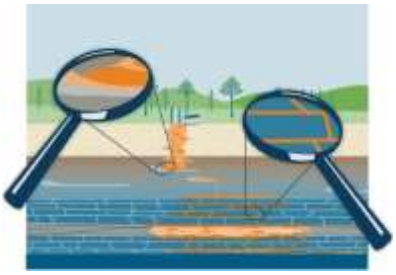
Back-to-Basics Part 1: Developing the CSM & Site Characterization

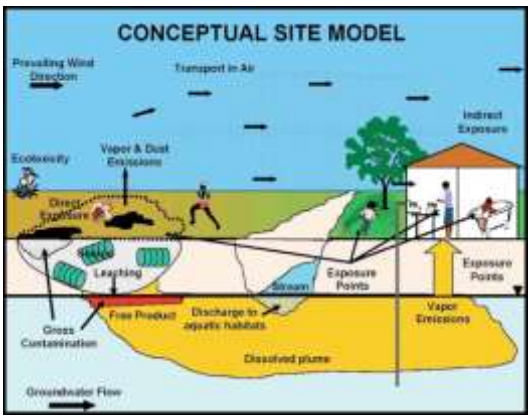
Agenda

- What is a CSM and how do you use it
- Physical Components (Geology, Hydrogeology, and Chemistry)
- Site Use History
- Likely Fate and Transport
- Lessons Learned



What is a CSM

What is a Conceptual Site Model (CSM) and how do you use it?



ITRC ISM-1 2012, https://www.itrcweb.org/ism-1/

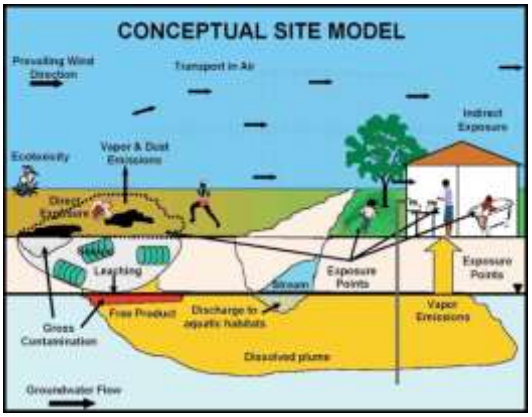
CSMs are essential elements of the systematic planning process.

A CSM serves to conceptualize the relationship between contaminant sources, site geology, and potential exposure pathways.

It presents the current understanding of the site, **helps to identify data gaps**, and helps to focus the data collection efforts. The CSM should be maintained and updated as new information is collected throughout the life cycle of the project**, including during remediation.**

What is a CSM

What is a Conceptual Site Model (CSM) and how do you use it?



ITRC ISM-1 2012, https://www.itrcweb.org/ism-1/

The CSM is more of a process than a final product. The CSM is essentially never complete.

The CSM should be maintained and updated as new information is collected throughout the life cycle of the project**, including during remediation.**

What is a CSM

"A conceptual site model is a written and/or illustrative representation of the conditions and the physical, chemical and biological processes that control the transport, migration and potential impacts of contamination (in soil, air, ground water, surface water and/or sediments) to human and/or ecological receptors."

(NJ DEP, 2011 Technical Guidance for Preparation and Submission of a Conceptual Site Model)

What is a CSM

"The goal of a conceptual site model is to provide a description of relevant site features and the surface and subsurface conditions to understand the extent of identified contaminants of concern and the risk they pose to receptors. **The conceptual site model is an iterative tool that should be developed and refined as information is obtained during review of the site history and continues throughout the site and/or remedial investigation.** The level of detail of the conceptual site model should match the complexity of the site and available data."

(NJ DEP, 2011 Technical Guidance for Preparation and Submission of a Conceptual Site Model)

CSM Components

For the purposes of this presentation, we can simplify the CSM into two primary components:

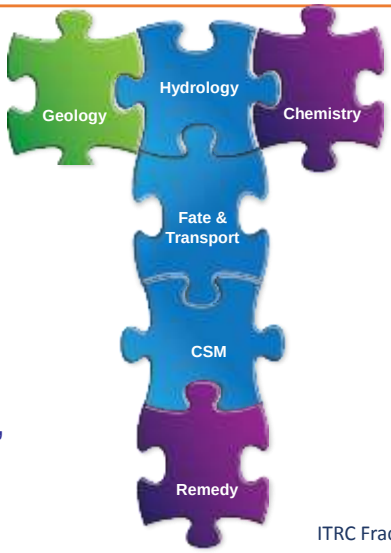
Site Specific Geological Physical CSM

Site Specific Land Use History CSM

CSM Components Geological/Physical Site Model

Contains:

- Geology
- Hydrogeology
- Chemistry
- Fate and Transport



Key to your success: a **team** with expertise in hydrogeology, sedimentology, structural geology, geophysics, geochemistry, and engineering

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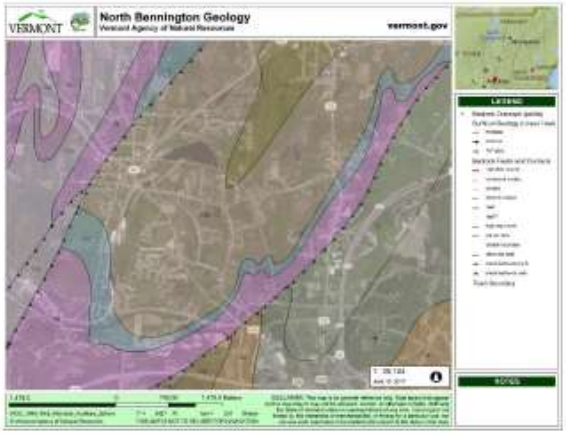
CSM Components Geological/Physical Site Model

Initial CSM can be developed with:

- Published literature:
  - State geological survey
  - Universities
- Previous site investigation reports
  - For your site
  - For nearby sites
- Aerial Photographs and Maps (geologic and other)



Courtesy VT DEC

CSM Components Site Specific Land Use History CSM

Equally important is the Site Specific Land Use component of the CSM:

An understanding of the land use history can facilitate and accelerate the development of a CSM

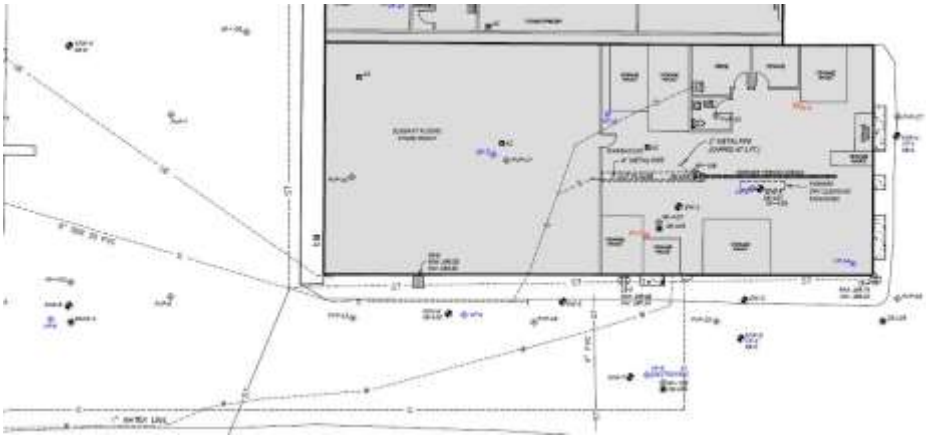
- It may suggest likely compounds of concern to help focus the sampling plan

