

# Groundwater Plume Analytics® Tools for Improved Conceptual Site Models at Bioremediation Sites

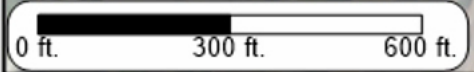
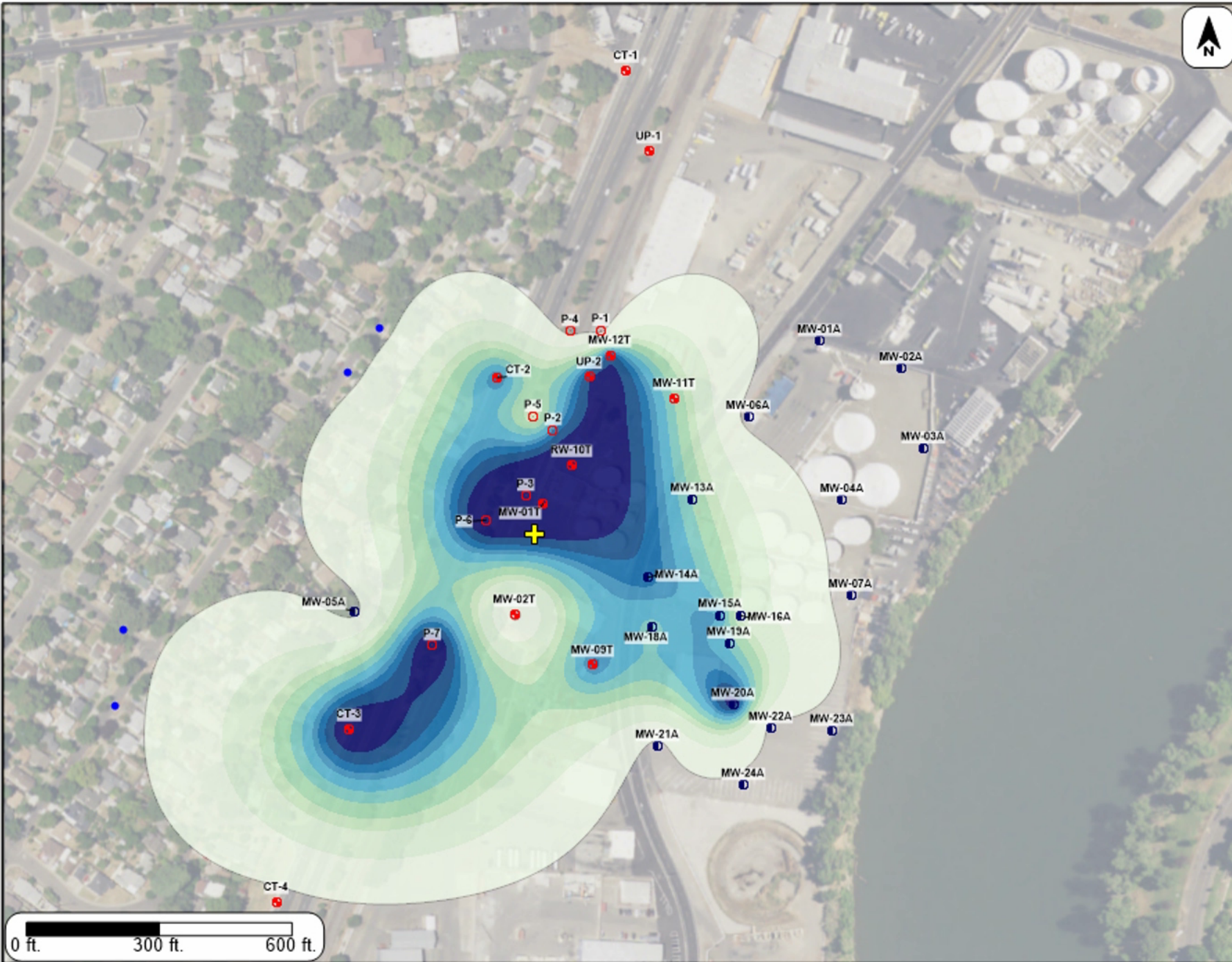
*Joe A. Ricker / joseph.ricker@wsp.com / Memphis, TN*

May 11, 2023



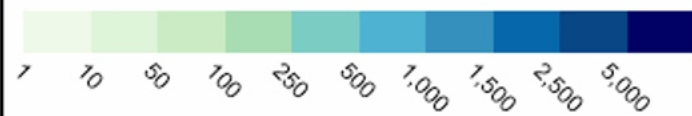
—**Analytics** is the discovery and communication of meaningful patterns in data. Especially valuable in areas rich with recorded information, analytics relies on the simultaneous application of statistics, computer programming and operations research to quantify performance. Analytics often favors data visualization to communicate insight.

- From Wikipedia, the free encyclopedia



**Benzene**  
**A-Zone**  
**Jan-1994**

Concentration ( $\mu\text{g/L}$ )

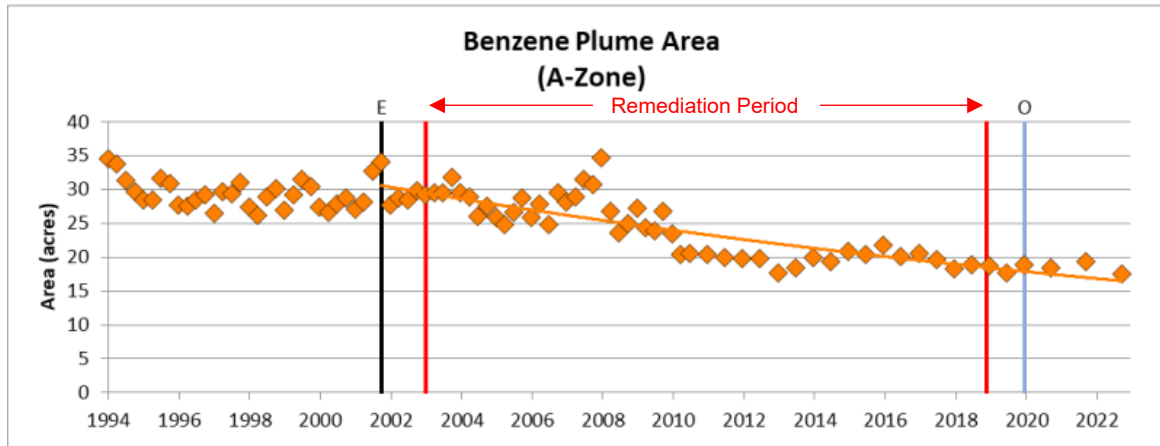


**Plume Characteristics**

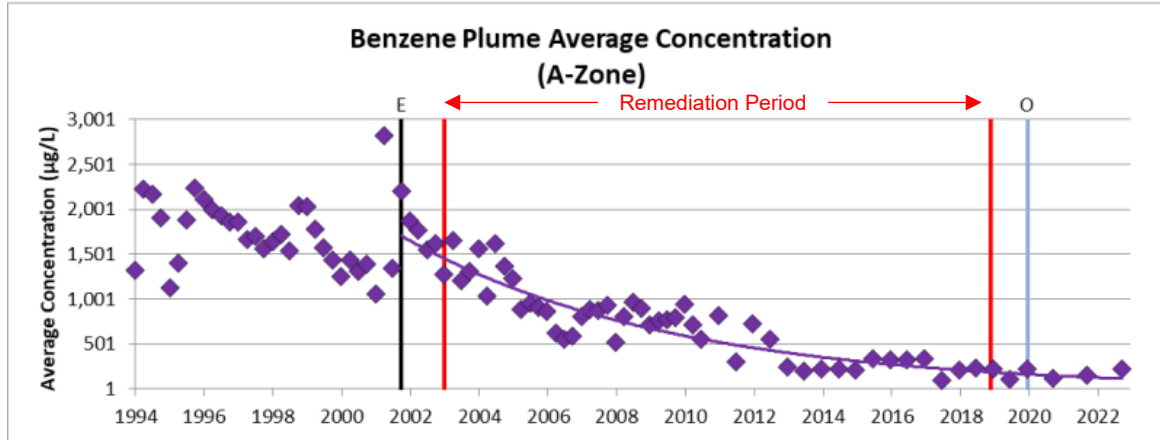
Plume Area: **34.6 acres**  
 Plume Average Concentration: **1,317  $\mu\text{g/L}$**   
 Plume Mass Indicator: **1,115 lbs**

- |                         |                             |
|-------------------------|-----------------------------|
| FTT Monitoring Well     | Sparge Well                 |
| FTT Piezometer          | U-Shaped Oxygen Well        |
| Buckeye Monitoring Well | Vapor Extraction Well       |
| 7-11 Monitoring Well    | Dual Phase Extraction Well  |
| Hanging Well            | Groundwater Extraction Well |
| Control Point           |                             |
| Plume Center of Mass    |                             |

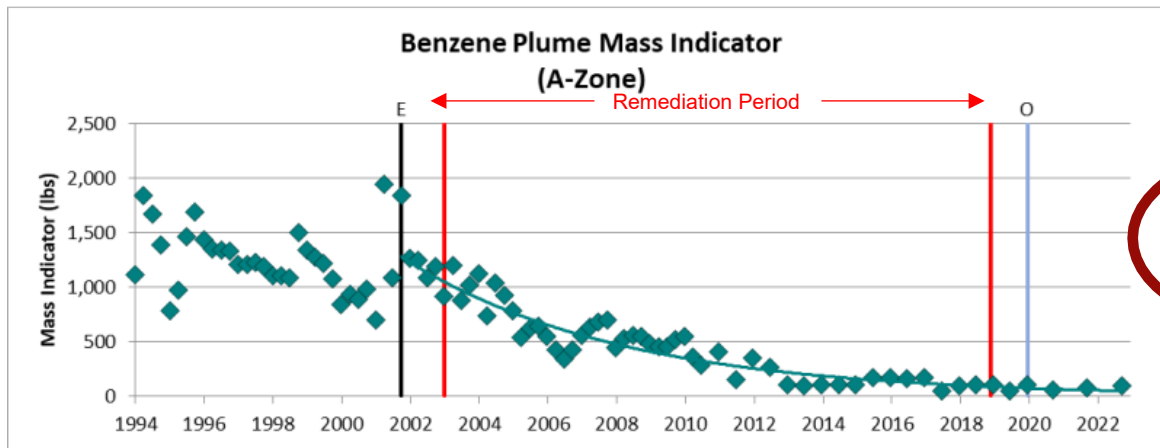




**Oct-2001 to Oct-2022**  
 Decreasing Trend  
 Mann-Kendall: >99% Confidence  
 Regression: >99% Confidence



**Oct-2001 to Oct-2022**  
 Decreasing Trend  
 Mann-Kendall: >99% Confidence  
 Regression: >99% Confidence

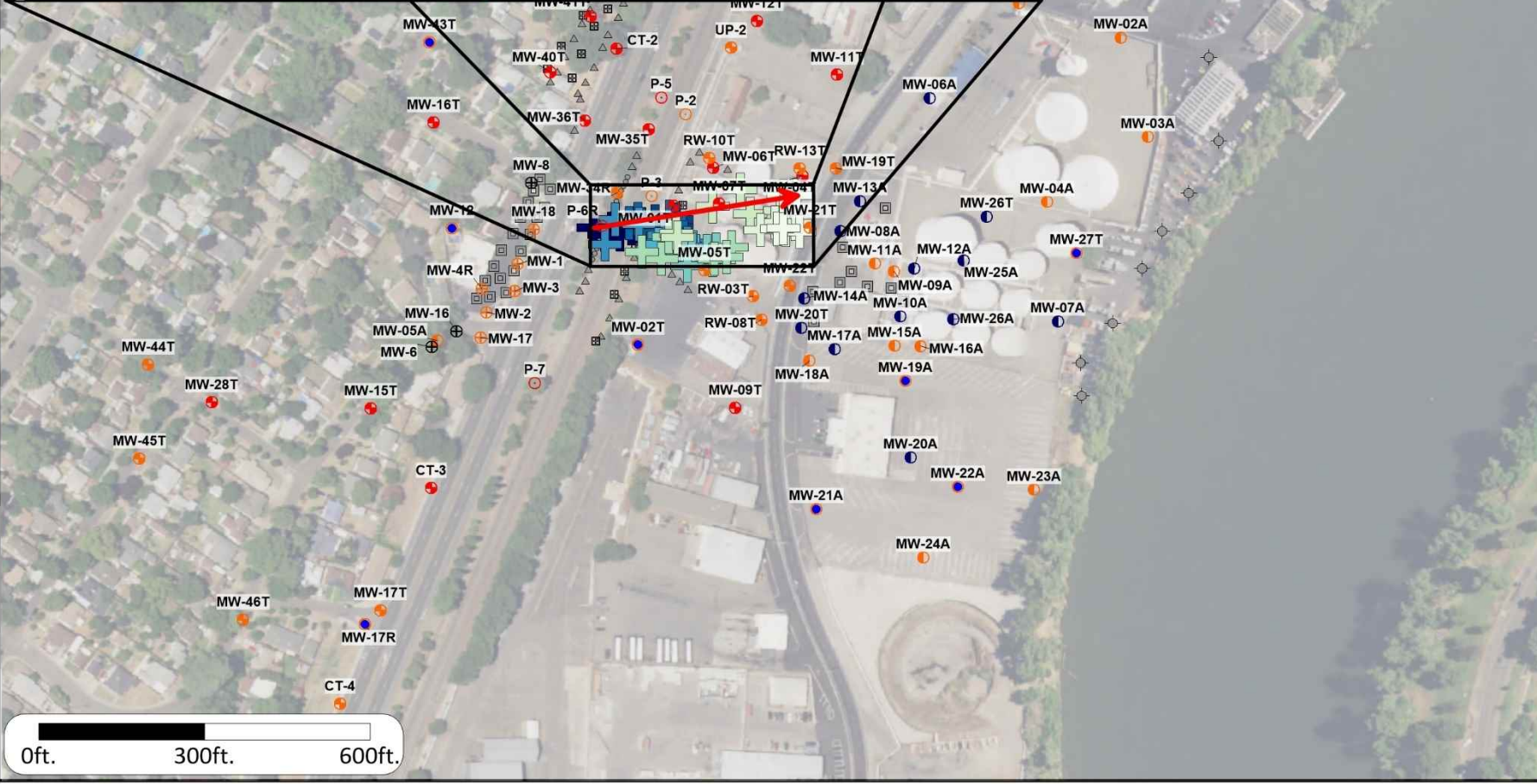
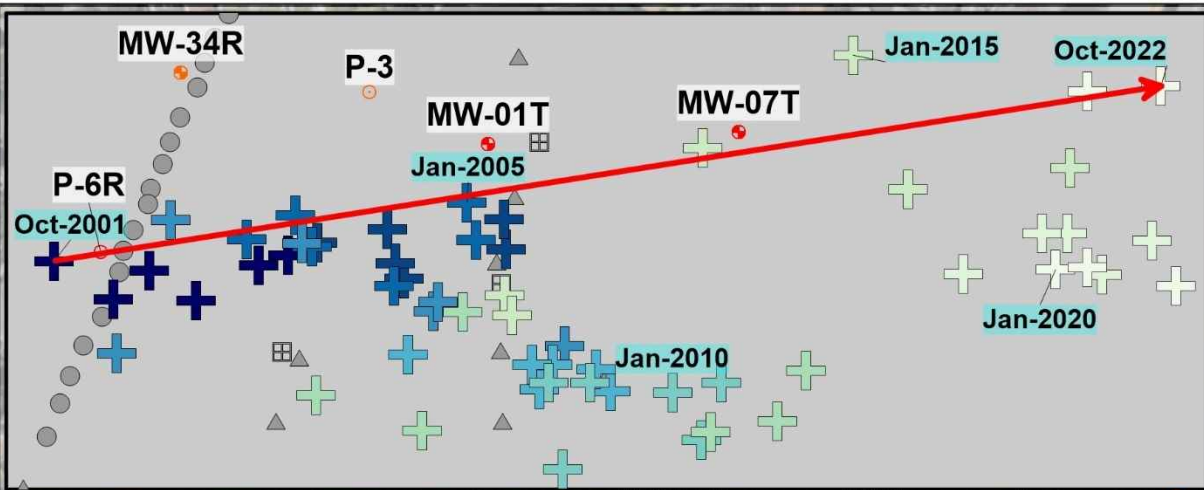


**Oct-2001 to Oct-2022**  
 Decreasing Trend  
 Mann-Kendall: >99% Confidence  
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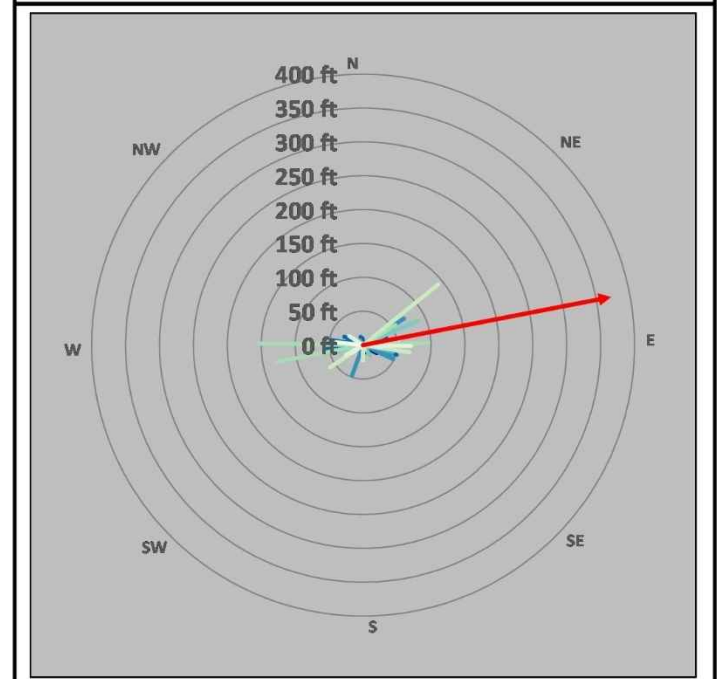
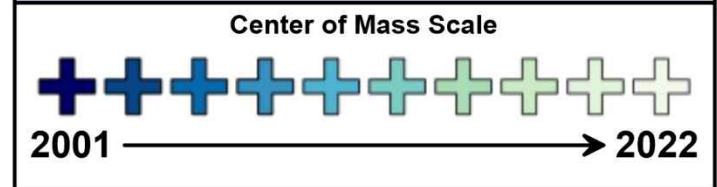


E – Network Expansion  
 O – Optimization





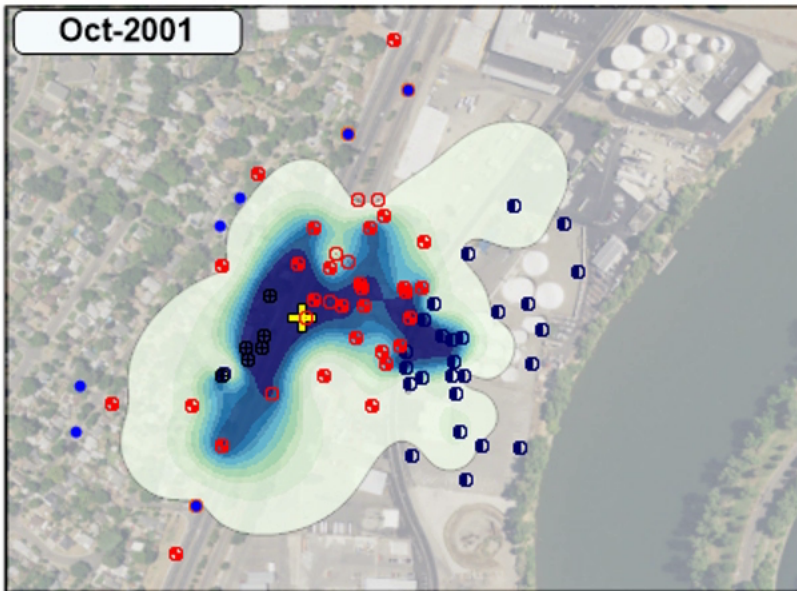
## Benzene A-Zone



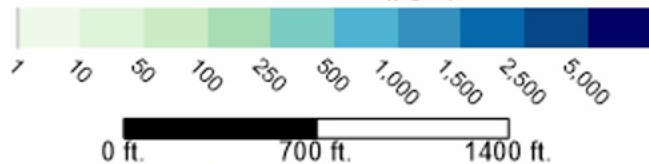
- |  |                         |  |                             |
|--|-------------------------|--|-----------------------------|
|  | Monitoring Well         |  | Sparge Well                 |
|  | Hanging Well            |  | U-Shaped Oxygen Well        |
|  | Control Point           |  | Vapor Extraction Well       |
|  | Center Of Mass Movement |  | Dual Phase Extraction Well  |
|  | Net Movement            |  | Groundwater Extraction Well |



