Aerobic Cometabolic Remediation of Chlorinated Ethenes as a Barrier to Impacted Groundwater Discharge to a Brook

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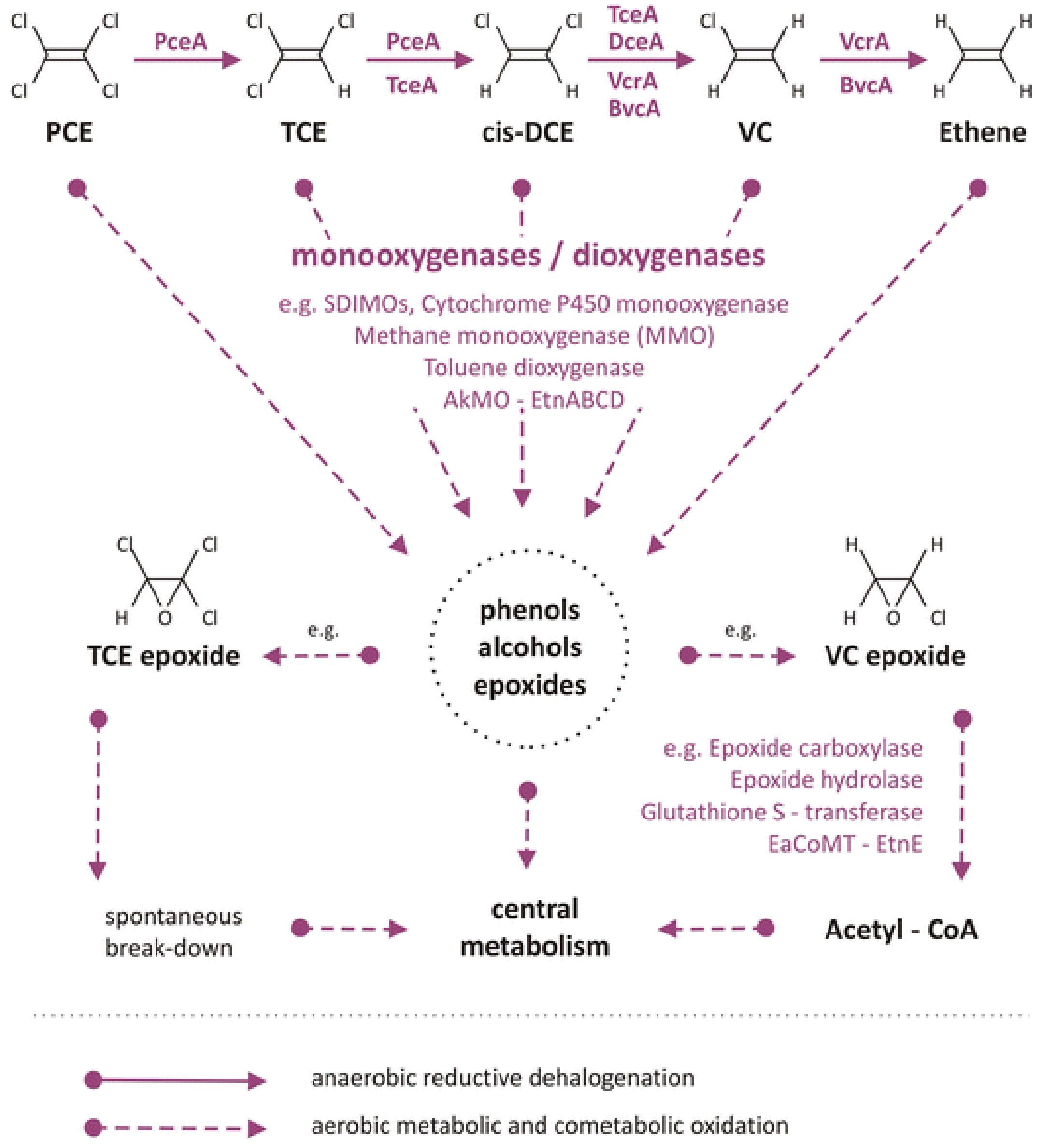
Co-Metabolic Process

- Can Occur Aerobically or Anaerobically
- Break down byproducts
  - Ethene
  - Co2 and water
- Applicable where there are chlorinated and BTEX plumes mixed together
- Also applicable where a growth substrate is injected




HW-29S
1
HW-9S
1
HW-44I
1
HW-44S
126
10
HW-45I
1
HW-58I
1
HW-1S
1.9
100
10
1000
HW-32S
2200
HW-41S
15600
HW-41I
64.1
HW-43S
22.2
HW-31BS
265
HW-58S
582
HW-45S
27.9
100
HW-40S
5730
HW-43I
0.8
HW-31S
2420
HW-35S
13900
10000
HW-46S
41
HW-32BS
173
HW-30S
1
HW-33S
87
HW-36S
15.3
HW-30BS
17.4
HW-14S
1
HW-23S
1

Knowns/Unknowns

- Residual product impacts in ROM area - VOC concentrations in 2020 and in intermediate and deep VOC concentrations in 2021.