CSM Components Site Specific Land Use History CSM

- It may help identify areas where contaminants may have been released

CSM Components Site Specific Land Use History CSM

- It must include an analysis of the subsurface utilities infrastructure



CSM Components Site Specific Land Use History CSM

Start by conducting a historic land use analysis

- Sanborn Fire Insurance Maps
  - Need to understand how to read these maps
- City Directories
  - "Backwards" phone book
- Aerial Photos
  - Universities, Soil Conservation Service, State Mapping Agencies, State Geological Surveys
- Local/State Historical Societies
- State Archival Libraries
- Interviews

CSM Components Site Specific Land Use History CSM

When assessing past land uses, get as much detail about the site specific manufacturing processes as possible, **don't assume similar facilities use the same chemicals:**

- At a tannery, you might expect chromium as this was commonly use in tanning. At one facility however, the in depth study of the site history demonstrated that the facility used leaves to tan the leather. Chromium was not a Contaminant of Concern.
- Manufacturing processes change over time:
  - Coal Gasification Plants commonly used a variety of processes and sources of fuel to manufacture gas. These created different types of "coal tars", including DNAPL, LNAPL, and "Neutral" NAPL.
  - Printing processes have a long history of modifications in the formulas of inks, lubricants, solvents
  - The components of paint and other wall and floor coverings have changes significantly over time
- Dry cleaners often used PCE but may have used Stoddard Solvent, or used other cleaners such as turpentine, camphor oil, benzene, naphtha, white spirits (gasoline), TCE, Carbon-Tet, and kerosene.

CSM Components Site Specific Land Use History CSM

Subsurface Utilities Infrastructure:

- These can create **significant** preferential pathways.
  - Foundation drains, water and sewer lines, abandoned water and sewer lines, drain tiles, electrical conduits
  - Topographic lows (valleys, ravines, swamps) filled with unknown materials
  - Channelized or relocated streams
  - On-site landfills both formal and informal

- These anthropogenic preferential pathways can transport contaminants in direction different than the general groundwater flow
  - These pathways may allow contaminated soil vapor to enter homes
  - Can create a potential explosive risk depending on the contaminant

CSM Components

Site Specific Land Use History CSM

Estimating Quantities released:

- Company records
  - UST Product Deliveries vs Sold
  - UST Depth to Product
  - Recorded Spills During Delivery and Operation
- Regulatory Spill Response Reports
- Interviews

Estimations of quantities released can be very difficult and inaccurate

Developing the CSM

Initial CSM:
Can be simple

Release in Karst Limestone

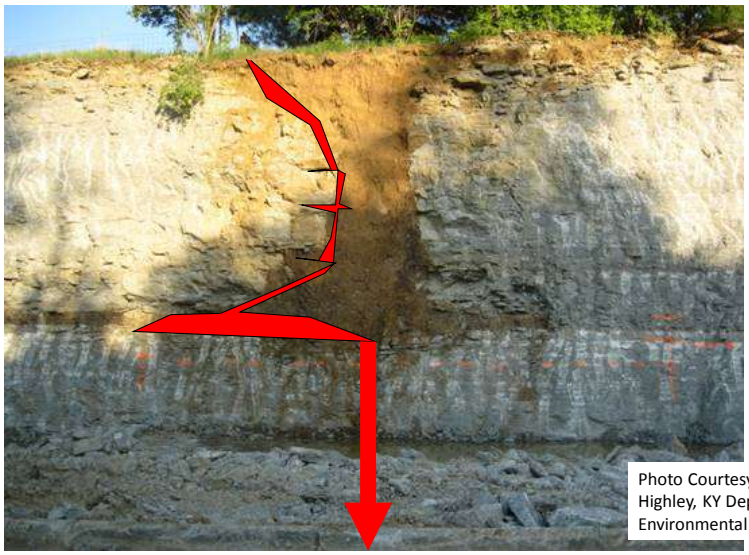


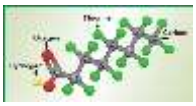
Photo Courtesy of Brad Highley, KY Dept. for Environmental Protection

Developing the CSM

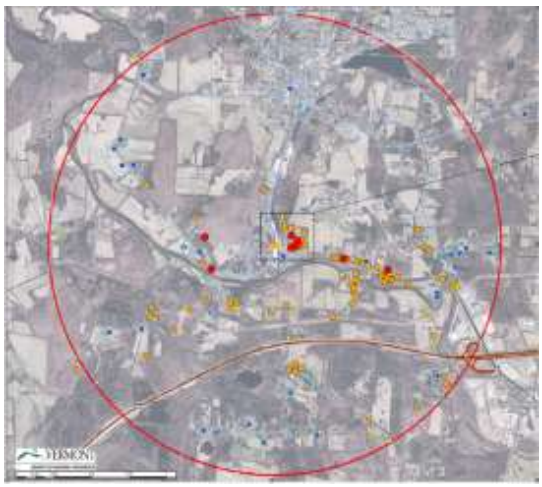
1. Develop Problem Statement
2. Develop Preliminary Conceptual Site Model
3. Identify Significant Data Gaps

"a problem well stated is a problem half solved"
(Charles F. Kettering, 1876-1958)

Developing the CSM



Example of Initial Site Specific Problem Statement: PFAS Bennington, VT



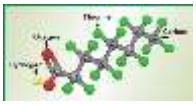
PFOA found in several domestic water wells near a former fabric waterproofing factory.

There is a documented significant problem with PFOA contamination caused by a similar factory in a neighboring state.

How large a problem is this in Bennington?

Courtesy VT DEC

Developing the CSM



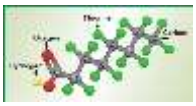
Initial CSM can be very simple:

For the Bennington, VT study:

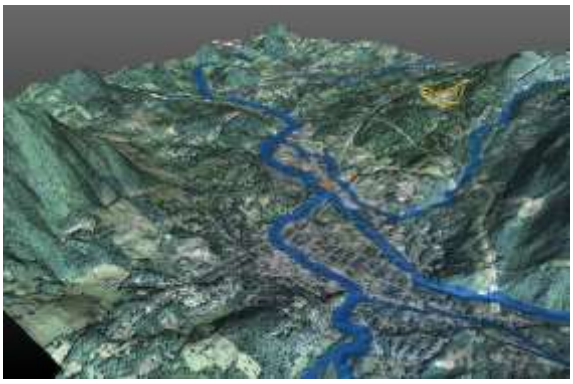
- A factory producing water proofed fabric used to operate in Bennington.
- The manufacturing process used PFAS.
- PFAS is know to have been released from similar facilities

This factory is a possible source.