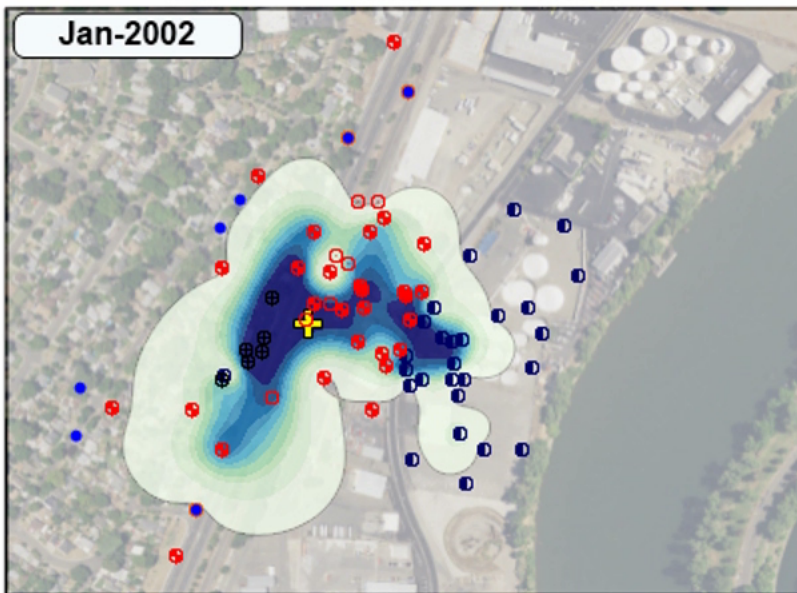
Oct-2001



Concentration ( $\mu\text{g/L}$ )



Jan-2002

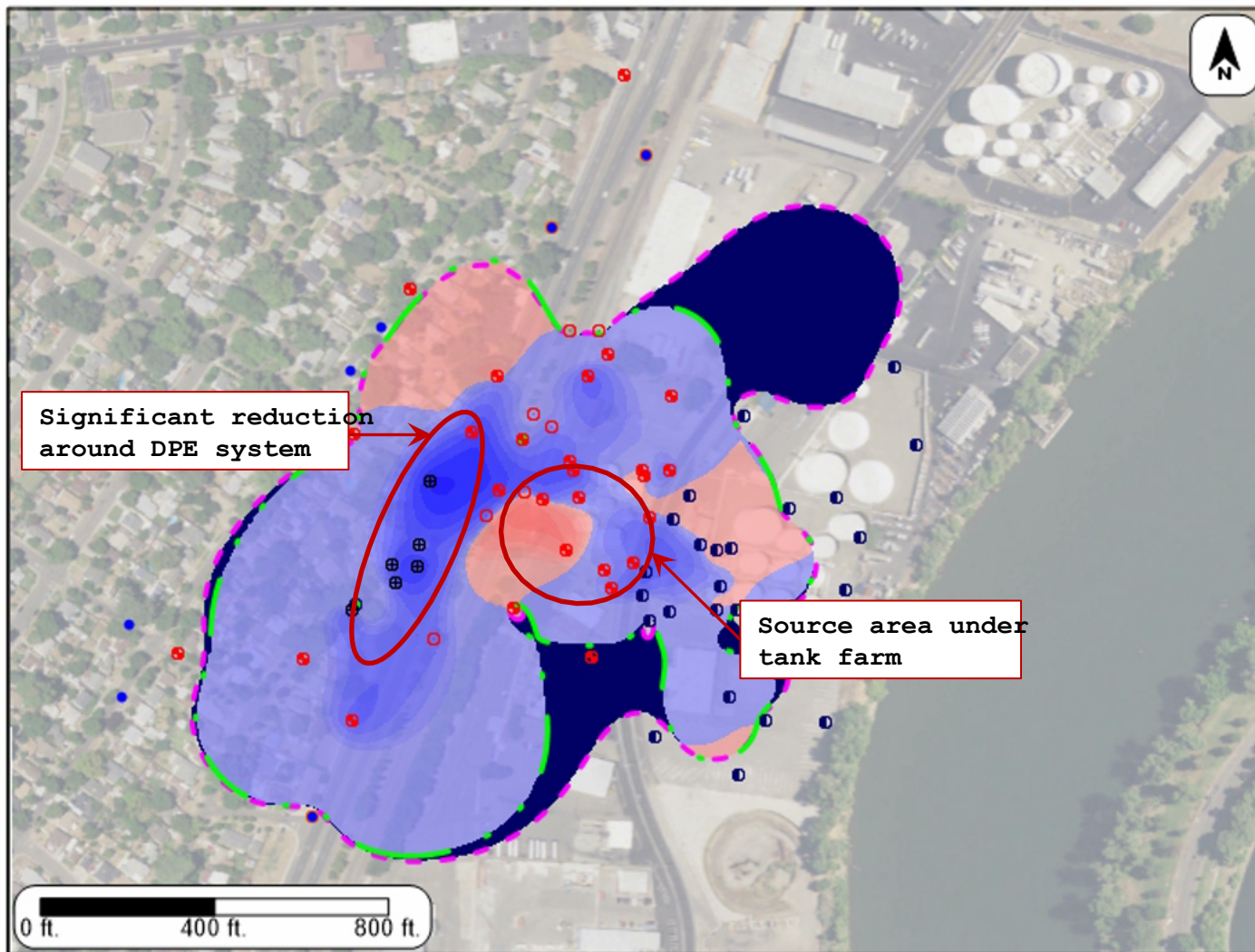


### Benzene A-Zone Spatial Changes Oct-2001 vs Jan-2002

#### Plume Characteristics

Area: **19% Decrease**  
 Average Concentration: **15% Decrease**  
 Mass Indicator: **31% Decrease**  
 Mass Increase: **19.3 lbs Increase**  
 Mass Decrease: **597 lbs Decrease**

- |                           |                               |
|---------------------------|-------------------------------|
| ⊕ FTT Monitoring Well     | △ Sparge Well                 |
| ○ FTT Piezometer          | ● U-Shaped Oxygen Well        |
| ⊖ Buckeye Monitoring Well | ⊞ Vapor Extraction Well       |
| ⊕ 7-11 Monitoring Well    | □ Dual Phase Extraction Well  |
| ⊕⊖⊕ Hanging Well          | ◆ Groundwater Extraction Well |
| ● Control Point           | — Oct-2001 Plume Boundary     |
| ⊕ Plume Center of Mass    | — Jan-2002 Plume Boundary     |



Spatial Change Indicator™  
Increase



Decrease



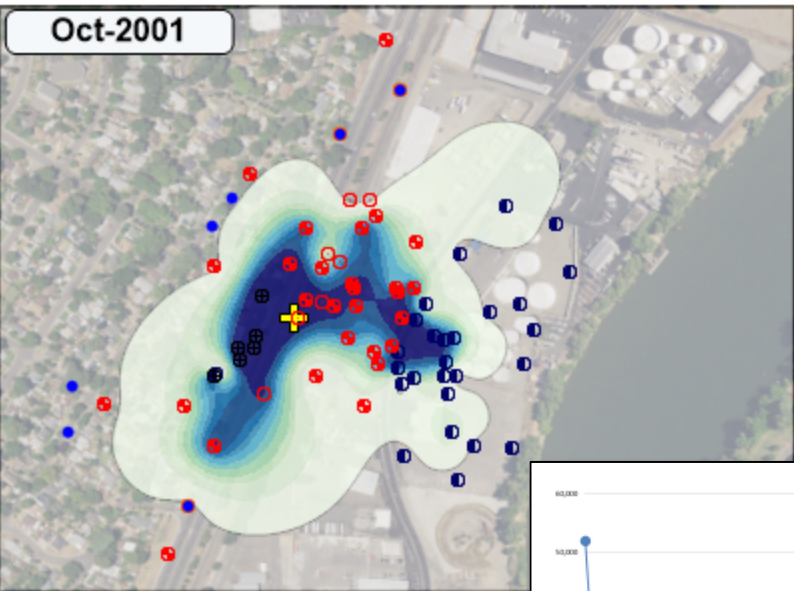
Oct-2001

# Benzene A-Zone Spatial Changes Oct-2001 vs Oct-2022

## Plume Characteristics

Area: **49% Decrease**  
 Average Concentration: **90% Decrease**  
 Mass Indicator: **95% Decrease**  
 Mass Increase: **22.0 lbs Increase**  
 Mass Decrease: **1,766 lbs Decrease**

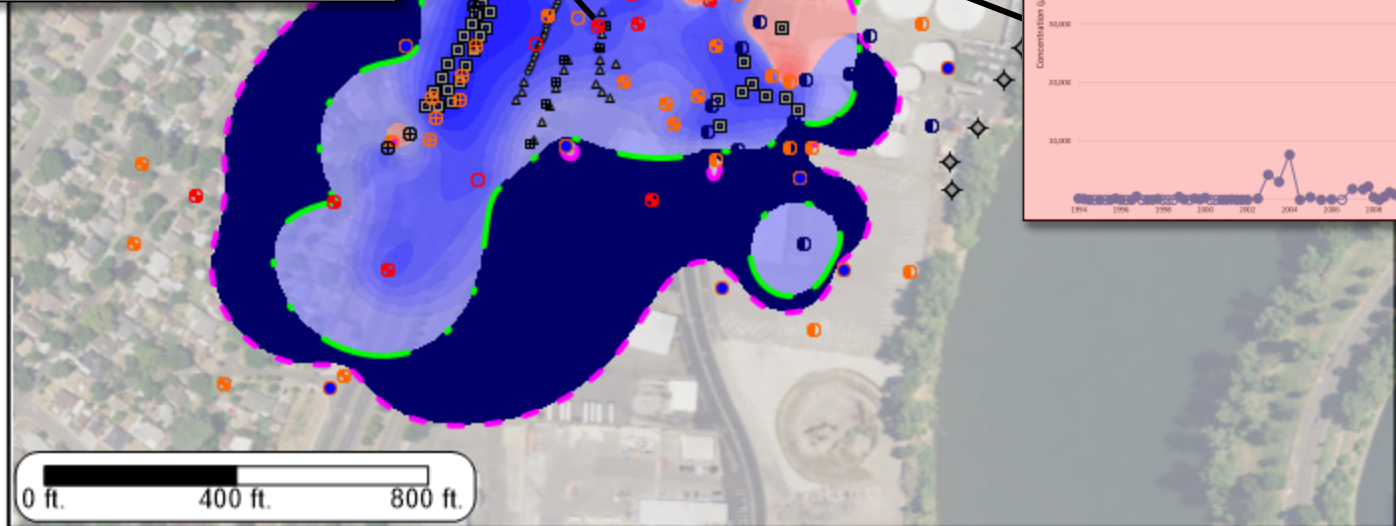
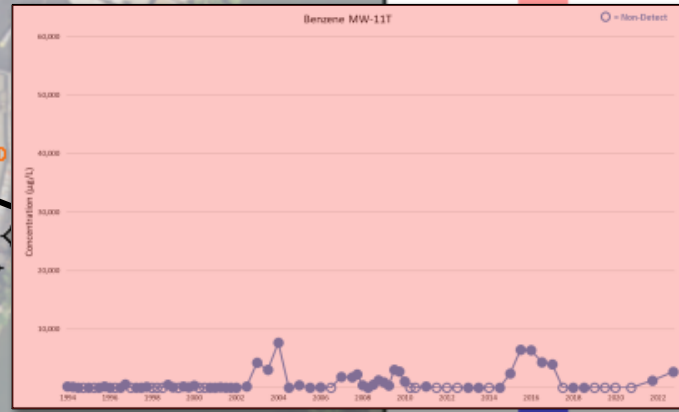
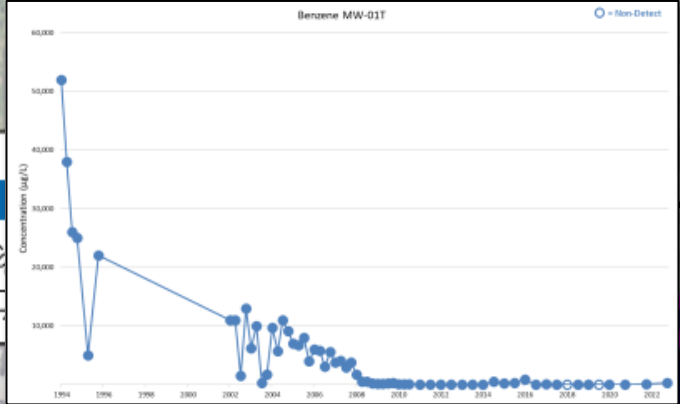
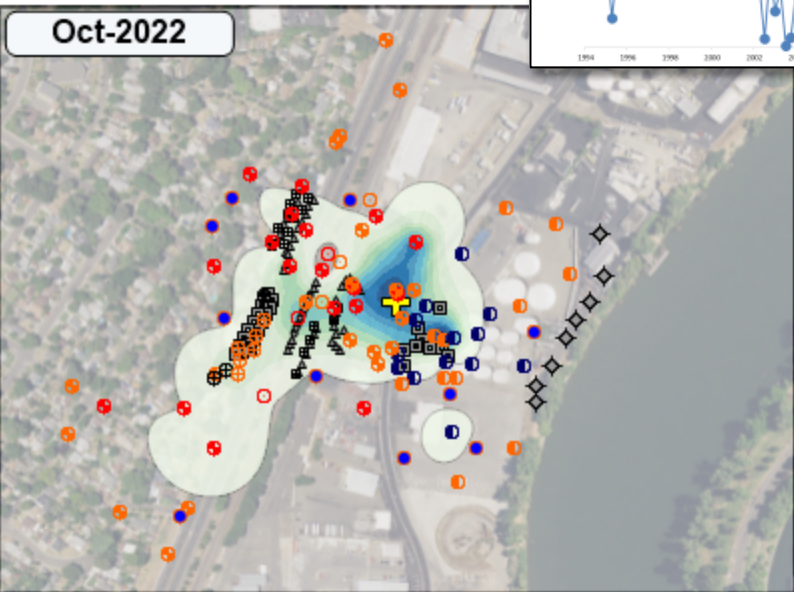
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|------|-------------------------|---|-----------------------------|
| ⊕    | FTT Monitoring Well     | △ | Sparge Well                 |
| ○    | FTT Piezometer          | ● | U-Shaped Oxygen Well        |
| Ⓜ    | Buckeye Monitoring Well | ⊞ | Vapor Extraction Well       |
| ⊕    | 7-11 Monitoring Well    | □ | Dual Phase Extraction Well  |
| ⊕⊕ⓂⓂ | Hanging Well            | ◆ | Groundwater Extraction Well |
| ●    | Control Point           | — | Oct-2001 Plume Boundary     |
| +    | Plume Center of Mass    | — | Oct-2022 Plume Boundary     |



