Chlorinated Solvent Plume:
A Case Study





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April 4, 2019

Massachusetts Contingency Plan (MCP)

Key Milestones

- Report a release
- Phase I (initial characterization) and Tier Classification
- Phase II – Comprehensive Site Assessment
- Phase III – Remedial Action Plan (identify possible remedial technologies and select the remedy)
- Phase IV – Remedy Implementation Plan (RIP)
- Phase V – Remedy Operation Status (ROS) – long term O&M
- Temporary Solution
- Permanent Solution – with or without conditions

Massachusetts Contingency Plan (MCP)

Numerical cleanup standards

- Method 1 – default numerical criteria
- Method 2 – slight modification of method 1 standards
- Method 3 – site specific risk characterization

<u>Method 1 Groundwater Categories</u>

- GW-1: Current or future uses of groundwater as drinking water
- GW-2: The potential for volatile material to migrate into indoor air
- GW-3: Potential environmental effects resulting from contaminated groundwater discharging to surface water

Massachusetts Contingency Plan (MCP)

Method 1 Soil Categories

- S-1: Current or future sensitive uses of the property and accessible soil
- S-2: Current or future property uses associated with moderate exposure and accessible soil
- S-3: Current or future restricted access and property with limited potential for exposure
    - Soil categories are sub-categorized by groundwater type, based on leaching potential of the contaminated soil

SOIL CATEGORY SELECTION MATRIX - HUMAN EXPOSURE POTENTIAL

	RECEPTOR CHARACTERISTICS							
	CHILDREN PRESENT				ADULTS ONLY PRESENT			
	HIGH FREQUENCY		LOW FREQUENCY		HIGH FREQUENCY		LOW FREQUENCY	
Accessibility of Soil	**High Intensity**	**Low Intensity**	**High Intensity**	**Low Intensity**	**High Intensity**	**Low Intensity**	**High Intensity**	**Low Intensity**
ACCESSIBLE (SURFICIAL) SOIL 0 <= 3' (unpaved)	CATEGORY S-1			S-2	S-1	CATEGORY S-2		S-3
POTENTIALLY ACCESSIBLE SOIL 3 <= 15' (unpaved) or 0 <= 15' (paved)	S-1	CATEGORY S-2		S-3	S-2	CATEGORY S-3		
ISOLATED SUB-SURFACE SOILS > 15' or under the footprint of a building or permanent structure	CATEGORY S-3				CATEGORY S-3			

* - Category S-1 also applies to any accessible soil where the current or reasonably foreseeable use of the soil is for growing fruits and vegetables for human consumption

Project Understanding

Property acquired by a food and beverage company in 1975 – they do not use chlorinated solvents

Former uses included manufacturing metal products

UST investigation/removals in 1991/1992

Identified chlorinated solvents in groundwater

- Primary contaminant – tetrachloroethylene (PCE)
- Secondary contaminant – trichloroethylene (TCE)

Source is unknown, only the general release location

MCP Criteria for PCE/TCE

Groundwater Categories

- GW-1: 5 µg/L / 5 µg/L
  - Drinking water standards
- GW-2: 50 µg/L / 5 µg/L
  - Groundwater within 30-feet of a building and less than 15 feet deep
- GW-3: 30,000 µg/L / 5,000 µg/L
  - All other groundwater

MCP Criteria for PCE/TCE

Soil Categories

Categories/ Standard	S-1	S-2*	S-3*
GW-1	1 / 0.3	1 / 0.3	1 / 0.3
GW-2	10 / 0.3	10 / 0.3	10 / 0.3
GW-3	30 / 30	200 / 60	1,000 / 60

* Use of S-2 or S-3 standards require an Activity and Use Limitation (AUL)

All values are µg/g (ppm)

Project Understanding

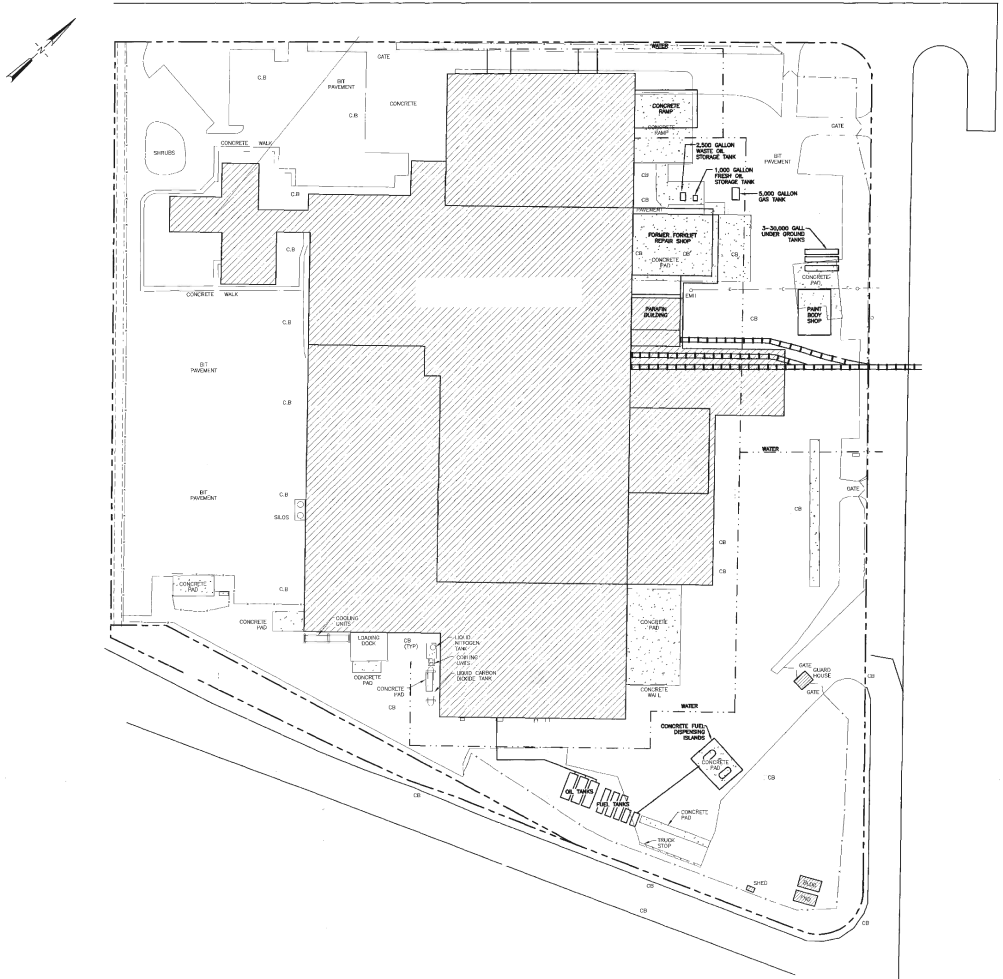
Potential Sources?

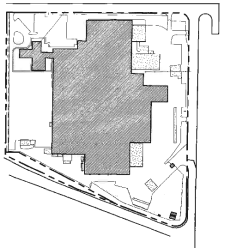
11 USTs removed in 1992

- All contained petroleum products
  - » Releases (stained soils) excavated
  - » No solvents in tanks or soils, but detected in groundwater from one area (source area)
  - » No further action on tank closures

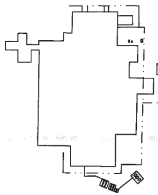
Review of historical site plans

- Body shop/paint shop and forklift repair rooms (all removed prior to 1975 property purchase)
- Railroad spur into the property (distant from source area)



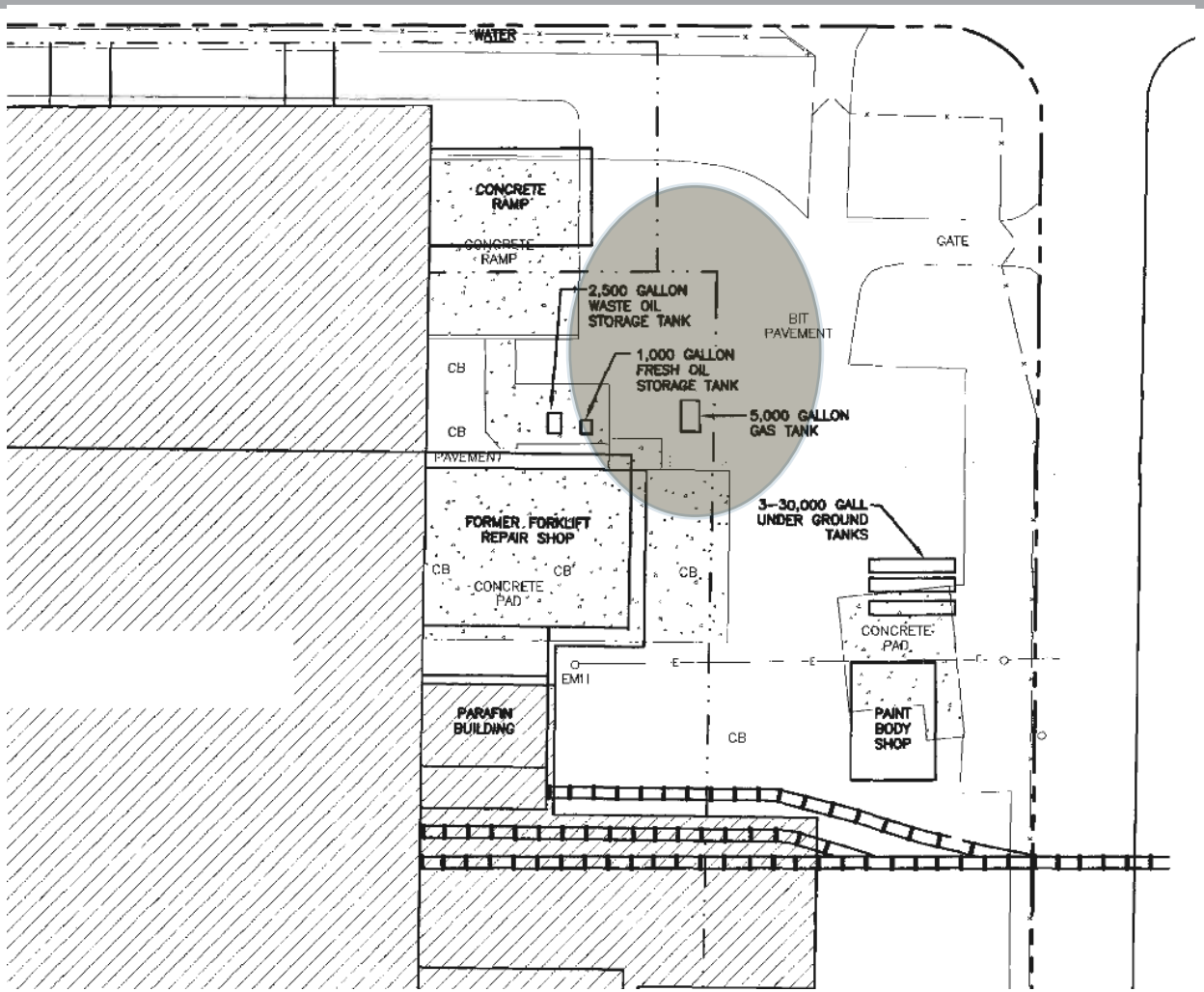


SITE – 1995



SITE – 1977

SITE – 1962


WATER
CONCRETE RAMP
CONCRETE RAMP
2,500 GALLON WASTE OIL STORAGE TANK
1,000 GALLON FRESH OIL STORAGE TANK
5,000 GALLON GAS TANK
BIT PAVEMENT
GATE
CB
CB
PAVEMENT
FORMER FORKLIFT REPAIR SHOP
CB
CB
CB
CONCRETE PAD
3-30,000 GALL UNDER GROUND TANKS
CONCRETE PAD
EM11
PARAFIN BUILDING
CB
PAINT BODY SHOP

Generic Conceptual Site Model

PCE/TCE
density is greater than water

Solubility limits:

- PCE – 150 mg/L
- TCE – 1,280 mg/L

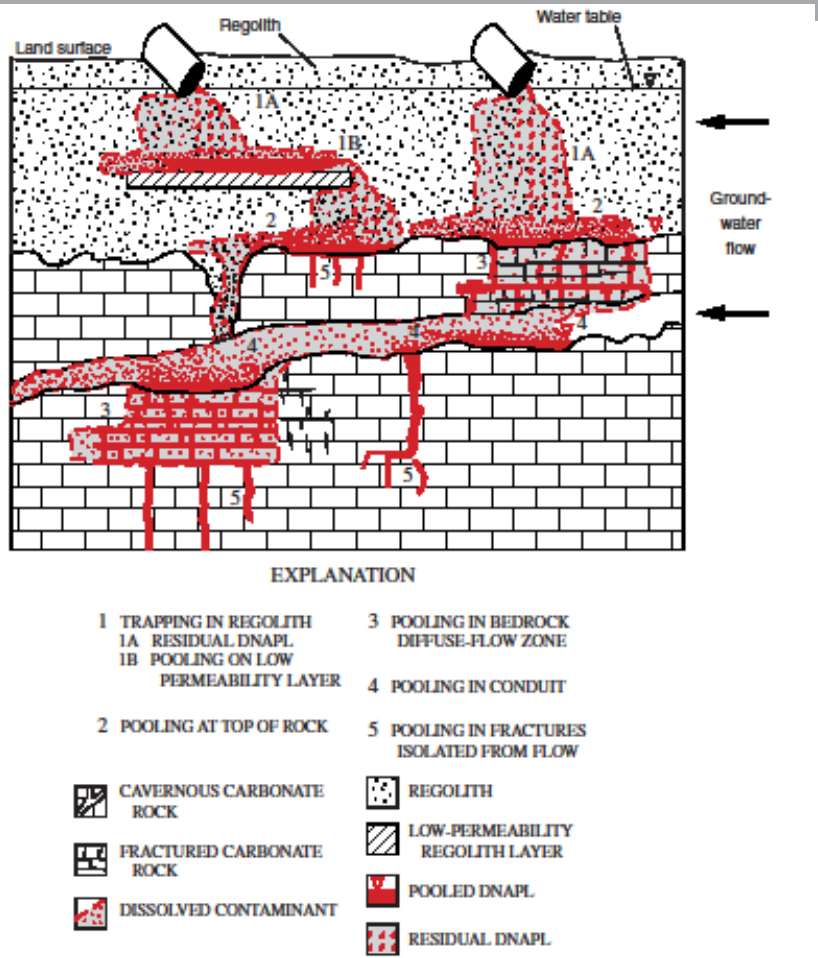


Figure 12. Distribution of potential DNAPL-accumulation sites in a hypothetical karst setting.