- Anticipate long-term source contributions from groundwater

- Shallow groundwater impacts in Upper Vincentown primarily consist of VOCs DCE, VC, absent PCE and TCE. Brook Sampling Finds VC in stream

- Toluene and xylene present in the northern part of the Site.

- Mostly aerobic/anoxic, with low DO concentrations. BioTrap genetic evidence of potential aerobic co-metabolic processes for biodegradation of TCE, DCE, VC in groundwater

- Site appears to be in DCE/VC Stall. Anaerobic Degradation could increase DCE/VC concentrations

Knowns/Unknowns

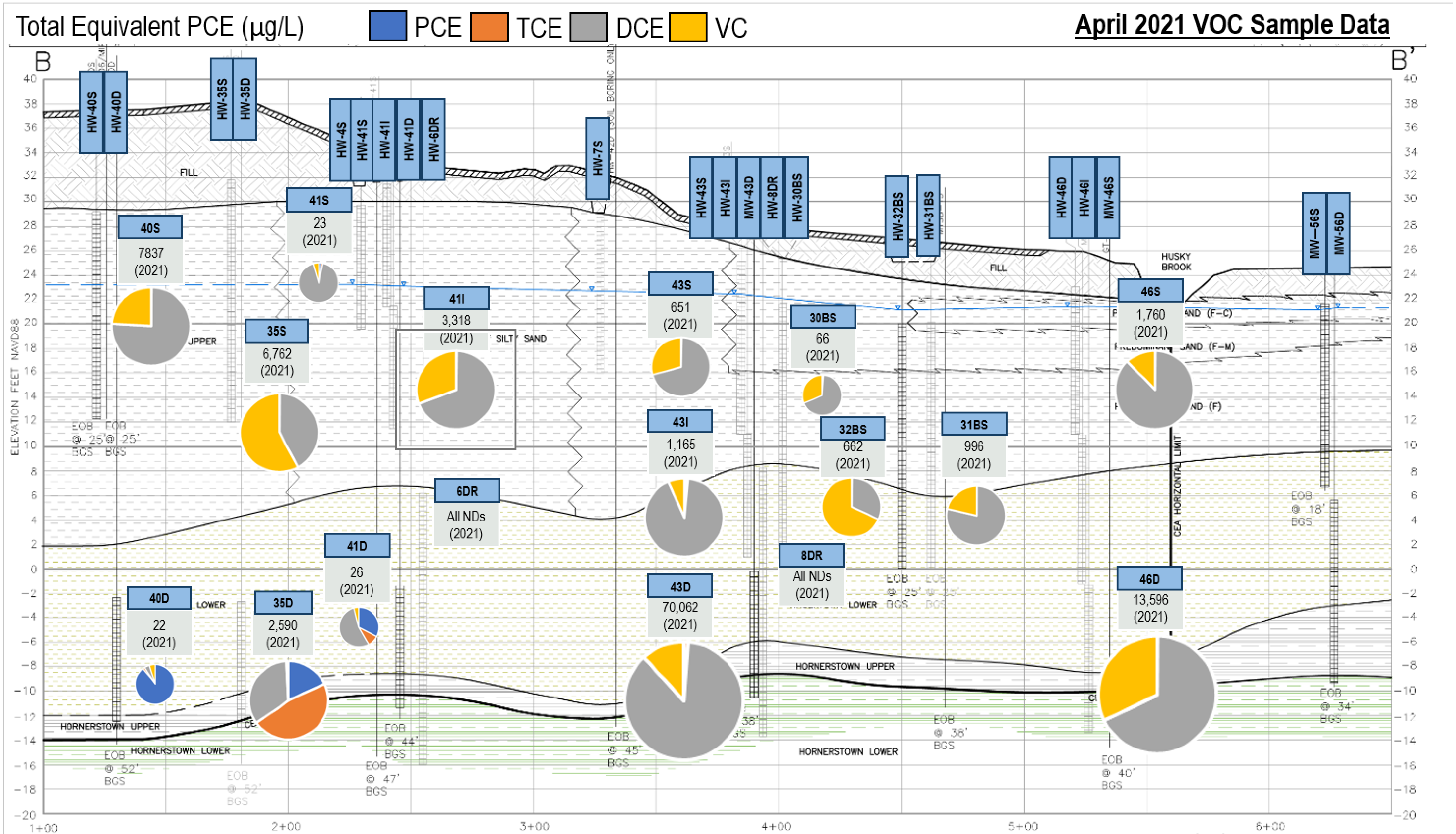
- Historical evidence of BTEX plume upgradient of CVOC impacts
- Groundwater velocity in upper Vincentown 0.33 ft/day upgradient to 1.5 ft/day downgradient, order of magnitude less in lower Vincentown.
- Deep groundwater in Lower Vincentown low to no DO. PCE present along with degradation byproducts, at HW-43D DCE and VC predominate.
- A series of technologies have been implemented at the site with varying levels of success.
  - *Several Removal Actions to Eliminate Soil Sources to groundwater*
  - *Site-wide ISCO*
  - *Groundwater Pump and Treat*
- Vinyl Chloride impacts had still reached the Stream
- Subsequent to ISCO Site was redeveloped, building (box store) installed prior to Site Closure
- Residuals could be beneath building contributing to long term groundwater impacts