**Spatial Change Indicator™**  
 Increase



Oct-2022

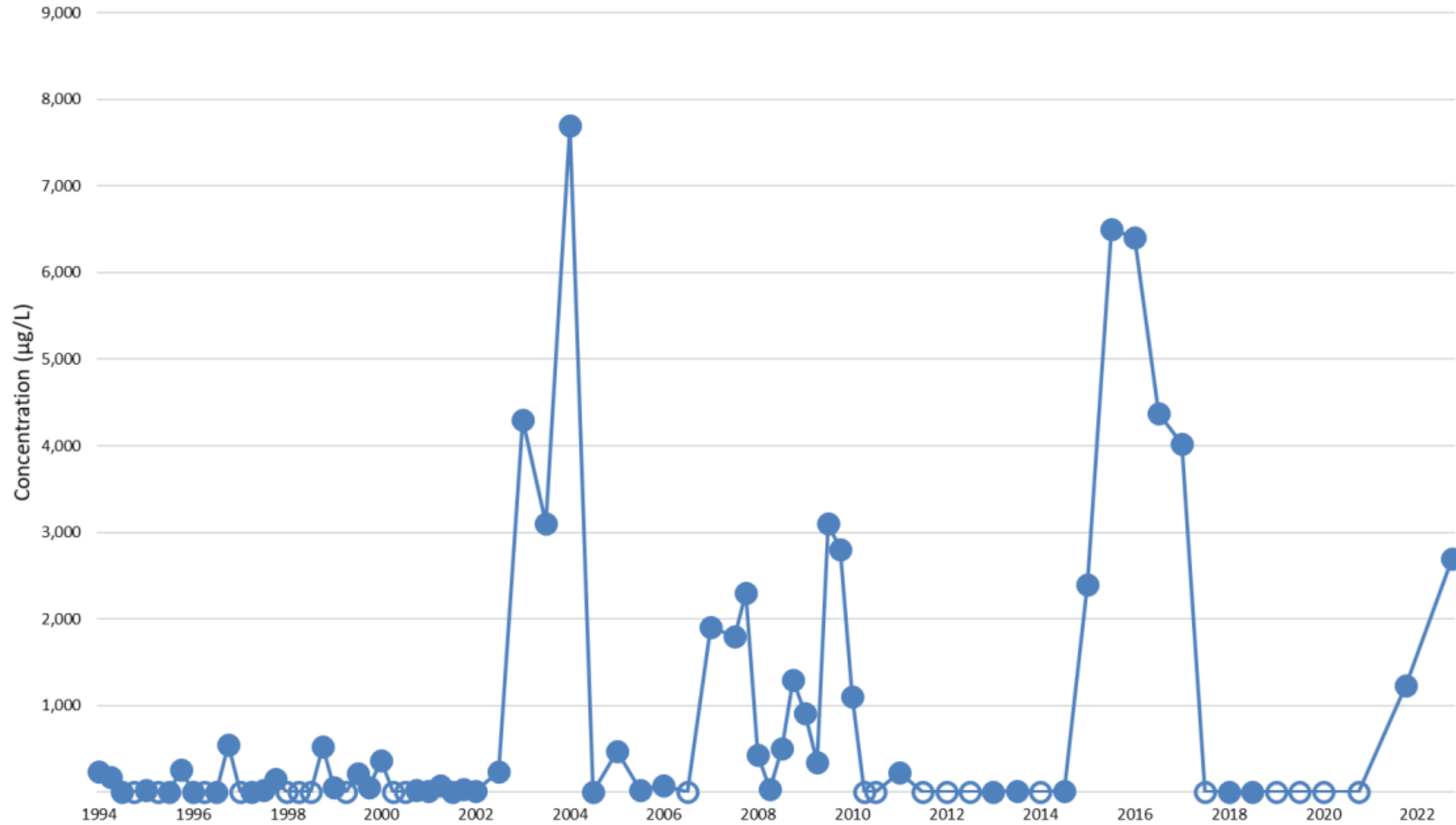


Decrease



# Benzene MW-11T

○ = Non-Detect





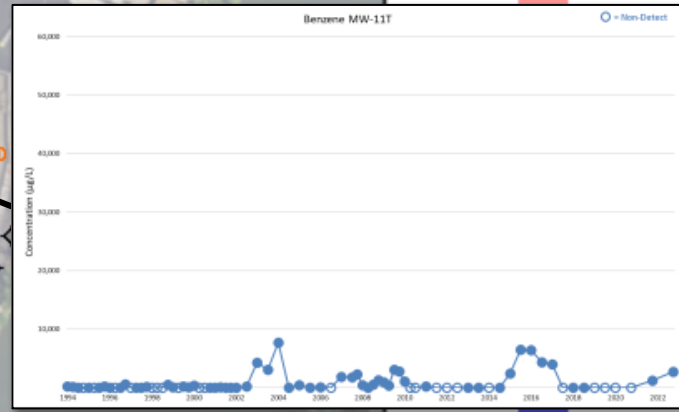
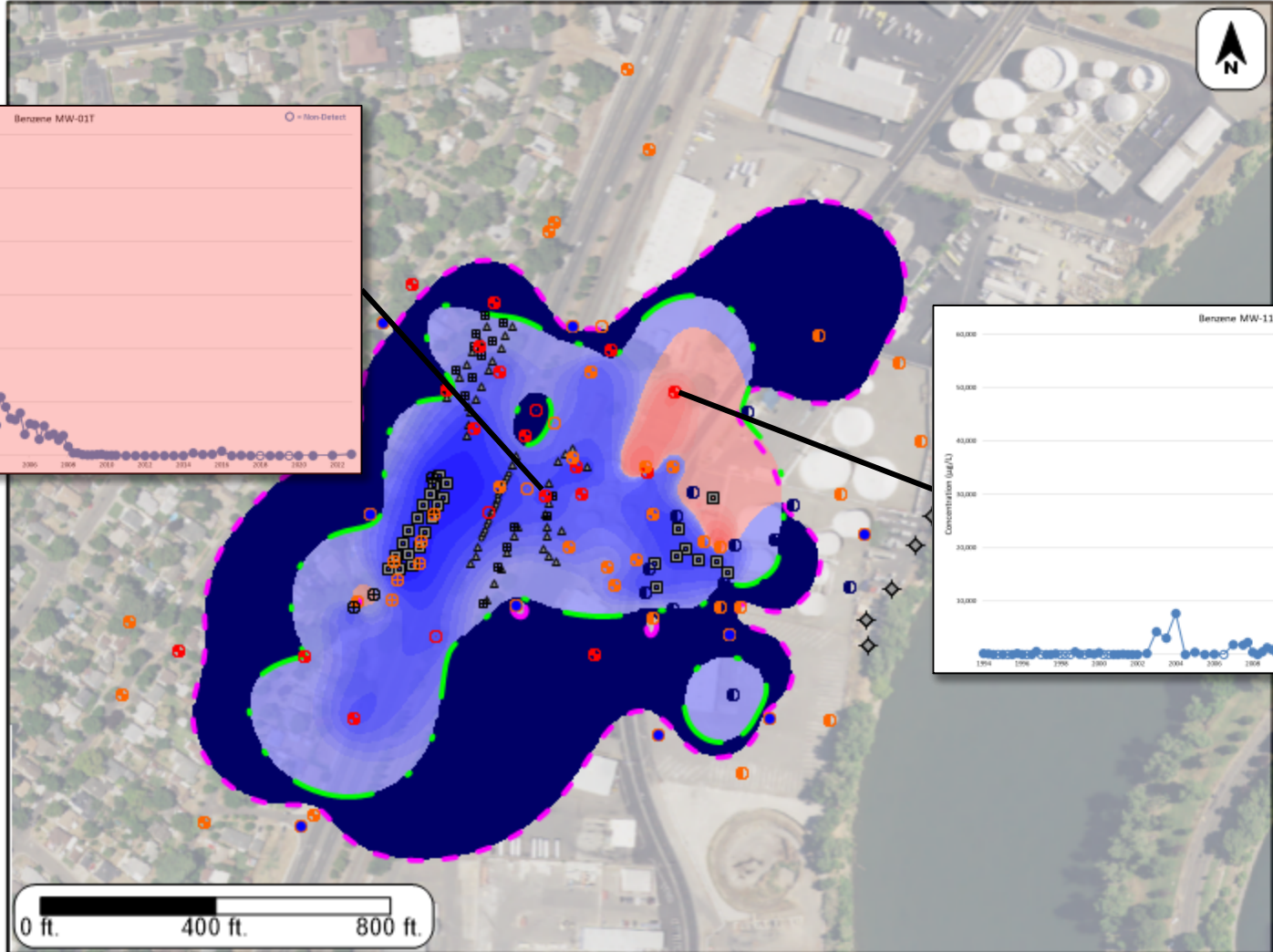
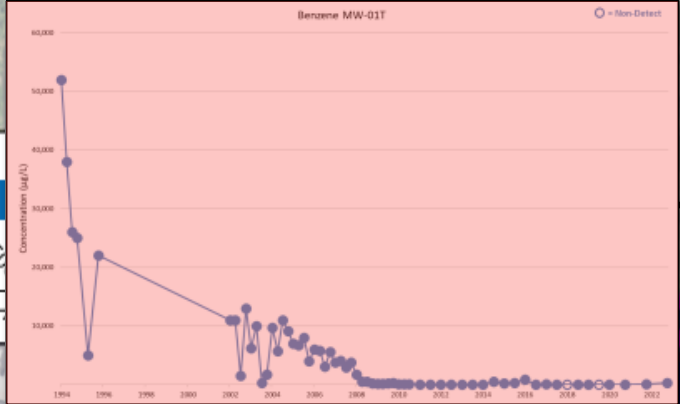
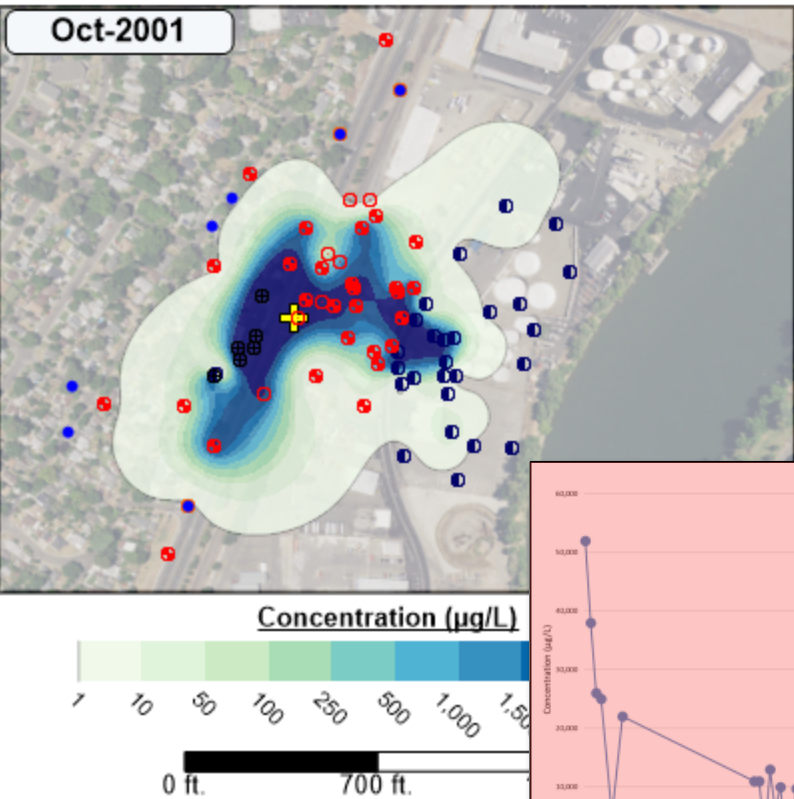
Oct-2001

# Benzene A-Zone Spatial Changes Oct-2001 vs Oct-2022

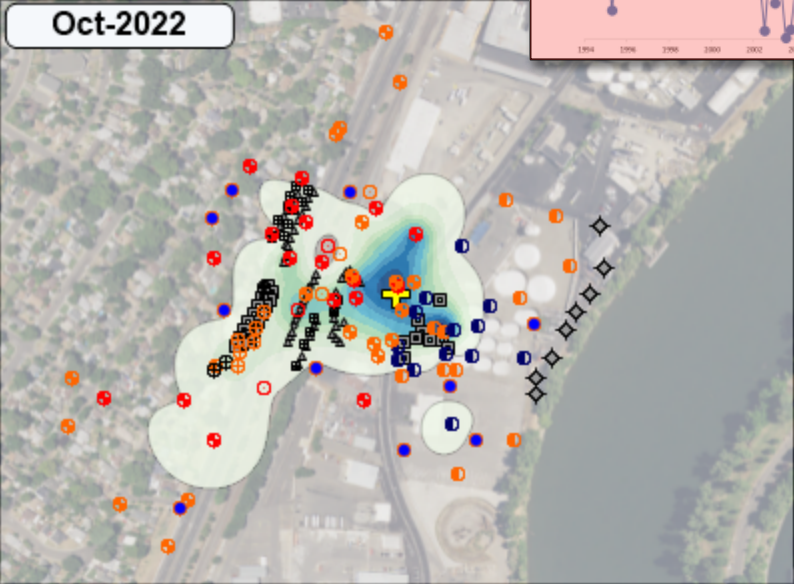
## Plume Characteristics

Area: **49% Decrease**  
 Average Concentration: **90% Decrease**  
 Mass Indicator: **95% Decrease**  
 Mass Increase: **22.0 lbs Increase**  
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- |      |                         |   |                             |
|------|-------------------------|---|-----------------------------|
| ⊕    | FTT Monitoring Well     | △ | Sparge Well                 |
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| Ⓜ    | Buckeye Monitoring Well | ⊞ | Vapor Extraction Well       |
| ⊕    | 7-11 Monitoring Well    | □ | Dual Phase Extraction Well  |
| ⊕⊕ⓂⓂ | Hanging Well            | ◆ | Groundwater Extraction Well |
| ●    | Control Point           | — | Oct-2001 Plume Boundary     |
| +    | Plume Center of Mass    | — | Oct-2022 Plume Boundary     |

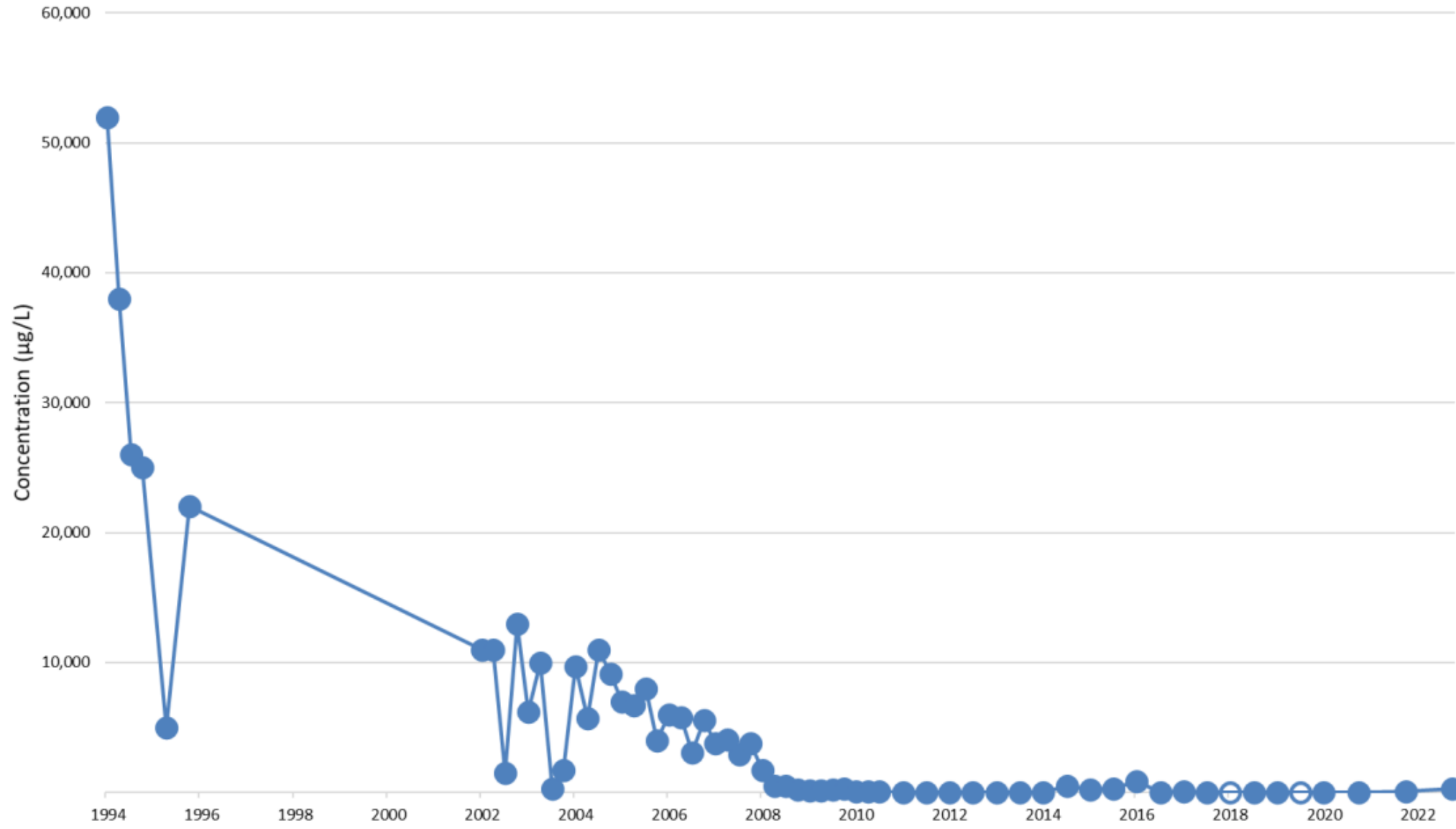


Oct-2022

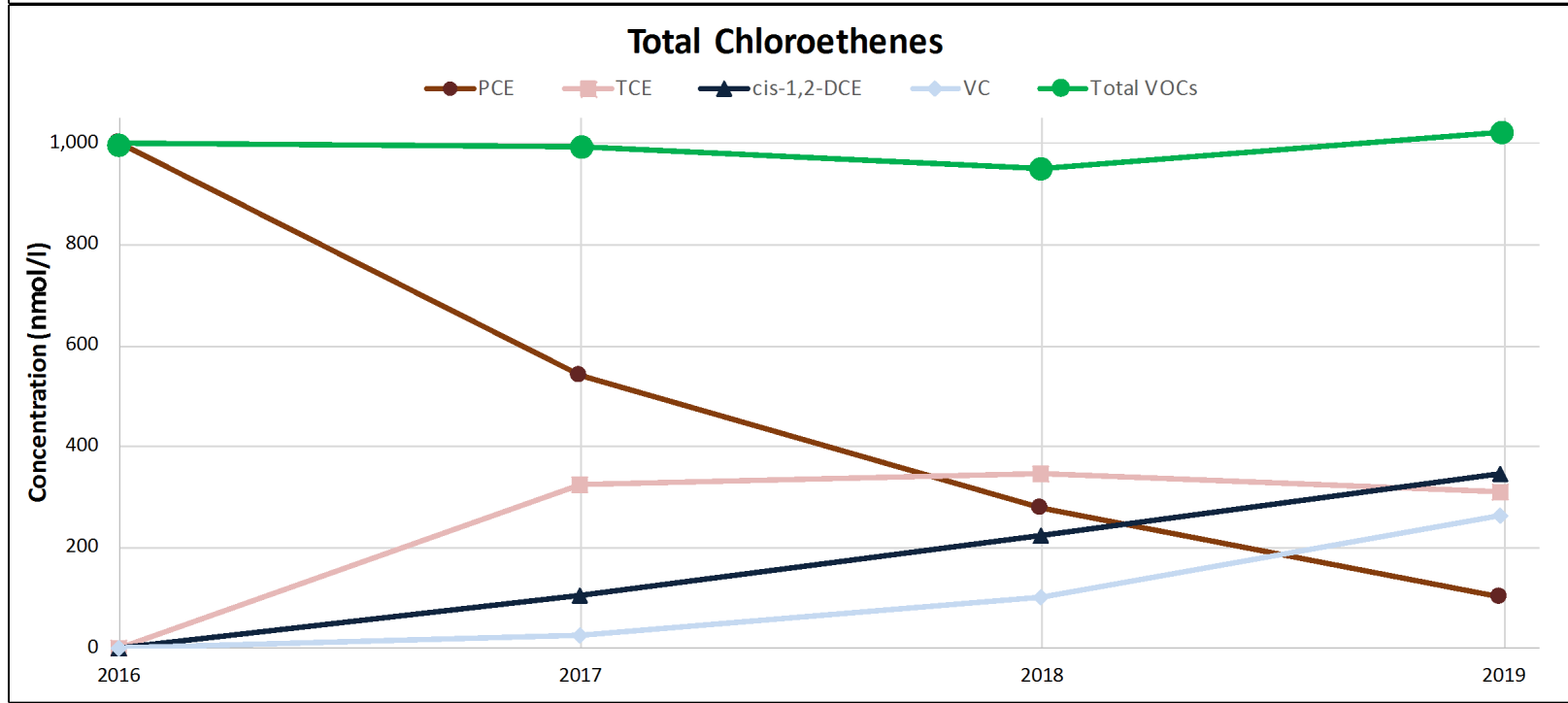
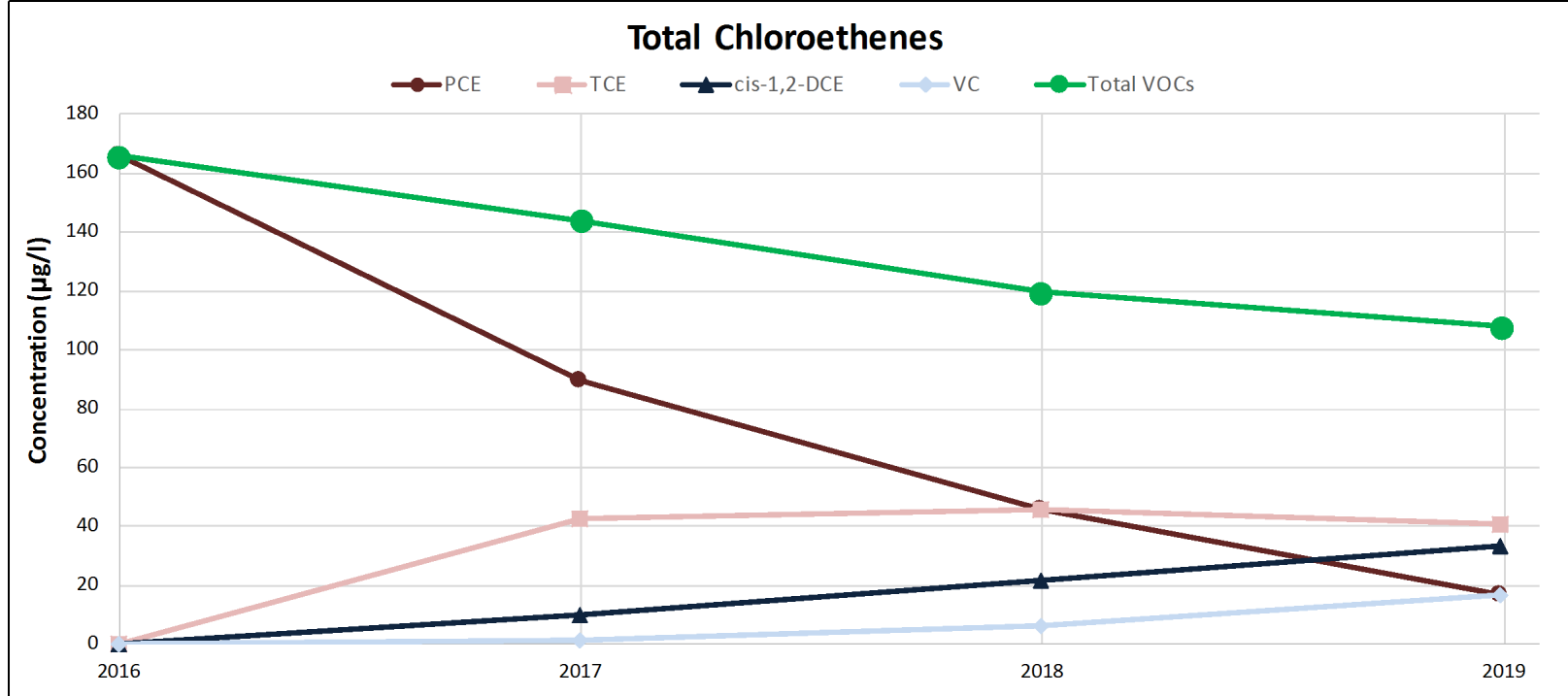


