



**The importance of a
good 3D Conceptual Site
Model in remediation of a
chlorinated VOC
impacted groundwater
site in eastern Ontario**

Jonathan Coakley, Ph.D



Outline

- Background
- Development of the Conceptual Site Model (CSM)
- Refining the CSM
- Limitations
- Future work
- Summary

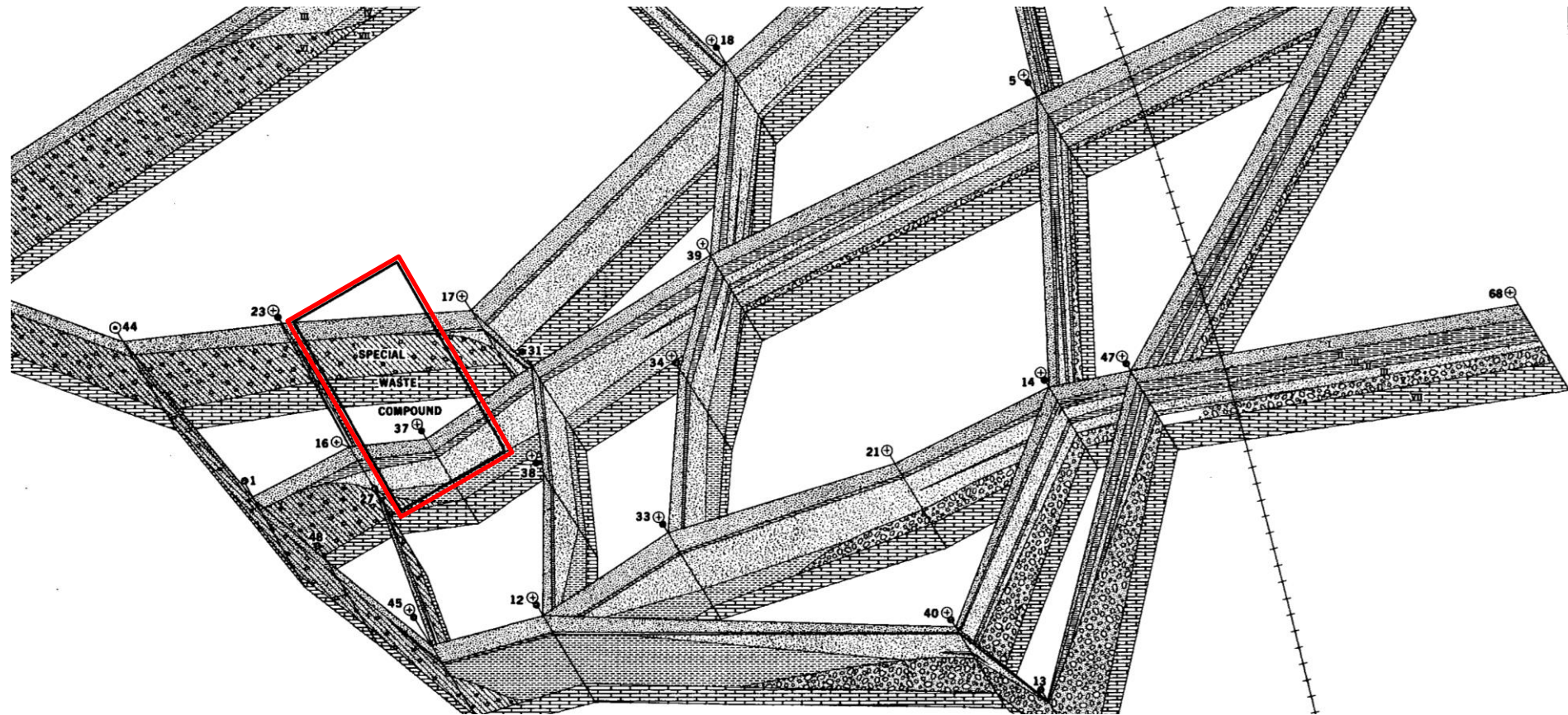


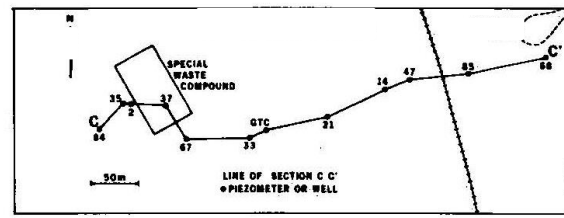
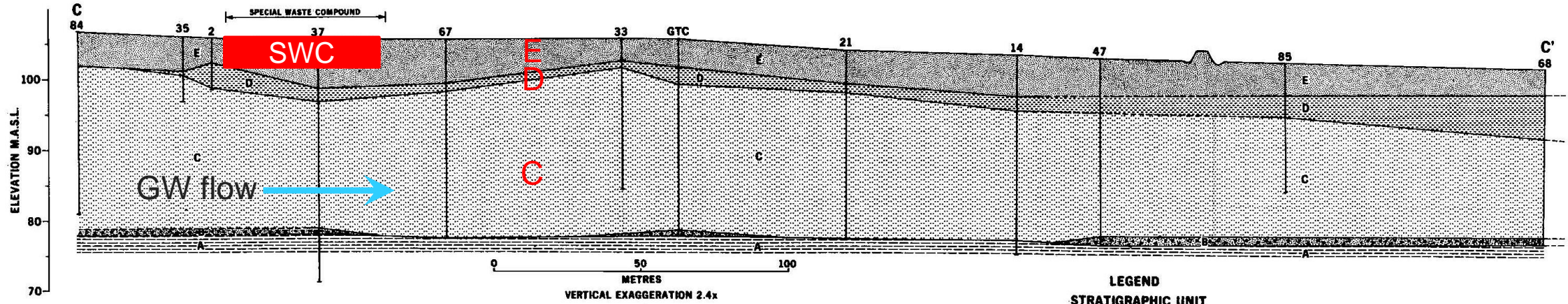
Background








Background

- Situated on a complex sequence of fluvio-glacial and littoral deposits





- LEGEND**
- STRATIGRAPHIC UNIT**
-  **A** Limestone; shaley limestone interlayers
 -  **B** Till; Coarse angular cobbles and boulders in sand and silt matrix
 -  **C** Sub-aqueous outwash poorly sorted gravels, sands and silts
 -  **D** Stratified clayey silt and silt
 -  **E** Regressional sands and gravels