Previous Investigation/Remedial Actions

1991 – Phase I Site Assessment

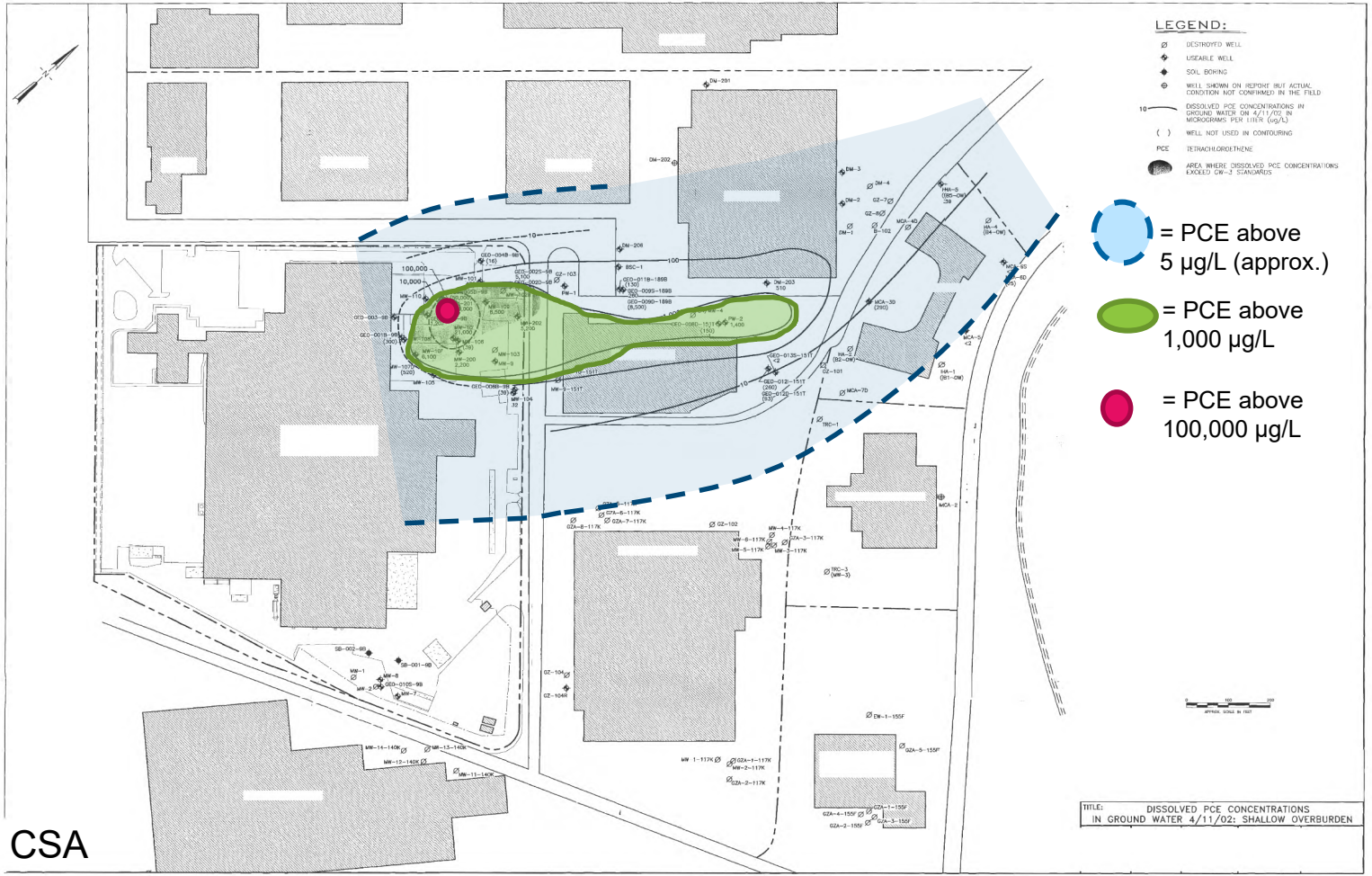
1997 – Tier II classification

1998 Investigation

- PCE detected in soil and groundwater
- TCE in groundwater only

2002 – Phase II CSA (site characterization is complete)

- PCE in unsaturated soils at the NE corner of property (source area)
- Delineation of groundwater impacts in the overburden


LEGEND:
DESTROYED WELL
USEABLE WELL
SOIL BORING
WELL SHOWN ON REPORT BUT ACTUAL CONDITION NOT CONFIRMED IN THE FIELD
DISSOLVED PCE CONCENTRATIONS IN GROUND WATER ON 4/11/02 IN MICROGRAMS PER LITER (ug/L)
( ) WELL NOT USED IN CONTOURING
PCE TETRACHLOROETHENE
AREA WHERE DISSOLVED PCE CONCENTRATIONS EXCEED CW-3 STANDARDS
= PCE above 5 µg/L (approx.)
= PCE above 1,000 µg/L
= PCE above 100,000 µg/L
TITLE: DISSOLVED PCE CONCENTRATIONS IN GROUND WATER 4/11/02: SHALLOW OVERBURDEN

2002 CSA

Previous Investigation/Remedial Actions

2002 – Phase IV RIP

- Selected Remedy is In-situ Chemical Oxidation (ISCO) using $KMnO_4$

2003 – Pilot test

- 18,400 gallons of 1.5% $KMnO_4$ solution injected into 4 wells (2 shallow, 2 deep) within a 50-foot X 50-foot cell
- Significant reduction of PCE in groundwater after 6 months

2007-2008 – Remedial Action

- On-site: 72,000 gal of 1.7 % $KMnO_4$ solution injected into subsurface
- Off-site: 108,000 gal of 1.7 % $KMnO_4$ solution injected into subsurface
- PCE concentrations significantly decreased after 6 months

2008 – ROS Opinion submitted

Previous Investigation/Remedial Actions

2010 – Groundwater sampling showed increased PCE (rebound)

2012 – ROS Termination and RAO Statement

- Remedy is no longer effective!
- Residual PCE in subsurface and possibly bedrock an on-going source
- ROS is no longer appropriate
- Permanent solution is not feasible
- Additional Characterization activities:
  - GPR survey, soil gas survey, MIP survey, soil sampling, groundwater sampling, soil vapor sampling, indoor air sampling
- Temporary Solution - condition of “No Substantial Hazard”

Previous Investigation/Remedial Actions

2013 Investigation

- PCE in one soil sample above Method 1 S-1/GW-3
- PCE in new bedrock monitoring well above the Method 1 GW-3 standard
- Extent of impact in the bedrock is NOT delineated
  - Doesn't meet the performance standards of RAO and Temporary Solution
  - Request to extend Tier II classification (back to characterization status)

2014 – Notice of Non-compliance issued

- Established new submittal deadlines
- Required vapor intrusion (VI) testing at downgradient properties
  - Testing showed VI pathway is incomplete

Previous Investigation/Remedial Actions

2015 - GHD contracted for LSP oversight

- Submitted updated Scope of Work for Phase II Investigation
- MassDEP issued Notice of Non-compliance (NON) with new deadlines
  - ❑ Updated Phase II CSA within one year
  - ❑ Phase III RAP and Phase IV RIP three months later
  - ❑ Permanent Solution, Temporary Solution or ROS within 2 years

New Investigation

Soil

- New MIP investigation
- Source area soil sampling (including evaluation of historical data)
- Test pits
- Core^{DFN} analysis

Groundwater

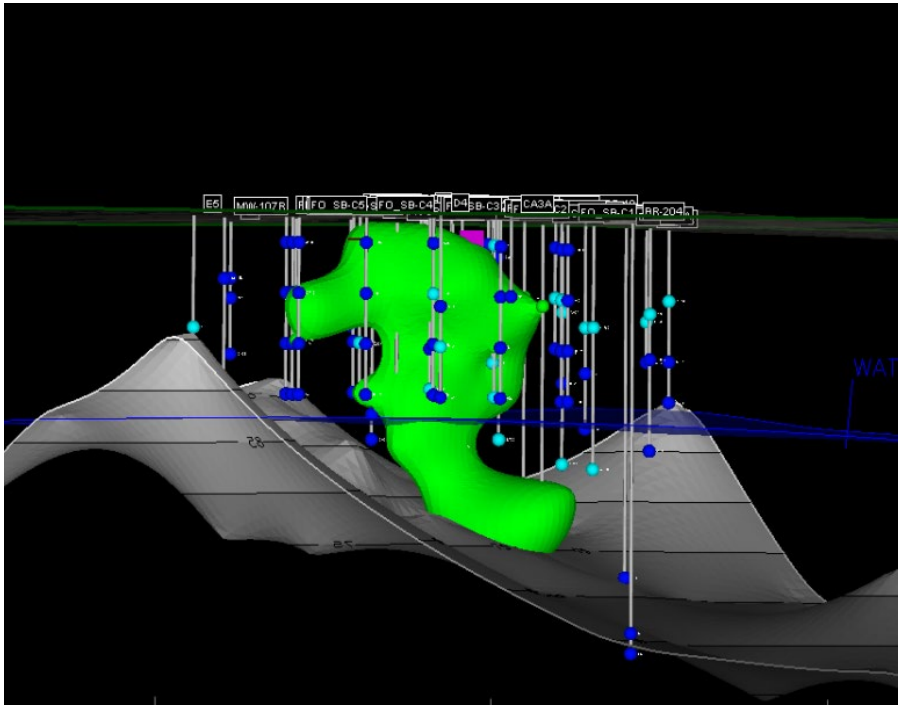
- Expanded network of shallow and deep overburden wells, bedrock wells
- Geophysical testing of bedrock wells
- Bedrock well pump test

Vapor Intrusion Re-evaluation

- Samples collected at different times of the year to confirm previous data

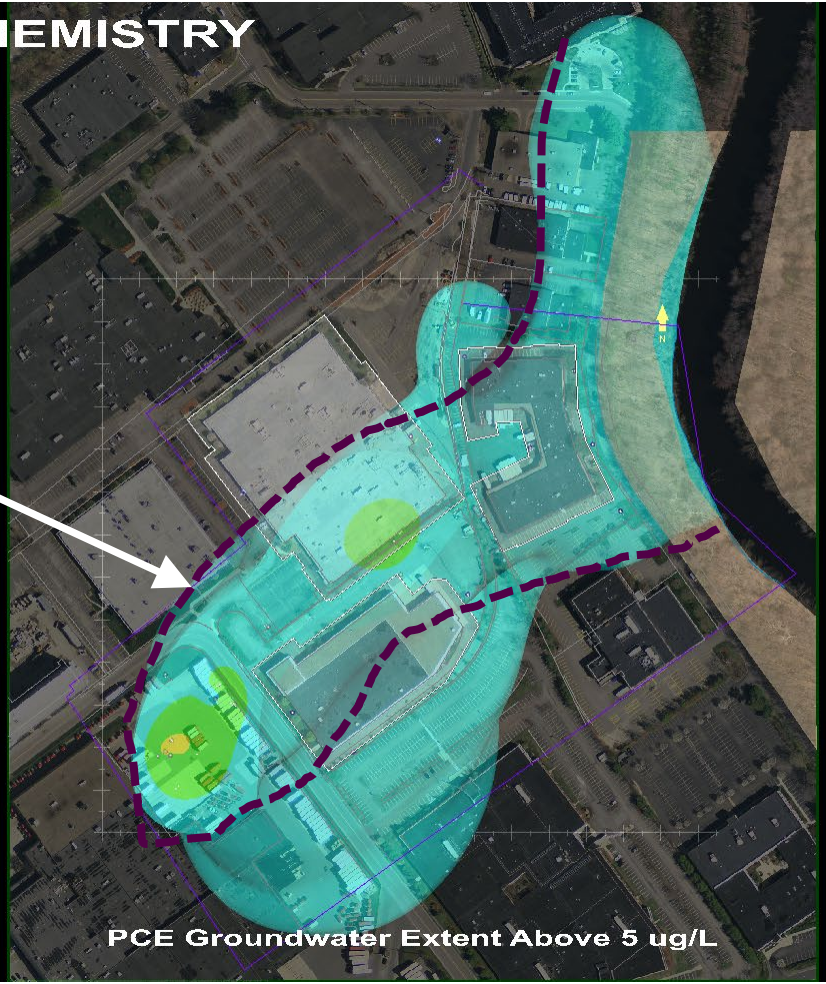
- Historical Source Identified!