# Benzene MW-01T

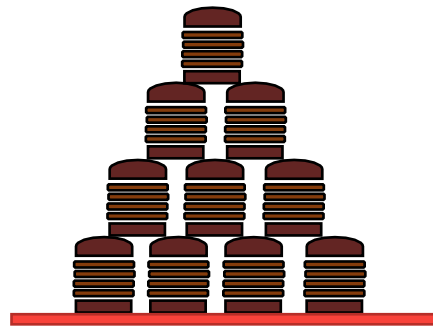
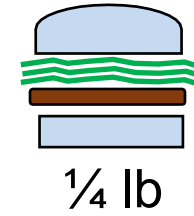
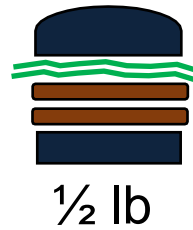
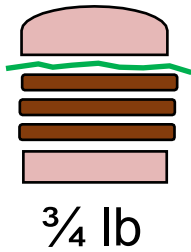
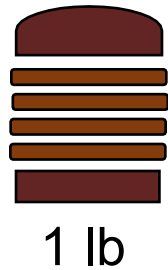
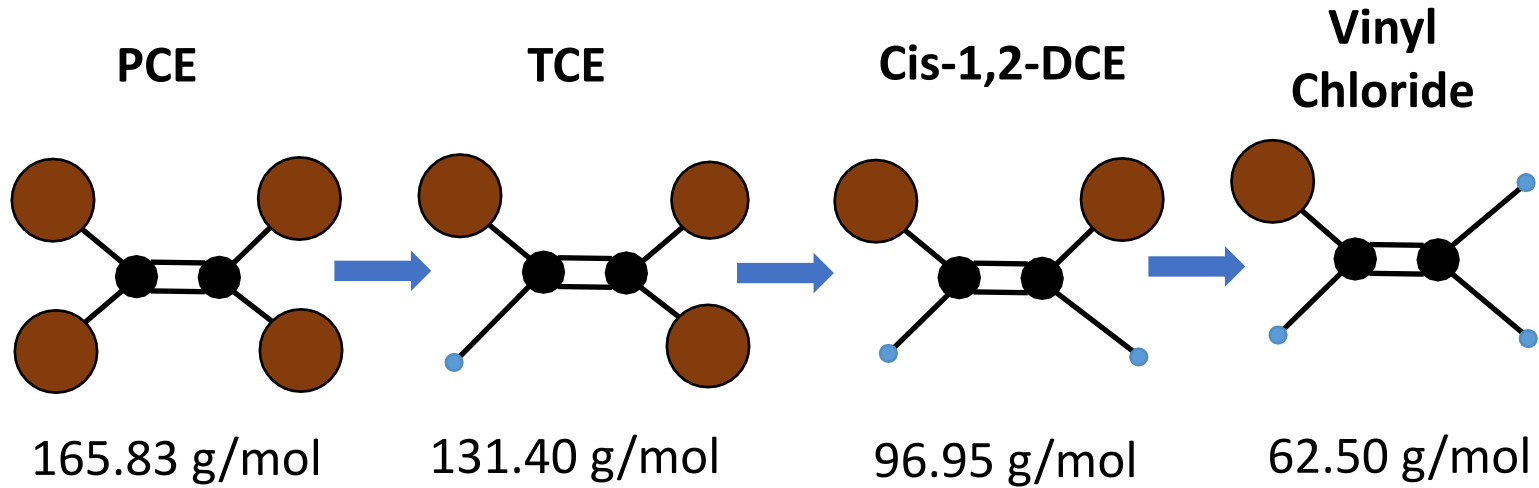
○ = Non-Detect



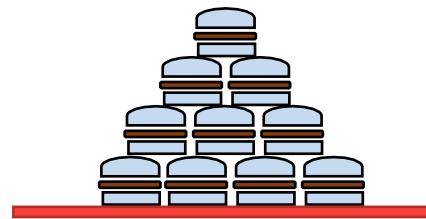
# Chlorinated Solvent Sites



● Chlorine ● Carbon ● Hydrogen

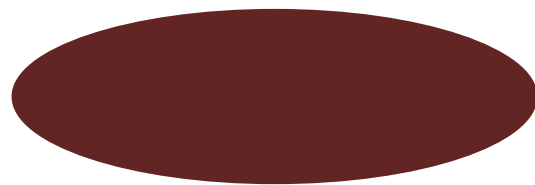
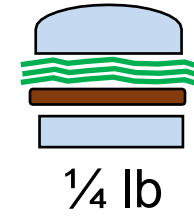
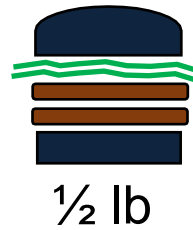
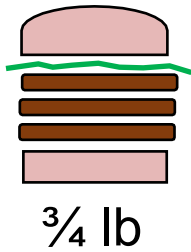
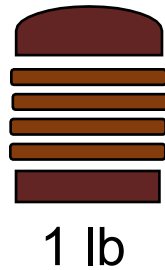
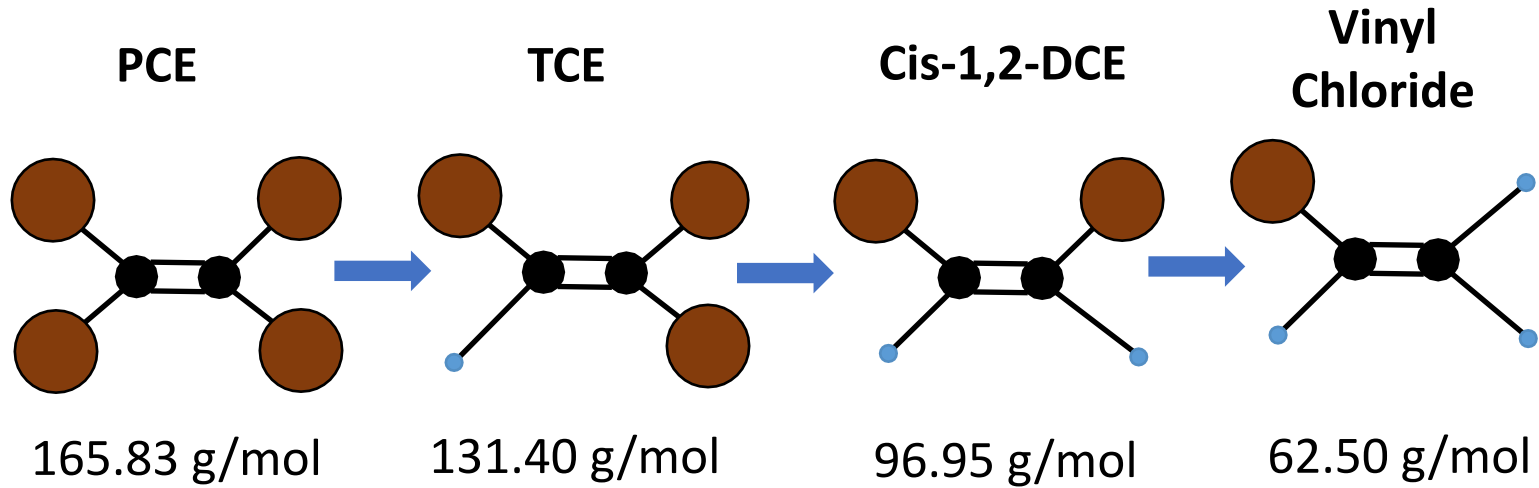


Total Burgers: 10  
Total weight: 10 lbs



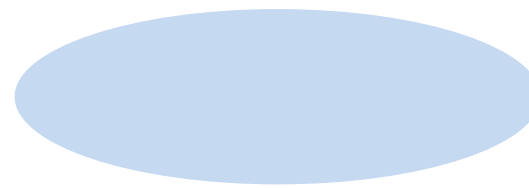
Total Burgers: 10  
Total weight: 2.5 lb

● Chlorine ● Carbon ● Hydrogen



**PCE Plume Mass: 3.7 lbs (10 mol)**

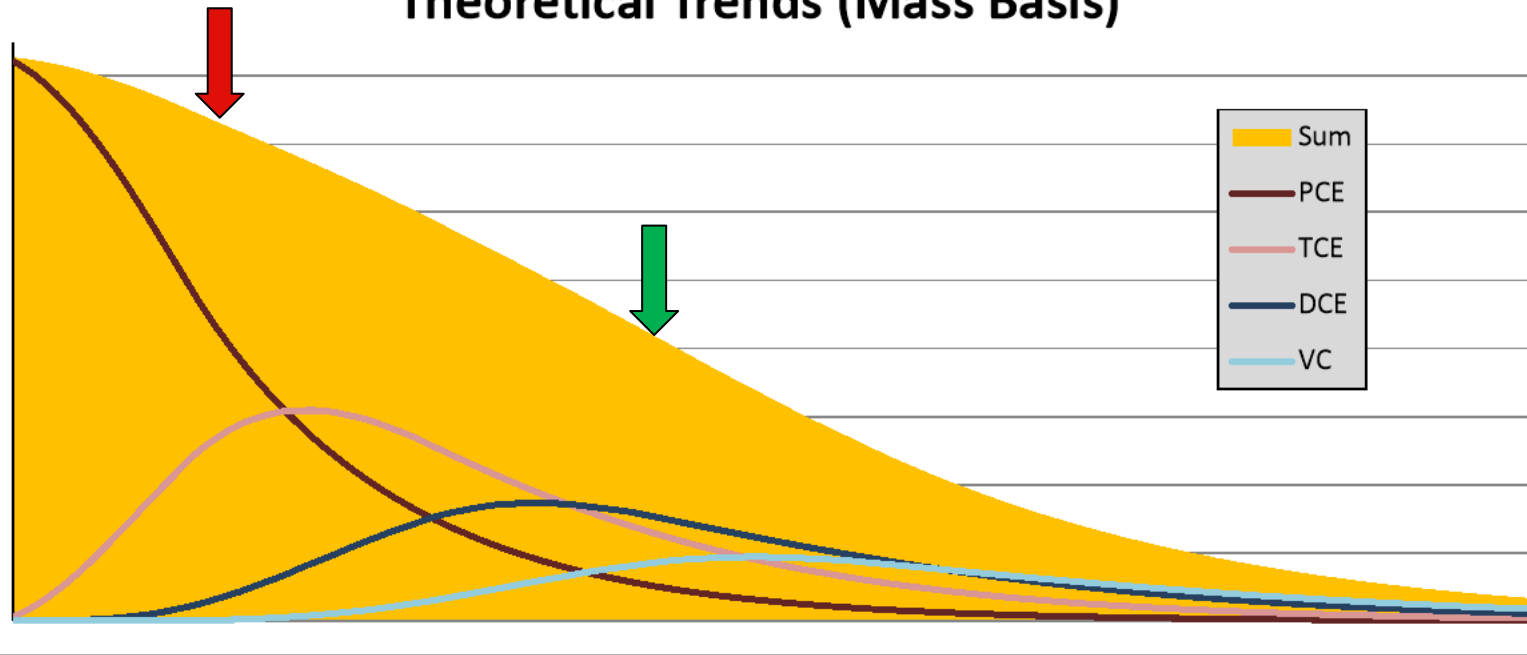
**PCE Concentration: 10 mg/l**



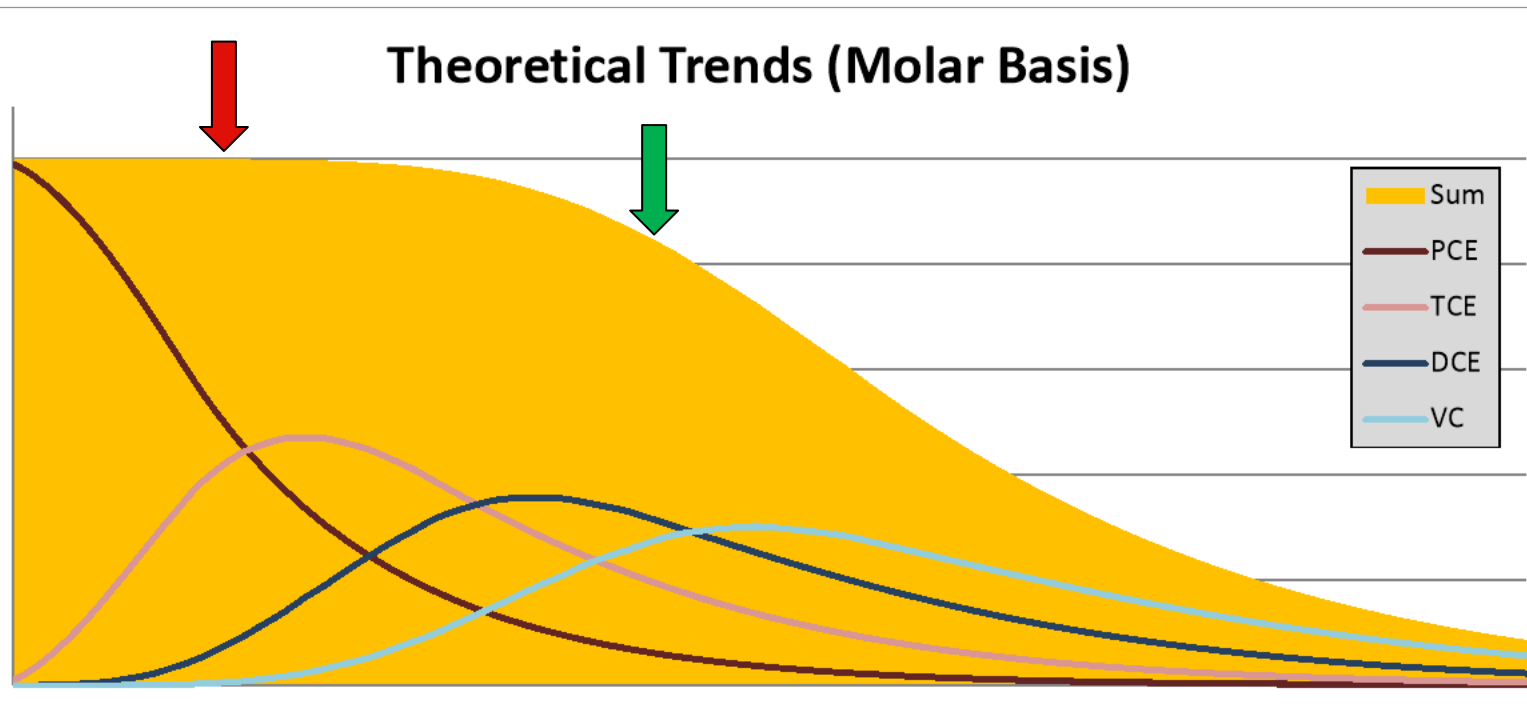
**VC Plume Mass: 1.4 lbs (10 mol)**

**VC Concentration: 3.8 mg/l**

### Theoretical Trends (Mass Basis)



### Theoretical Trends (Molar Basis)



# Chem-Dyne Superfund Site – Hamilton, Ohio

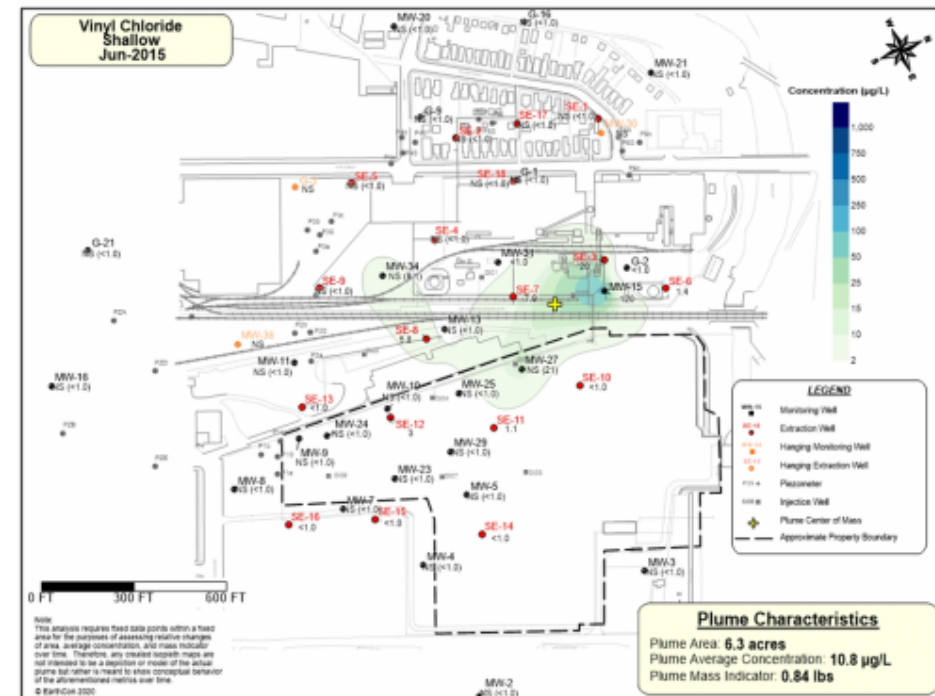
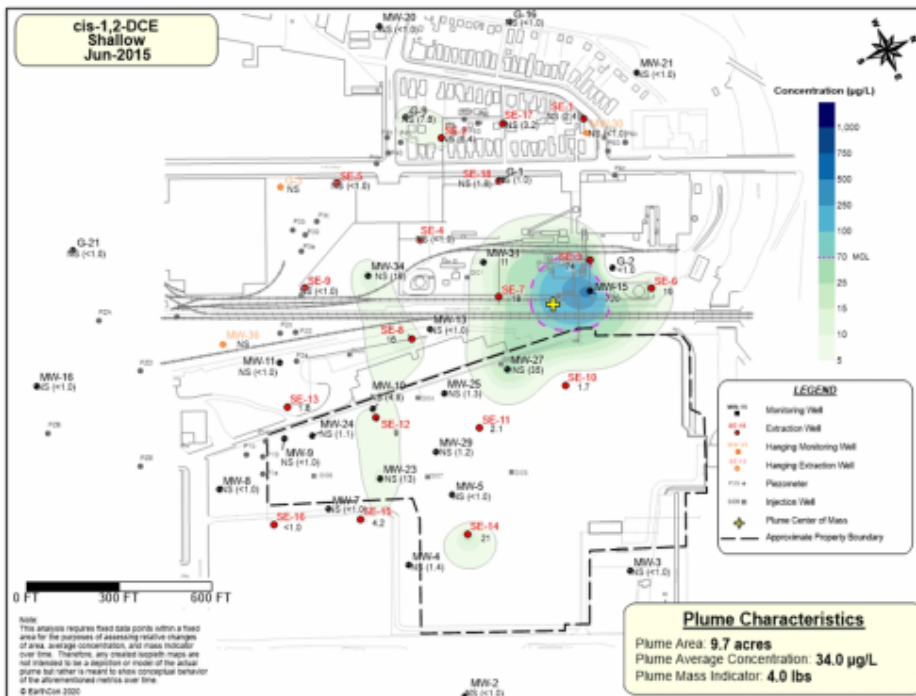
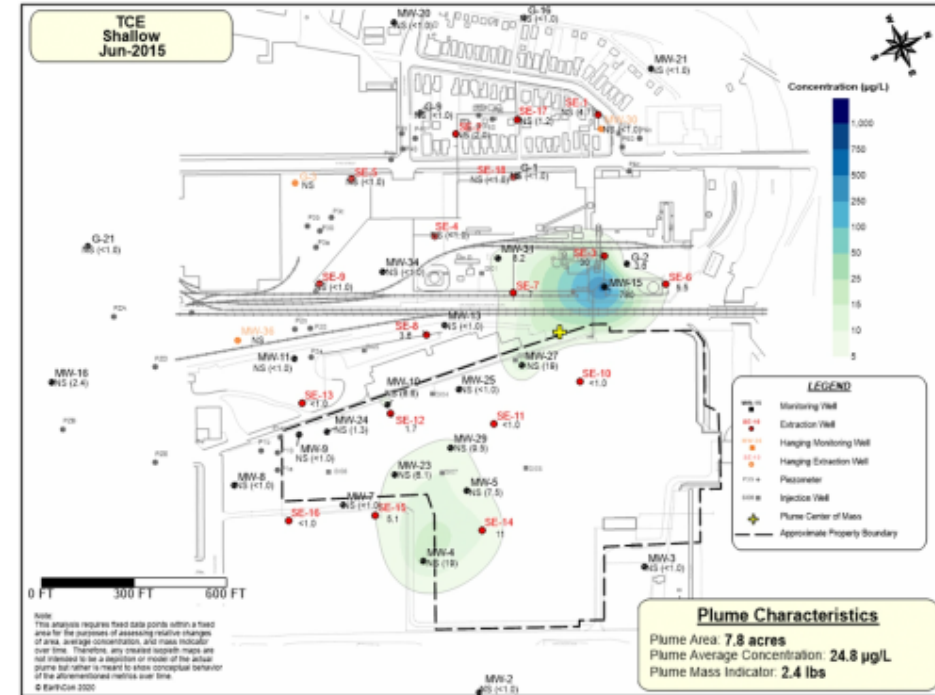
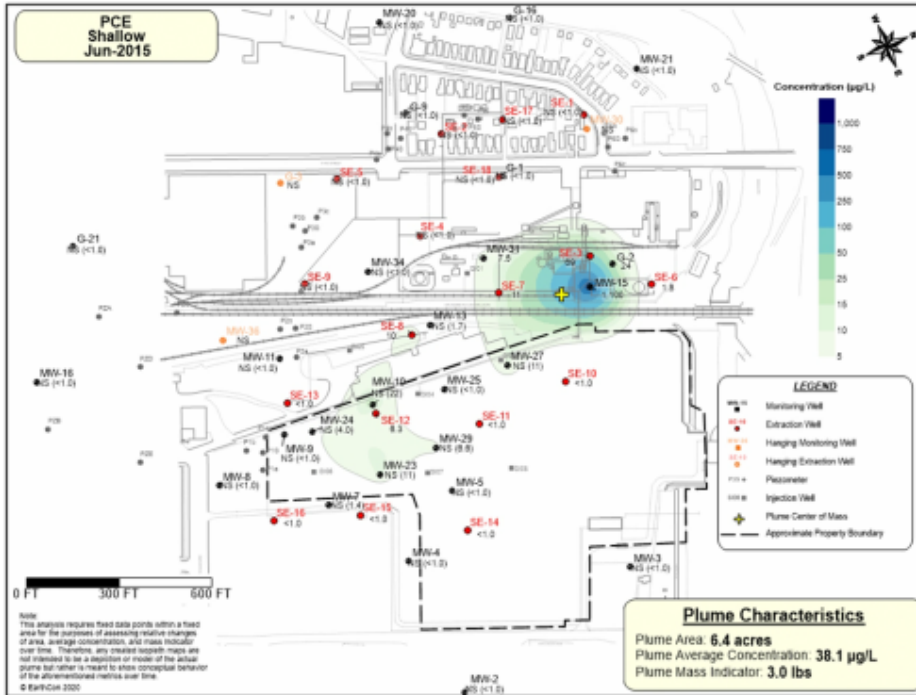
## Background

