U.S. EPA "State of VI Science" Workshop
Evaluating Alternative Vapor Intrusion Strategies Through Simulations Using Data-Rich Case Studies

Vapor Intrusion Site Investigation, Mitigation and/or Remediation Simulation: Effective and Efficient Project Management

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Simulation Objectives and Rules

Purpose

- Examine the economic and environmental protection tradeoffs between various approaches to managing vapor intrusion sites
- Simulate 20 years of decision making and data collection in 3 hours.
- Reflect, learn, and grow as VI professionals by exercising our project management experience.

Why do a simulation?

- “Simulations allow individuals to experience errors and failures and learn about their consequences in a safe environment.”
  https://www.upstate.edu/psych/research/sms.php

- "Tell me and I forget. Teach me and I remember. Involve me, and I learn" — Benjamin Franklin
- Learning these skills on one site can take an entire career

https://collider.com/matrix-5-in-development/

The Challenge of VI Site Assessment

- Multiple lines of evidence are crucial for accurate vapor intrusion (VI) site investigations.
- Minimizing false negatives and confirming source attribution requires substantial sampling.
- Traditional VI investigations can be complex, time-consuming, and expensive.

Debating Sampling Strategies

- “outside in” approach where groundwater sampling is followed by external soil gas, and then only if required indoor air/subslab soil gas

- “indoor air early” approach in which soil gas samples may only be collected/analyzed to answer questions of source for observed VOCs in indoor air above screening levels.

Alternative Strategies

- Preemptive Mitigation
  - Some project managers and guidance documents have allowed "preemptive mitigation".
  - Rationale: Mitigating without extensive initial investigation can be faster and, in some cases, more cost-effective.
- Vadose Zone Remediation
  - EPA requires remediation, but will it be cost-effective?
  - Question: Could remediating the source in the vadose zone be less expensive overall than house-by-house sampling and mitigation?

Method/Rules – Part 1

- An anonymized site has been prepared as a “simulation environment”
- The anonymized site is based heavily on publicly available concentration information on one real site, that has 25 years of data collection in multiple media. It has been unusually well studied over a large scale of space and time and had an unusually high homeowner participation rate so we know a lot about indoor air, groundwater concentrations and how well mitigation and remediation systems worked.
- Economic costs are not from the actual site, but calculated from an engineers estimate of typical costs as would apply to the anonymized site conditions in 2025 dollars.
- The live workshop audience will “play through” the simulation by audience participation. As time allows, the group will go back in time and “play through again” with different choices.
- Remediation and mitigation efforts can provide information about pollutant distributions. Investigation, mitigation and remediation can be combined in any order and iterated. The simulation is not strictly bound by the details of the CERCLA or RCRA processes.
- The results will be “Scored” on three metrics:
  - Percentage of homes needing protection from VOC exposures that received it.
  - Long term total cost (cash flow is not constrained)
  - Time to provide protection of unacceptable exposures

  We don’t know how to score stakeholder satisfaction or confidence, but encourage that to be discussed…..
- We don’t have preconceived notions of what will turn out to be the most effective combination of steps to investigate, mitigate and remediate this site.

Method/Rules – Part 2

- Information about the site will be revealed/discovered gradually as data is “bought”.
- The starting point is the time when following some on site investigation, offsite investigation and vapor intrusion evaluation began.
- The amount of investigation and remediation typically required for groundwater ingestion protection when aquifer is not currently used is a “given”.
- Turns are roughly 1 year for the first 5 years, and then every 5 years.
- If you think you recognize the site, please don’t tell others/use that information. The judges reserve the right to modify reality for the educational purpose of simulation.
- Discussion based on your personal experience at other sites is encouraged. We seek to learn and will debrief as a group at the end.