Soil Investigation



GROUNDWATER CHEMISTRY
Tetrachloroethene

[March 2016]



Needham, MA
3x Vertical Exaggeration

Aerial Photo: April 2013

Limit Line
30ft Buffer

Concrete Structure
PPA
GW-2 Zone

ug/L

> 30,000
10,000 - 30,000
1,000 - 10,000
50 - 1,000
5 - 100
ND - 5

GROUNDWATER CHEMISTRY
Tetrachloroethene

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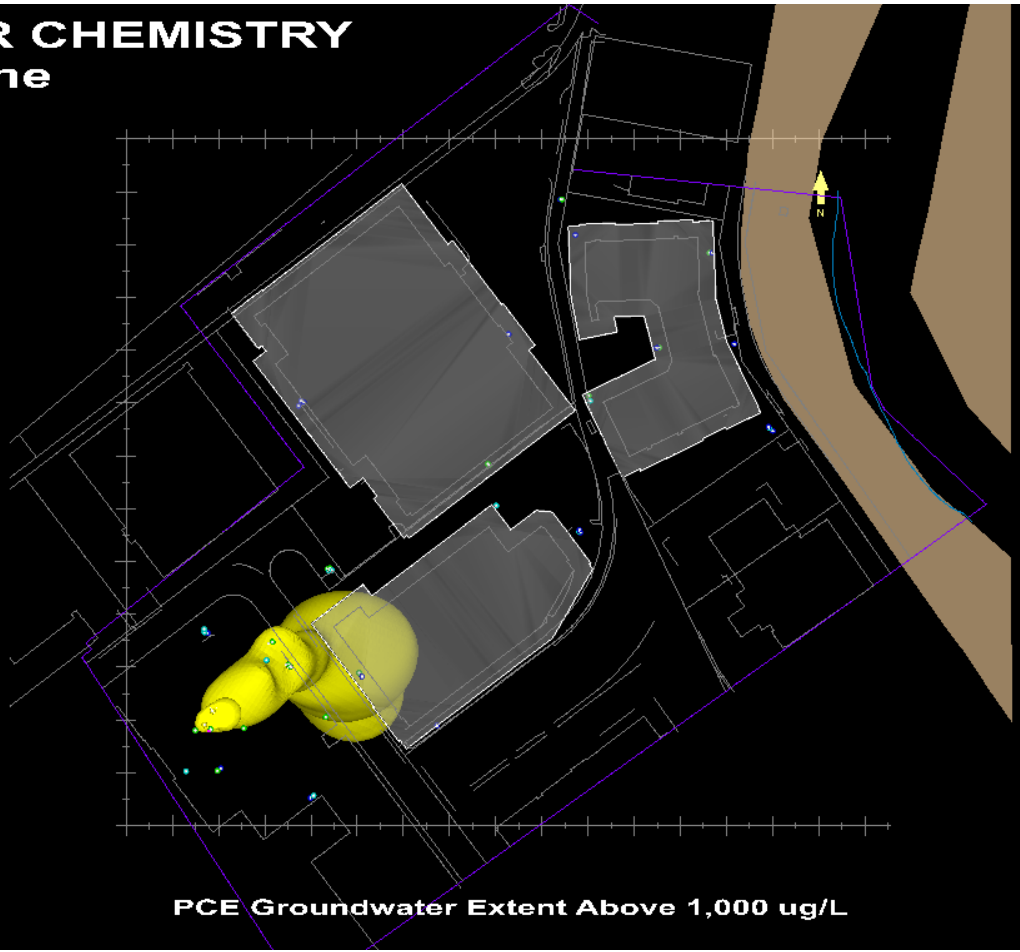

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ug/L

> 30,000
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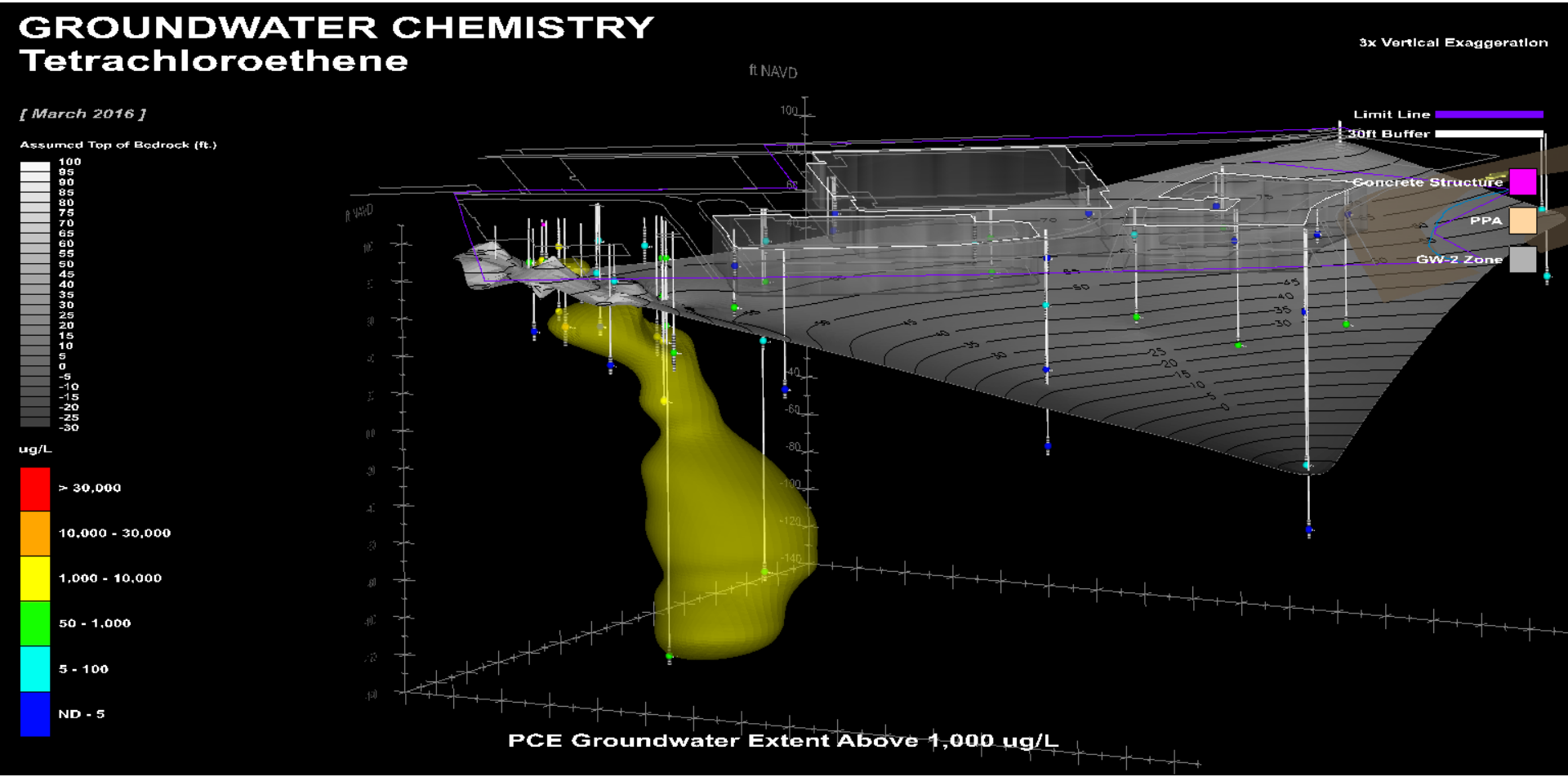
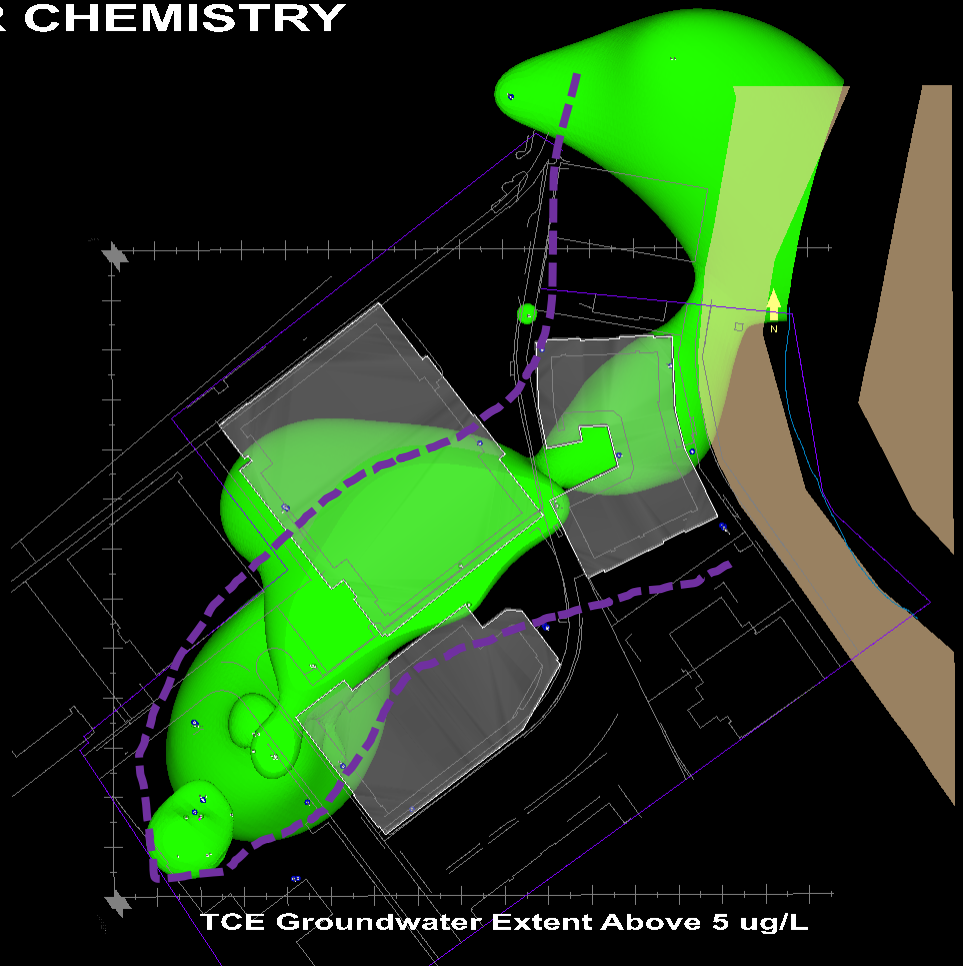
PCE Groundwater Extent Above 1,000 ug/L


GROUNDWATER CHEMISTRY
Tetrachloroethene
[March 2016]
3x Vertical Exaggeration
ft NAVD
Assumed Top of Bedrock (ft.)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
Limit Line
30ft Buffer
Concrete Structure
PPA
GW-2 Zone
ug/L
> 30,000
10,000 - 30,000
1,000 - 10,000
50 - 1,000
5 - 100
ND - 5
PCE Groundwater Extent Above 1,000 ug/L

GROUNDWATER CHEMISTRY
Trichloroethene

[March 2016]



3x Vertical Exaggeration

Limit Line
30ft Buffer

Concrete Structure
PPA
GW-2 Zone

ug/L

1,000 - 5,000
100 - 1,000
5 - 100
ND - 5

Chemical Forensic Analysis

Markers that help us identify a source for a contaminant and track its migration/ degradation through the formation.

