	
	☐	Contaminant types are clearly identified (petroleum, chlorinated, mixed, fill material) with key constituents listed.	Chloronated/CVOC
	☐	Plume footprint is clearly defined in plan view and cross-section (extent, depth, thickness).	☑
	☐	Known and potential receptors are identified (wells, surface water, utilities, basements, ecological receptors, property boundaries)	

In Summary...

- You learned what MNA is and how it can be used as a remedial alternative.
- You understand that RR-0156 establishes a foundation for MNA, and RR-614 and RR-699 help fill in the technical details.
- You heard how Linda applied RR-0156 and the MNA checklist to the Taxman Site.

CONNECT WITH US

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