Vinyl Chloride Mass Flux to [redacted] Brook

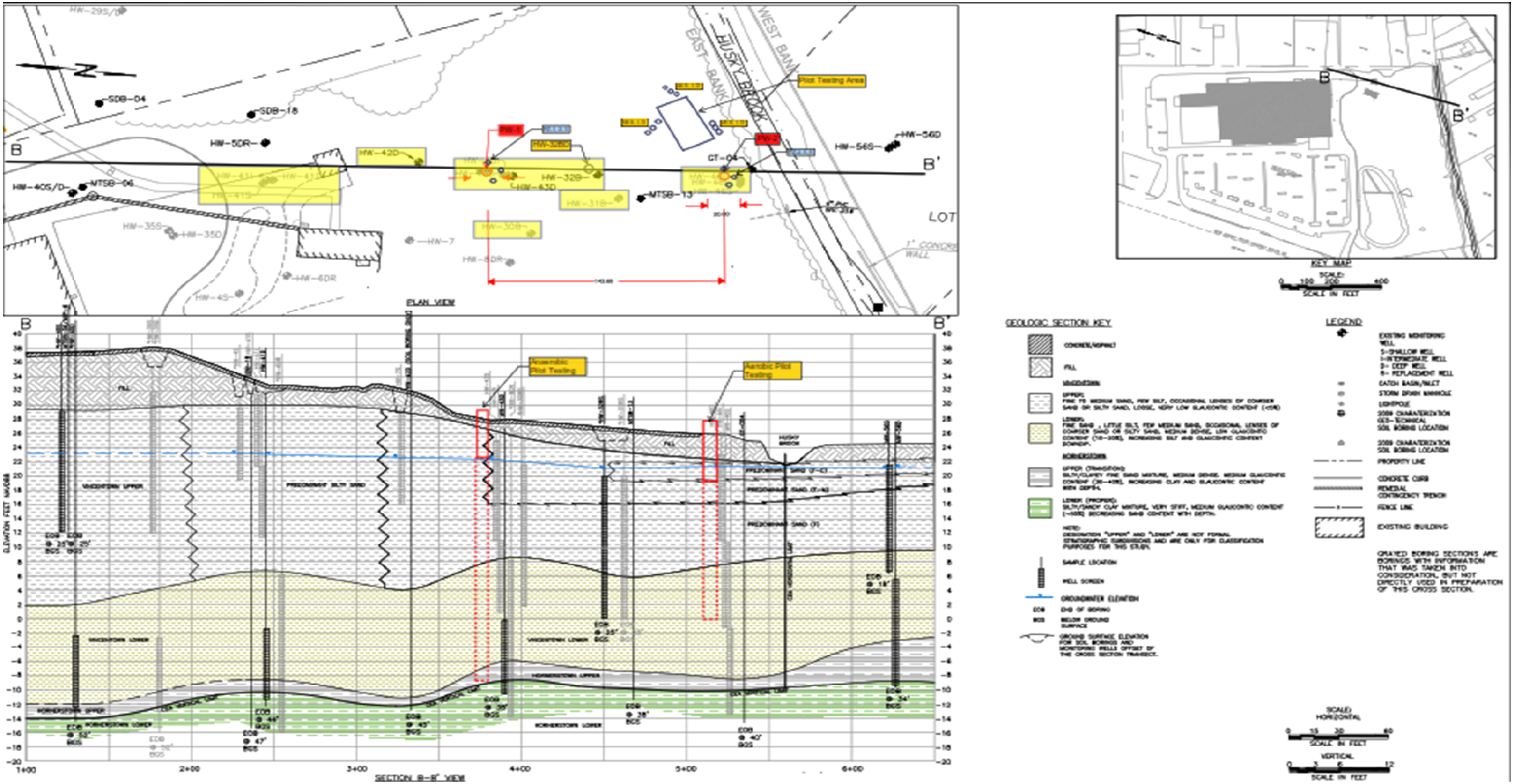
- Mass flux was calculated for [redacted] Brook river cells in the vicinity of the plume. These values were summed to obtain the total mass flux.

Scenario	Description	Total Mass Flux (g/day)	Percent Reduction
1	No Treatment	4.68	NA
2	Treatment in the Lower VT	4.22	10%
3	Treatment in the Upper VT	1.10	76%
4	Treatment in the lower and Upper VT	0.63	87%