Method/Rules – Part 3

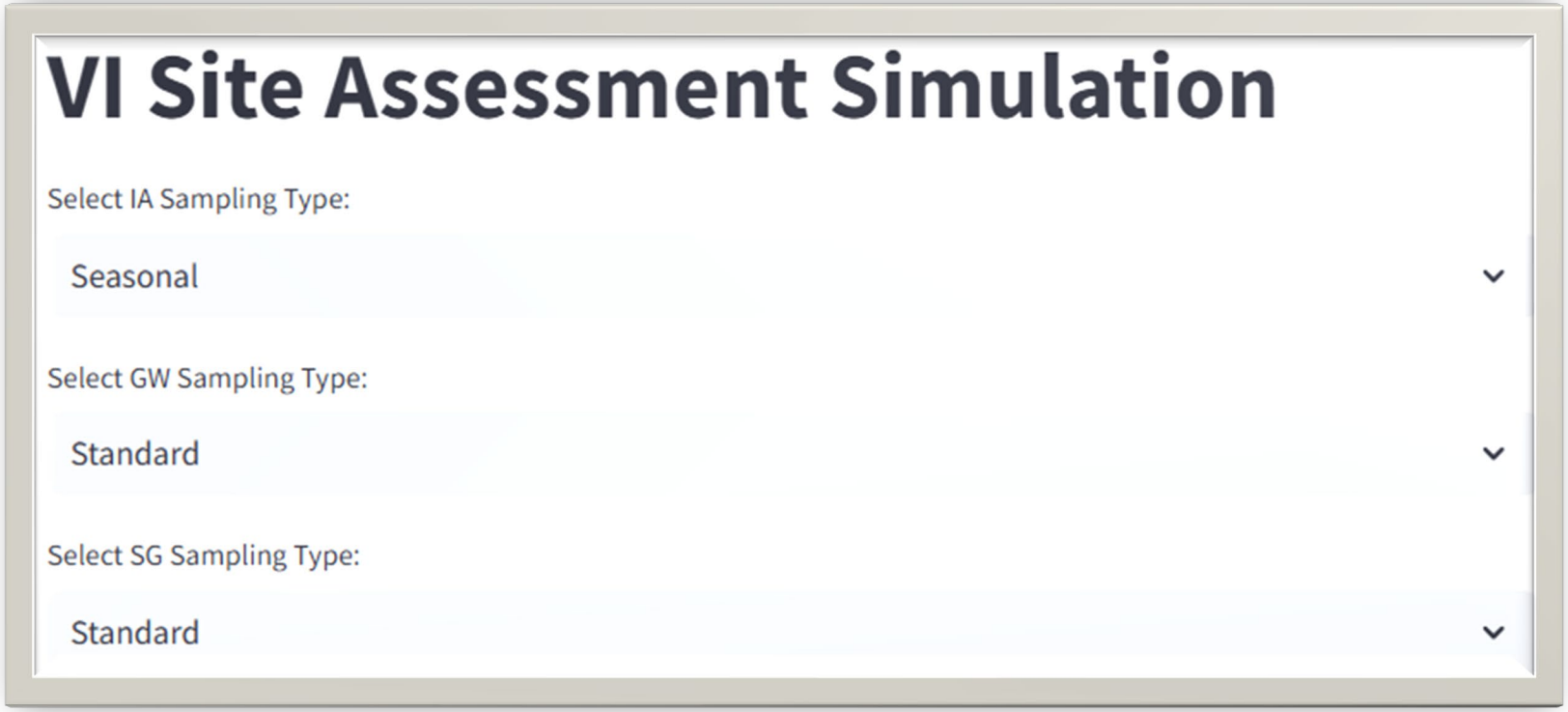
- We are assuming all costs are in 2025 dollars and all risk-based screening levels are based on 2025 VISLs at TCR 10^{-5} and HQ = 1.
- The participants have today's knowledge of VI, not the knowledge practitioners had in 2000 when the real site VI investigation started.
- The participants will get a "menu" of the proposed costs of various investigation, mitigation or remediation options for one to five year periods. This is a little better/more formalized economic information then real site managers usually have (unless they pay for a lot of feasibility studies and put a lot of alternatives out to bid).
- Thus, if we use different approaches then the real site management team did, it should not imply a criticism of them.
- There is unfortunately no grand prize other then knowledge and experience.

Trialing it out!