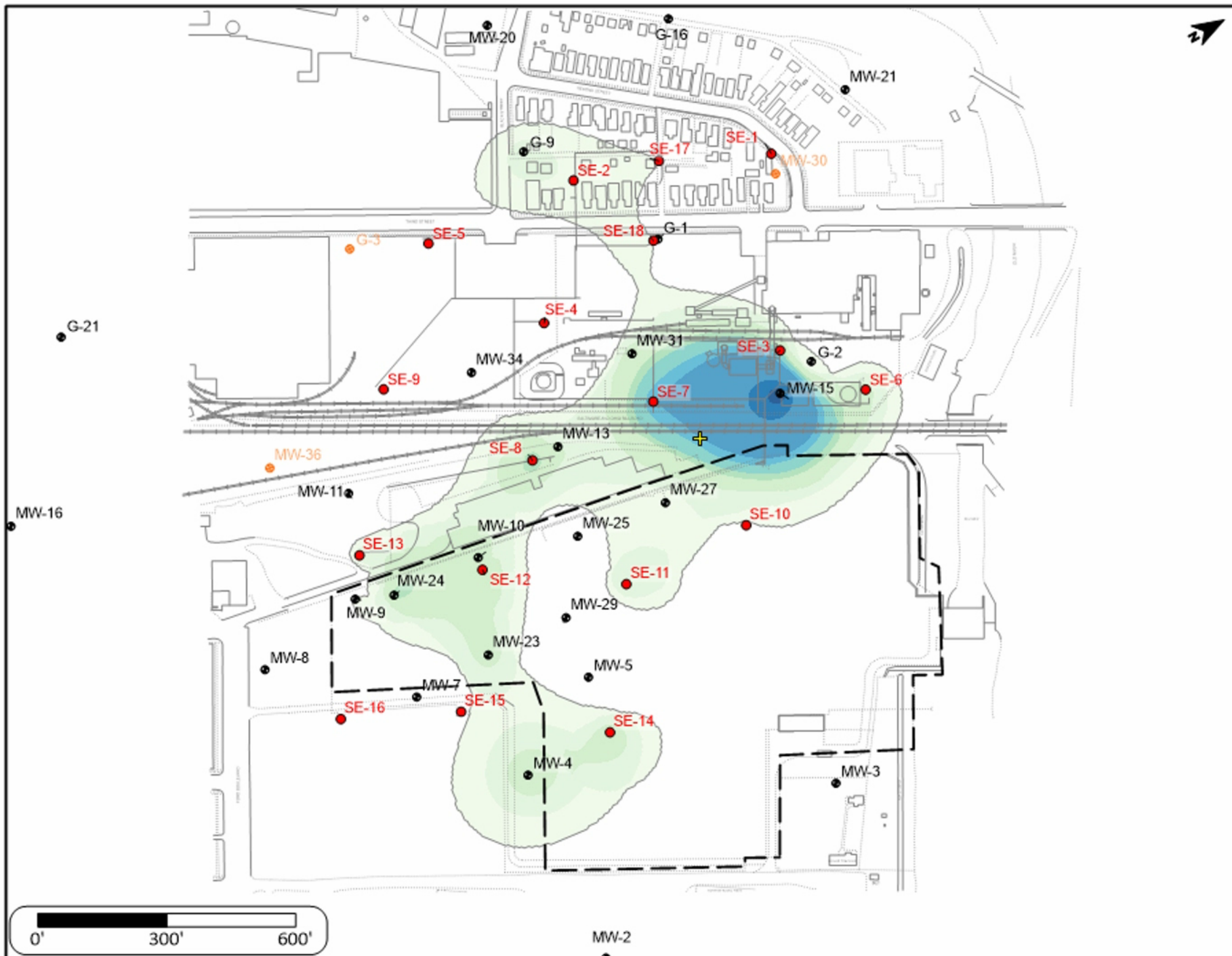
- Chemical recycling facility from 1974 through 1980
- Chloroethenes, chloroethanes, and chloromethanes, other VOCs
- Groundwater P&T system 1987 – 2015
- System shut down in June 2015 to transition to MNA

## Key Challenges

- Demonstrate biodegradation is occurring
- Evaluate DCE stall
- Determine attenuation rates
- Effectively communicate remediation progress

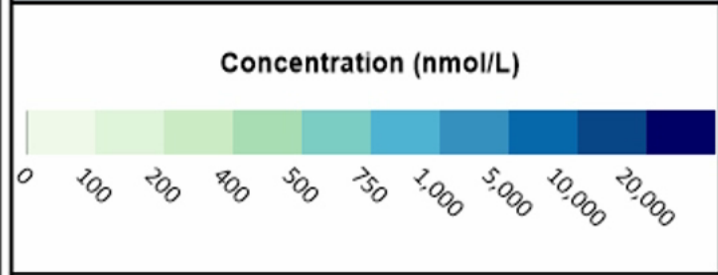






# Chloroethenes

## Mar-2010

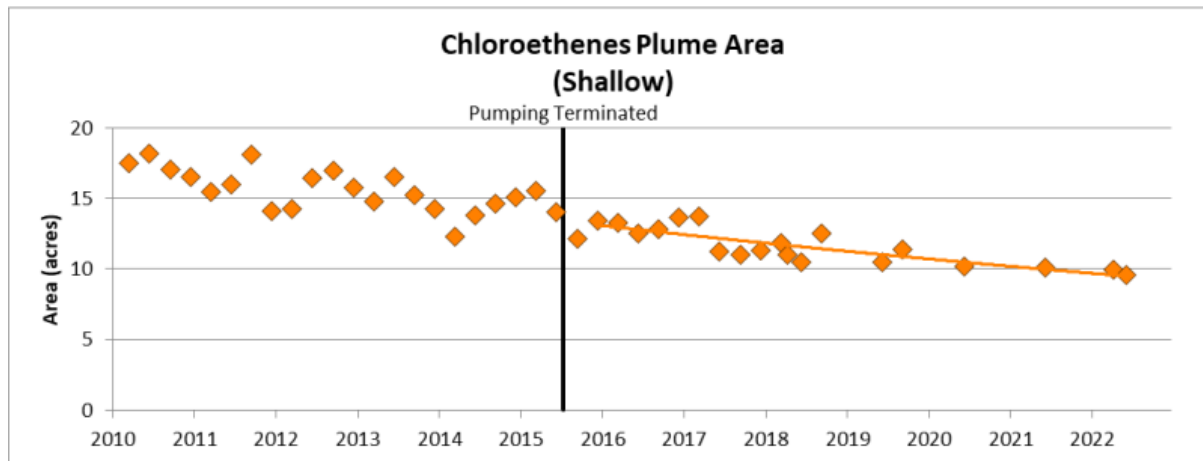


### Plume Characteristics

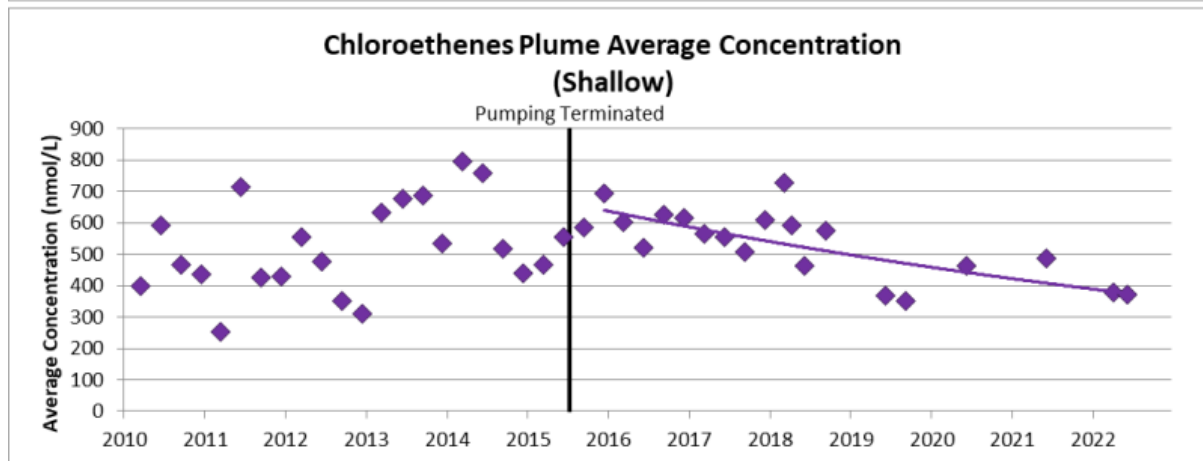
Plume Area: **17.5 acres**  
 Plume Average Concentration: **400 nmol/L**  
 Plume Mass Indicator: **38.8 moles**

- MW-15 Monitoring Well
- SE-10 Extraction Well
- Hanging Well
- Center of Mass
- Approximate Property Boundary

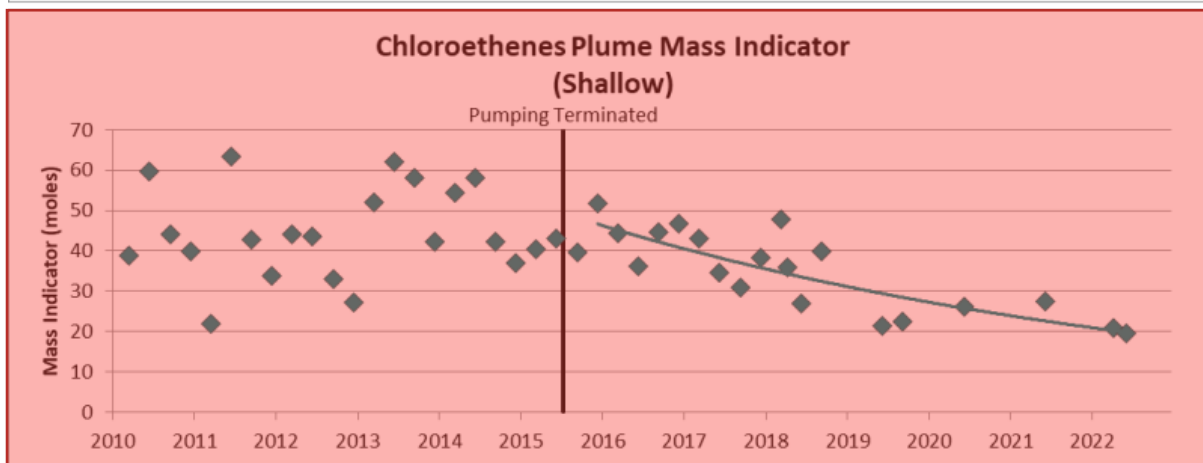
**Note:**  
 Chloroethenes is the sum of molar concentration for: PCE; TCE; cis-1,2-DCE, 1,1-DCE and VC.



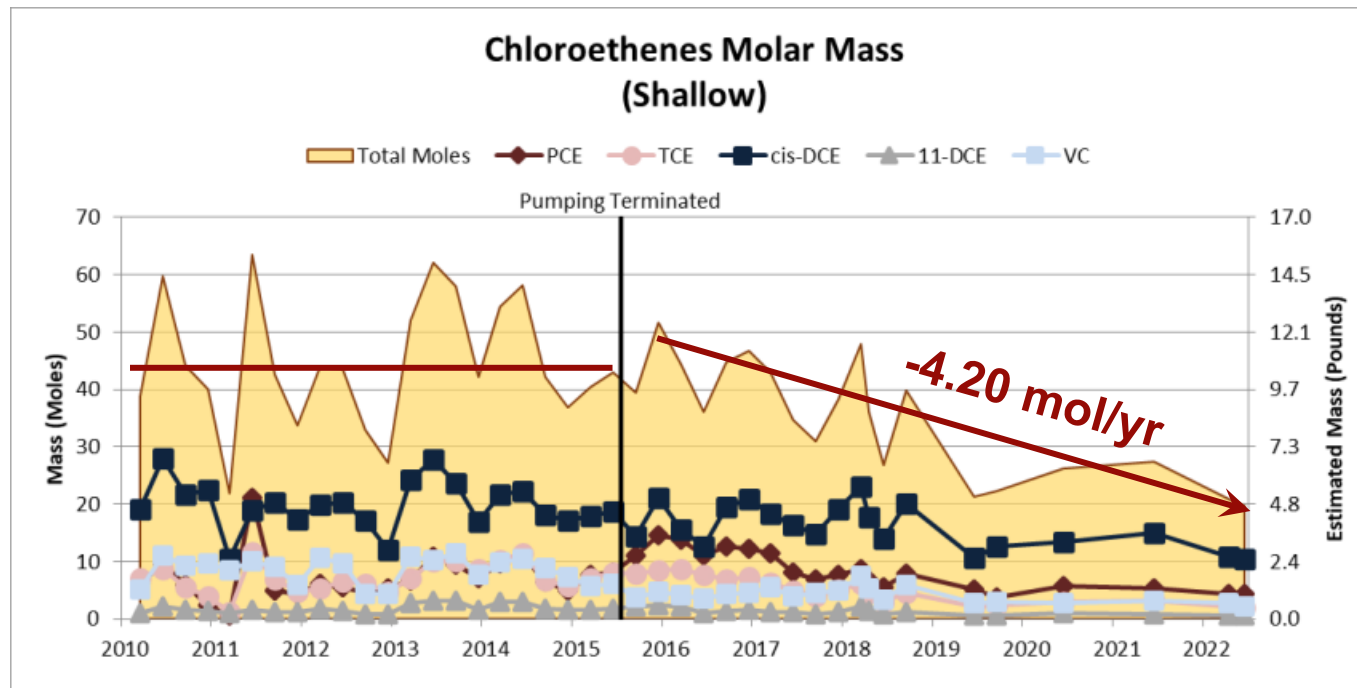
**Dec-2015 to Jun-2022**  
 Decreasing Trend  
 Mann-Kendall: >99% Confidence  
 Regression: >99% Confidence



**Dec-2015 to Jun-2022**  
 Decreasing Trend  
 Mann-Kendall: >99% Confidence  
 Regression: >99% Confidence

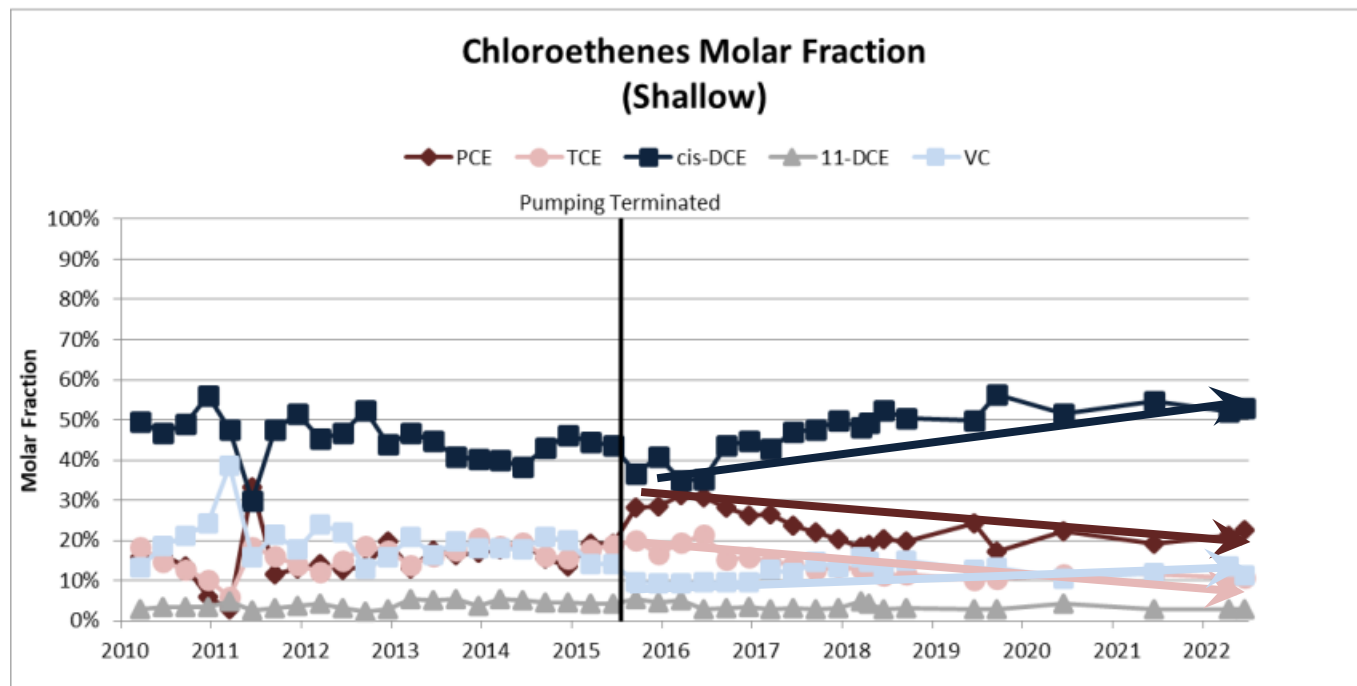


**Dec-2015 to Jun-2022**  
 Decreasing Trend  
 Mann-Kendall: >99% Confidence  
 Regression: >99% Confidence

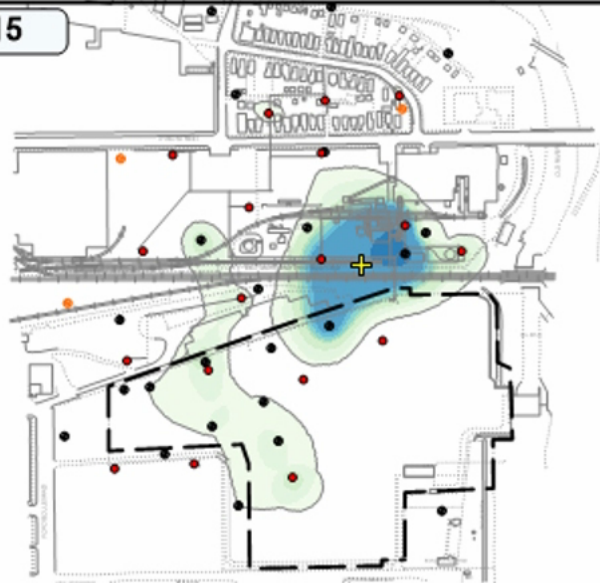


### Attenuation Rates

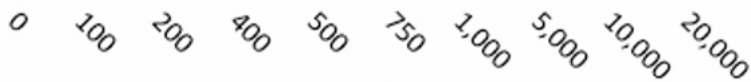
- PCE: -1.5 mol/yr
- TCE: -0.97 mol/yr
- cis-1,2-DCE: -1.2 mol/yr
- 1,1-DCE: -0.20 mol/yr
- VC: -0.36 mol/yr