Mutch Associates, LLC
Environmental Engineers and Scientists

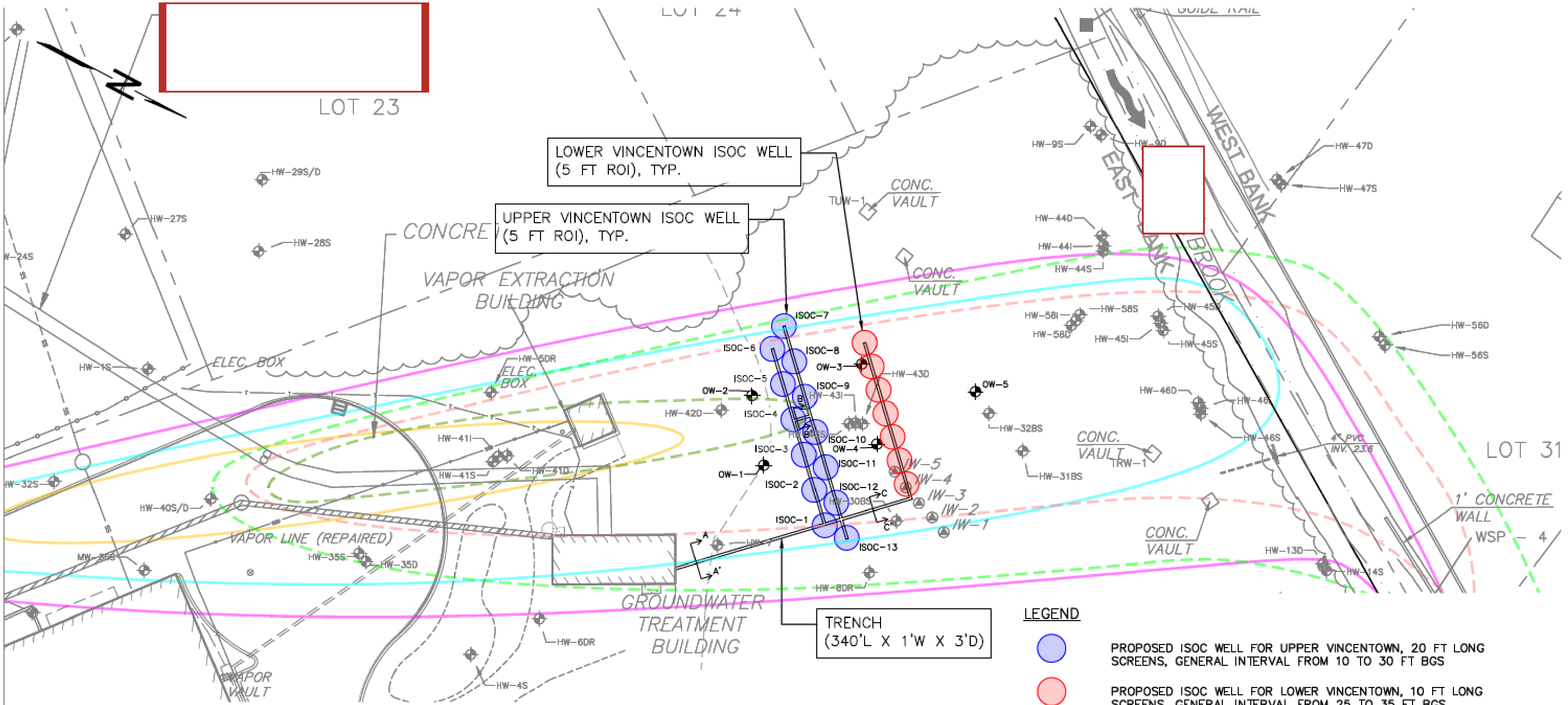


Total Equivalent PCE (µg/L)
PCE
TCE
DCE
VC
April 2021 VOC Sample Data
B
B'
ELEVATION FEET NAVD88
40S
7837
(2021)
41S
23
(2021)
35S
6,762
(2021)
41I
3,318
(2021)
6DR
All NDs
(2021)
41D
26
(2021)
40D
22
(2021)
35D
2,590
(2021)
43S
651
(2021)
30BS
66
(2021)
43I
1,165
(2021)
32BS
662
(2021)
31BS
996
(2021)
8DR
All NDs
(2021)
43D
70,062
(2021)
46S
1,760
(2021)
46D
13,596
(2021)
HW-40S
HW-40D
HW-35S
HW-35D
HW-4S
HW-41S
HW-41I
HW-41D
HW-6DR
HW-7S
HW-43S
HW-43I
MW-43D
HW-8DR
HW-30BS
HW-32BS
HW-31BS
HW-46D
HW-46I
MW-46S
MW-56S
MW-56D
FILL
HUSKY BROOK
HORNERSTOWN UPPER
HORNERSTOWN LOWER
CEA HORIZONTAL LIMIT
1+00
2+00
3+00
4+00
5+00
6+00



PLAN VIEW
SECTION B-B' VIEW
KEY MAP
SCALE IN FEET
GEOLOGIC SECTION KEY
LEGEND
Pilot Testing Area
Anaerobic Pilot Testing
Aerobic Pilot Testing
HUSKY BROOK
EAST BANK
WEST BANK
LOT
SDB-04
SDB-18
HW-5DR
HW-42D
HW-32BD
HW-32B
HW-43D
HW-31B
HW-30B
HW-40S/D
MTSB-06
MTSB-13
HW-35S
HW-35D
HW-7
HW-6DR
HW-4S
HW-8DR
HW-56S
HW-56D
GT-04
PW-1
PW-2
B
B'
FILL
VINCENTOWN UPPER
VINCENTOWN LOWER
HORNERSTOWN UPPER
HORNERSTOWN LOWER
ELEVATION FEET NAVD88
1+00
2+00
3+00
4+00
5+00
6+00