Background

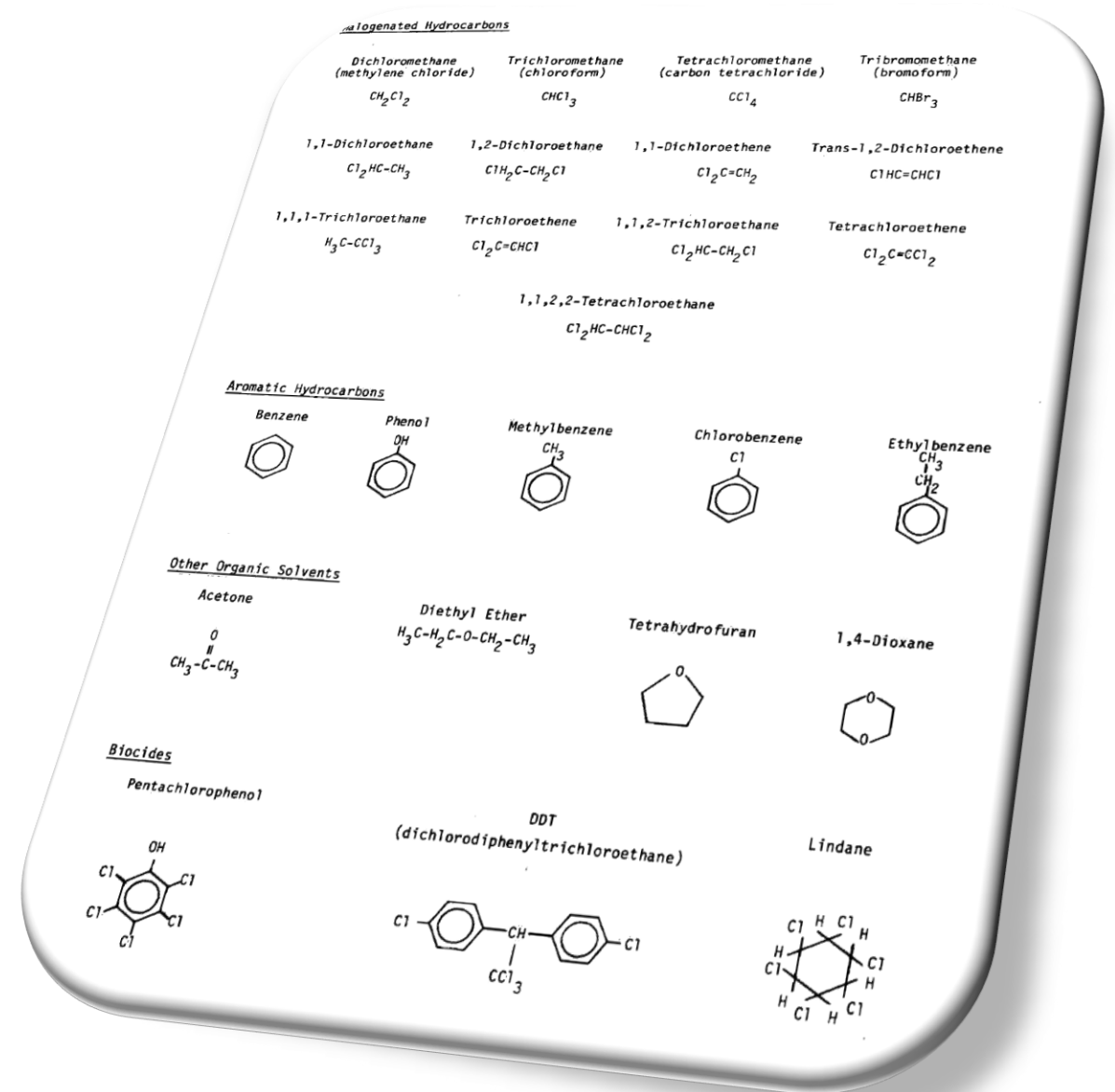
- Hazardous waste disposed between ~1957 and 1980
- Various government agencies involved
- “Indiscriminate” disposal of hazardous wastes
- Improper management (e.g., incineration, detonation of explosives within the waste)
- Deposited in trenches within the “Special Waste Compound”





Background

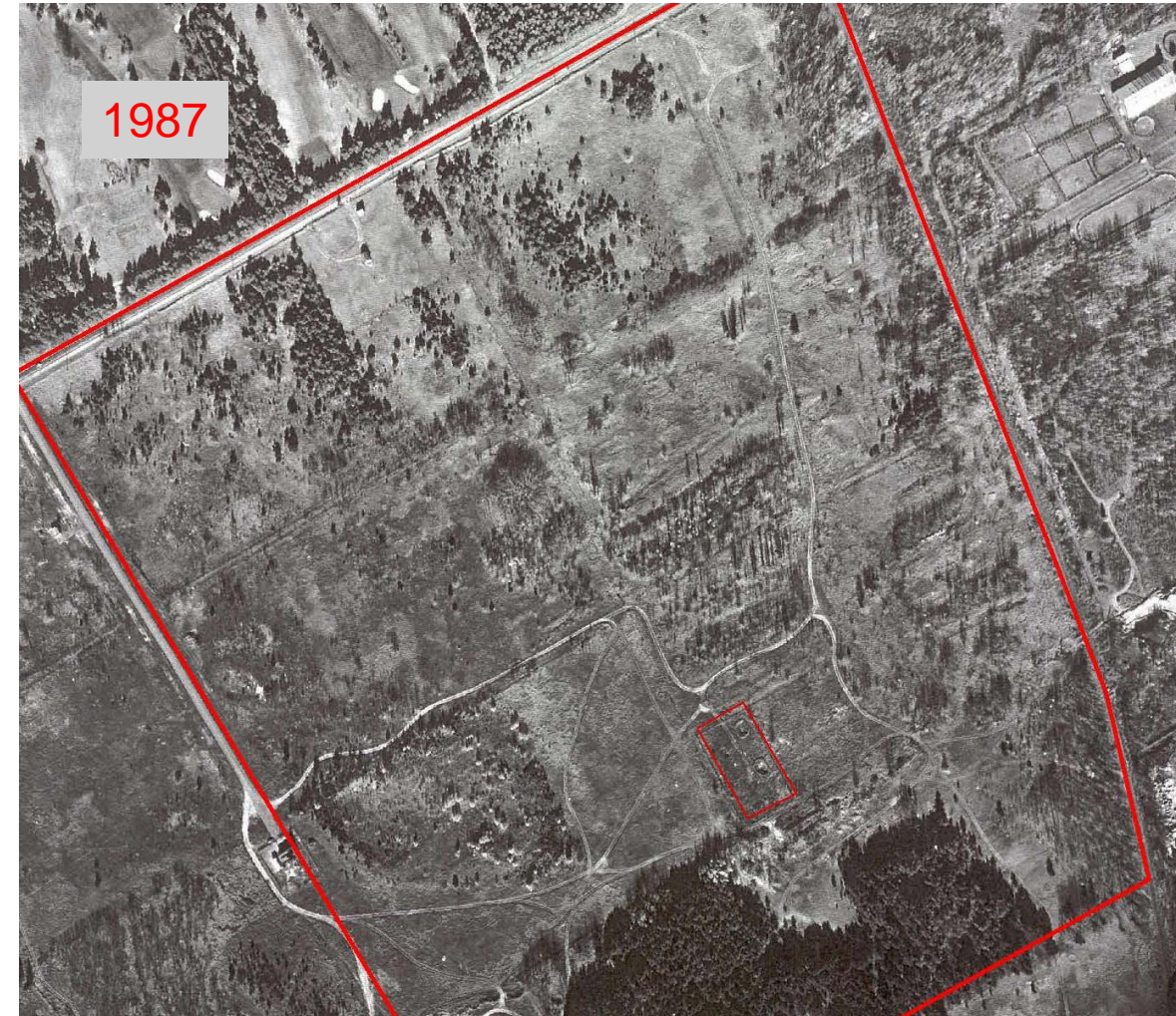
- Laboratory and hospital organic solvents were disposed in large quantities
- Other wastes: pesticides, acids, bases, mercuric salts
- Key contaminants of concern:
 - Tetrachloroethylene (PCE)
 - Trichloroethylene (TCE)