Developing the CSM



Example of Identified Data Gaps: PFAS Bennington, VT

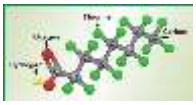


Did the factory release PFAS?

- How could releases occur?
  - Aerial Deposition?
  - Surface/Floor Drain releases?
  - Spreading composted sanitary waste sludge?
- Is anyone being exposed to PFAS

Courtesy VT DEC

Developing the CSM



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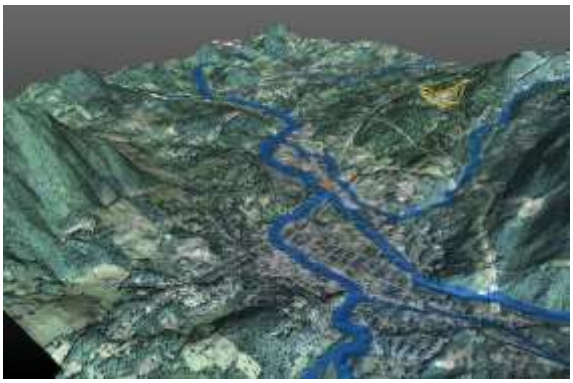


What is the local geology, structure, rock types, major faulting, brittle structure fractures, fracture connectivity, and how does it affect flow and transport?

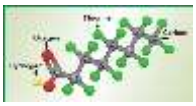
Is the PFOA in the environment affecting agricultural products? (Maple Syrup!!!)

What is the mass in the soil?
Is it in surface water?
Is it in fish?

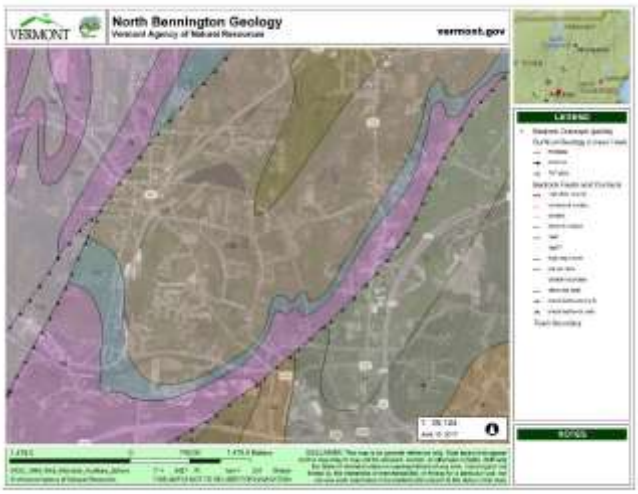
- If so, how extensive

Courtesy VT DEC

Developing the CSM



Additions to Initial CSM: Bedrock Geology

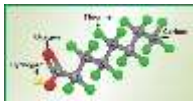


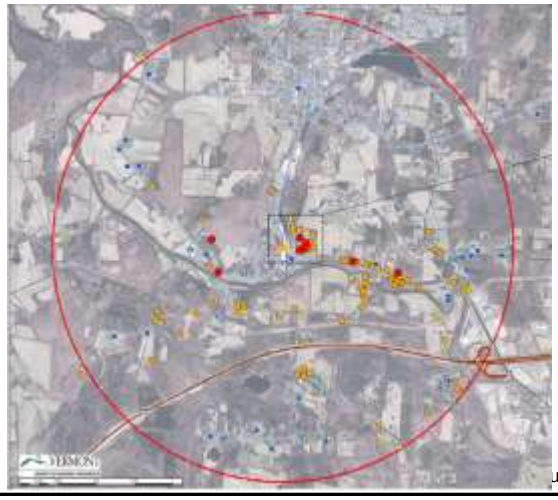
Several thrust faults

Primarily carbonate rocks in area of contamination

Developing the CSM

The Site Specific Problem Statement Grows



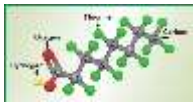


50 wells sampled

- 22 results : ND
- 9 results : 0-20 ng/l
- 8 results : 20-100 ng/l
- 11 results : > 100 ng/l

urtesy VT DEC

Developing the CSM



The Site Specific Problem Statement Grows More

- 541 samples collected from private wells

  >60% of all wells had some level of PFOA
- 199 results : ND (37%)
- 76 results : 0-20 ppt (14%)
- **266 results : >20 ppt (49%)**

Courtesy VT DEC

Developing the CSM

Example of Initial Site Specific Problem Statement: PCE VI Manchester, VT

PCE was found in indoor air in a Day Care facility that was being monitored in response to a known release from the former dry cleaning facility south of the day care.

We assumed the source of the PCE in the Day Care indoor air is from a dry cleaner.

Is the PCE from the known release or from the active dry cleaning facility located just north of the Day care?

Courtesy VT DEC

Developing the CSM

Example of Detailed Initial Unconsolidated CSM: PCE VI Manchester, VT

The State reviewed the existing site investigation reports and CSM from the known dry cleaner site:

- Surficial geology is glacial outwash with horizontally bedded gravel
- Drilling logs and site observations indicate this has been reworked by recent alluvial action, is more heterogeneous than might be expected.
- Groundwater flow is generally SW towards the Battenkill river
- Groundwater and soil vapor contamination above standards exist

Courtesy VT DEC

Developing the CSM

Example of Detailed Initial Unconsolidated CSM: PCE VI Manchester, VT

- The release at the dry cleaner was most likely a long term, ongoing slow release
  - Staining indicated drips, etc.
  - No dumping outside of facility indicated
- **Both dry cleaning facilities used PCE**
- Main source in subsurface is directly below the location of the former dry cleaning machinery
- Large soil vapor plume is present
- Groundwater contamination is found southwest of the dry cleaner (above standards but not significant)

Courtesy VT DEC

Developing the CSM

Example of Detailed Initial Unconsolidated CSM: PCE VI Manchester, VT

- Most of the area surrounding the facility is paved
  - Helped allow creation of the large vapor plume
  - Subsurface utilities may have facilitated vapor migration
  - While the vapor plume extends north, the majority is south and southwest of the facility

Courtesy VT DEC

Developing the CSM

Example of Detailed Initial Unconsolidated CSM: PCE

- **The former dry cleaner located south of the day care is not the source of the VI in the day care**
- **The most likely source of VI in the day care is the dry cleaner directly north of the day care**

Courtesy VT DEC

Developing the CSM

Example of Identified Data Gaps: PCE VI Manchester, VT

The VT DEC requested the owner of the northern dry clearer to investigate the apparent PCE contamination and remediate the VI issue in the day care

"Surprisingly", the owner and his insurance company refused. They claimed the source was more likely the other dry cleaner

Courtesy VT DEC

Developing the CSM

Example of Identified Data Gaps: PCE VI Manchester, VT

The VT DEC needed to demonstrate, that the northern dry cleaner was the source of the VI issues in the day care. Data gaps included:

- Was there a release at the northern dry cleaner?
- What was the release mechanism?
  - Spill during PCE transfer or delivery?
  - Back door disposal?
  - Other?
- Is there environmental PCE contamination?
  - Unconsolidated materials?
  - Groundwater?
  - Soil vapor?