Technology	ISCO	ISCR and ERD	ERD	Cometabolism
Technology Description	In Situ chemical oxidation (ISCO) includes injection of Klozur® SP..Approximately 135,000 lbs of Klozur® SP and 185,000 lbs of 25% NaOH.	In Situ chemical reduction (ISCR) and enhanced reduction dichlorination (ERD) includes injection of biogeochemical reagents that are specifically designed to perform chemical reduction, biological reduction and generate reactive iron sulfide minerals	ERD includes injection of a complex organic substrate and Dhc microbial bacteria to enhance anaerobic bioremediation of chlorinated VOCs present at the Site.	Installation of a injection system for compressed gases (primary substrate) and nutrients to support cometabolism. Site requires increasing the current populations of microbial organisms at the Site on a primary substrate (e.g. propane).
Implementability	Klozur® SP is soluble and can be applied using direct push temporary or permanent injection wells in the treatment area ranging from approximately 30 ft bgs to 42 ft bgs. Mobilization of metals at high pH is not anticipated to occur as the site has adequate base buffering capacity 0.40 g 25% NaOH /kg dry soil. Injection pressure and flow relationship should be tested on the first day of injection.	GeoForm® Extended Release is typically slurried with water (25 to 35% solution) and injected using direct push point using medium injection pressure (>30 psi). Typical ROI will be 5 to 7 ft, . Thinner slurry will promote permeation into more permeable formations, whereas a more concentrated/more viscous slurry will promote fracturing and horizontal propagation into more fine-grained formations. Metal mobilization is not anticipated to occur as insitu generation of iron sulfide minerals will prevent it.	ELS® microemulsion is soluble and can be applied using direct push temporary or permanent injection wells in the treatment area Groundwater velocity of 0.13 ft per day "tighter formation" and may have a low radius of influence ~10 to 12 ft of injected reagents. Mobilization of naturally existing iron may occur as reducing conditions persist that enhances the dissolution of iron from the soil..	Permanent wells and an automated injection system will be required for injection of compressed gases. When diffusion based injection technology is used it can lead to larger ROI over time. Permit by rule application will be required prior to starting field injection work.
Cost	High. Cost of injection reagents alone is over $300k due to high SOD value(>15 mg/Kg), Additional injection rounds could significantly increase cost.	Medium. Cost of material is ~$105k.Drilling (direct push) and Injection duration is estimated to be 10 days @ $5,000 per day.	Low. Cost of material is ~$50k to $100k. Drilling (direct push) and Injection duration is estimated to be 10 days @ $5,000 per day.	Low to Med. Assuming incorporation of UV System modifications and piping.. Annual O&M cost low .,



LEGEND

PROPOSED ISOC WELL FOR UPPER VINCENTOWN, 20 FT LONG SCREENS, GENERAL INTERVAL FROM 10 TO 30 FT BGS

PROPOSED ISOC WELL FOR LOWER VINCENTOWN, 10 FT LONG SCREENS, GENERAL INTERVAL FROM 25 TO 35 FT BGS

PROPOSED MONITORING WELL

Upper Vincentown Formation VC Iso-concentration Contours

- VC – 10 mg/L Contour
- VC – 1 mg/L Contour
- VC – 0.1 mg/L Contour

Lower Vincentown Formation VC Iso-concentration Contours

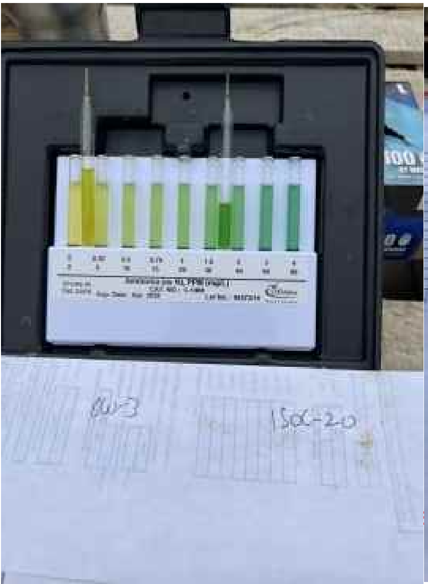
- VC – 10 mg/L Contour
- VC – 1 mg/L Contour
- VC – 0.1 mg/L Contour

NOTES:

ROI Radius of Influence
ft feet

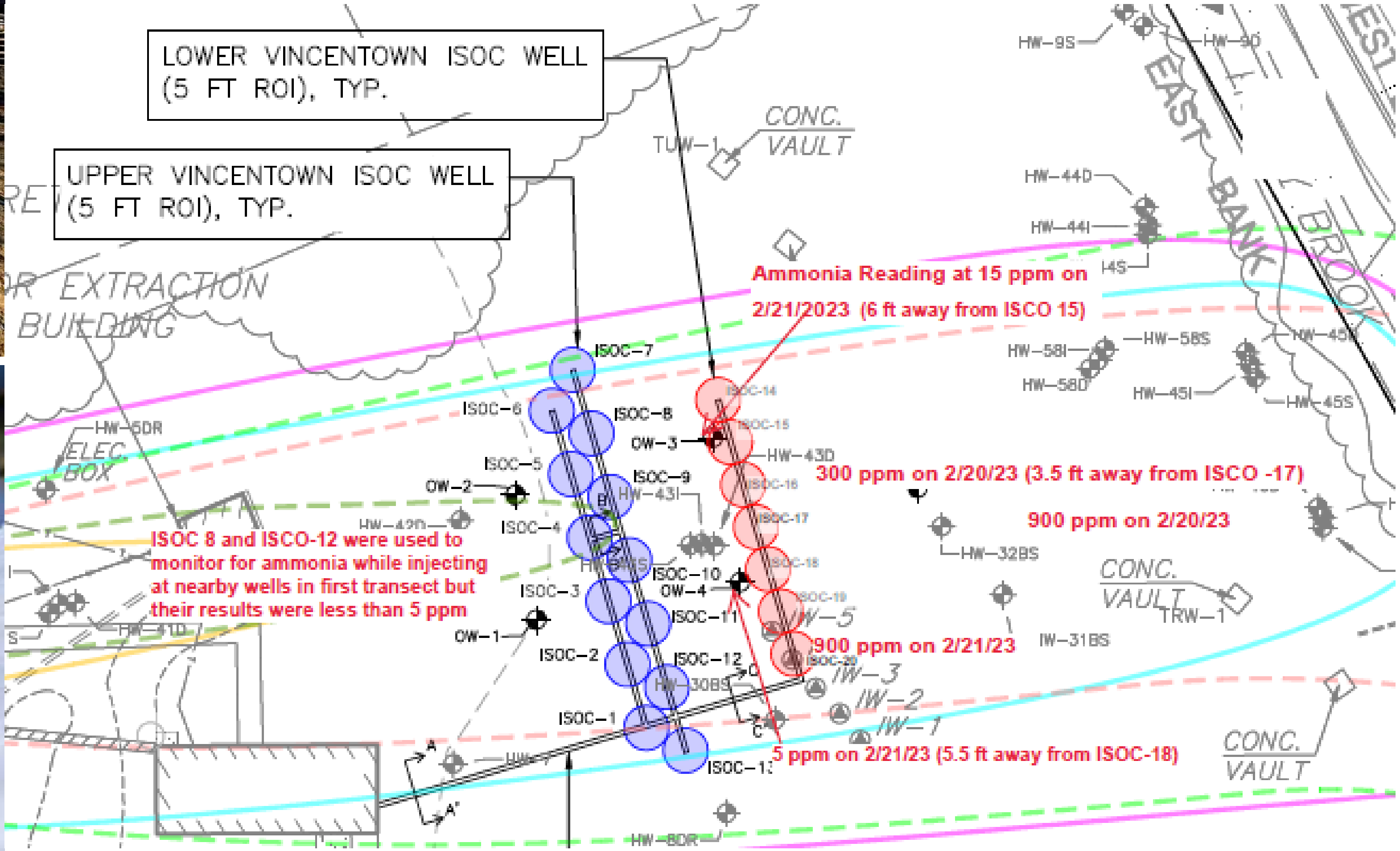
1. THE APPROXIMATE LOCATION OF VINYL CHLORIDE CONTOURS ARE BASED ON THE GROUNDWATER MODELING PRESENTED IN FIGURE 6-3 (LAYER 3 AND LAYER 13): "VINYL CHLORIDE-UPPER & LOWER VINCENTOWN TREATMENT" PREPARED BY MUTCH ASSOCIATES, LLC.
2. THE WELL SCREEN AND RISER WILL BE CONSTRUCTED FROM POLYVINYL CHLORIDE (PVC) SCHEDULE 40 AND ALL BURIED PIPE SLEEVES SHALL BE EITHER PVC SCHEDULE 80 OR HIGH DENSITY POLYETHYLENE (HDPE) SDR 11 OR MATERIALS APPROVED BY THE ENGINEER.
3. BEFORE BEGINNING OF TRENCHNG AND WELL INSTALLATION ACTIVITIES, TREES AND STUMP REMOVAL WILL BE PERFORMED TO FACILITATE REMEDIATION RELATED INTRUSIVE ACTIVITIES.
5. UNDERGROUND UTILITIES AND STRUCTRES TO BE LOCATED THRU ABOVE GRADE UTILITY LOCATING TECHNIQUES. THE LOCATION OF THESE UTILITIES ARE NOT EXACT AND SHOULD BE CONSIDERED APROXIMATE. THE CONTRACTOR SHALL VERIFY THE LOCATION OF ALL EXISTING UTILITIES OR STRUCTURES IN THE AREA OF WORK (CALL BEFORE YOU DIG: NJ 1 CALL).
6. CONTRACTOR SHALL OBTAIN ALL LOCAL PERMITS AND APPROVALS TO EXECUTE THE SCOPE OF WORK.
7. ALL WORK WILL BE CONDUCTED WEEKDAYS BETWEEN THE HOURS OF 8:00 AM AND 6:00 PM, IN ACCORDANCE WITH MUNICIPAL CODES AND ZONING ORDINANCE REQUIREMENTS.
8. THE CONTRACTOR SHALL DOCUMENT EXISTING CONDITIONS PRIOR TO EXCAVATION WORK.