Conventional Strategy

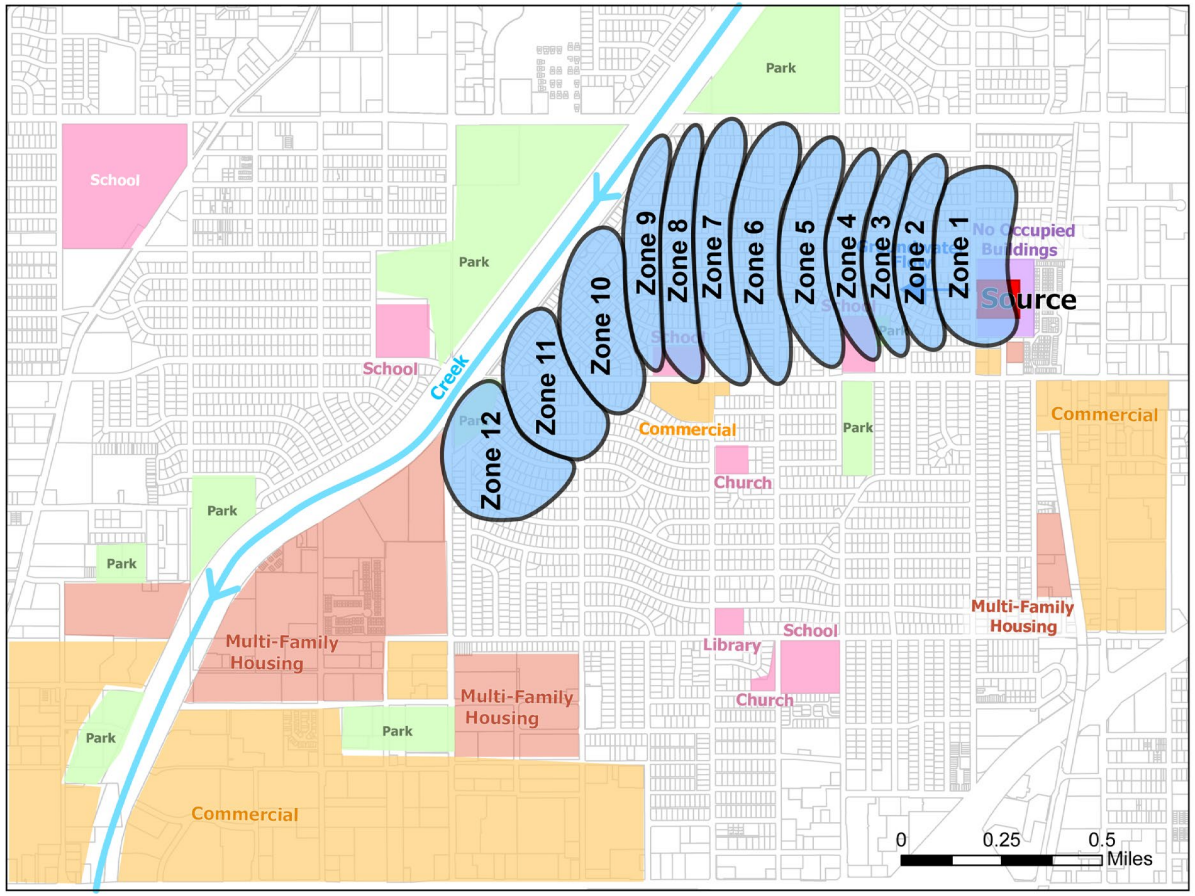
- Initial Sampling Strategy: Groundwater focus
- Use Groundwater sampling to Identify areas impacted.
- Once areas are identified, move to External Soil Gas
- Monitor SG until we identify several zones with issues
- Assess need for mitigation with Indoor Air Sampling
- Mitigation in households in response to indoor air sampling