Courtesy VT DEC

Developing the CSM

Example of Identified Data Gaps: PCE VI Manchester, VT

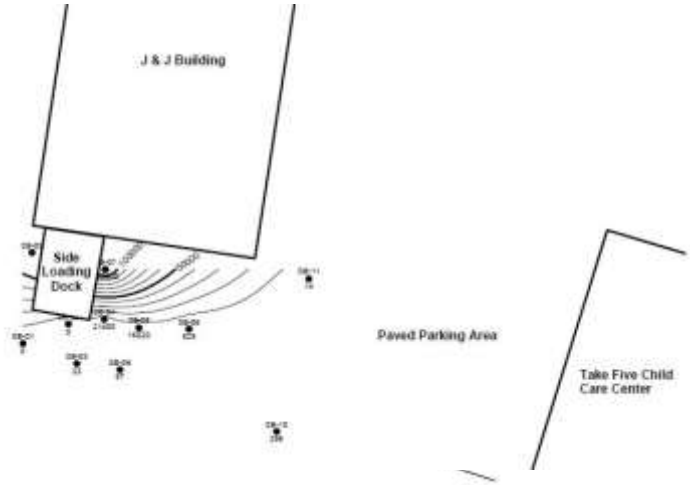
- If the unconsolidated materials and groundwater are contaminated:
  - what is the extent?
  - does the contamination extend to below the day care? if so, in what media?
  - is there chance the bedrock is contaminated?
  - what is the geology of the site?
- Are there any other potential receptors?
- What are the fate and transport mechanisms?

Courtesy VT DEC

Developing the CSM

Response to Identified Data Gaps: PCE VI Manchester, VT

- US EPA Removals Program conducted a 3.5 day high resolution preliminary site assessment under a dynamic work plan using direct push equipment to collect soil, soil vapor, and groundwater samples. These were analyzed on site in real time to allow the SI to focus on identified issues



Courtesy VT DEC

Developing the CSM

Develop Initial Fractured Rock CSM, 30,000 ft view

Can Start by Using Terrane Analysis

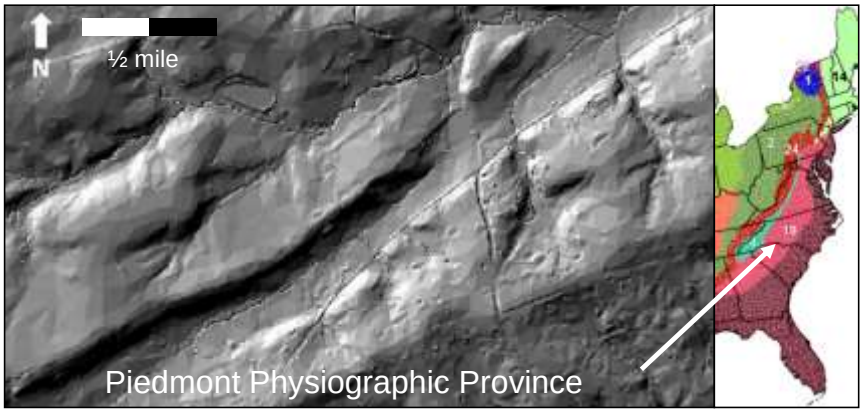
This can provides data on:

1. Regional physical setting (e.g., physiographic provinces)
2. Bedrock lithology and stratigraphy
3. Structural geology and tectonic setting
4. Anisotropy and heterogeneity
5. Hydrology

Developing the CSM

Fractured Rock Example

1. Regional Setting



Note NE-SW trend in landscape and arrangement of physiographic provinces: initial clue to bedrock and groundwater flow characteristics.

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Developing the CSM

Fractured Rock Example

2. Bedrock lithology and stratigraphy
3. Structural geology and tectonic setting
4. Anisotropy and heterogeneity
5. Hydrology

Rock type, layering, and structure impart directional component to hydrology and groundwater flow.

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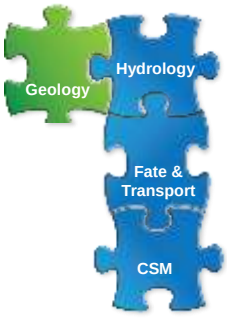
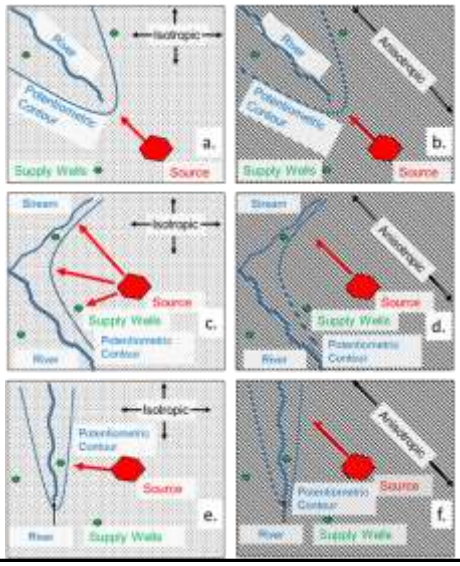
Developing the CSM

Fractured Rock Example





Assemble source, hydraulic gradient, bedrock influence, hydrology, and receptors for initial CSM.

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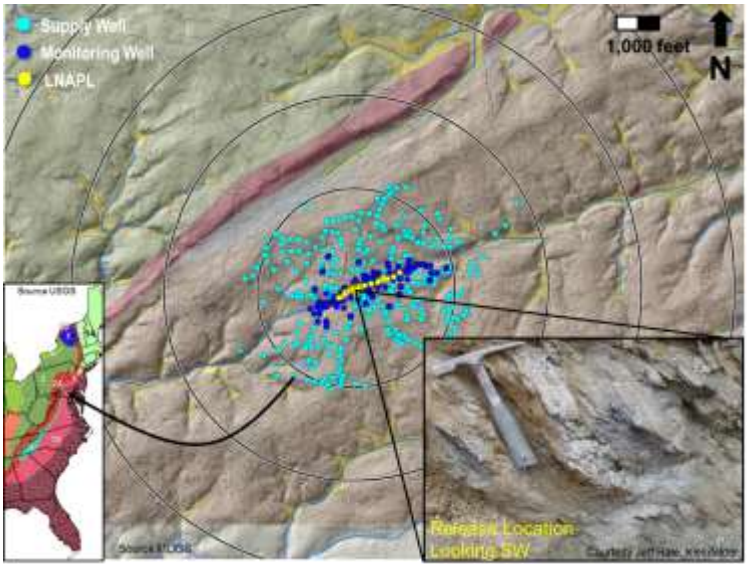
Developing the CSM