Using:

- Logic
- Site history
- A deep understanding of the mechanism(s)

Techniques

- Biodegradation and physical (isotopes) markers
- Tracking reaction progress
- Differing source materials

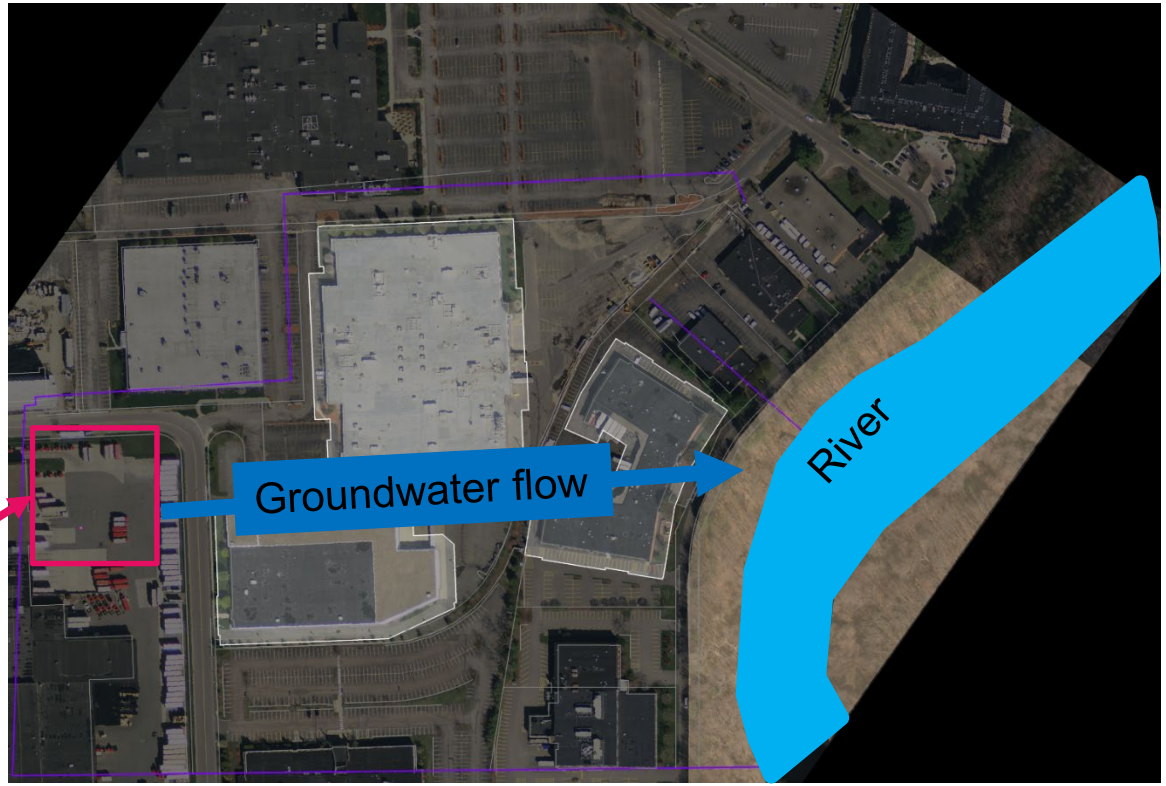
Holistic Approach

Things are connected. Try looking at the “whole system”

- Operational History
- Physical geometry of the suspected source/plume
- Contaminant transport properties in various media
- Groundwater flow directions
- Understand the underlying chemical processes/mechanisms

Making the pieces fit together

Facility Overview



The Hypothesis

Two source areas and two plumes

Based on:

- Source location
- Groundwater flow direction
- Compound concentrations

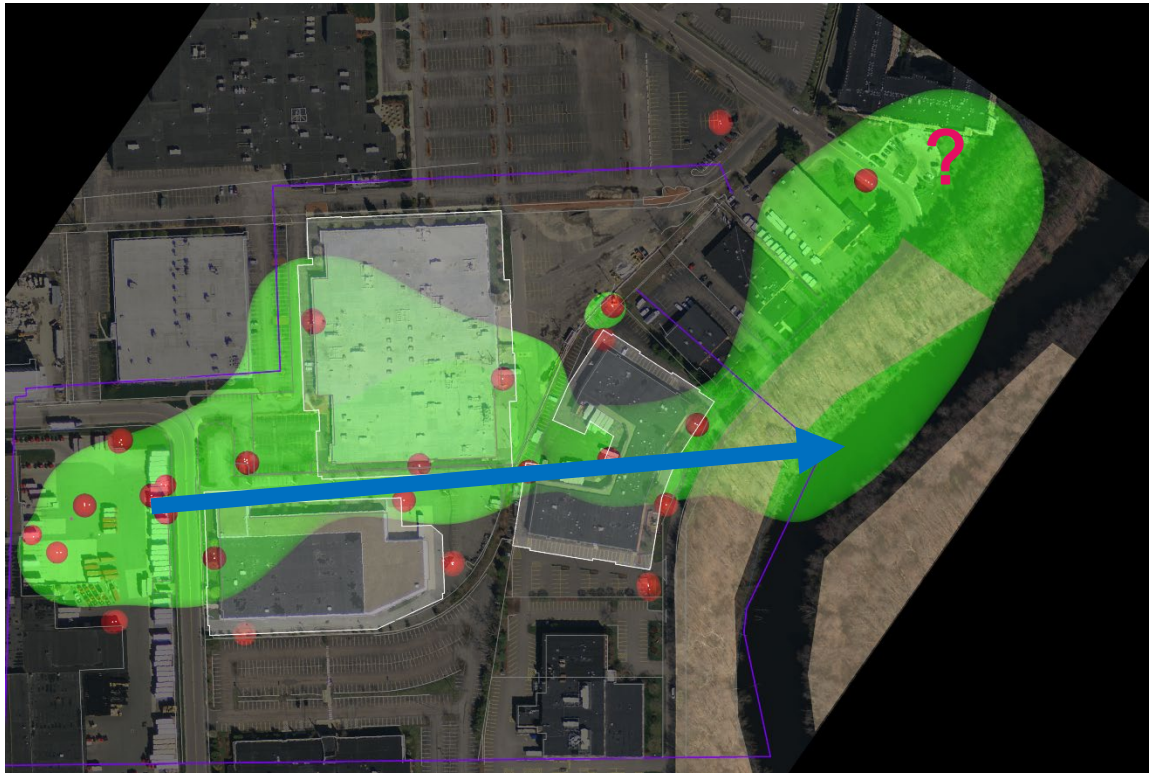
Evaluate:

- Physical system
- Chemical characteristics of the plume
- Isotopic evaluation of the plume

Phase I

First round of arguments:

- Groundwater flow
- Discharge to the river
- Impacted areas



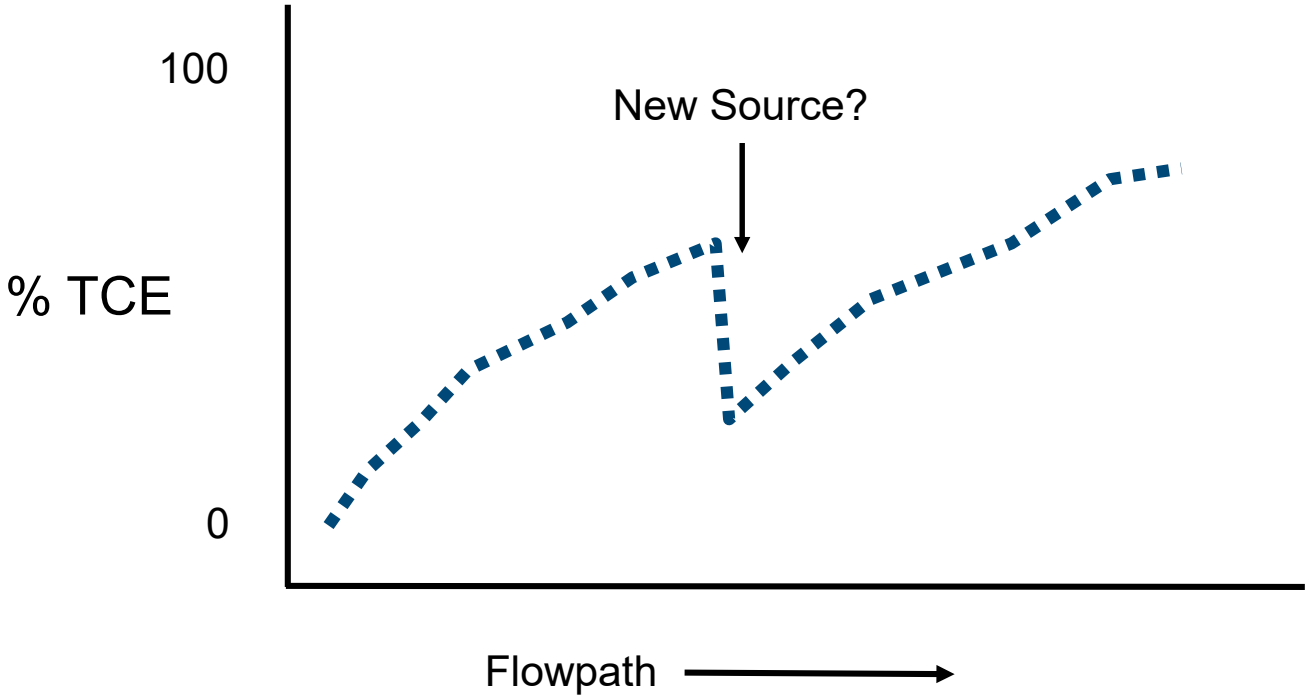
Compound Ratios

Processes occurring along the groundwater flowpath

- Dilution
- Dispersion
- Diffusion
- Sorption
- Biodegradation

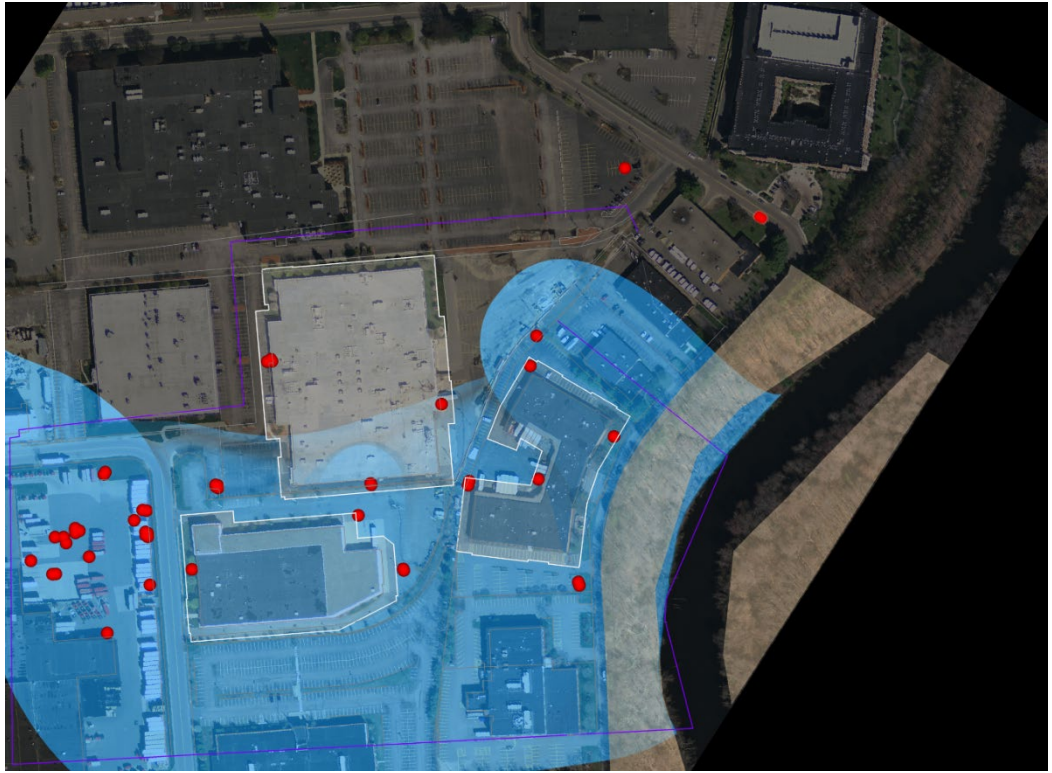
PCE → TCE

Concentration Ratios Along the Flowpath



TCE Ratio (<30%)

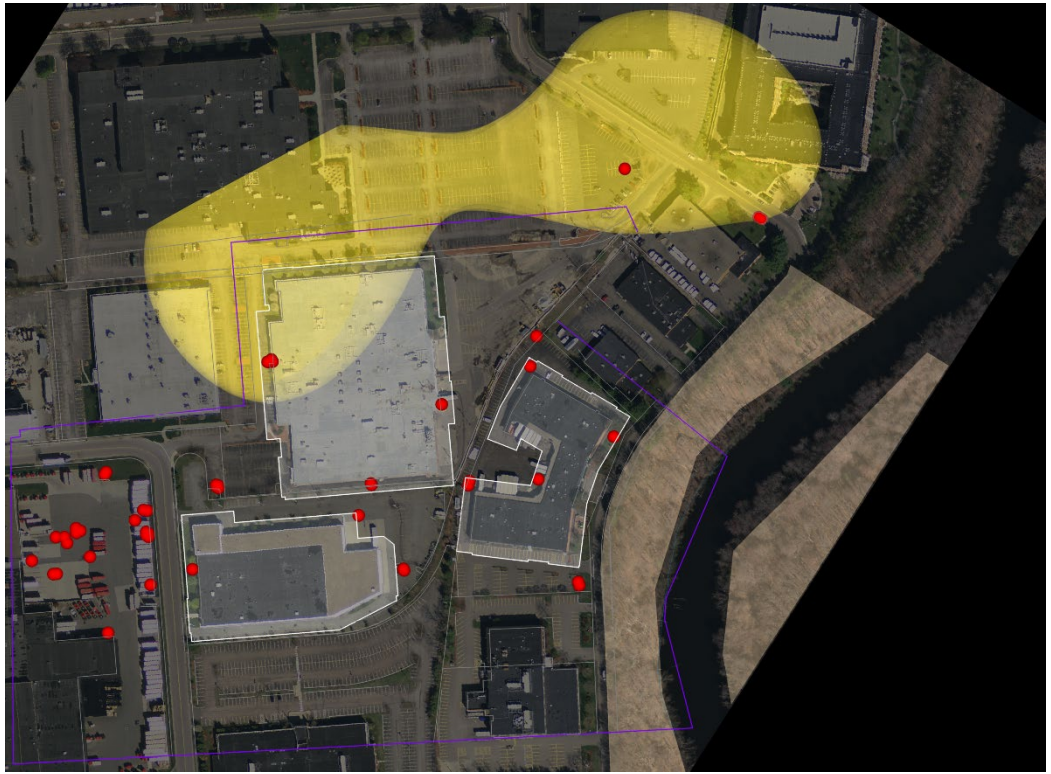
PCE source area and
“Flowpath 1”



TCE Ratio (>70%)

Cross-gradient to source area and “Flowpath 1”

“Flowpath 2”?