Selecting our sample types

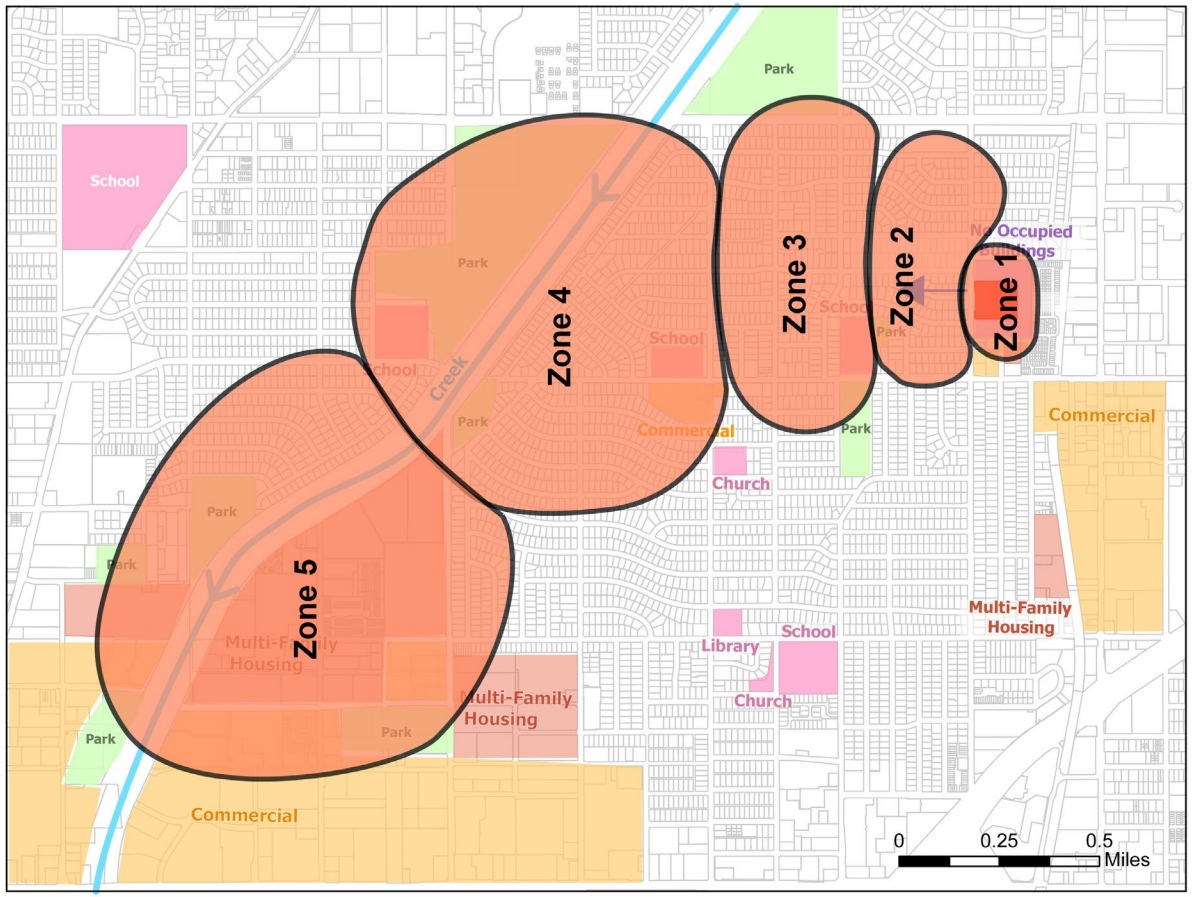


Zone Breakdown

Indoor Air Zones



Groundwater Zones

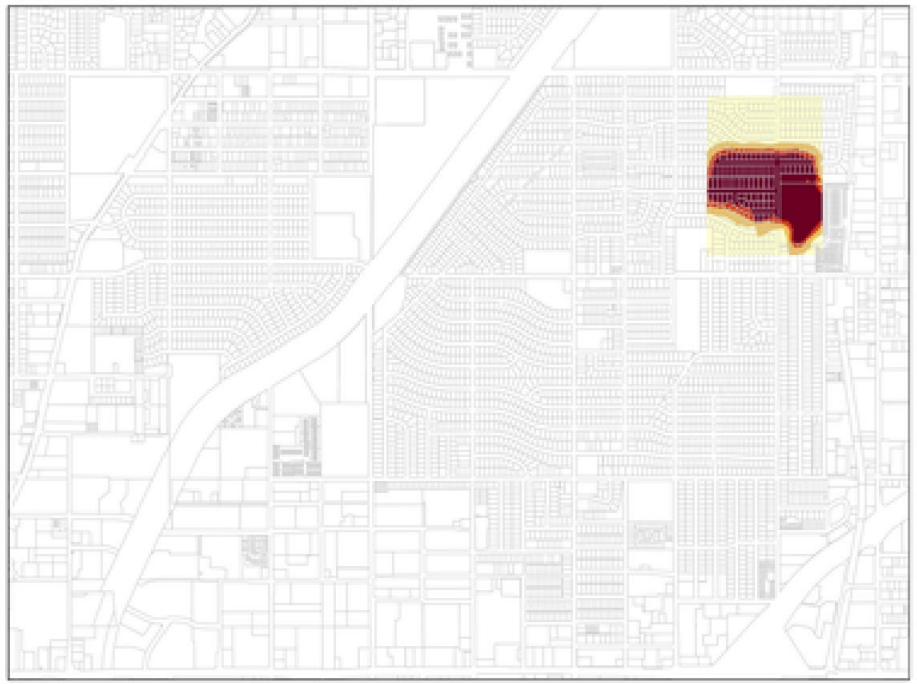


Initial Selection

- Let’s write a QAPP to do groundwater sampling
- Get permits for installing the wells
- Conduct our first round of sampling
- ~1 year of effort (all at the push of a button)
- (zone 1 is the source so we’re selecting both zone 1 and 2 initially)

Results from Round 1

- We (unsurprisingly) see all the GW wells at the source with an exceedance