Background

- Decision in 1980 to halt disposal activities
- Excavation of the waste materials for disposal offsite
- Following excavation, groundwater investigations in the late 1980s led to discovery of a highly contaminated plume
- PCE and TCE are key contaminants of concern
- No direct evidence of NAPL
- Deep aquifer is most affected
- Pump and treat system installed in 1992 until 2013





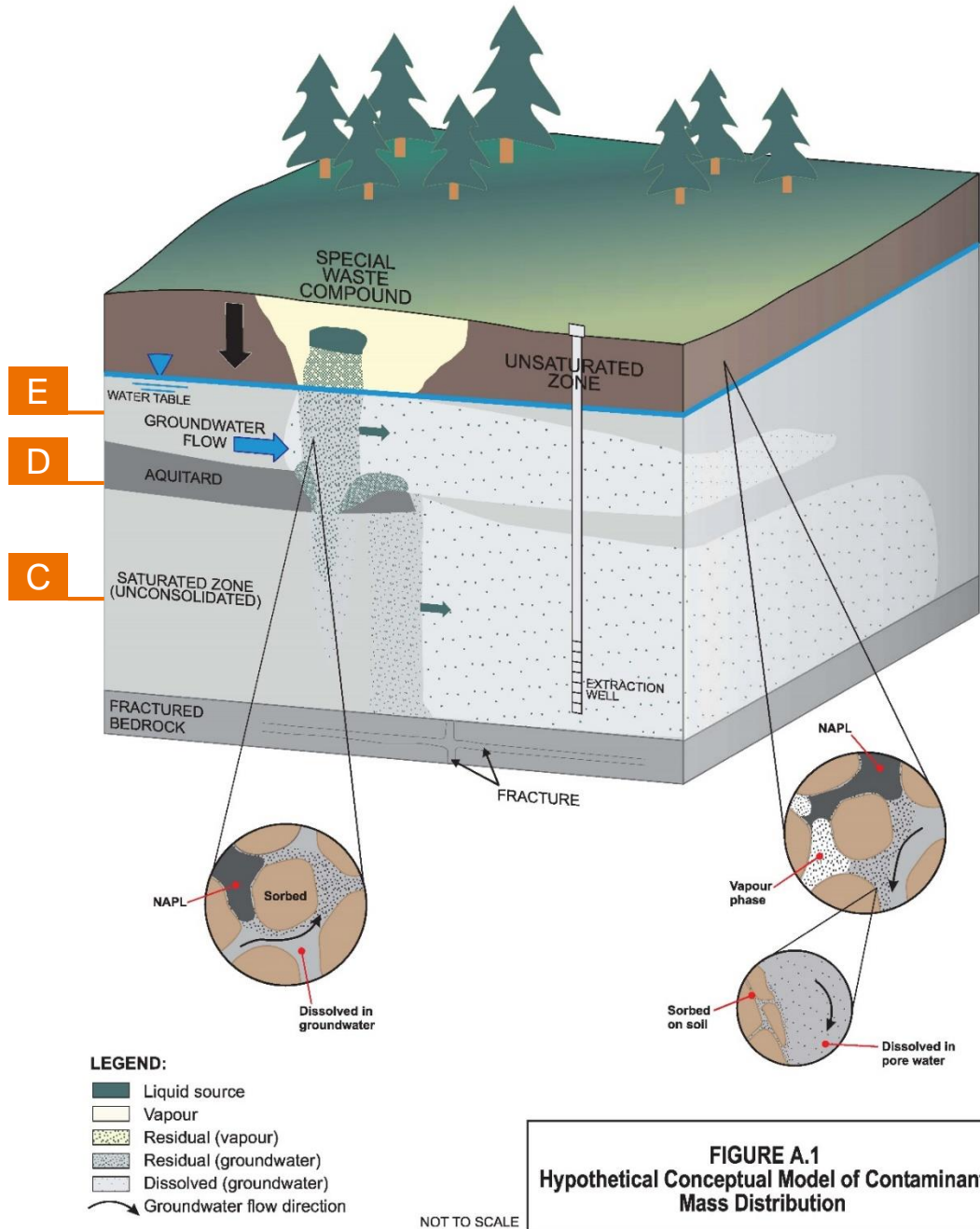
1999

BACKGROUND





Development of the CSM

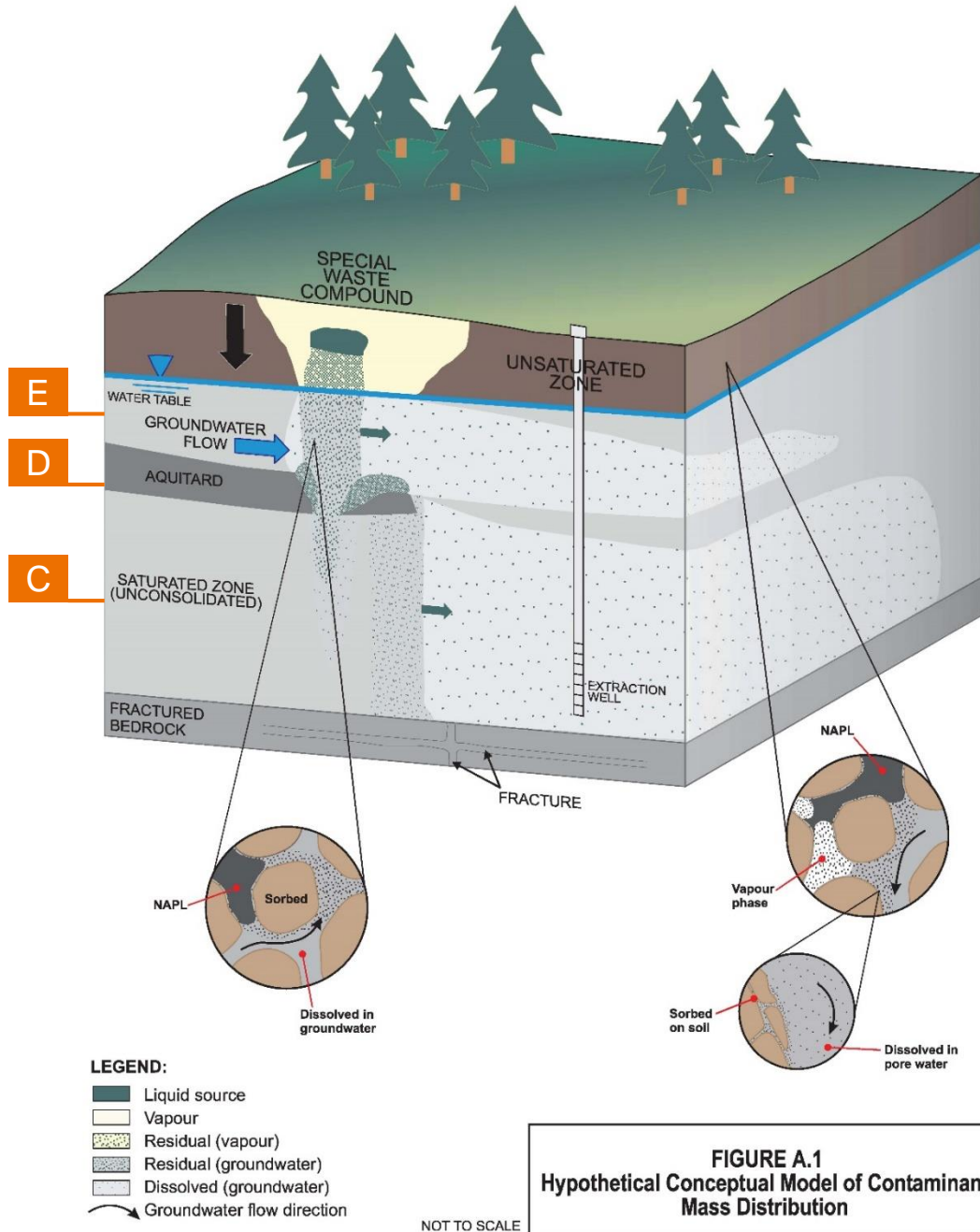


Development of the CSM