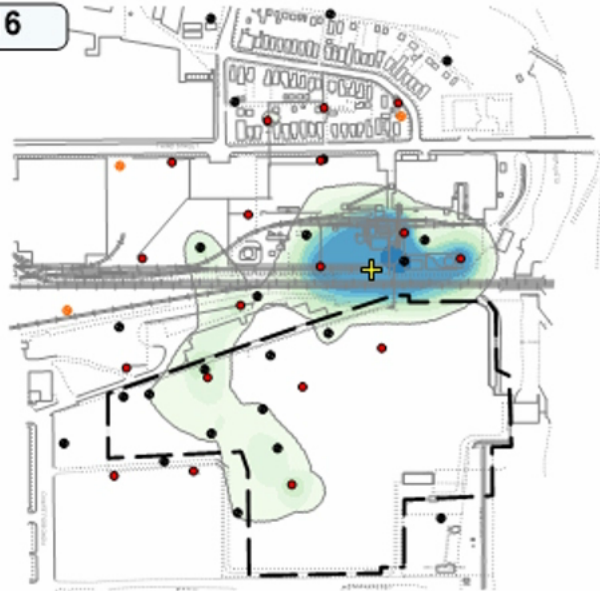
Dec-2015



Concentration (nmol/L)



Mar-2016

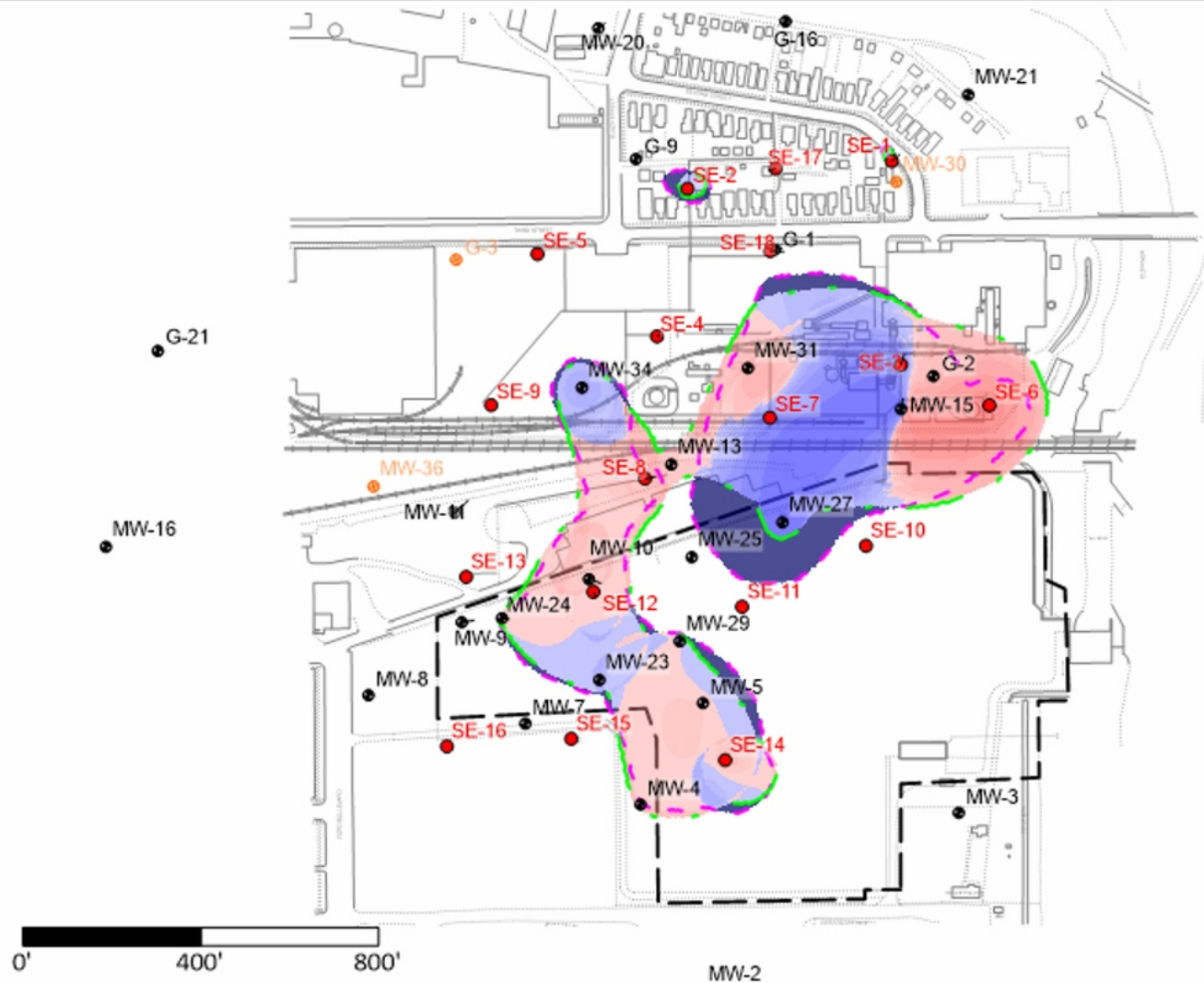


# Chloroethenes Shallow Spatial Changes Dec-2015 vs Mar-2016

## Plume Characteristics

Area: **1% Decrease**  
 Average Concentration: **13% Decrease**  
 Mass Indicator: **14% Decrease**  
 Mass Increase: **5.98 moles Increase**  
 Mass Decrease: **13.4 moles Decrease**

- MW-15 Monitoring Well
- SE-10 Extraction Well
- Orange square Hanging Well
- Yellow cross Center of Mass
- Purple dashed line Dec-2015 Plume Boundary
- Green solid line Mar-2016 Plume Boundary
- Black dashed line Approximate Property Boundary

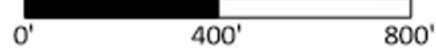


## Spatial Change Indicator™

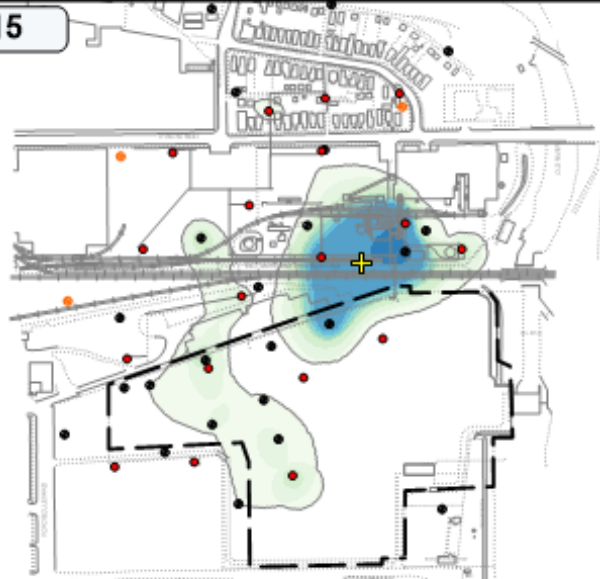
Increase



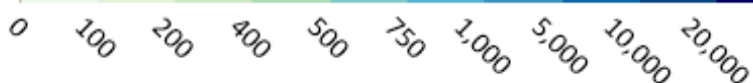
Decrease



Dec-2015



Concentration (nmol/L)



Jun-2022

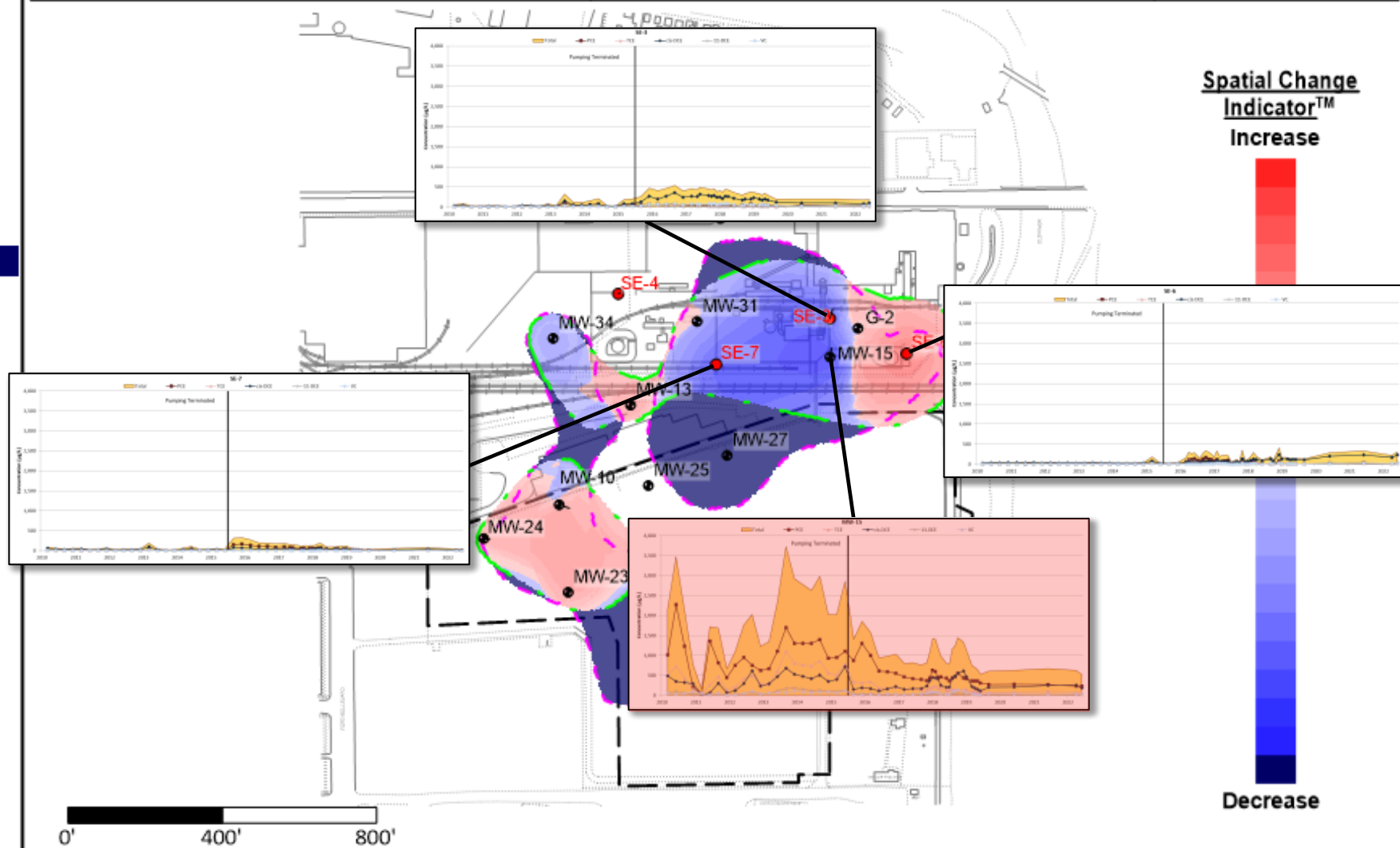


# Chloroethenes Shallow Spatial Changes Dec-2015 vs Jun-2022

## Plume Characteristics

Area: **29% Decrease**  
 Average Concentration: **47% Decrease**  
 Mass Indicator: **62% Decrease**  
 Mass Increase: **5.44 moles Increase**  
 Mass Decrease: **37.5 moles Decrease**

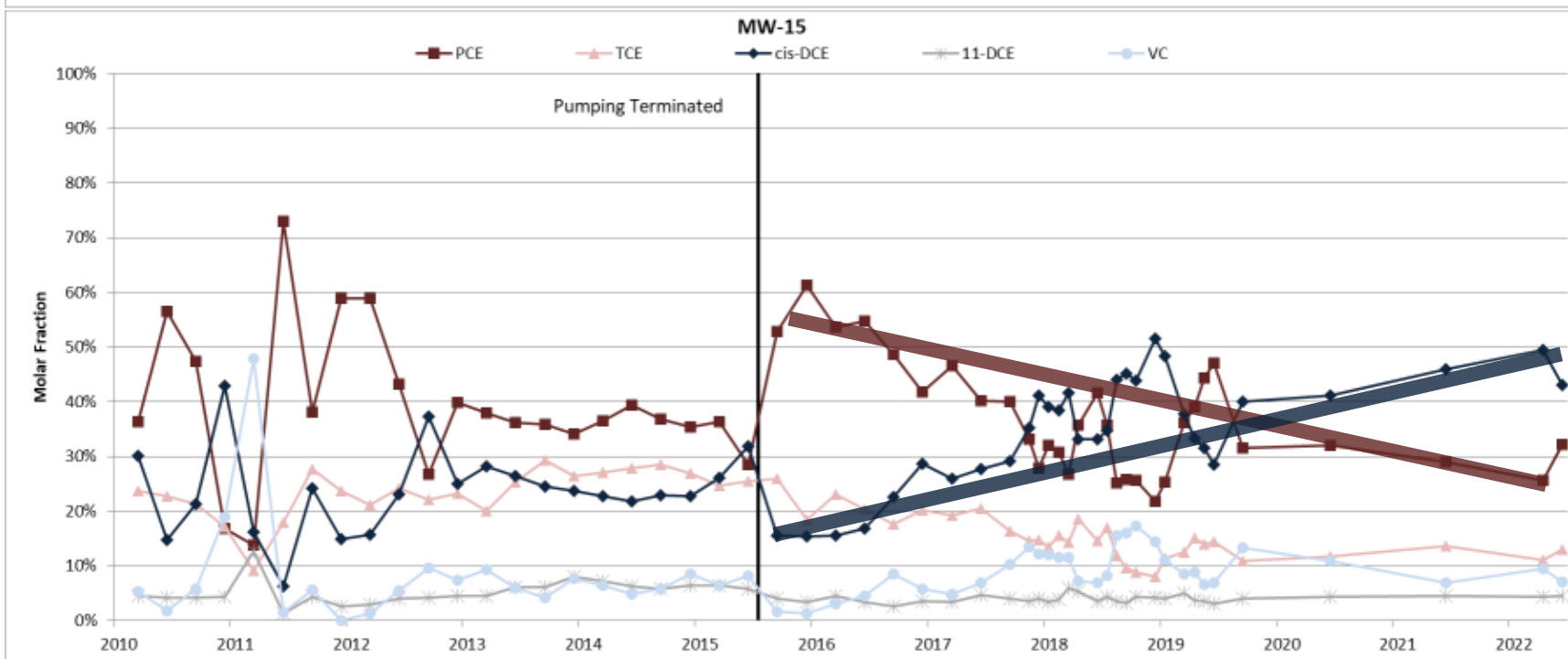
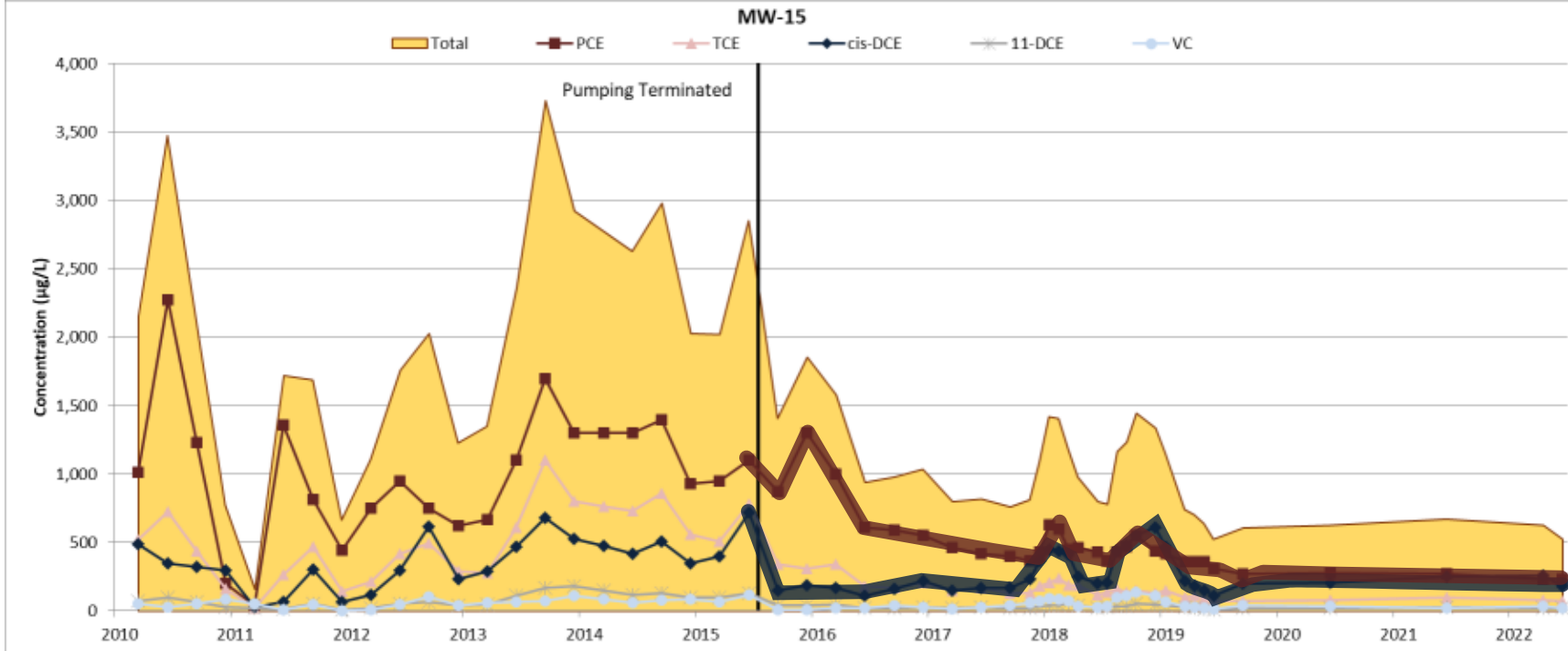
- MW-15 ■ Monitoring Well
- SE-10 ● Extraction Well
- G-2 ○ Hanging Well
- ⊕ Center of Mass
- Dec-2015 Plume Boundary
- Jun-2022 Plume Boundary
- Approximate Property Boundary



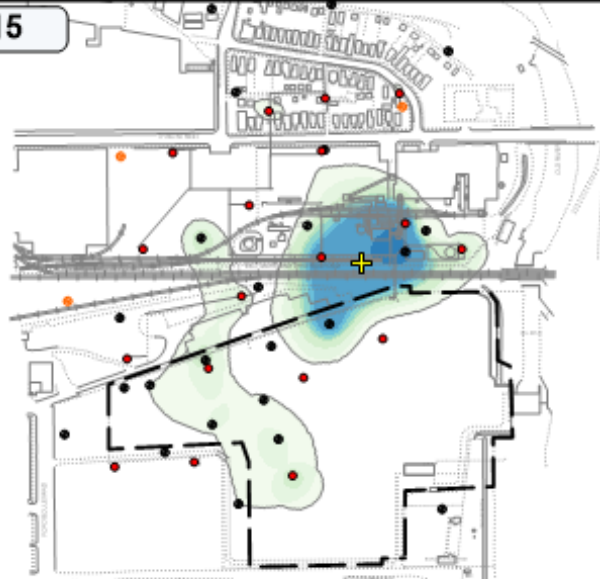
Spatial Change Indicator™  
Increase

Decrease

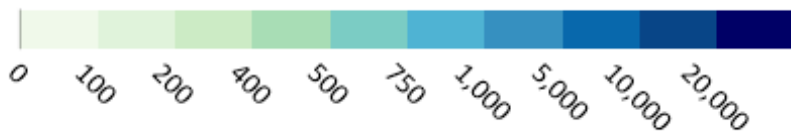
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Dec-2015