- Many wells downstream of the source also high in TCE and DCE



Historical GW Exceedances

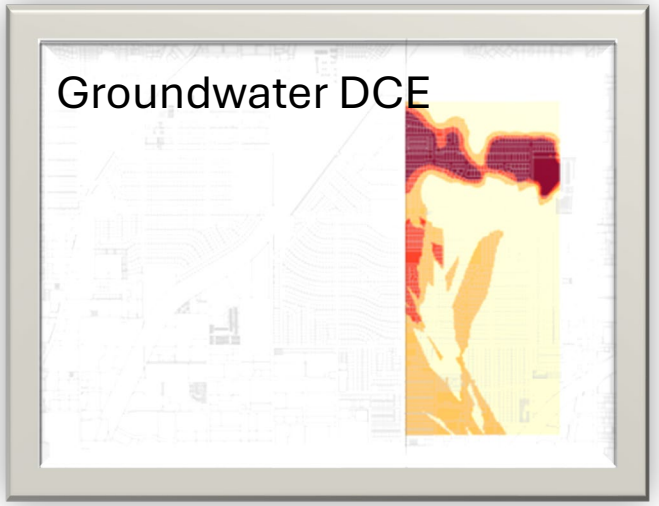
GW Zone	Wells Sampled	DCE	TCE
1	25	25	25
2	25	14	12
Total	50	39	37

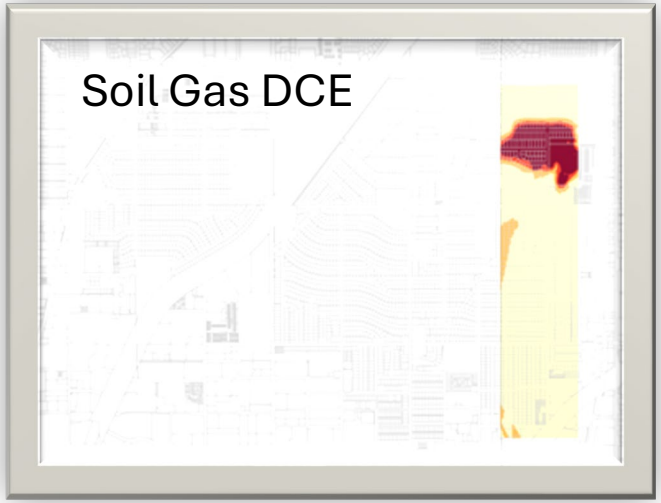
Next Steps

- Get a second year of GW samples in zones 1 and 2
- Expand our GW plume identification to zone 3
- Install and start sampling Soil Gas (SG) wells

Results from round 2

- Our groundwater plume is growing
- We've now tested water from 75 wells with 50 exceeding DCE guideline values and 49 exceeding TCE guidelines