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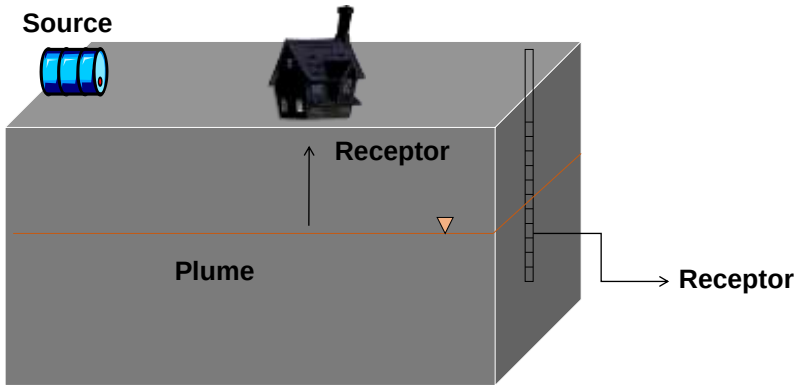
Reinforcing Key Ideas

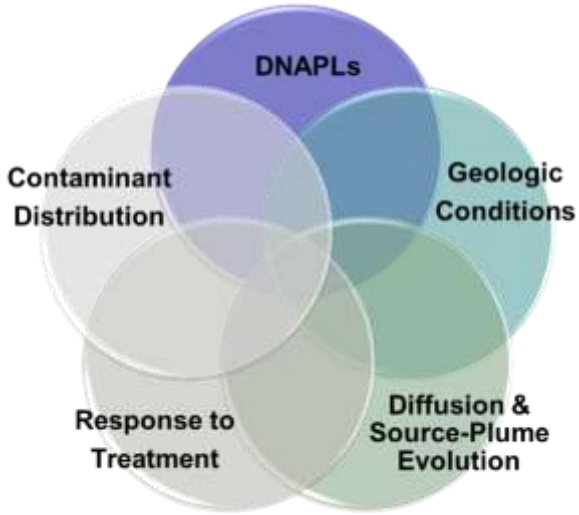
- At its most basic level, the CSM connects contaminant sources, site geology, and potential exposure pathways
- The initial CSM should therefore have elements of:
  - Geology/lithology
  - Hydrogeology
  - Contaminants, including non-aqueous phases
  - Some assessment of transport mechanisms
  - Key site features – utilities, use/purpose, etc.
- Still, CSM's can come in all shapes and sizes

Status of Your CSM

- **You might need to update your CSM if …?**



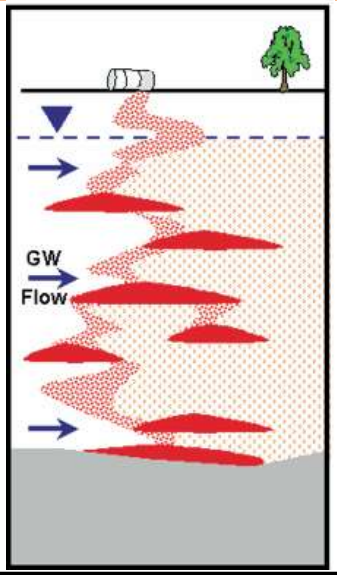
Technical Concepts Related to CSM



Simple CSM

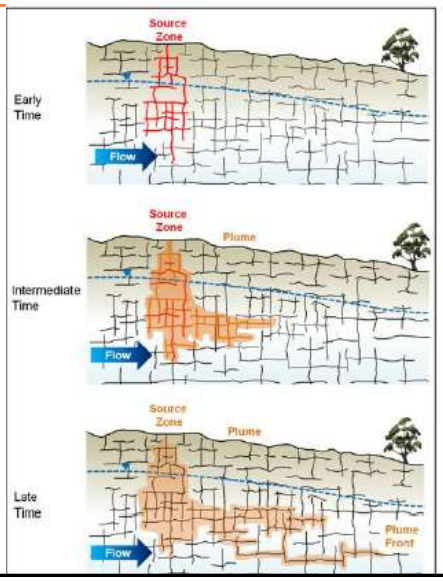
- Simplistic view of DNAPL migrating downward at an unconsolidated site
- Key features:
  - NAPL
  - Vapor phase
  - Aqueous phase

(Modified from Parker et al, 2002)



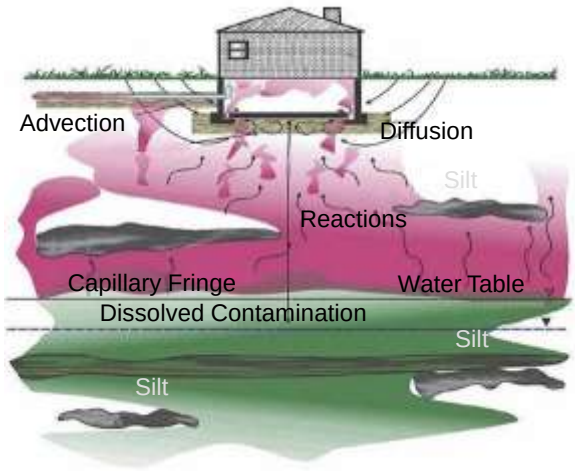
More Complex CSM

- DNAPL migrating downward at a fractured rock site
- Key features:
  - NAPL
  - Vapor phase
  - Aqueous phase
  - Horizontal fractures
  - Vertical fractures
  - Matrix storage/diffusion



CSM for Soil Gas / Vapor Intrusion

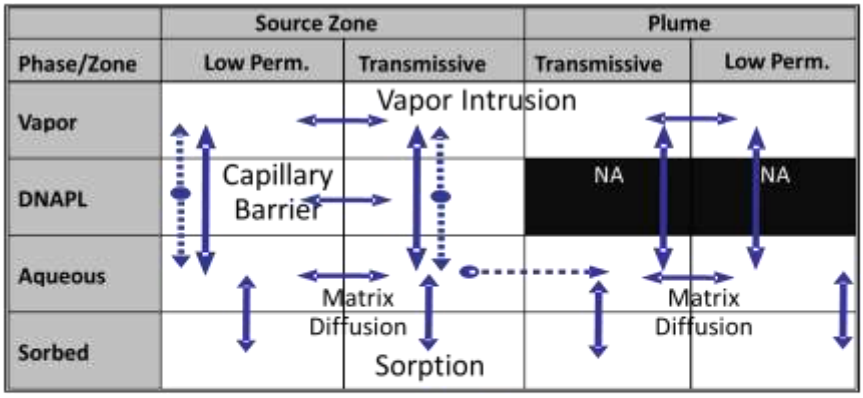
- Vapor risk may be driver
- Key element of CSM
- Common approach - reverse calculate groundwater cleanup target
- KEY ISSUE - Clear understanding of treatment process and groundwater-vapor relationship
- CAUTION - Equilibrium assumptions vs. non-equilibrium conditions