Studies since the 1980s

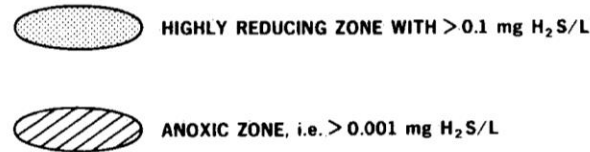
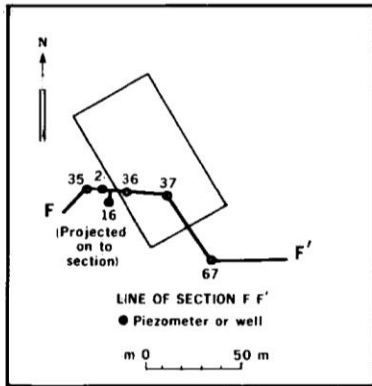
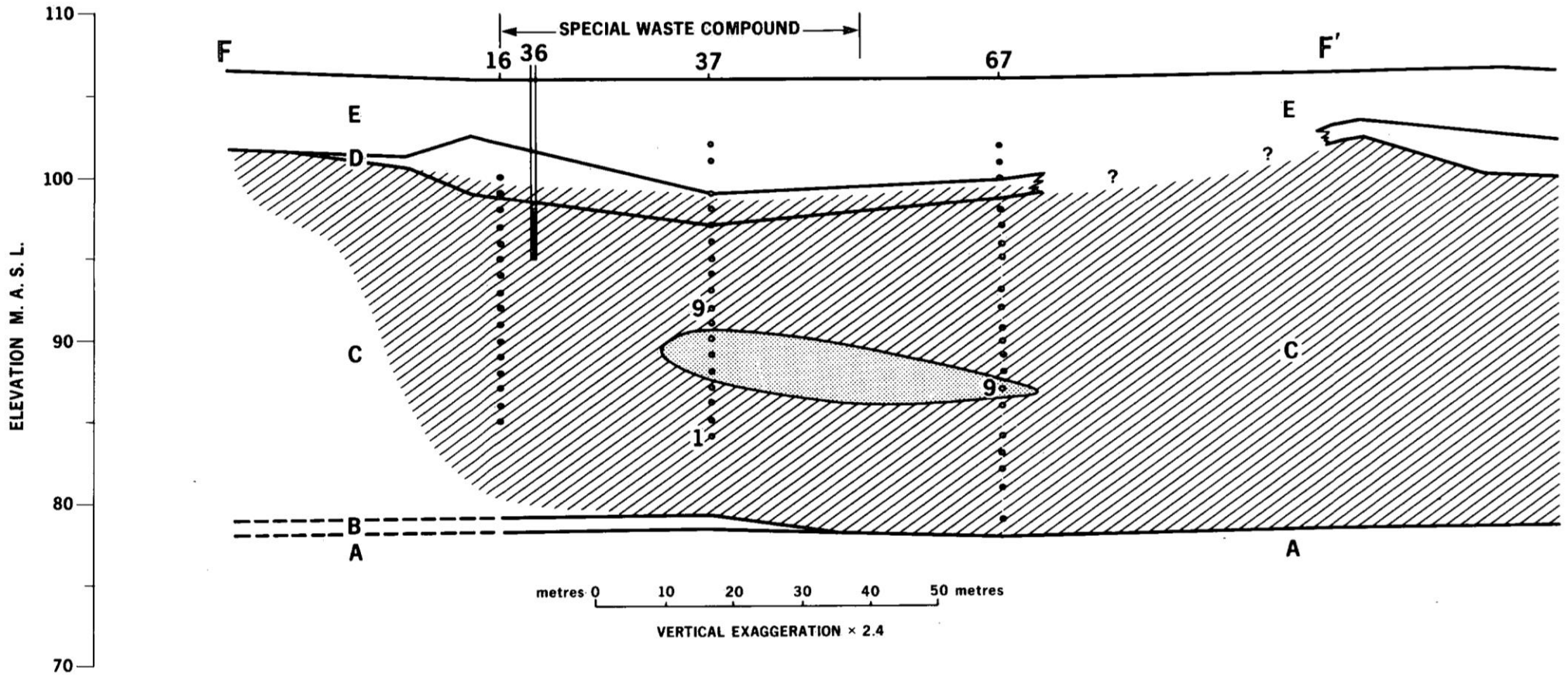
3 main sub-surface stratigraphic groups

- Deep aquifer
 - Unit C – 80 to 98 m amsl
- Clay/silt confining layer
 - Unit D – 98 to 100 m amsl
- Shallow aquifer
 - Unit E – 100 to 106 m amsl



Development of the CSM

- Identified “windows” provide a pathway for contamination to migrate between aquifers
- Deep aquifer flow to the East
- Shallow aquifer flow is heterogeneous
- Anaerobic reducing zones present within Unit C