Historical GW Exceedances

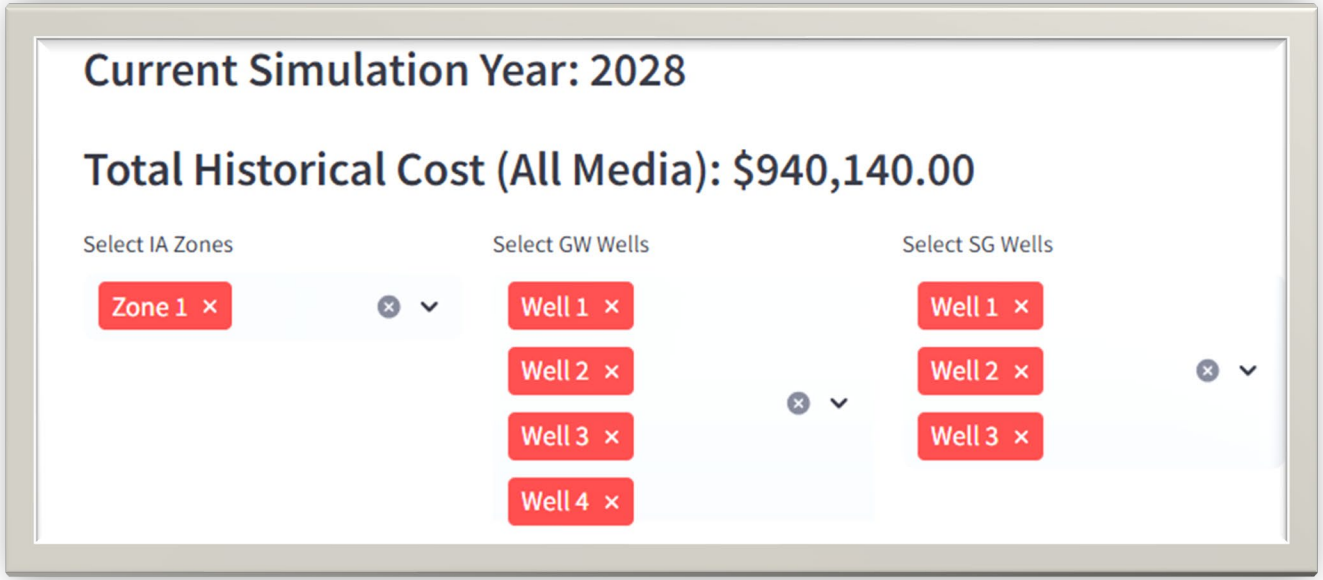
GW Zone	Wells Sampled	DCE	TCE
1	25	25	25
2	25	14	13
3	25	11	11
Total	75	50	49

Historical SG Exceedances

SG Zone	SG Points Sampled	DCE	TCE
1	25	25	24
2	25	12	10
Total	50	37	34

Next Round

- Expand GW and SG sampling
- Draft IA QAPP
- Approach 30 houses to sample
- Conduct initial evaluation in 10 houses

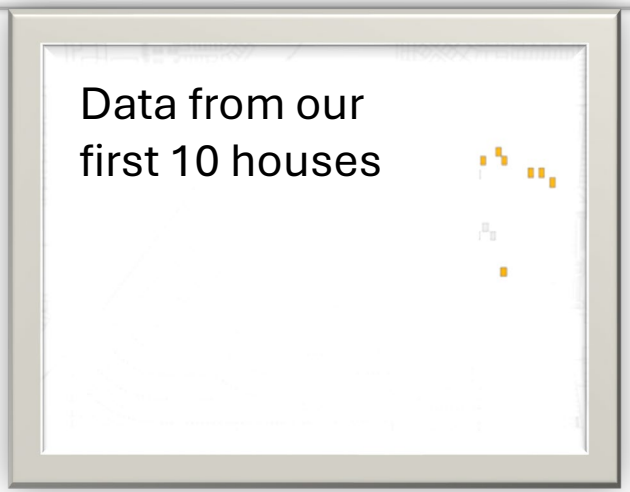


Results from round 3

- We have data from our first 10 houses
- 7 of them exceed TCE guidelines
- Our GW plume is expanding
- As we expand our exceedance rate goes down