DAP Injection



- 1,000 gallons @900 ppm of DAP was injected in each ISCO well followed by 100 gallons of fresh water

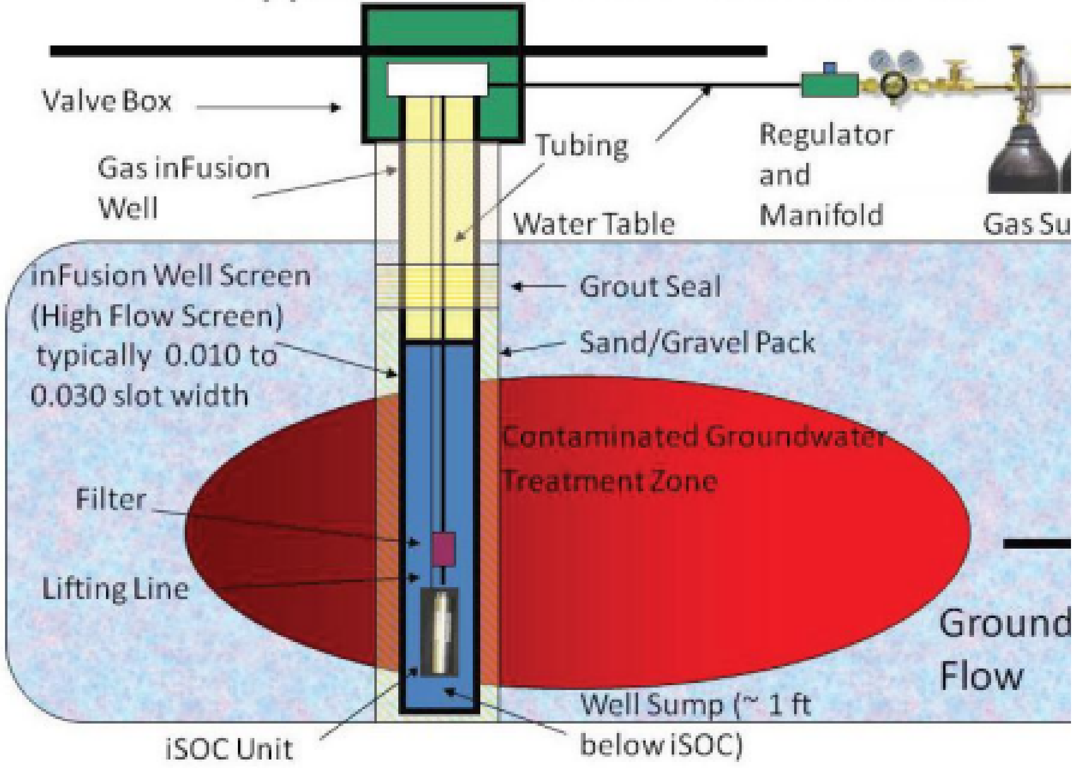
- Measuring Ammonia concentration using field colorimetric kit was challenging- tint was not perfect match due to presence of iron and chlorine in the water



How iSOC® Works

The patented gas infusion technology achieves supersaturated levels of dissolved gases in liquids. iSOC® features a structured polymer mass transfer device containing a hydrophobic microporous hollow fiber that provides an enormous surface area – approximately 7,000 square feet of interface area per cubic feet of material – for excellent mass transfer. The internal control valve maintains proper gas pressure ensuring mass transfer without bubbles or sparging.

Typical iSOC Well Schematic



Remedial Approaches

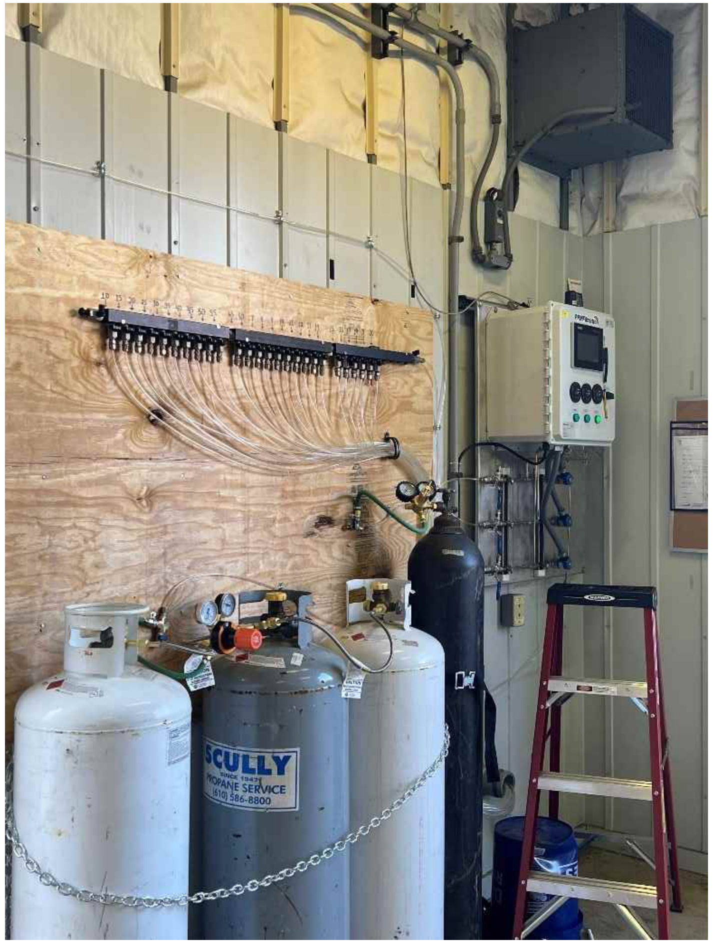
- O_2 for aerobic degradation - hydrocarbons, MTBE, vinyl chloride
- H_2 for anaerobic degradation of chlorinated compounds **(HiSOC®)**
- Alkane gas and O_2 for cometabolic degradation of recalcitrant compounds