ITRC IDSS-1, Figure 2-10, Conceptual Model for subsurface vapor pathways (EPA, 2002)

Another Tool – 14 Compartment Model

- "Compartment" consists of chemical phase within either the source zone or plume and in either transmissive or low permeability zone
- Highly conceptualized depiction of potential for contaminant mass flux between compartments

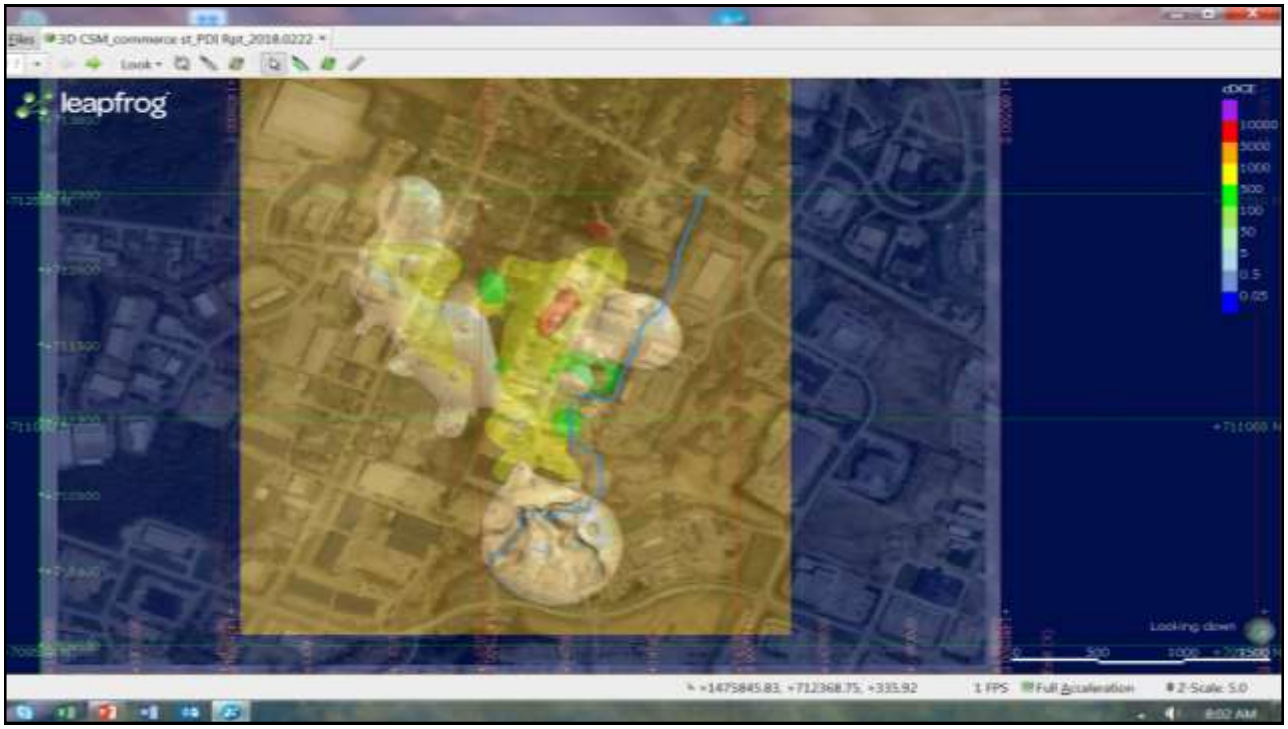


ITRC IDSS-1, Table 2-2 from Sale and Newell 2011

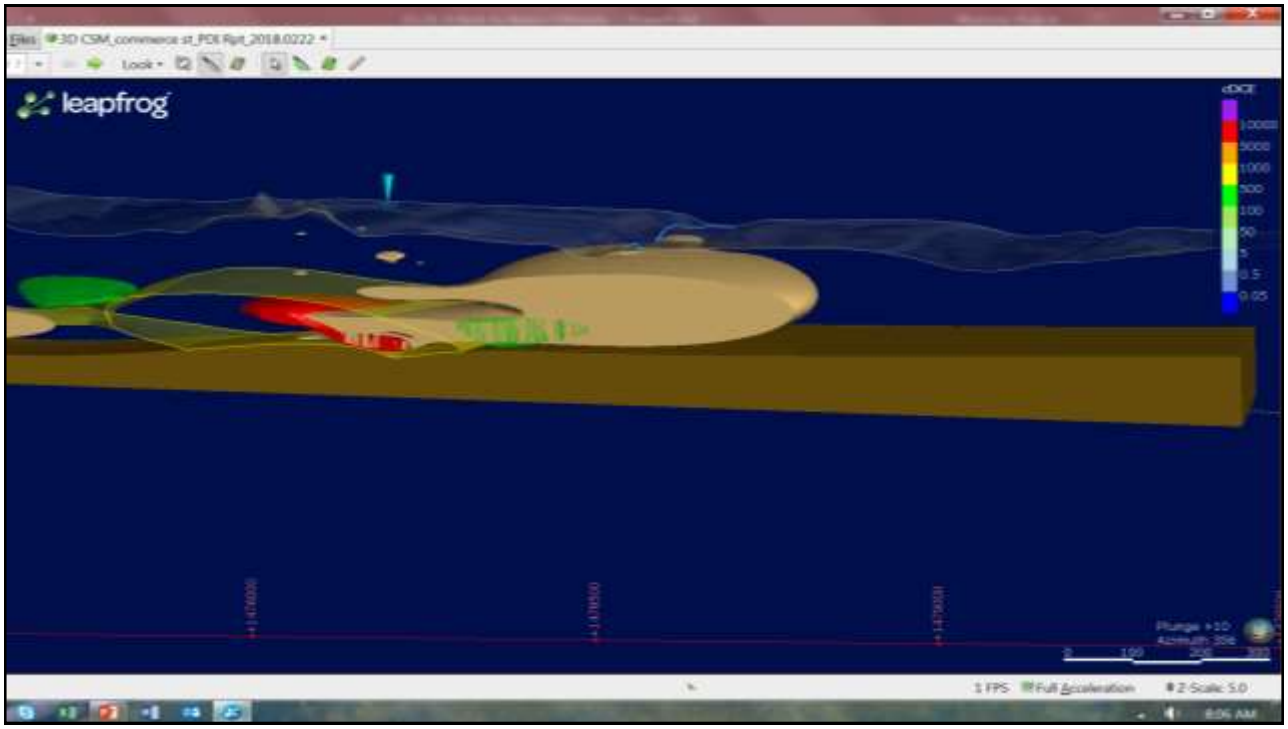
KEY POINT: **The 14-Compartment Model helps Stakeholders align on the Life Cycle of the Site and Characterization Objectives**