Historical IA Exceedances

Zone	Houses Approached	Houses Participating	DCE	TCE	Both
1	30	10	0	7	0

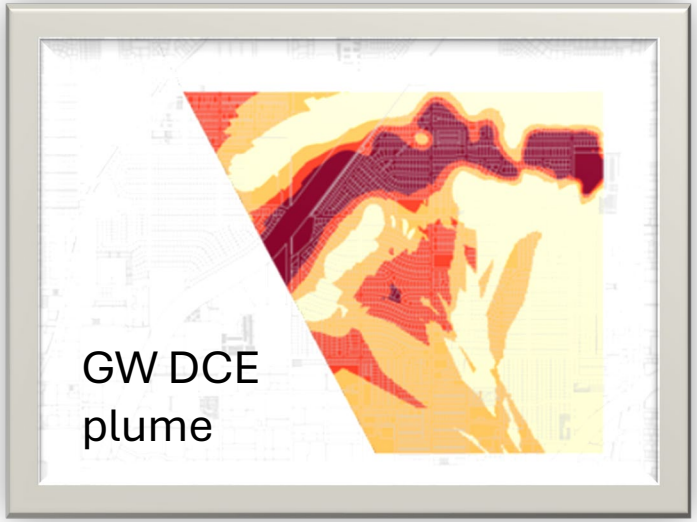


Historical GW Exceedances

GW Zone	Wells Sampled	DCE	TCE
1	25	25	25
2	25	14	13
3	25	12	11
4	25	11	9
Total	100	62	58

Historical SG Exceedances

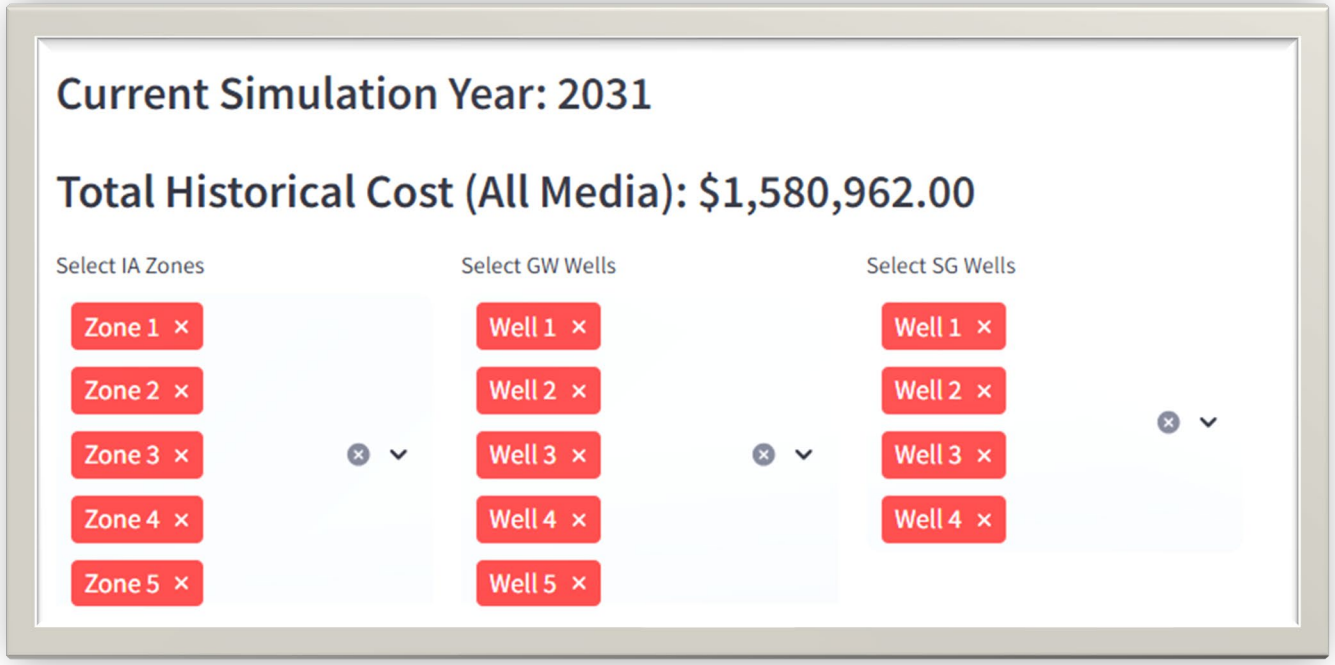
SG Zone	SG Points Sampled	DCE	TCE
1	25	25	24
2	25	12	10
3	25	11	11
Total	75	48	45



Next Round

- Start Mitigation
- Expand IA sampling reach
- Expand GW and SG reach
- And so on…

- Pausing here so we don’t ruin the endgame for everyone. We’ll share the final results once we run our live session.