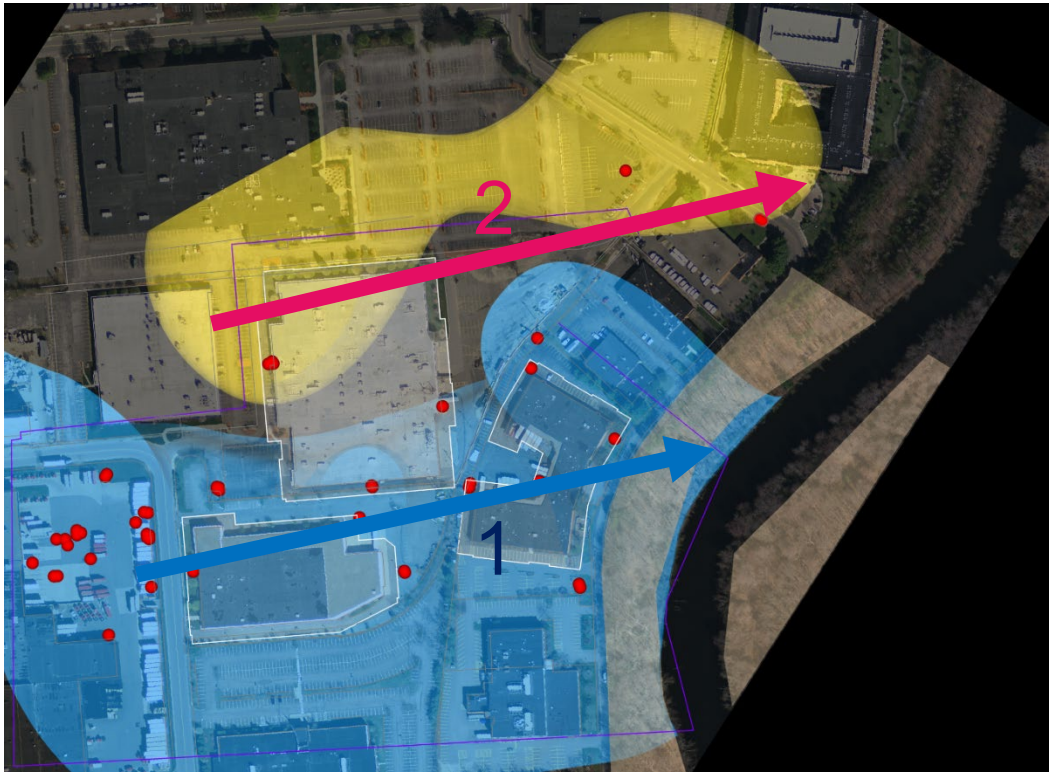


Both Plumes Together

Two-flowpath hypothesis

1: Low %TCE, High %PCE

2: High %TCE, Low %PCE



Isotopes

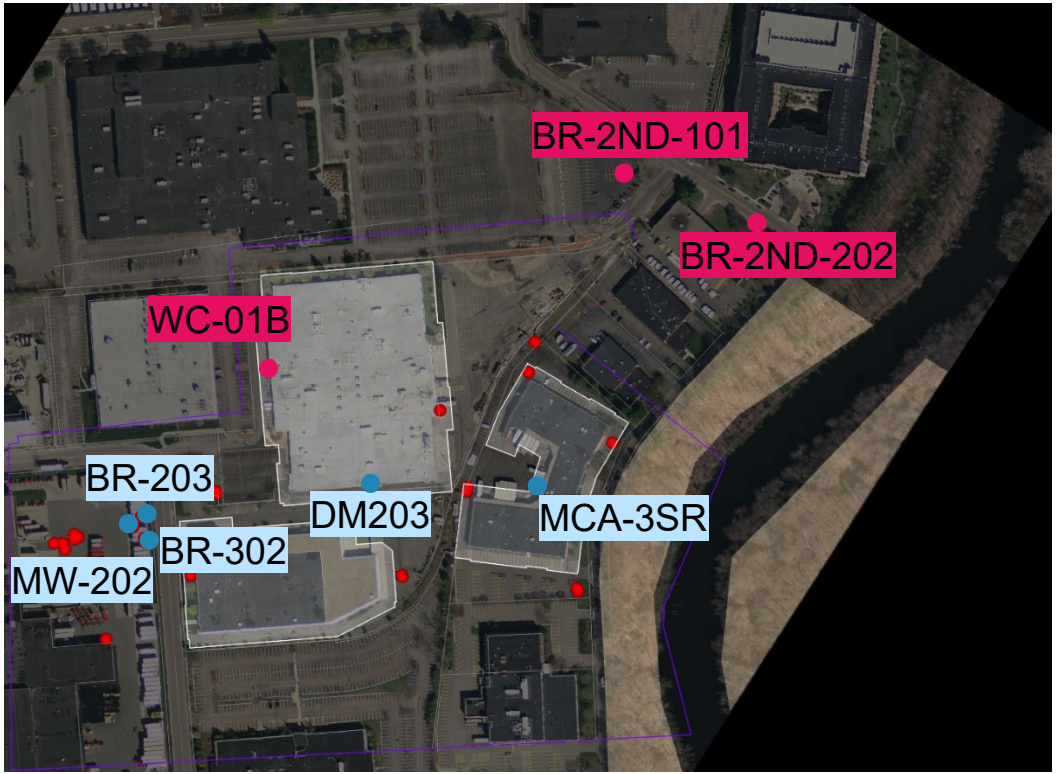
Compound-Specific Isotope Analysis (CSIA)

- ^{13}C and ^{37}Cl
- PCE
- TCE
- Concentration of DCE and VC too low for isotope analysis

Selected Wells

5 on Flowpath 1:
- Known source area
- Downgradient

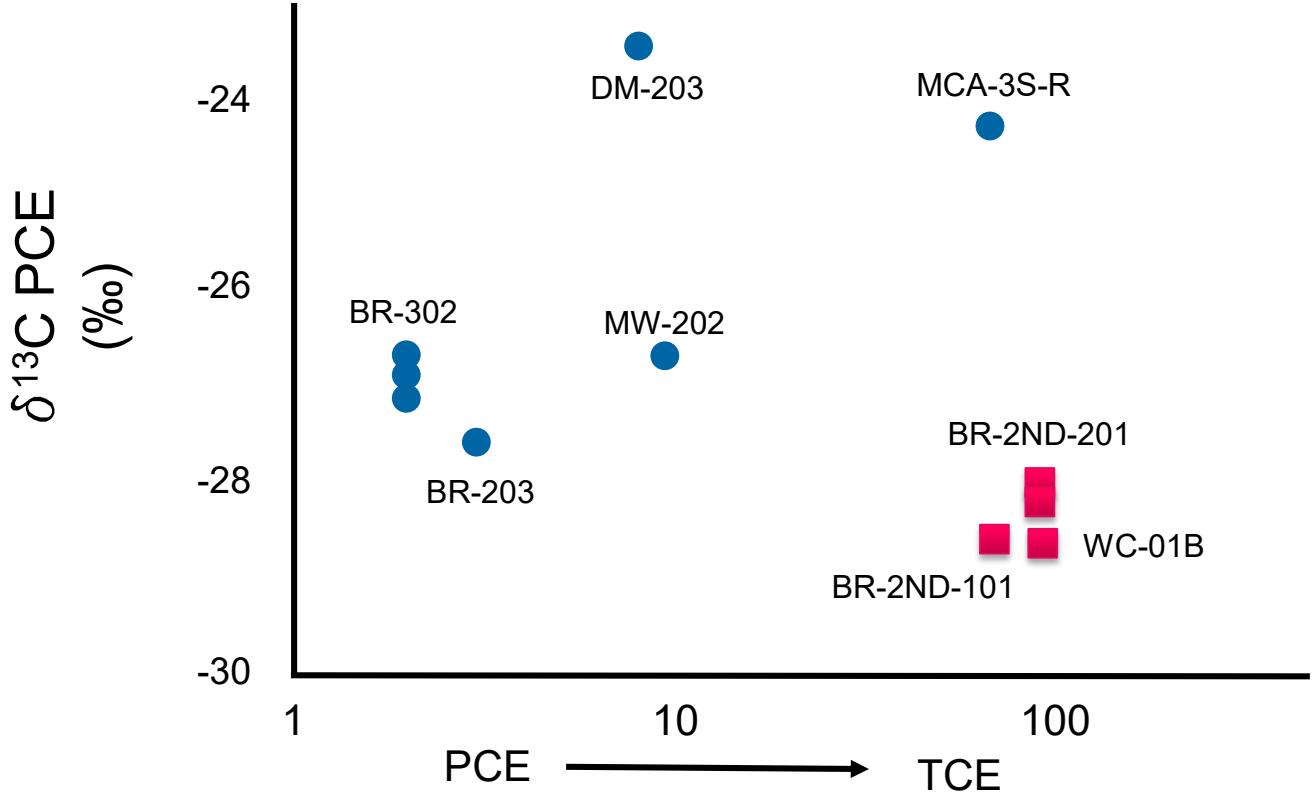
3 on Flowpath 2:
- Distal wells
- Potential source area



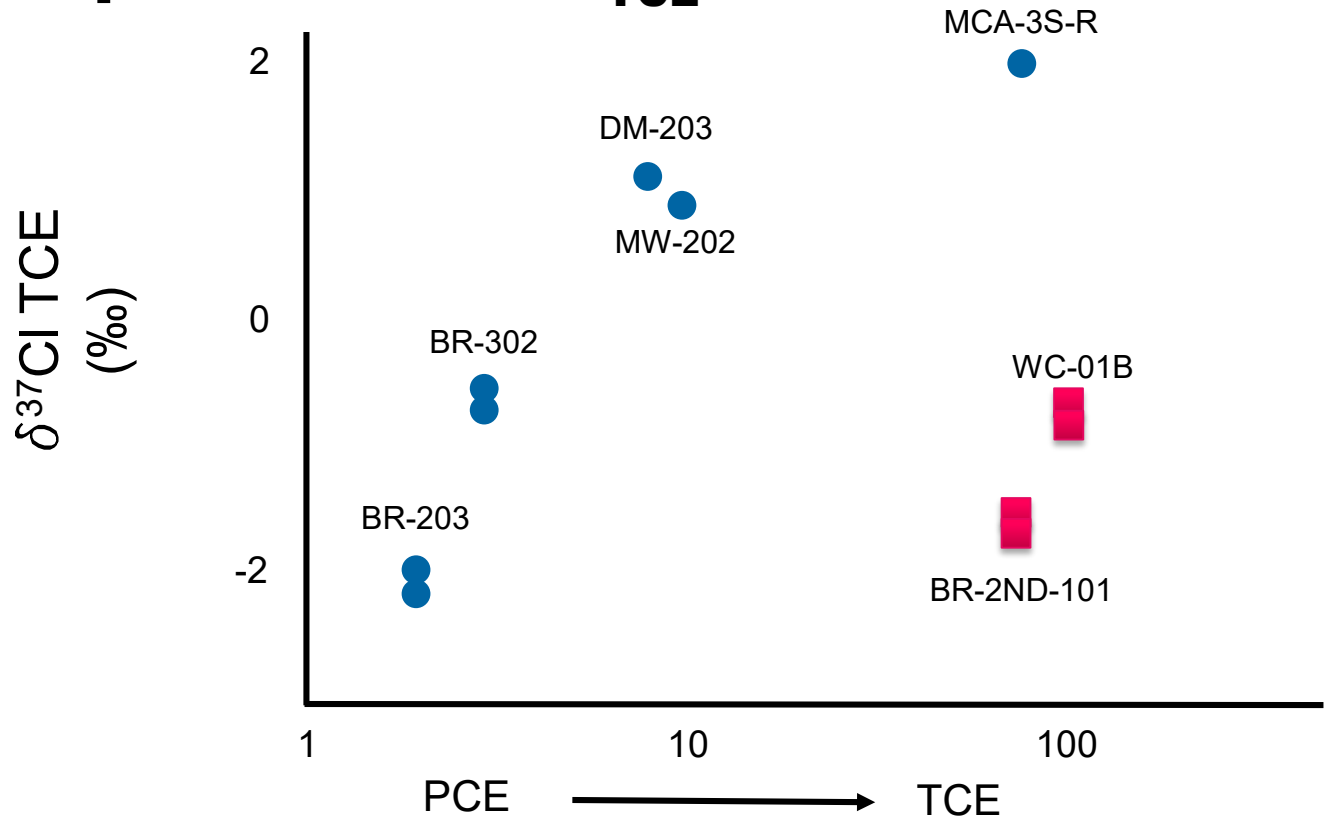
Isotope Results

Well	PCE - $\delta^{13}C$ ‰	PCE - $\delta^{37}Cl$ ‰	TCE - $\delta^{13}C$ ‰	TCE - $\delta^{37}Cl$ ‰	PCE µg/L	TCE µg/L
BR-203	-27.5	-0.35	-37.7	-0.74	9,800	240
BR-302	-26.8	-0.18	-42.1	-2.07	3,300	51
MW-202	-26.8	-0.22	-26.3	0.91	640	53
DM-203	-23.0	-0.19	-27.0	1.19	360	24
MCA-3S-R	-24.2	BQL	-26.2	1.99	9.6	22
WC-01B	-28.6	BQL	-23.6	-0.81	1.7	36
BR-2ND-101	-28.6	BQL	BQL	-1.45	7.5/7.5	14/12
BR-2ND-202	-28.0	BQL	BQL	BQL	1.1/ND	9.1/2.8