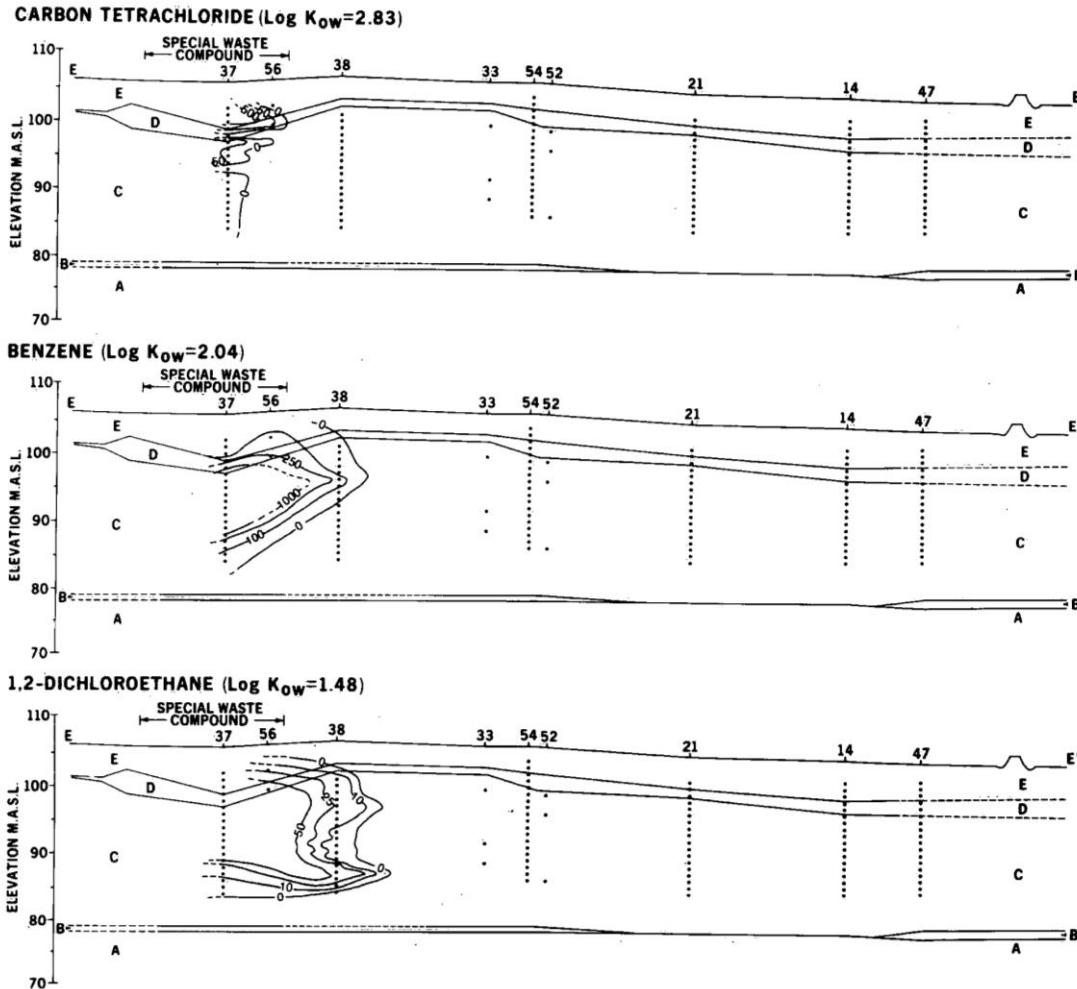
LEGEND
STRATIGRAPHIC UNIT

- A** LIMESTONE; SHALEY LIMESTONE INTERLAYERS
- B** TILL; COARSE ANGULAR COBBLES AND BOULDERS IN SAND AND SILT MATRIX
- C** SUB AQUEOUS OUTWASH; POORLY SORTED GRAVELS, SANDS AND SILTS
- D** STRATIFIED CLAYEY SILT AND SILT
- E** REGRESSIONAL SANDS AND GRAVELS



Development of the CSM

- Integration of groundwater monitoring since 1993
- Refinement of the 1980s 2D CSM to evaluate vertical and lateral plume dispersion
- 1990s findings showed majority of dissolved PCE/TCE in Unit E - 95 to 100 m amsl
- In comparison, the 1980s CSM had showed majority of dissolved PCE/TCE in Unit C - 90 to 95 m amsl





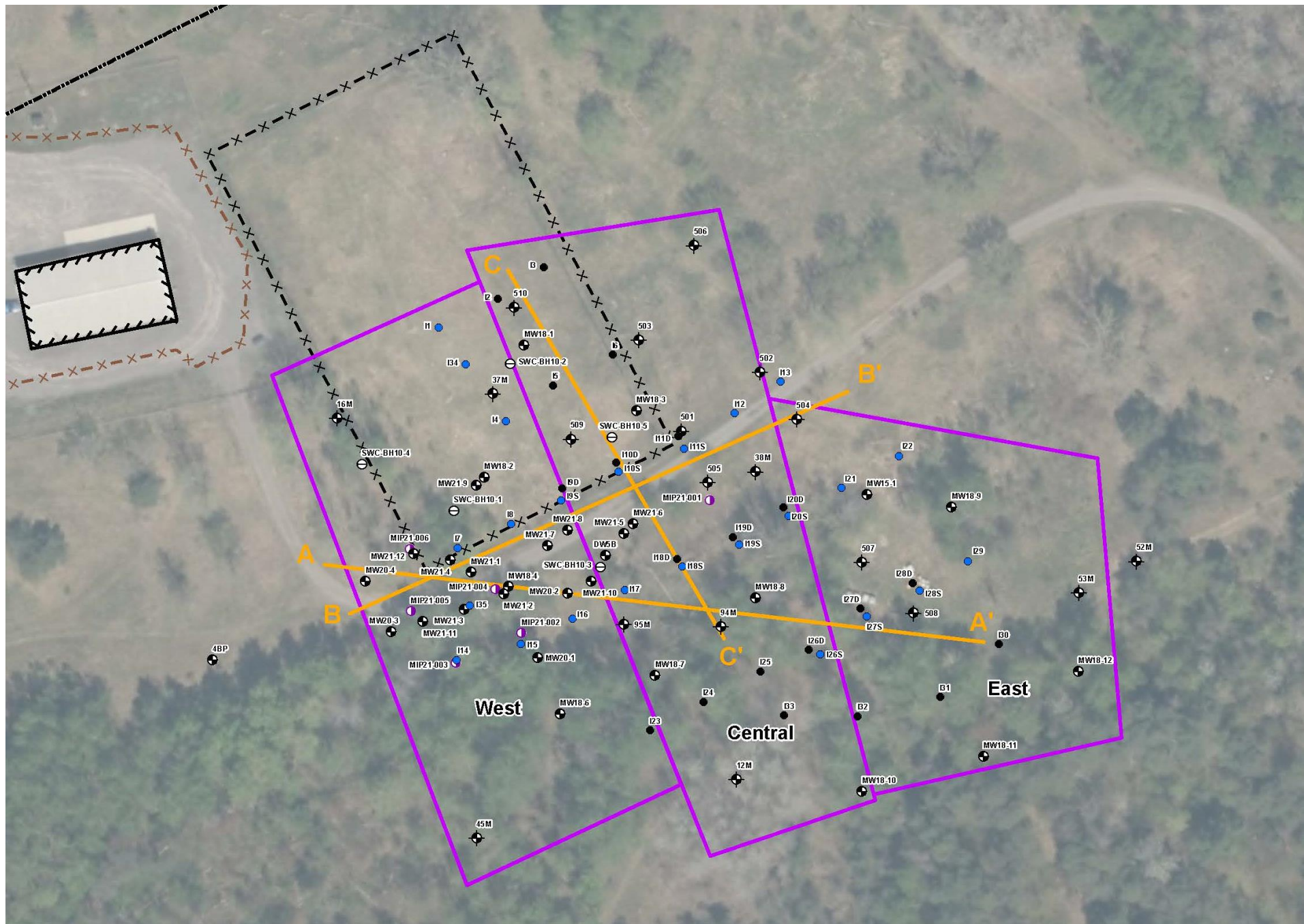
Refining the CSM



Refining the CSM

- Limitations in continuing with the pump-and-treat system were identified in 2013
- There was a switch in 2019 to inject molasses as the organic substrate to stimulate anaerobic biodegradation of the chlorinated VOCs
- 7 Molasses Substrate Solution Injection Events (MSSIE) between 2019 and 2021
- Monitoring showed TOC released from MSSIE were not reaching all affected areas within the aquifer
- Upper portions of Unit C (deep aquifer) not receiving substrate in sufficient concentrations (<75 mg/L)
- Placement of injection well screens was re-evaluated