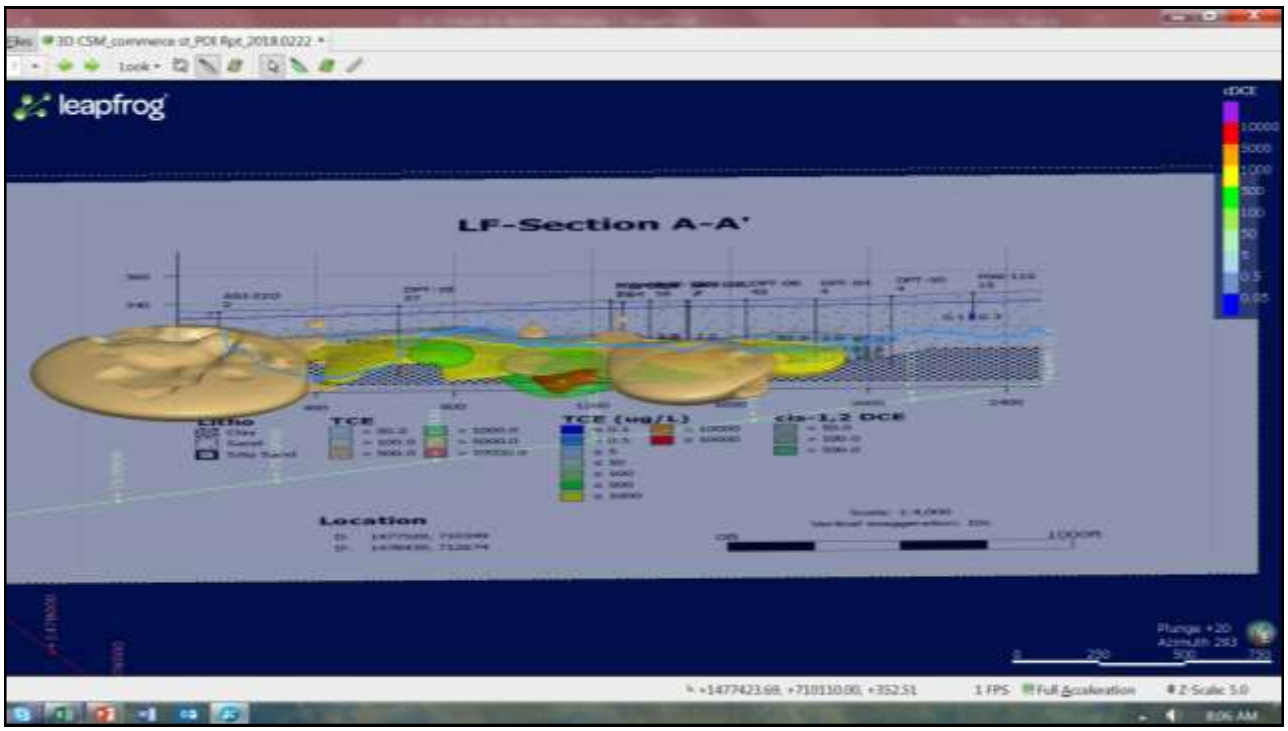
"Next Generation" CSM – 3D Visualization