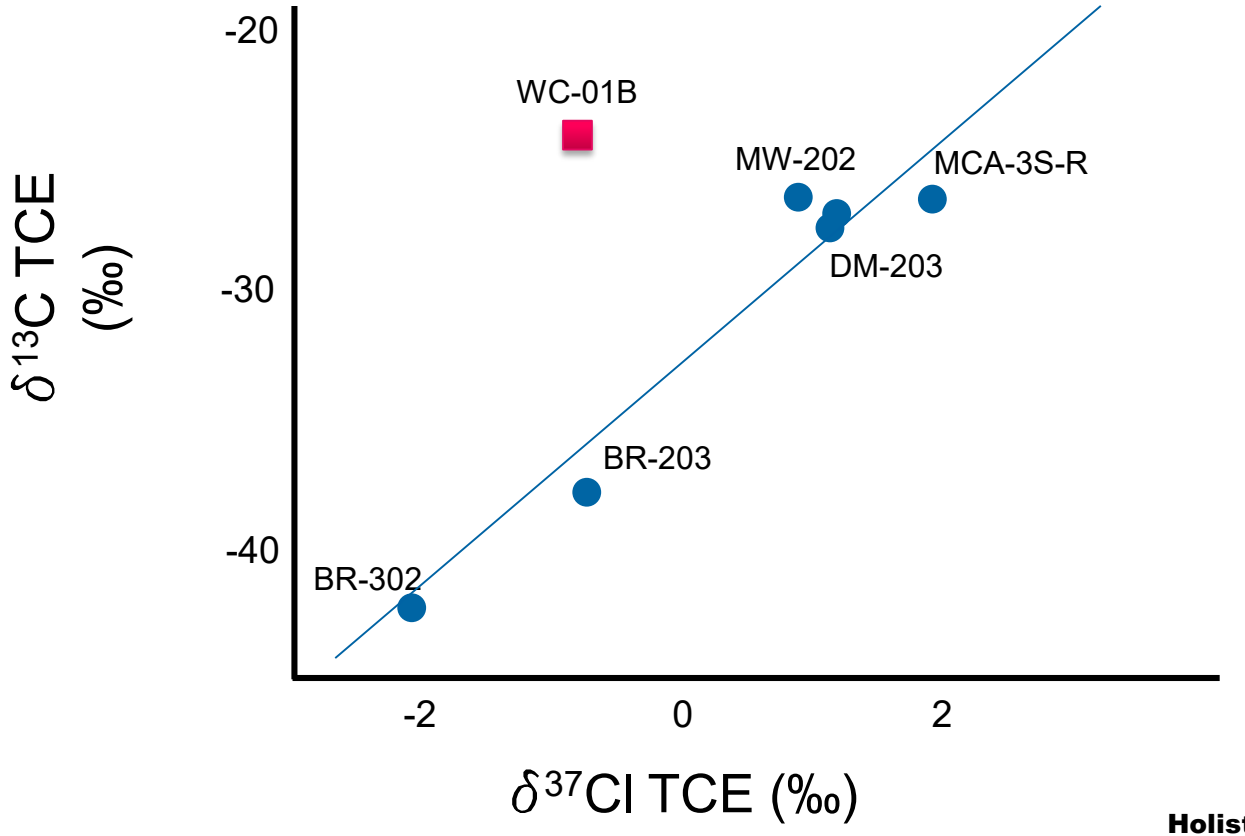
Isotope Results $^{13}C_{PCE}$



Isotope Results $^{37}Cl_{TCE}$



^{13}C and ^{37}Cl for TCE



Outcome

- Multiple lines of evidence used to demonstrate that a secondary TCE plume is present
- Delineation: Complete!
- Able to submit updated Phase III CSA and move into remedy phases

Remedy evaluation - Soil

Source Area

- Approximately 60-ft. by 100-ft. area
- Impacted soils from 5-ft. below grade to bedrock (30-ft. ± deep)
- Total impacted volume = 6,500 CY
- Located in front of distribution center loading docks

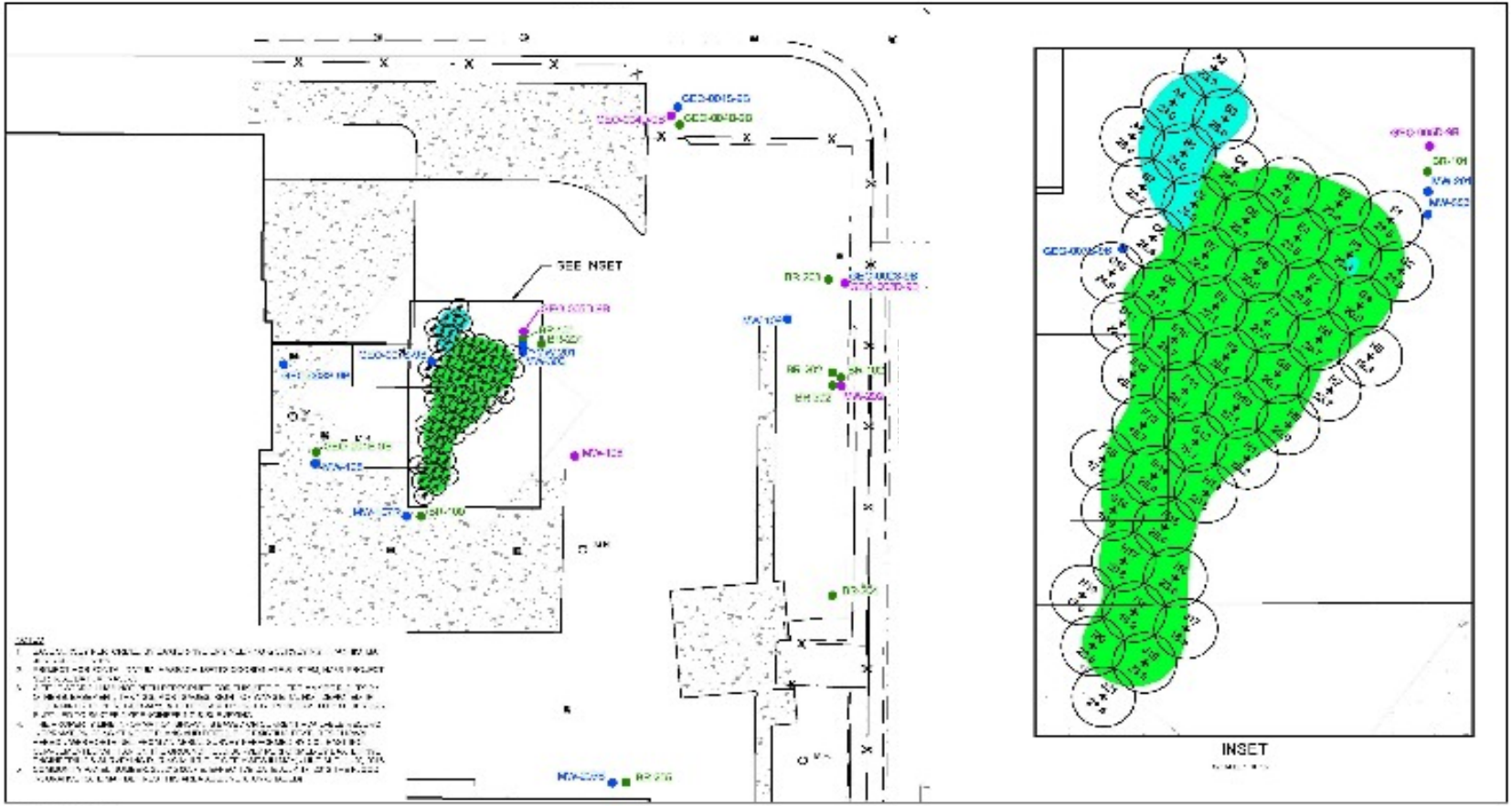
Technologies considered

- Excavation
- In-situ thermal desorption
- Air sparge/soil vapor extraction
- ISCO/soil mixing

Selected Soil Remedy

ISCO/Soil Mixing

- Entire column treated in one pass
- Work zone limited to impacted soil area
- Field work completed in 6 weeks (working 12-hr days and 6-days/week)
- Cement activator, when cured, provides structural stability to soils



GHD

ISSM DETAILS

FIGURE 6

Remedy Evaluation – Groundwater

PCE Plume

- Plume is migrating off-site – discharges to river 1,500 feet away
- Plume migrates beneath multiple properties (potential VI hazard)
- Plume is beneath a downgradient Sensitive Receptor (daycare facility)

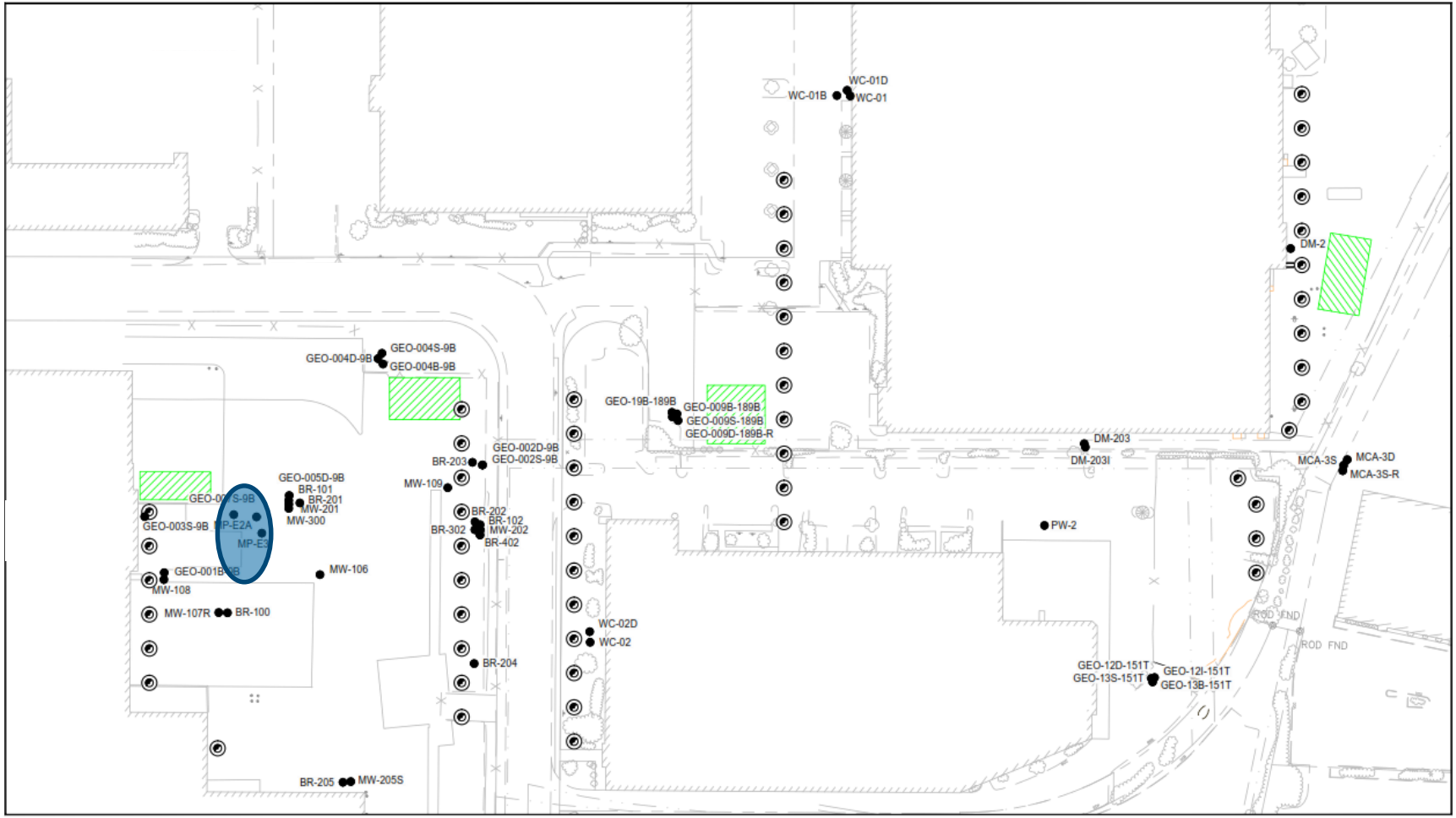
Remedial Options

- Monitored natural attenuation
- Bioremediation
- ISCO
- SVE
- Thermal treatment
- Pump & treat

Selected Groundwater Remedy

ISCO remedy

- Able to complete the work with minimal disruption of operations
- Previously documented as successful approach
- Mixture of sodium persulfate activated with sodium hydroxide
- Solution mixed and pumped into the formation
- Installed 4 “fence lines” of nested injection wells
  - Wells have 10-ft. or 15-ft. well screens
  - For deeper saturated overburden (greater than 25 feet), two or three nested wells installed with the screens separated by a min. of 5-ft.
  - Total of 108 wells at 75 locations across the plume