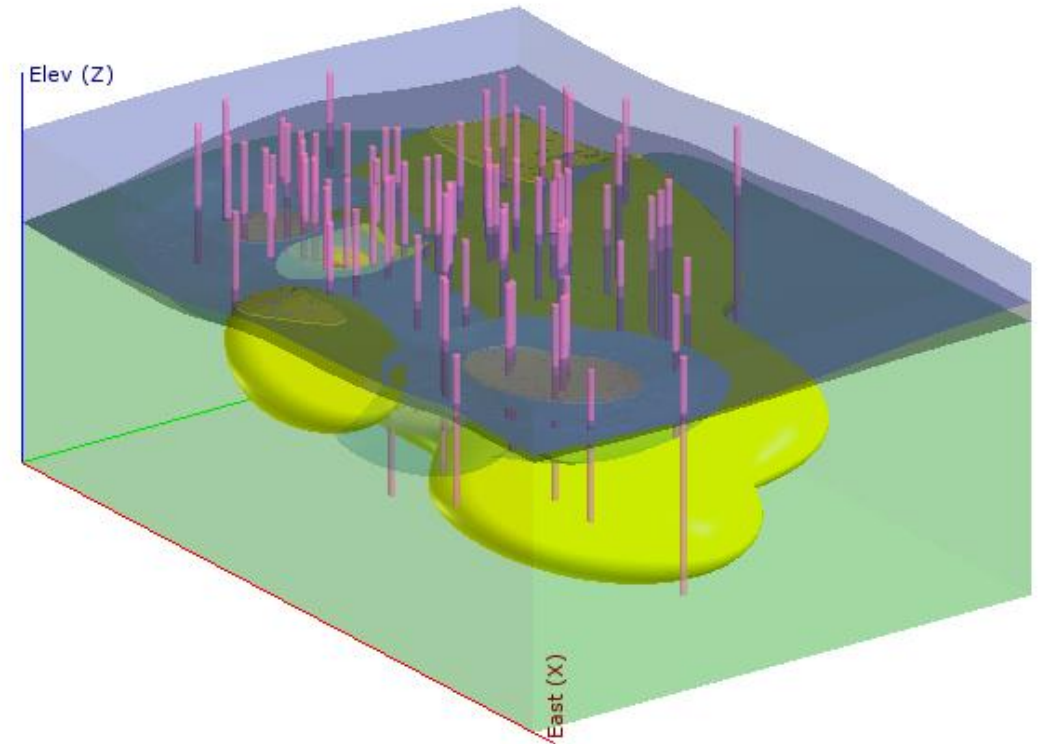


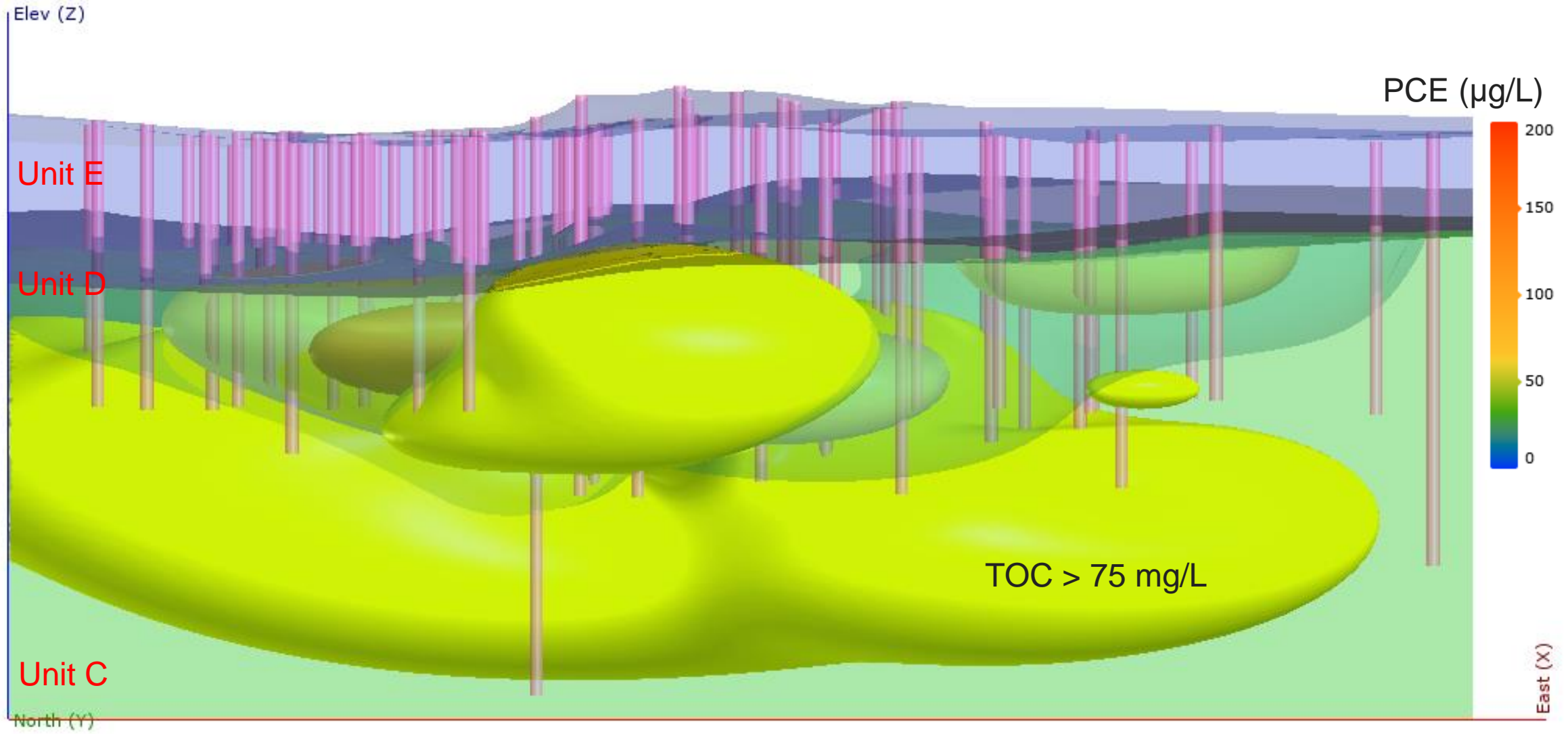




Refining the CSM

- Use of LeapFrog + Hydrogeology™
- Overburden stratigraphy was characterized from all past and current investigations
- 3D rendering of the VOC contaminant plume
- Focus on PCE & TCE
- 3D rendering of the remedial substrate plume
- TOC, Dhc, Br, Fe, sulphate
- 3D model updated with new information from targeted monitoring programs