These remedial approaches have been used on active gas stations, rail yards, landfills, remote pipeline sites, chemical and industrial facilities; brownfields, residential, commercial, institutions and manufactured gas plants.

System Installation

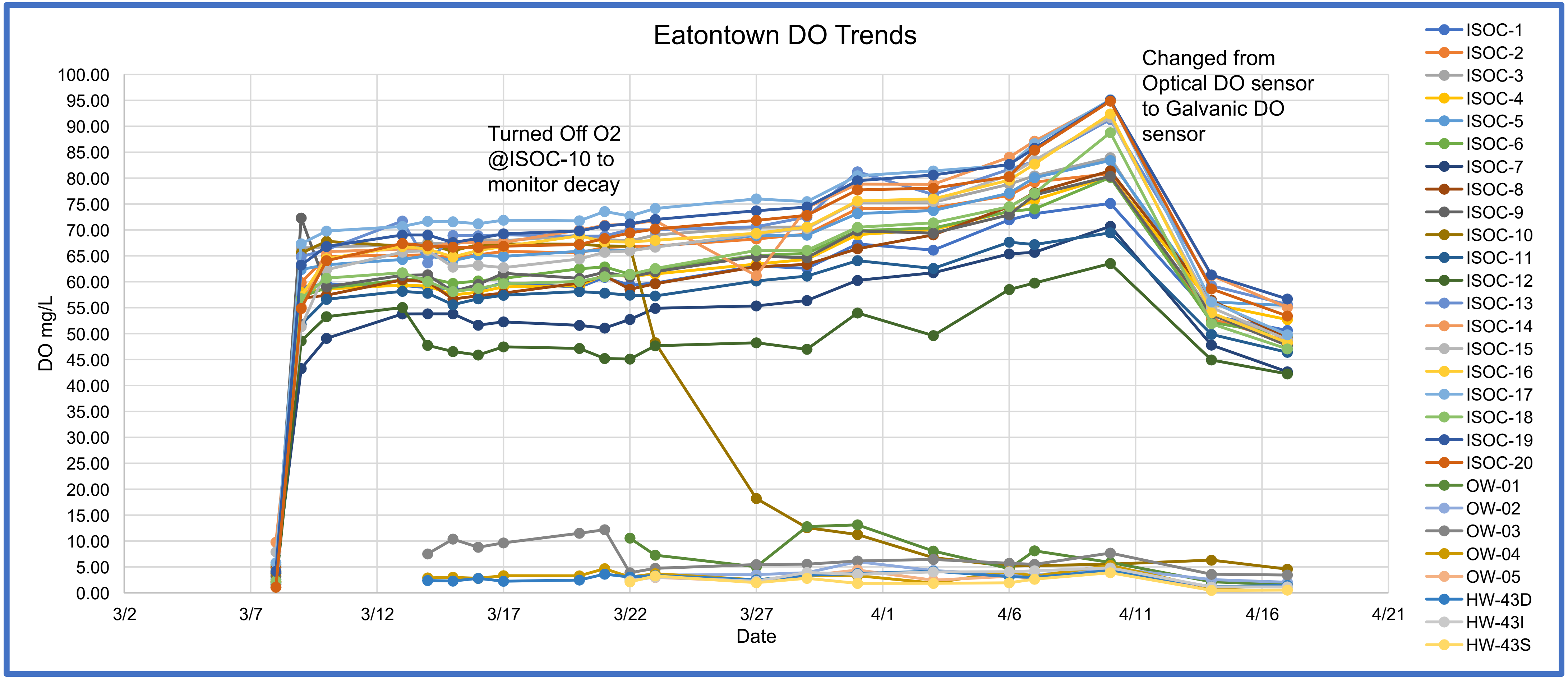
Testing of ISOC Units

Installation of ISOC Units



Control Panel and Manifolding

Field DO Monitoring



- DO at ISOC-10 plummeted from ~48 ppm to 4.5 ppm 25 days
- Manual bailing versus Downhole Probe DO monitoring will lead to different results

Thank You

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