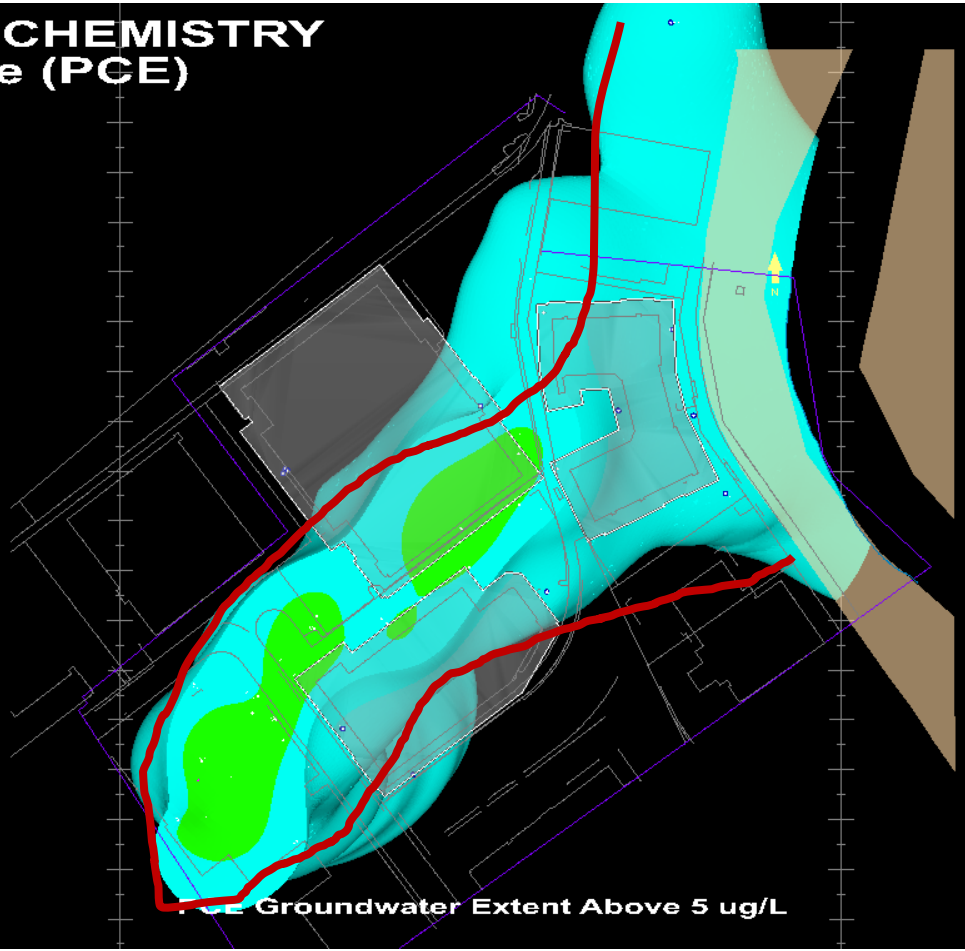


Source: KCI TECHNOLOGIES, SHALLOW MONITORING WELL LOCATIONS


Residence
CCP

GROUNDWATER CHEMISTRY
Tetrachloroethene (PCE)

[March 2018]



3x Vertical Exaggeration

Limit Line
30ft Buffer

Concrete Structure
PPA
GW-2 Zone

ug/L

> 30,000
10,000 - 30,000
1,000 - 10,000
50 - 1,000
5 - 50
ND - 5

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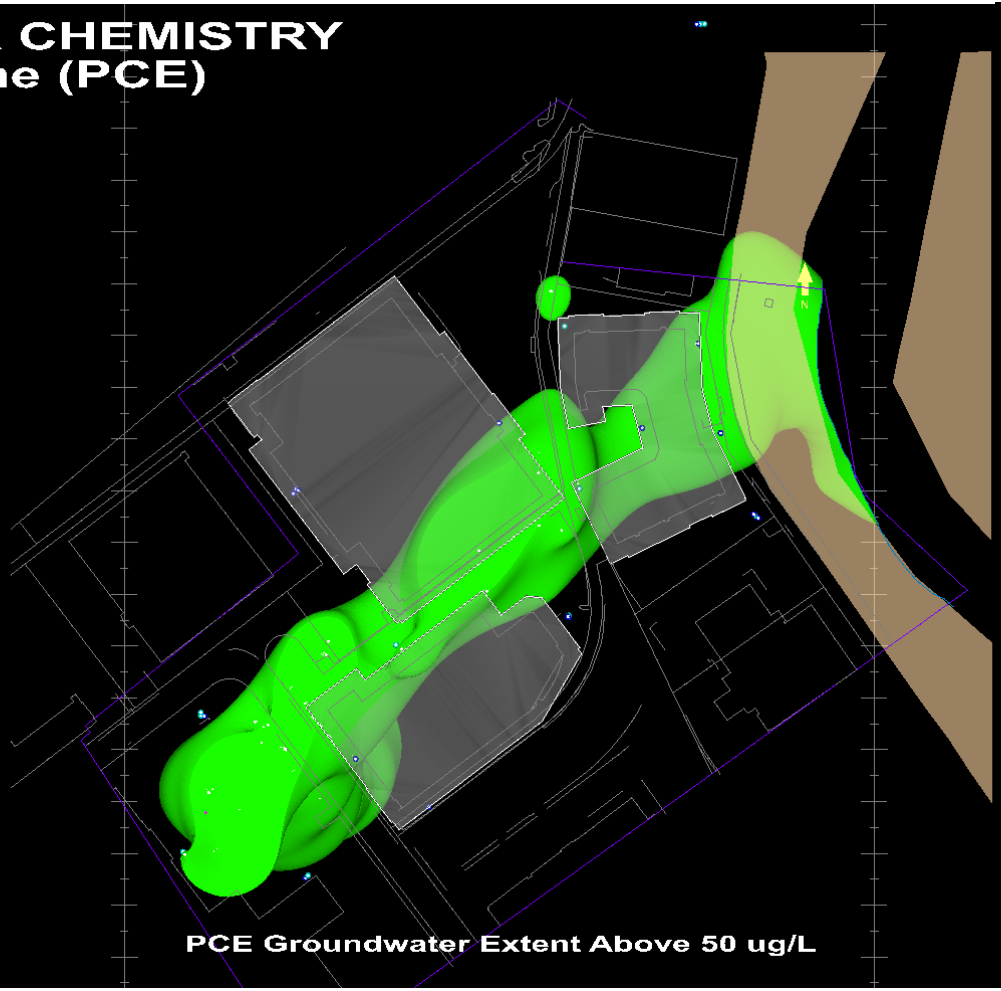

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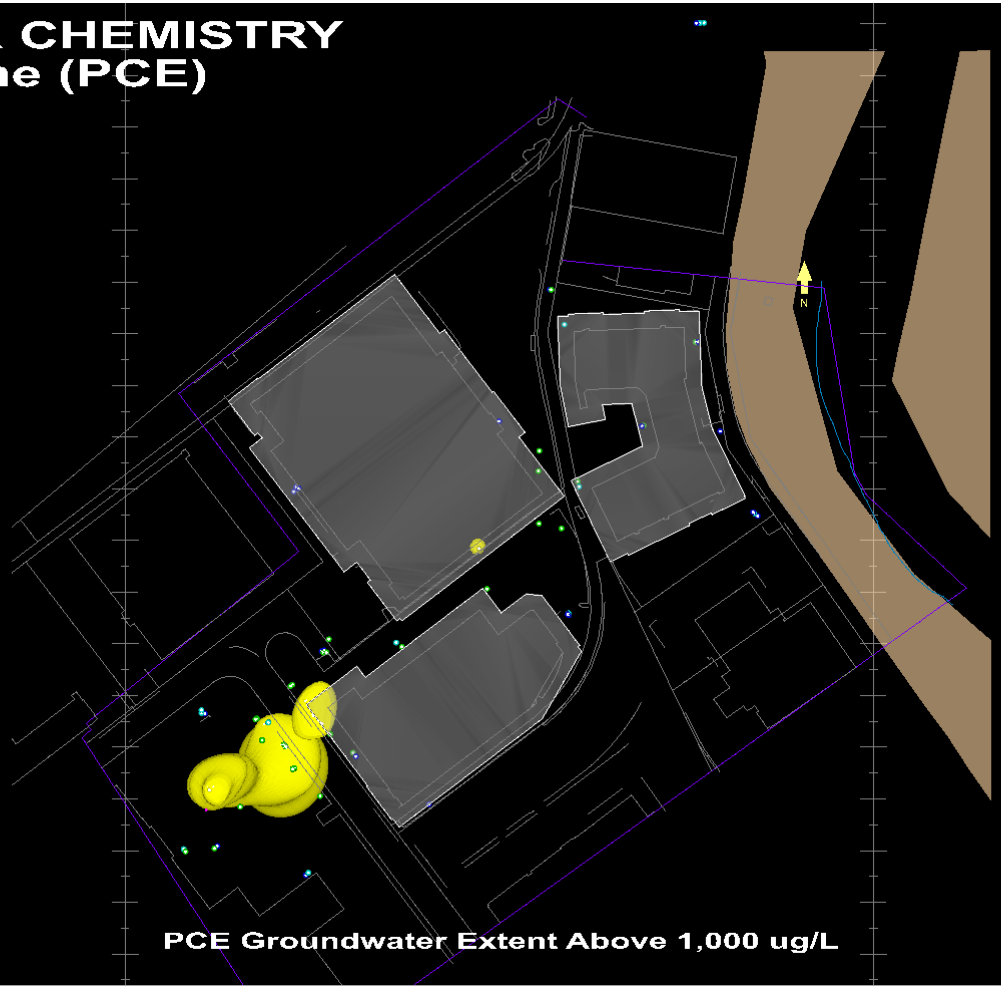

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GROUNDWATER CHEMISTRY
Tetrachloroethene (PCE)

[March 2018]

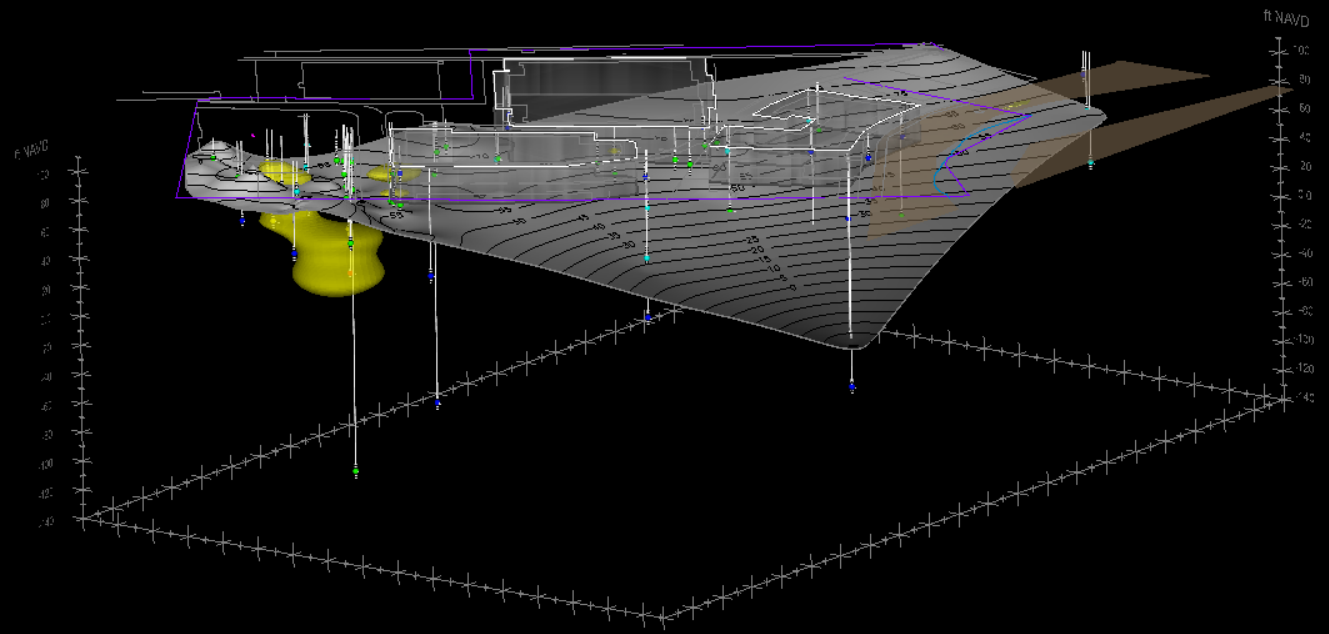
3x Vertical Exaggeration

Limit Line
30ft Buffer

Concrete Structure
PPA
GW-2 Zone

Assumed Top of Bedrock (ft.)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30