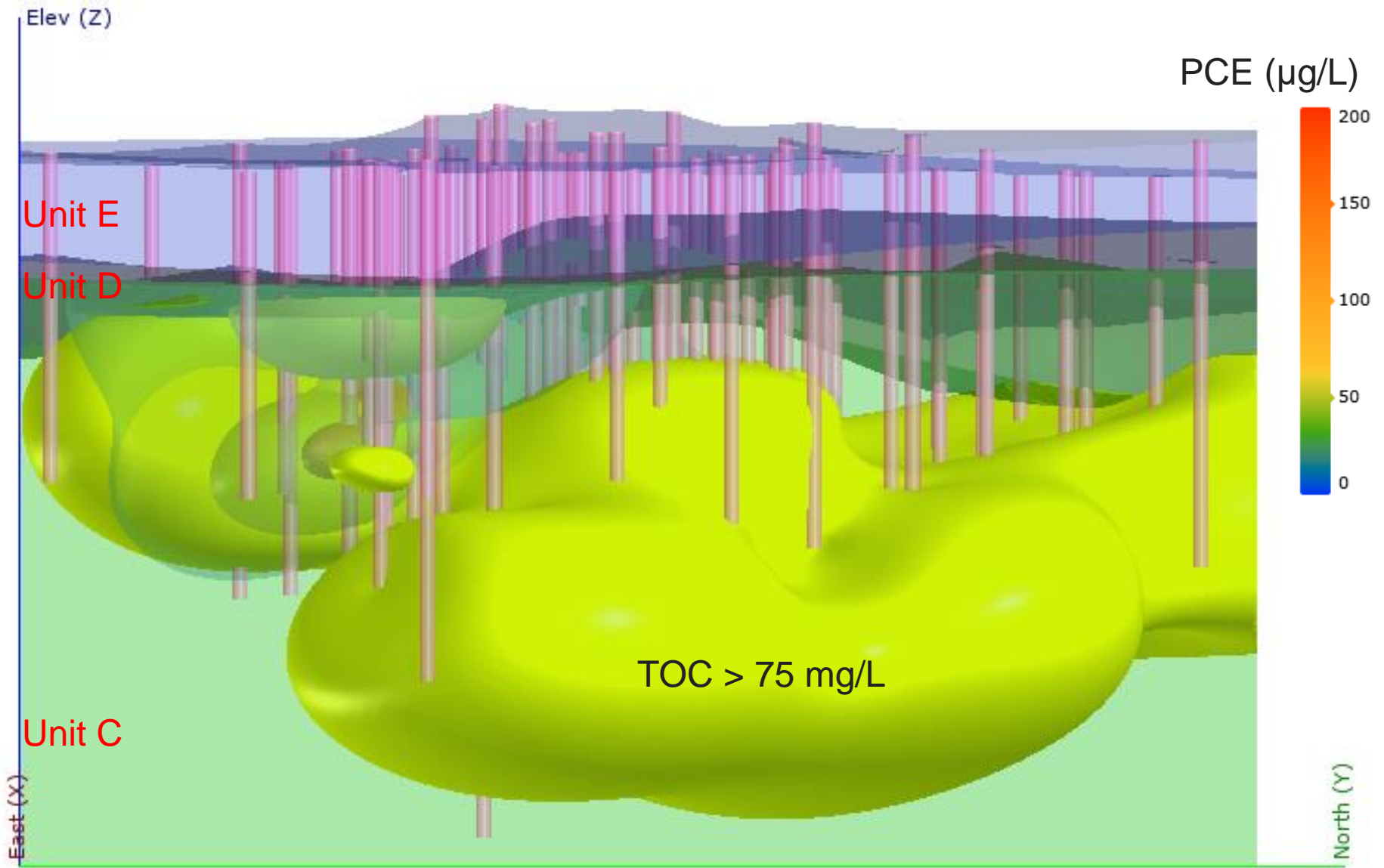




Figure 3a: PCE (ug/L) and TOC (mg/L) along A-A'

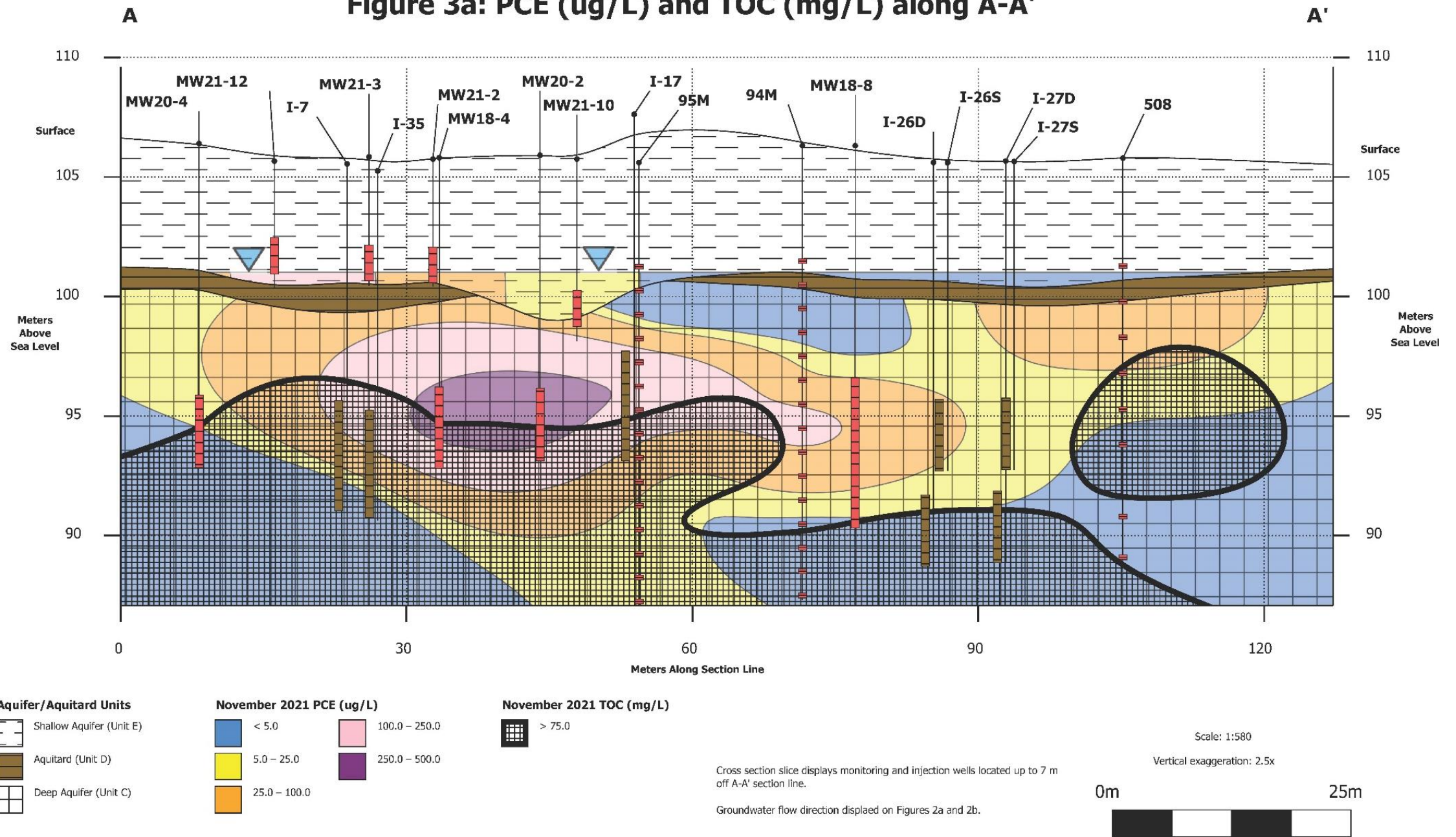
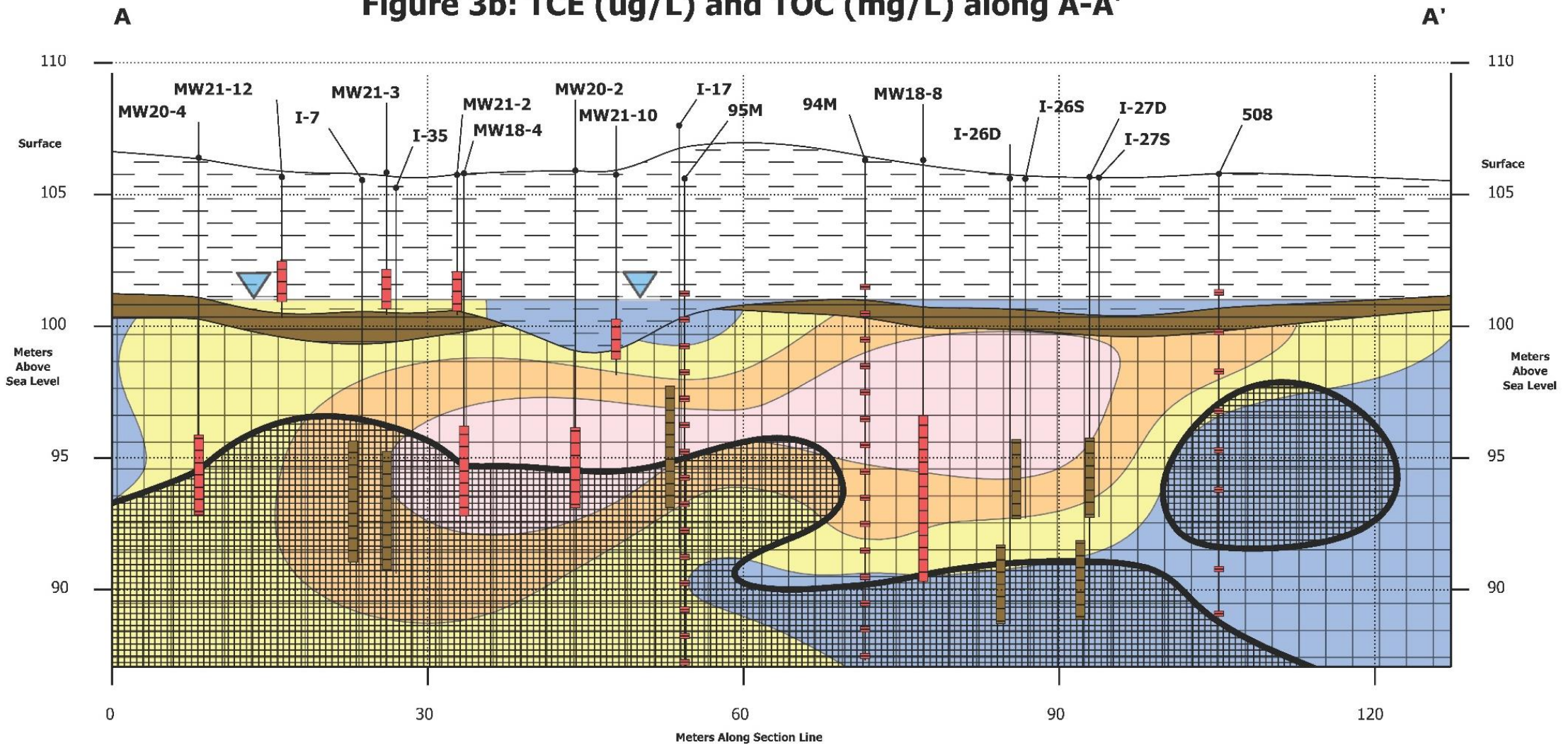