Concentration (nmol/L)



Jun-2022

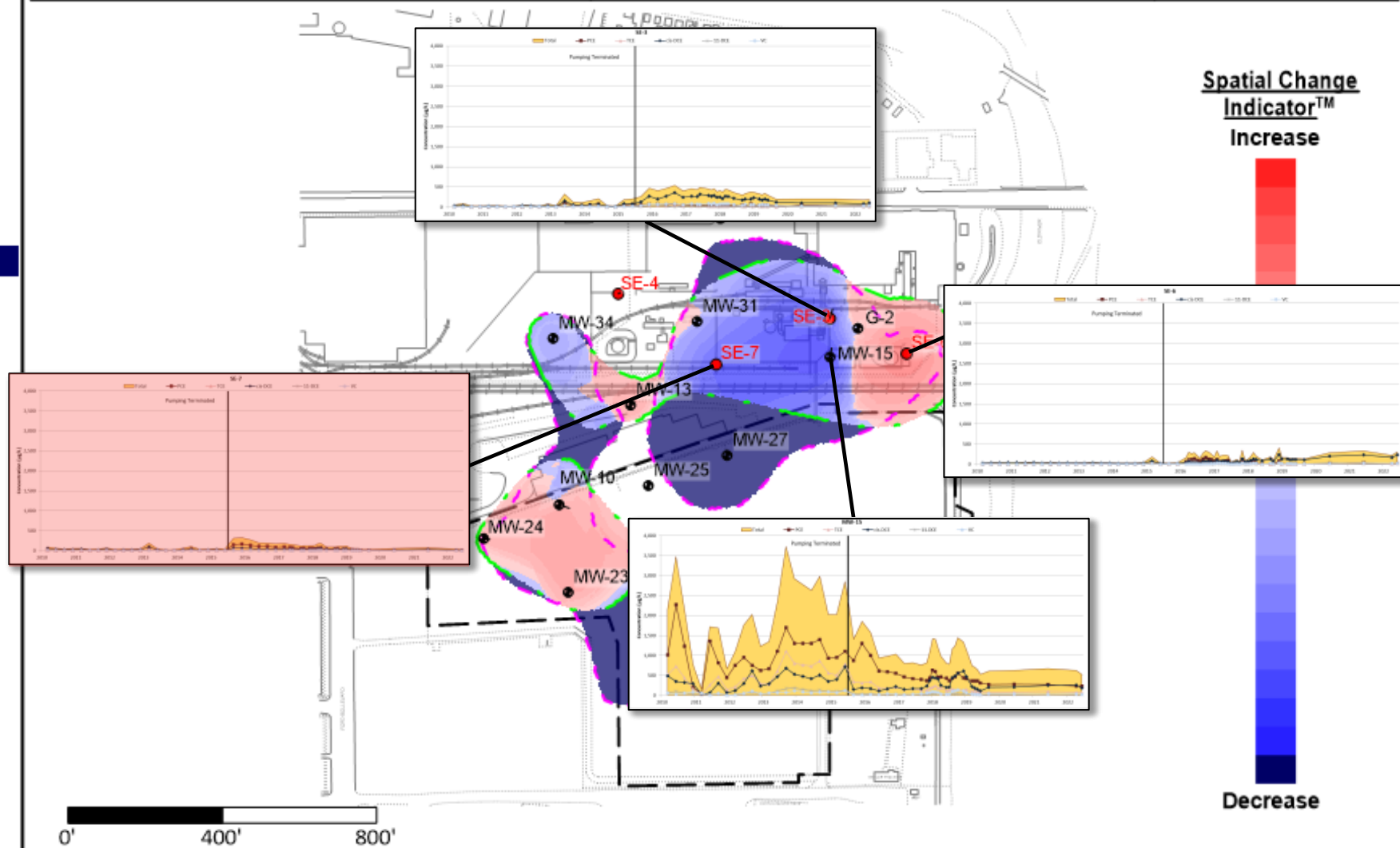


# Chloroethenes Shallow Spatial Changes Dec-2015 vs Jun-2022

## Plume Characteristics

Area: **29% Decrease**  
 Average Concentration: **47% Decrease**  
 Mass Indicator: **62% Decrease**  
 Mass Increase: **5.44 moles Increase**  
 Mass Decrease: **37.5 moles Decrease**

- MW-15 Monitoring Well
- SE-10 Extraction Well
- Hanging Well
- Center of Mass
- Dec-2015 Plume Boundary
- Jun-2022 Plume Boundary
- Approximate Property Boundary

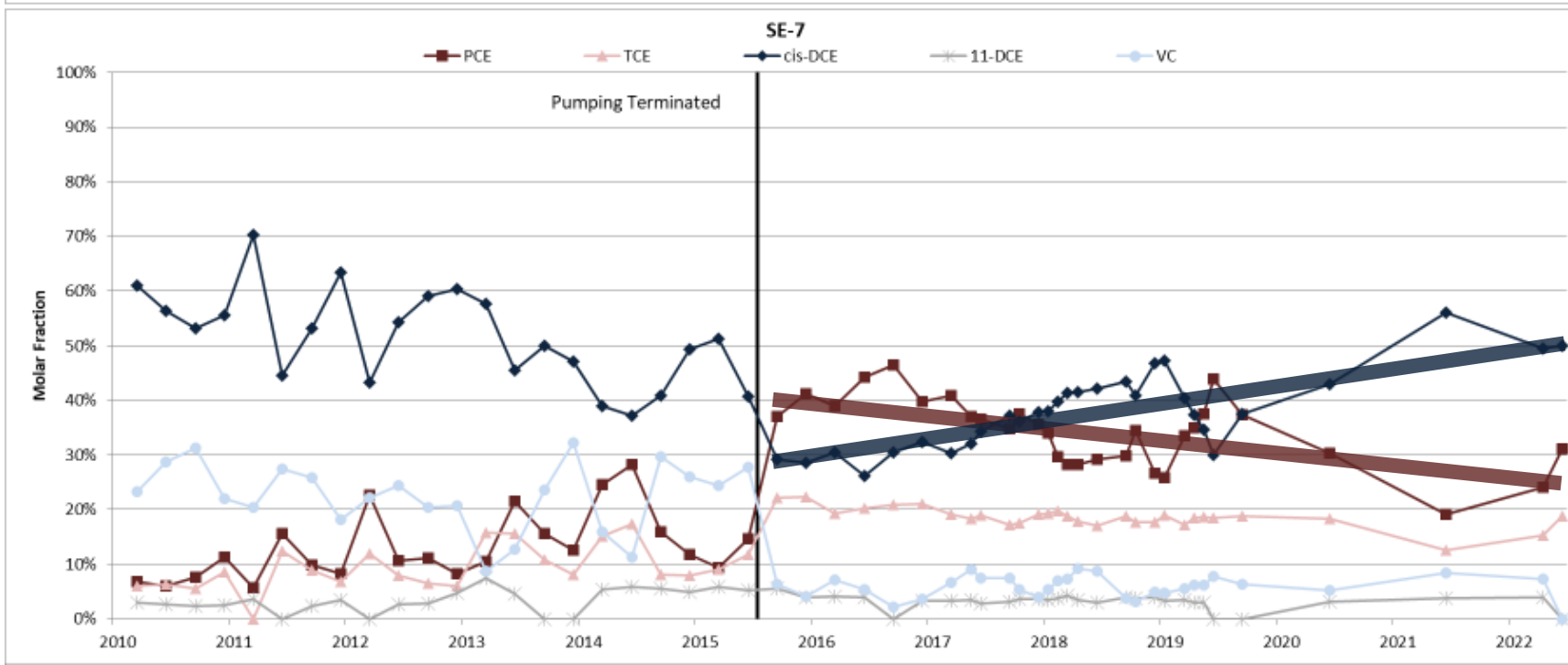
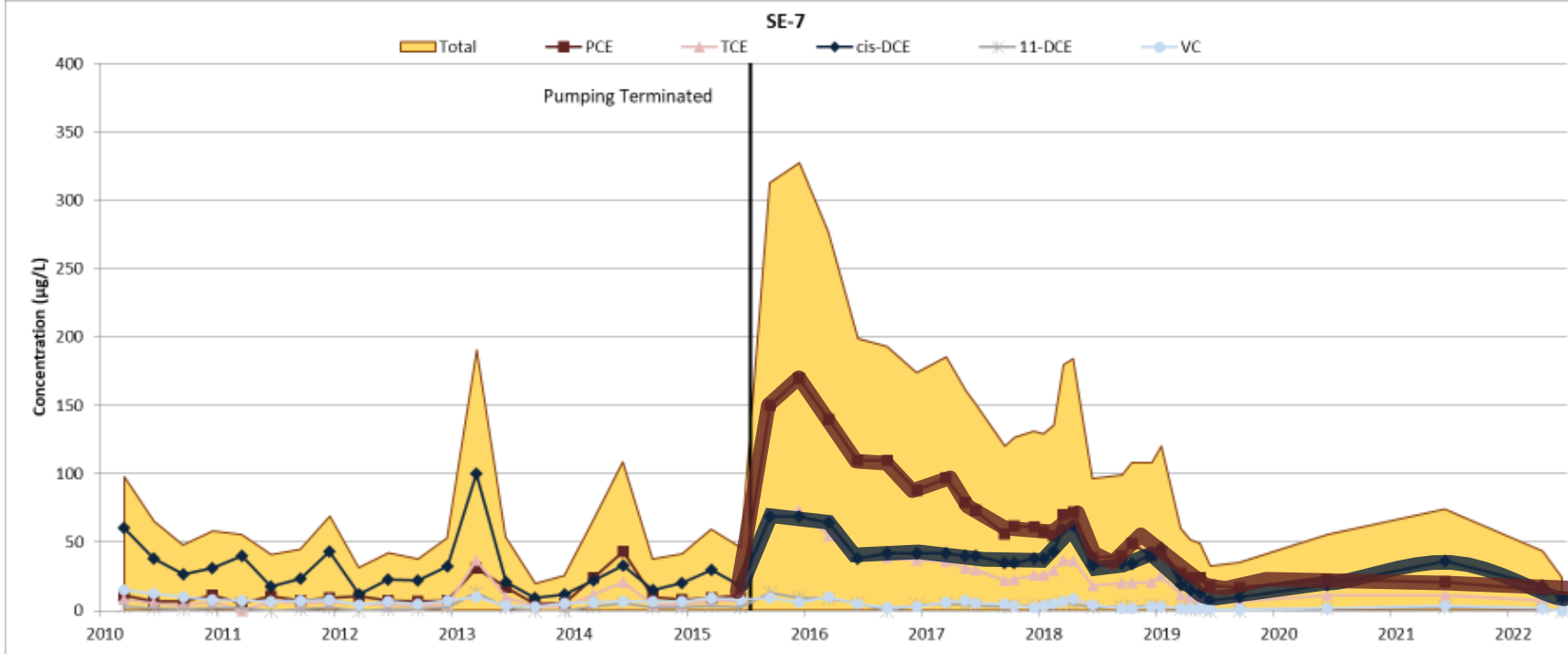


Spatial Change Indicator™  
Increase

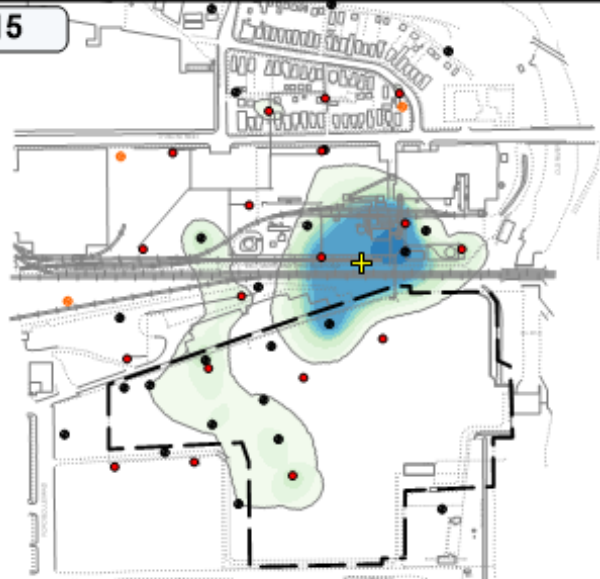
Decrease

0' 400' 800'

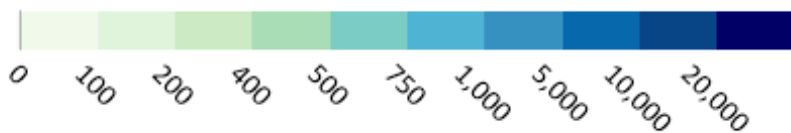




Dec-2015



Concentration (nmol/L)



Jun-2022

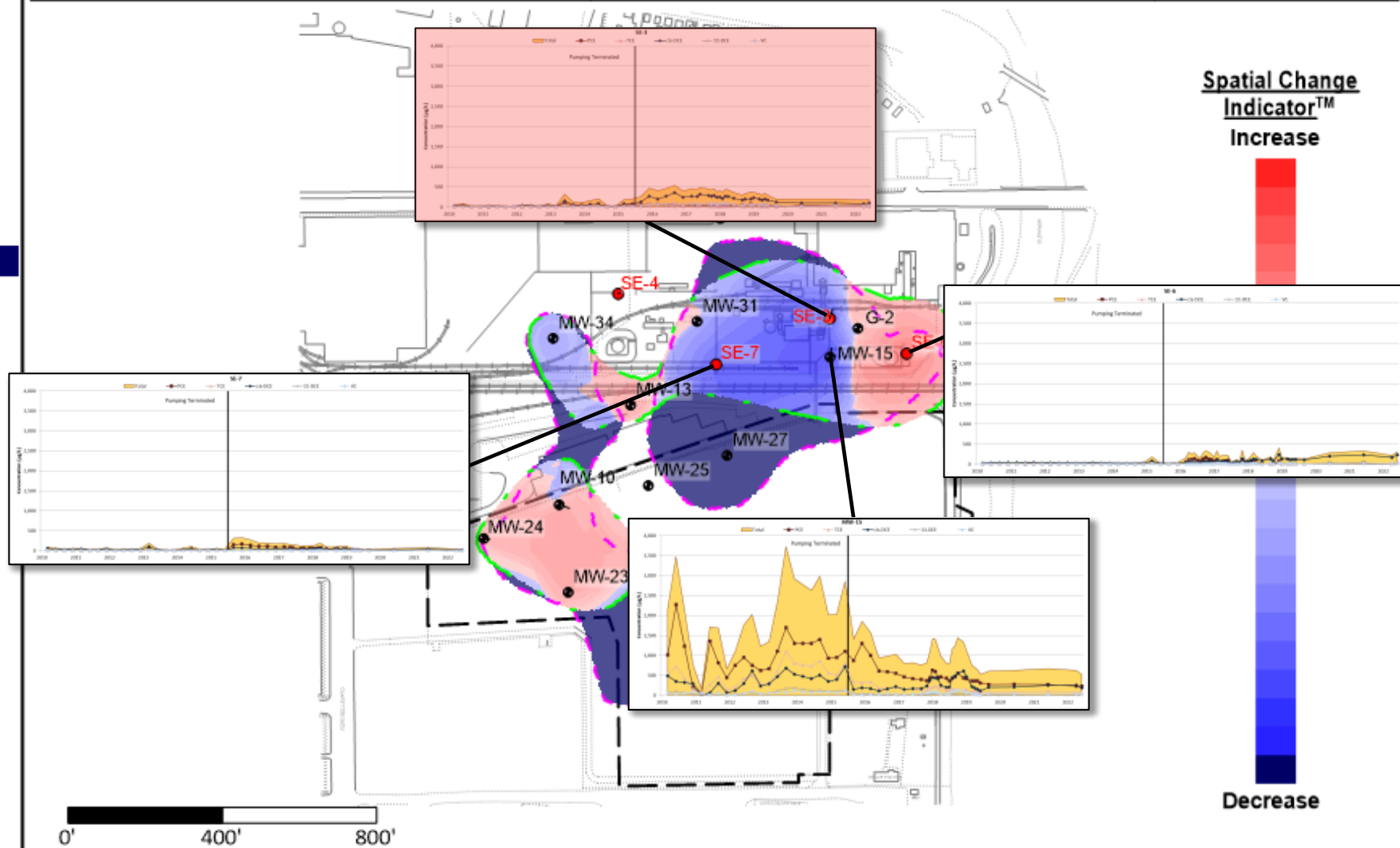


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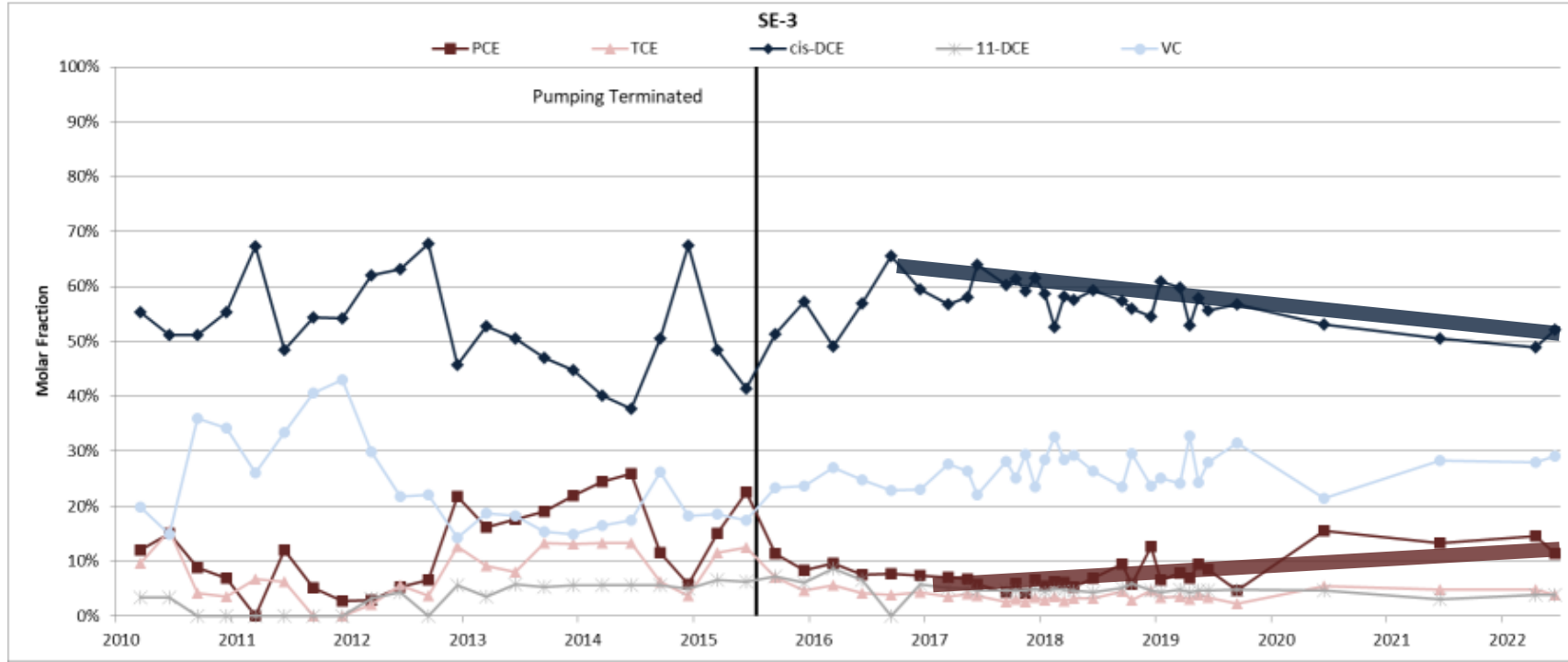
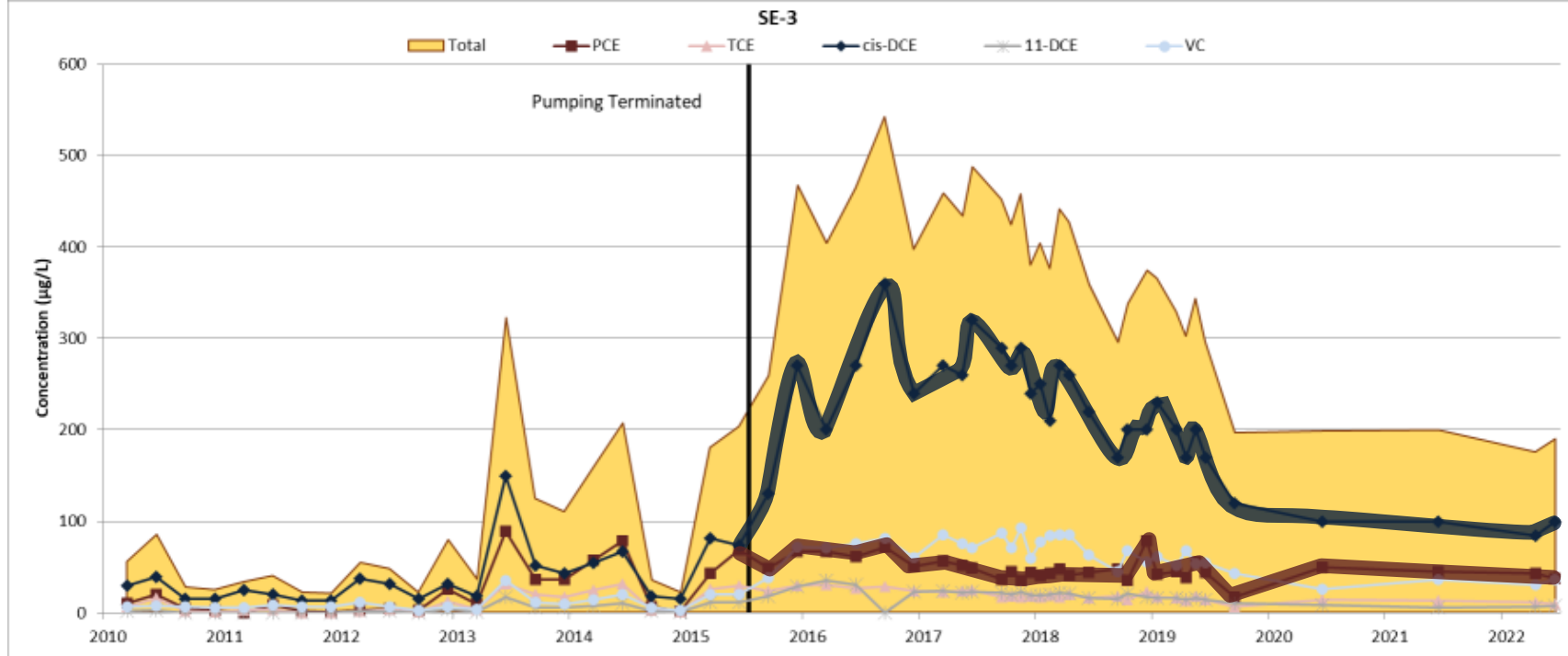
- MW-15 ■ Monitoring Well
- SE-10 ● Extraction Well
- G-2 □ Hanging Well
- ⊕ Center of Mass
- Dec-2015 Plume Boundary
- Jun-2022 Plume Boundary
- Approximate Property Boundary