A few other pre-scripted scenarios

- We’ll share the results from these scenarios after we run a live session for comparison:
  - Speedy Scattershot
  - Quick yet thorough
  - An innovative approach

Speedy Scattershot Strategy

- Starting with both Indoor Air and External Soil Gas sampling
- Expand rapidly including multiple zone expansions per year
- Goal is to move to mitigation as quickly as possible
- Piecemeal mitigation
- Working to build movement momentum

Quick Yet Thorough

- Starting with both Indoor Air and External Soil Gas sampling
- Expand rapidly including multiple zone expansions per year
- Goal is to move to mitigation as quickly as possible
- Block level mitigation
- 20-30% of a block exceeds, you'd move to a neighborhood wide mitigation approach vs household

An innovative approach

- Use vapor monitoring points to test Groundwater and External Soil Gas
- Design a Soil Vapor Extraction system to provide large scale remediation

Debrief Questions

Site Statistics

1. Indoor Air
    1. Convenience Sampling
        1. DCE exceedance (>4.1 µg/m^3): 2 of 114 (2%)
        2. TCE exceedance (>2.1 µg/m^3): 12 of 114 (11%)
        3. DCE and TCE exceedances: 2 of 114 (2%)
    2. Seasonal Sampling
        1. DCE exceedance (>4.1 µg/m^3): 15 of 114 (13%)
        2. TCE exceedance (>2.1 µg/m^3): 44 of 114 (39%)
        3. DCE and TCE exceedances: 3 of 114 (3%)
    3. Month Long Sampling
        1. DCE exceedance (>4.1 µg/m^3): 20 of 114 (18%)
        2. TCE exceedance (>2.1 µg/m^3): 41 of 114 (36%)
        3. DCE and TCE exceedances: 4 of 114 (4%)
    4. ITS Sampling
        1. DCE exceedance (>4.1 µg/m^3): 34 of 114 (30%)
        2. TCE exceedance (>2.1 µg/m^3): 93 of 114 (82%)
        3. DCE and TCE exceedances: 59 of 114 (52%)

2. Mitigation systems installed

    377 of 727 (52%) houses at site were mitigated

Site Statistics

3. Groundwater wells
    1. 275 of 356 wells (77%) had DCE exceedance (>3.9 µg/L)
    2. 270 of 356 wells (76%) had TCE exceedance (>5.2 µg/L)

4. Soil Gas
    1. 281 of 356 (79%) had DCE exceedance (>138 µg/m^3)
    2. 271 of 356 (76%) had TCE exceedance (>70 µg/m^3)

Simulation Compare

Metric	Dry Run - Initial	Live Run – SG + SVE	Live Run – Yolo
Groundwater		$0	$ 0.3 M
Soil Gas		$ 0.4 M	$ 1.5 M
Indoor Air / Subslab		$ 5.1 M	$ 3.5 M
Mitigation		$ 12.7 M	$ 9.1 M
Total	$ 21.4 M	$ 18.2 M	$ 14.4 M
Time	15 years	20 years	10 years

Metric	Dry Run - Initial	Live Run – SG + SVE	Live Run – Yolo + IA + SVE
Groundwater	125 (5 yrs)	0	125
Soil Gas	125 (5yrs)	125 (1 yr)	
Indoor Air / Subslab	120 (10 yrs)	120 (20 yrs)	120 (10 yrs)
Mitigation Option	Individual households	SVE	SVE
Mitigation (houses controlled)	360	360	360
Mitigation (people protected)	900	900	900

After Action Review

- Which strategy in this case seemed to be the most effective combination of steps to investigate, mitigate and remediate this site?
- What site/project specific factors controlled which lines of evidence you wanted to collect first in this simulation?
- What site/project specific factors controlled when you chose to start mitigation or remediation in this simulation?
- How would your decisions change if:
  - The structures were more spread apart or some of the land was undeveloped?
  - The groundwater was much deeper (say 60’ to groundwater)
  - The groundwater was much shallower (say 5’ to groundwater)
  - The source (on site) was much stronger?
  - The housing stock was more diverse in age?
- What lessons/learnings can you apply to your real-life project management practice?

Additional potential after action review questions

- What were your initial reactions to the scenario/situation as it was first presented – did they turn out to be true in the end?
- What were the key decision points for you?
- What would have the public's perception been of how you managed this VI site investigation/mitigation/remediation?
- How did you adapt to unexpected data?
- Were you satisfied that the actions you took appropriately balanced cost and human health protection from unacceptable exposures?
- Are there policy or process constraints that prevent you from efficiently investigating/mitigating/remediating real sites?