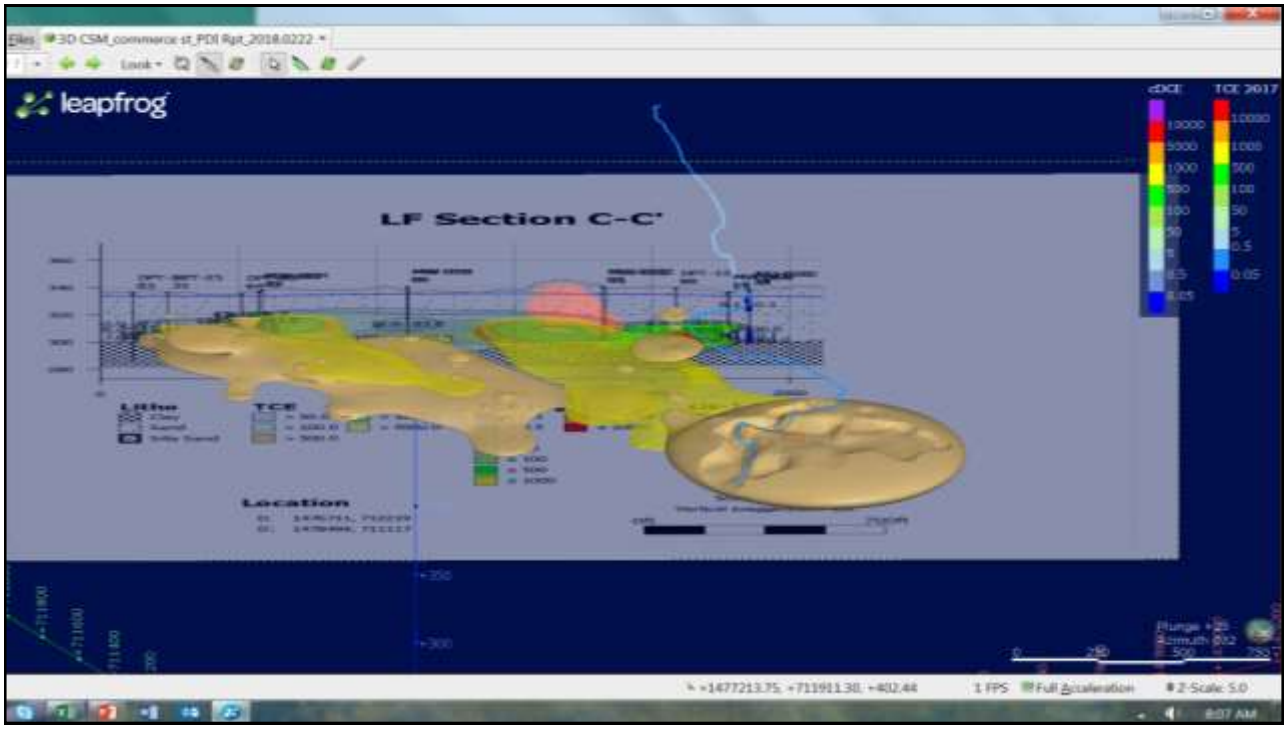
Show 3D LeapFrog Model

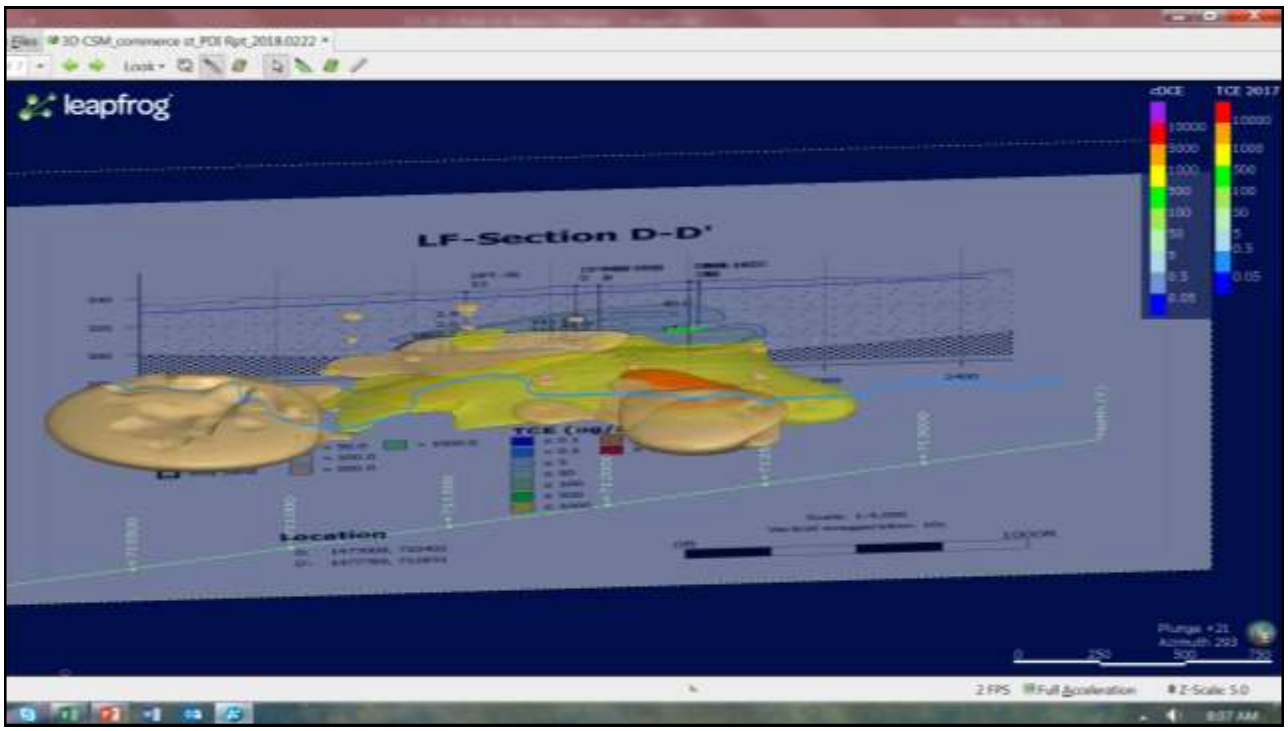

leapfrog
cDCE
10000
5000
1000
500
100
50
5
0.5
0.05
Looking down
1 FPS
Full Acceleration
Z-Scale: 5.0

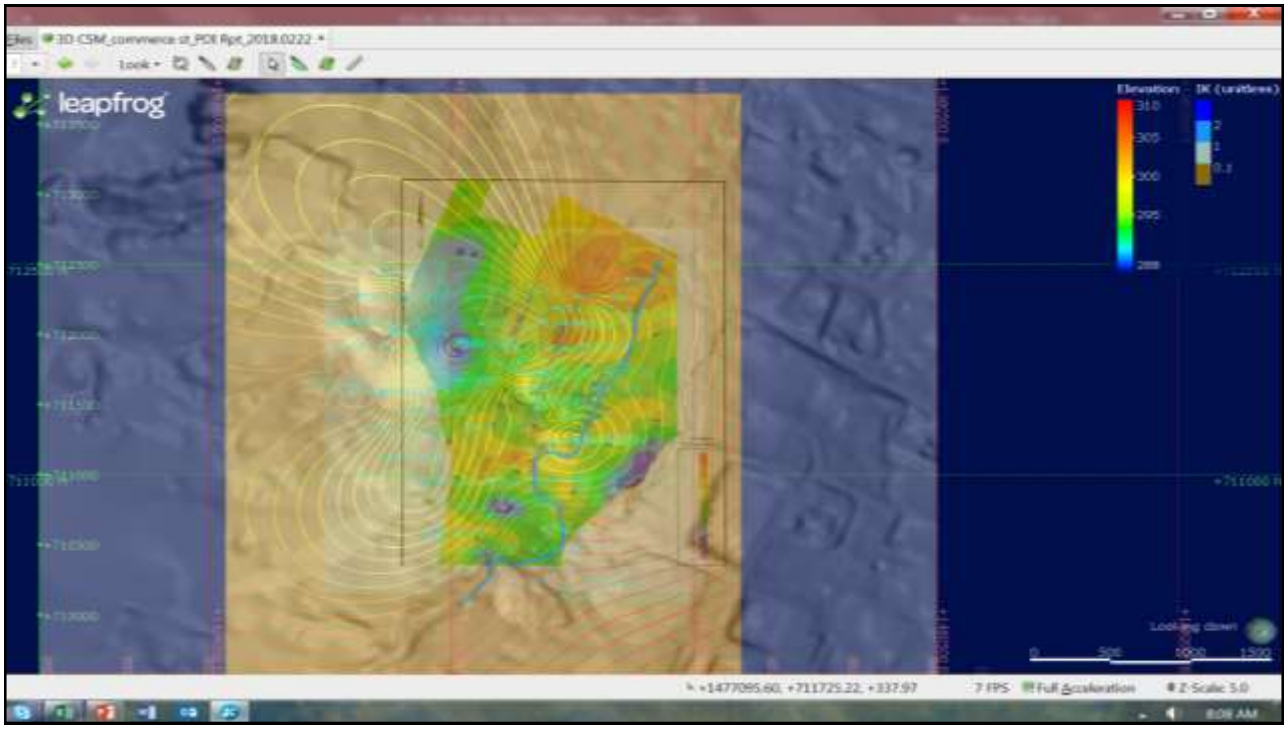

leapfrog
cDCE
10000
5000
1000
500
100
50
5
0.5
0.05
1 FPS
Full Acceleration
Z-Scale: 5.0


leapfrog
cDCE
10000
5000
1000
500
100
50
5
0.5
0.05
1 FPS
Full Acceleration
Z-Scale: 5.0


leapfrog
LF-Section A-A'
cDCE
10000
5000
1000
500
100
50
5
0.5
0.05
Lithio
TCE
TCE (ug/L)
cis-1,2 DCE
Location
1 FPS
Full Acceleration
Z-Scale: 5.0


leapfrog
LF Section C-C'
cDCE
TCE 2017
Lithe
TCE
Location


leapfrog
LF-Section D-D'
cDCE
TCE 2017
Location



Lessons Learned/Key Points

- Development of a CSM is not a one-time activity
  - The initial CSM is assembled based on available information
  - Identify data gaps
  - Plan activities to fill those data gaps
  - Evaluate data and update CSM with new information
  - Repeat!
- The CSM continues to evolve even as remediation is conducted – pilot testing and remedy construction/operation

Visual Example of how a CSM Changes over Time

LESSONS LEARNED/Questions