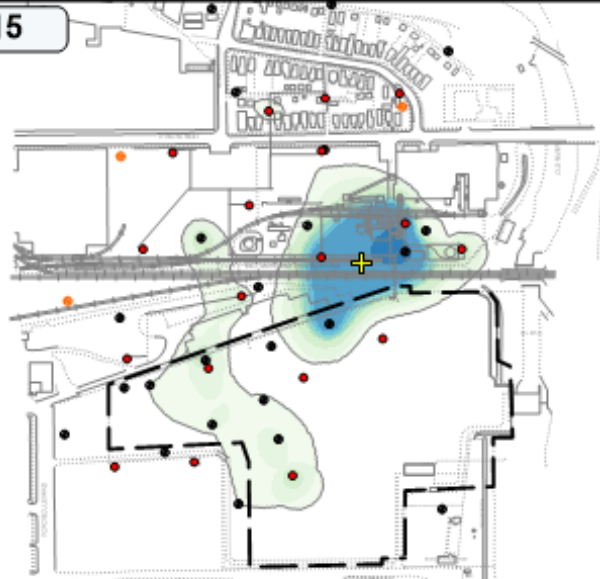
Spatial Change Indicator™  
Increase

Decrease

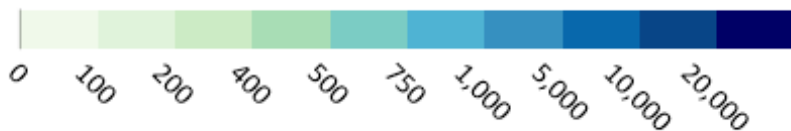
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Dec-2015



Concentration (nmol/L)



Jun-2022

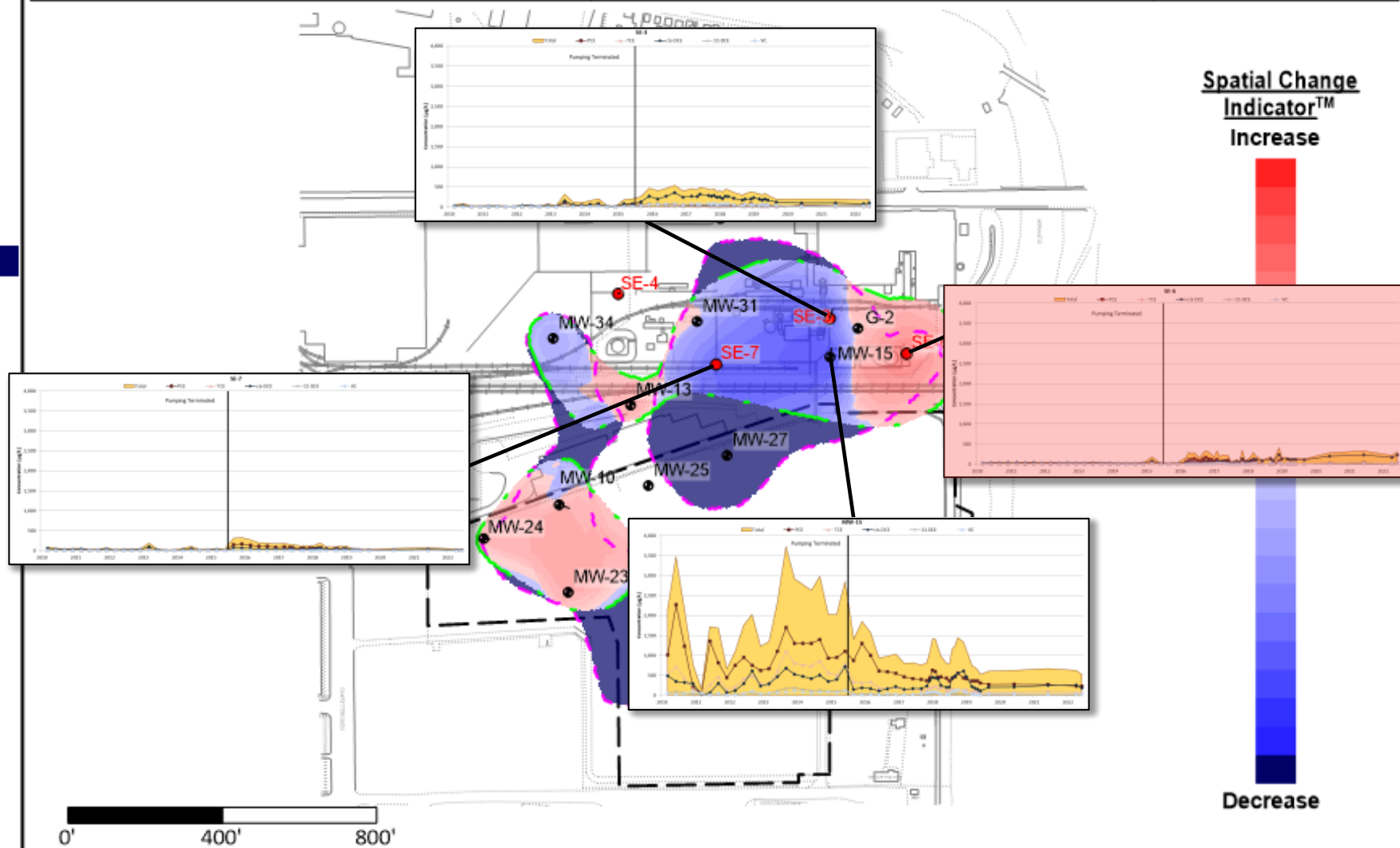


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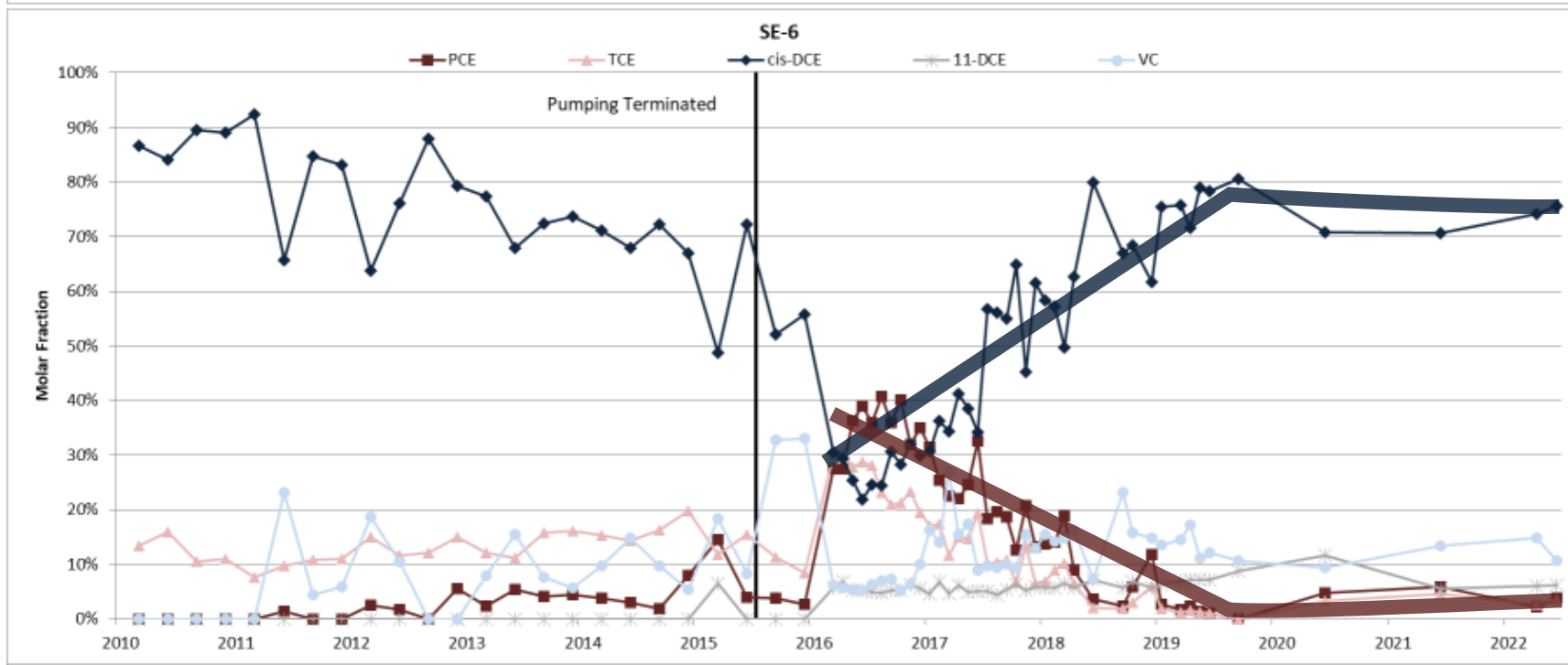
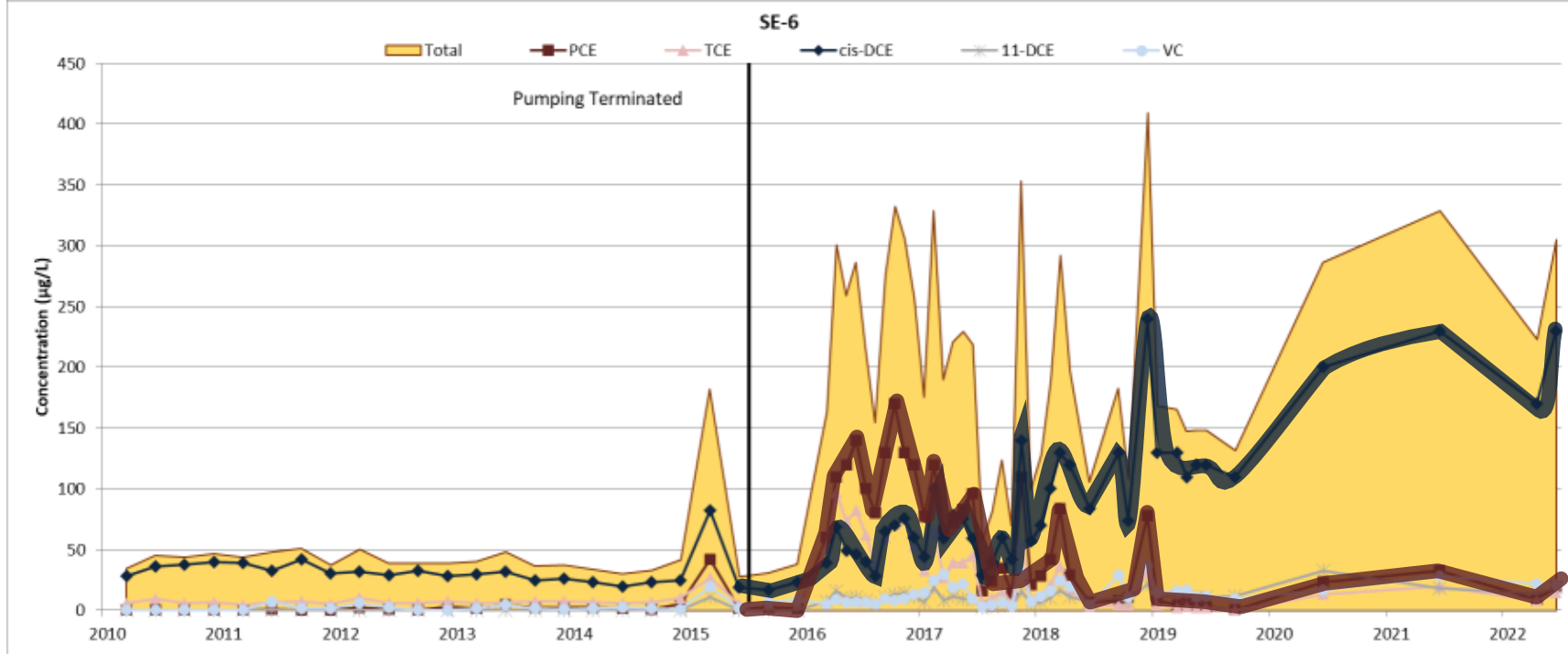
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- SE-10 Extraction Well
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- + Center of Mass
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- Approximate Property Boundary



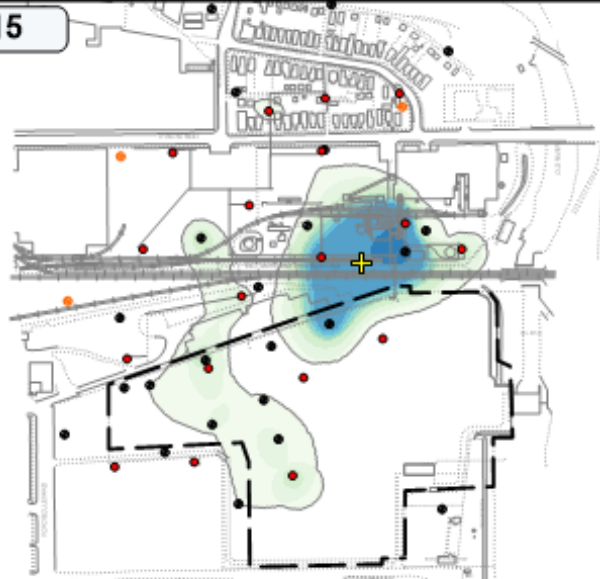
Spatial Change Indicator™ Increase

Decrease

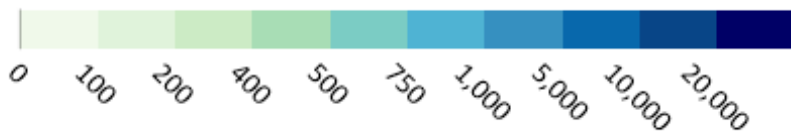
0' 400' 800'



Dec-2015



Concentration (nmol/L)



Jun-2022

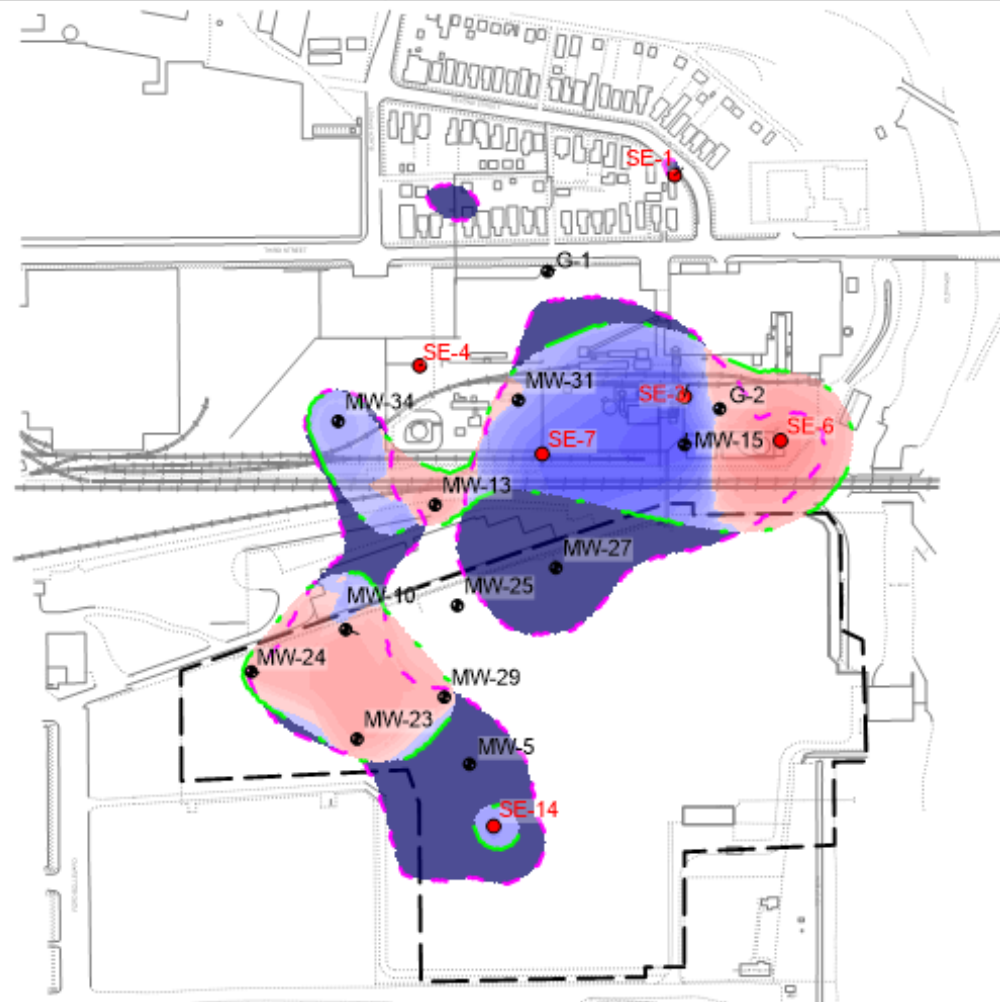


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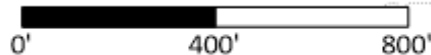
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Spatial Change Indicator™  
Increase



Decrease



# Chem-Dyne Superfund Site – Hamilton, Ohio

## Key Takeaways/Lessons Learned

- Strong empirical evidence of reductive dechlorination
- Although accumulation of daughter compounds observed, net attenuation can still be significant
- Will implement enhanced bioremediation in MW-15/SE-6 area



# Thank You

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