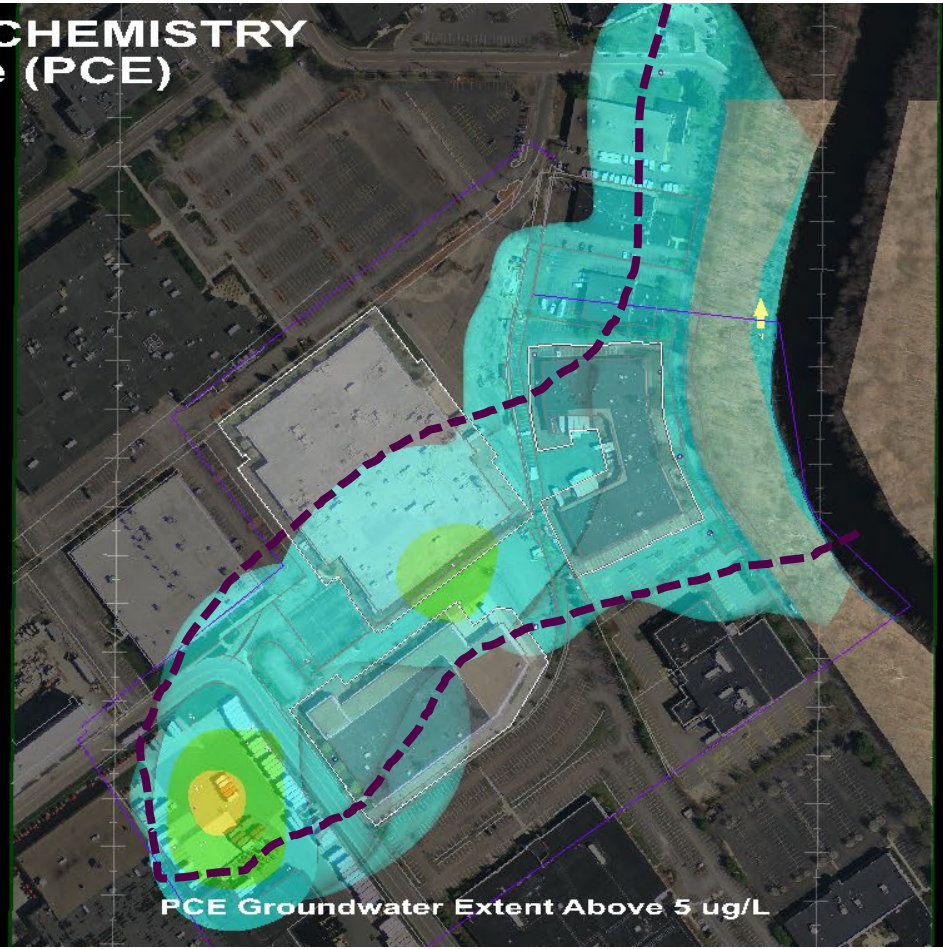
ug/L
> 30,000
10,000 - 30,000
1,000 - 10,000
50 - 1,000
5 - 50
ND - 5



PCE Groundwater Extent Above 1,000 ug/L

GROUNDWATER CHEMISTRY
Tetrachloroethene (PCE)

[November 2018]



3x Vertical Exaggeration

Aerial Photo: April 2013

Limit Line

30ft Buffer

Concrete Structure

PPA

GW-2 Zone

ug/L

> 30,000

10,000 - 30,000

1,000 - 10,000

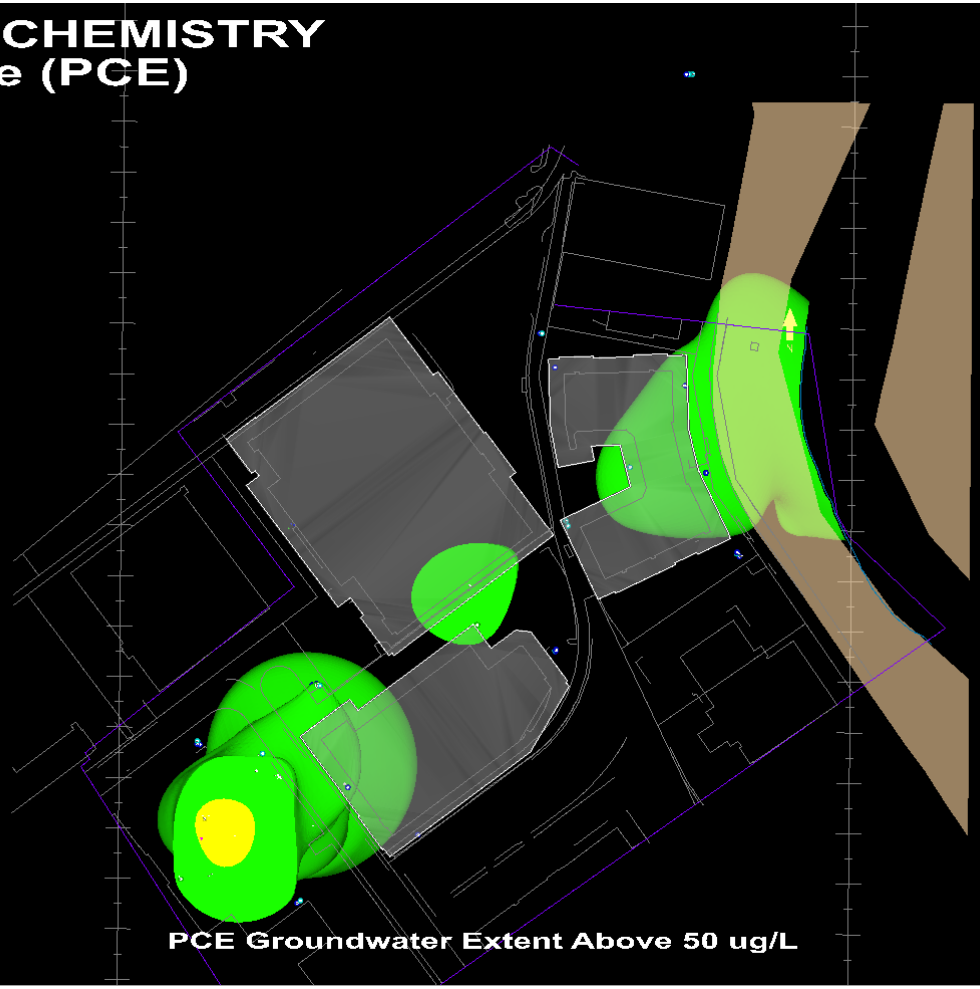
50 - 1,000

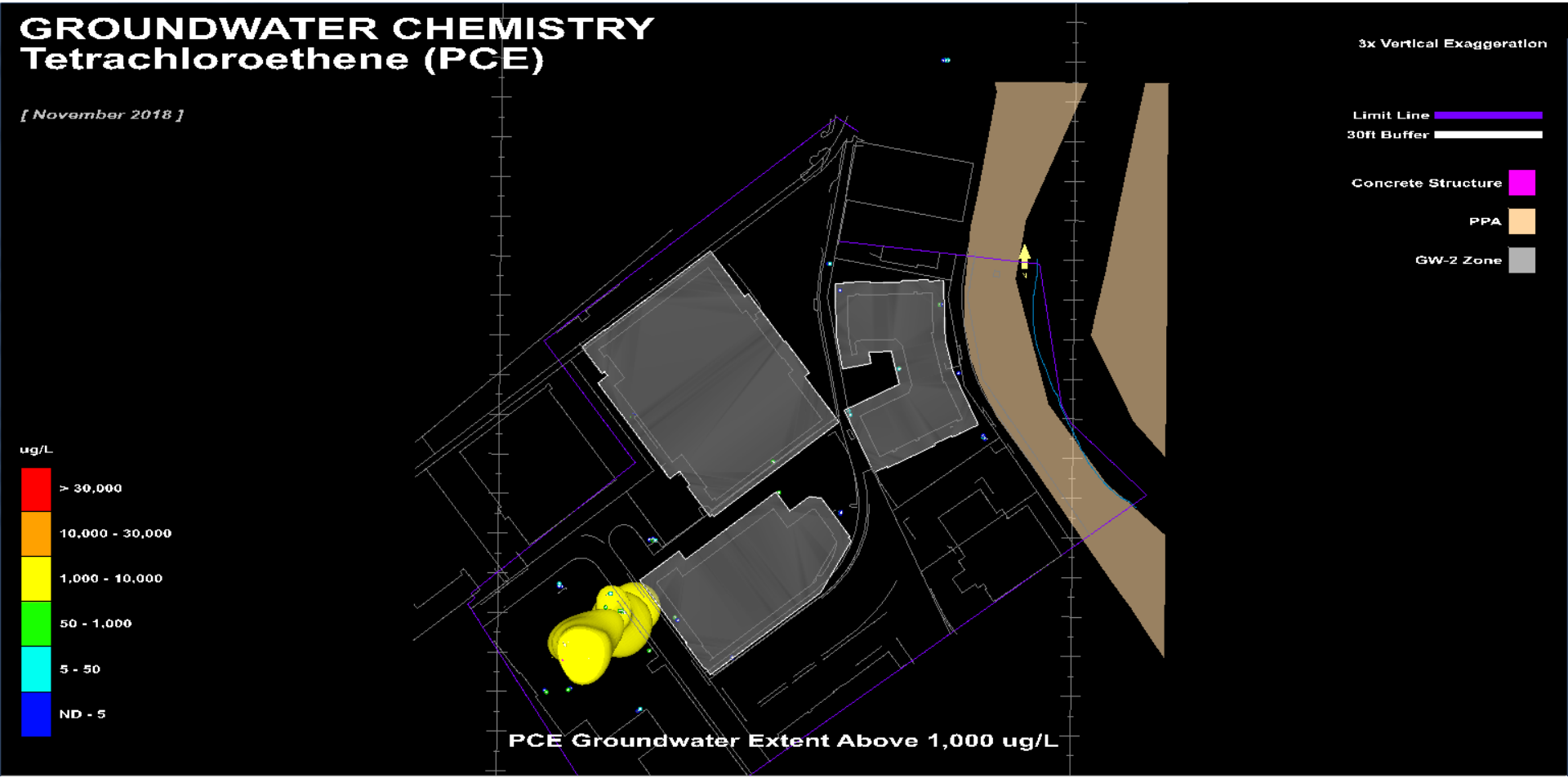
5 - 50

ND - 5

GROUNDWATER CHEMISTRY
Tetrachloroethene (PCE)

[November 2018]




GROUNDWATER CHEMISTRY
Tetrachloroethene (PCE)
[November 2018]
3x Vertical Exaggeration
Limit Line
30ft Buffer
Concrete Structure
PPA
GW-2 Zone
ug/L
> 30,000
10,000 - 30,000
1,000 - 10,000
50 - 1,000
5 - 50
ND - 5
PCE Groundwater Extent Above 1,000 ug/L

GROUNDWATER CHEMISTRY
Tetrachloroethene (PCE)

[November 2018]

3x Vertical Exaggeration

Limit Line
30ft Buffer

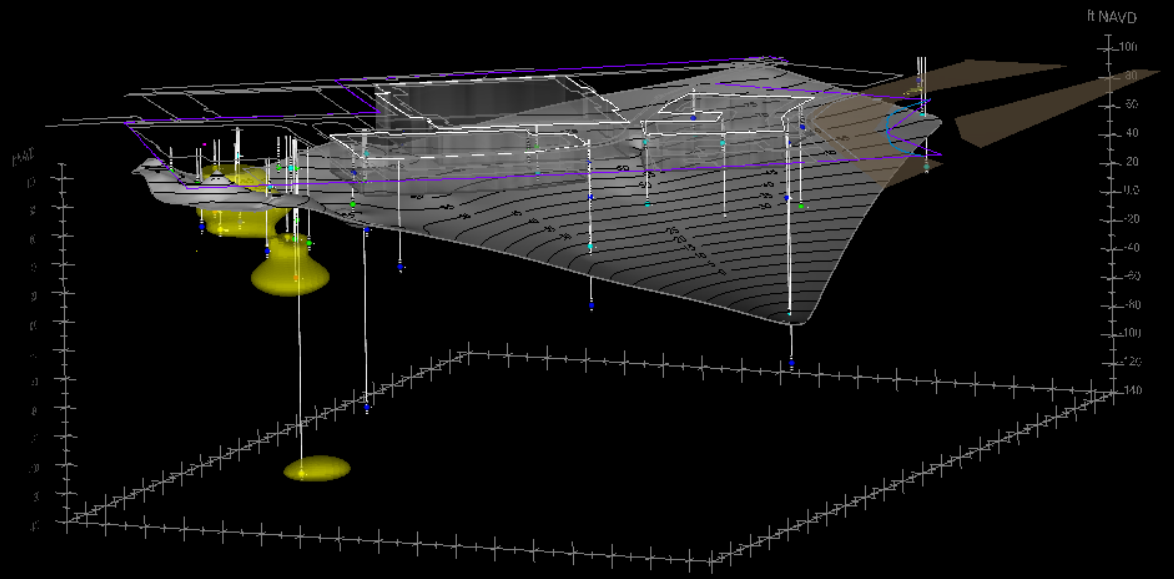
Concrete Structure
PPA
GW-2 Zone

Assumed Top of Bedrock (ft.)

100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30

ug/L

> 30,000
10,000 - 30,000
1,000 - 10,000
50 - 1,000
5 - 50
ND - 5



PCE Groundwater Extent Above 1,000 ug/L

GROUNDWATER CHEMISTRY
Trichloroethene (TCE)

[November 2018]

TCE Groundwater Extent Above 5 ug/L

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