Figure 3b: TCE (ug/L) and TOC (mg/L) along A-A'



Aquifer/Aquitard Units

- Shallow Aquifer (Unit E)
- Aquitard (Unit D)
- Deep Aquifer (Unit C)

November 2021 TCE (ug/L)

- < 5.0
- 5.0 – 25.0
- 25.0 – 50.0
- > 50.0

November 2021 TOC (mg/L)

- > 75.0

Cross section slice displays monitoring and injection wells located up to 7 m off A-A' section line.

Groundwater flow direction displayed on Figures 2a and 2b.

Scale: 1:580

Vertical exaggeration: 2.5x



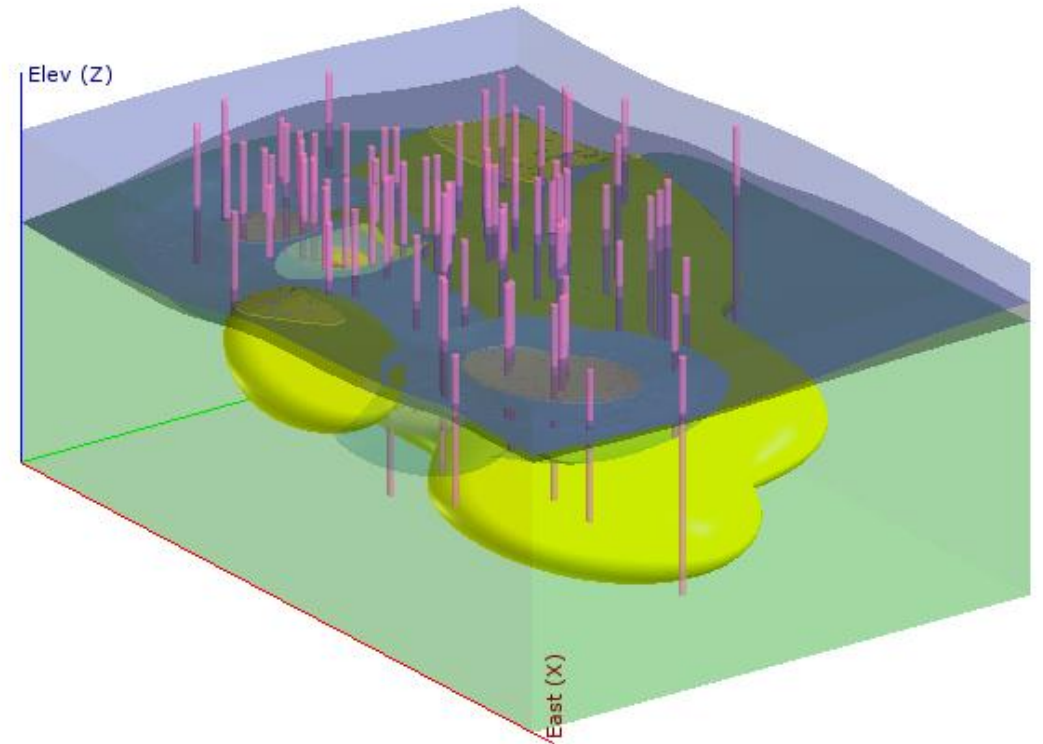


Limitations



Limitations

- Monitoring information is limited
 - Understanding of the confining silt/clay layer (Unit D) structure is limited
 - Contaminant distribution and mobilization in the shallow aquifer is not well characterized
- Enhanced reductive dechlorination pathway and fate of degradation products is complex
- Presence of NAPL, sorption to soil affects treatment efficiency
- Modelling is a “good guess” only
 - Not the only method for decision-making at the site





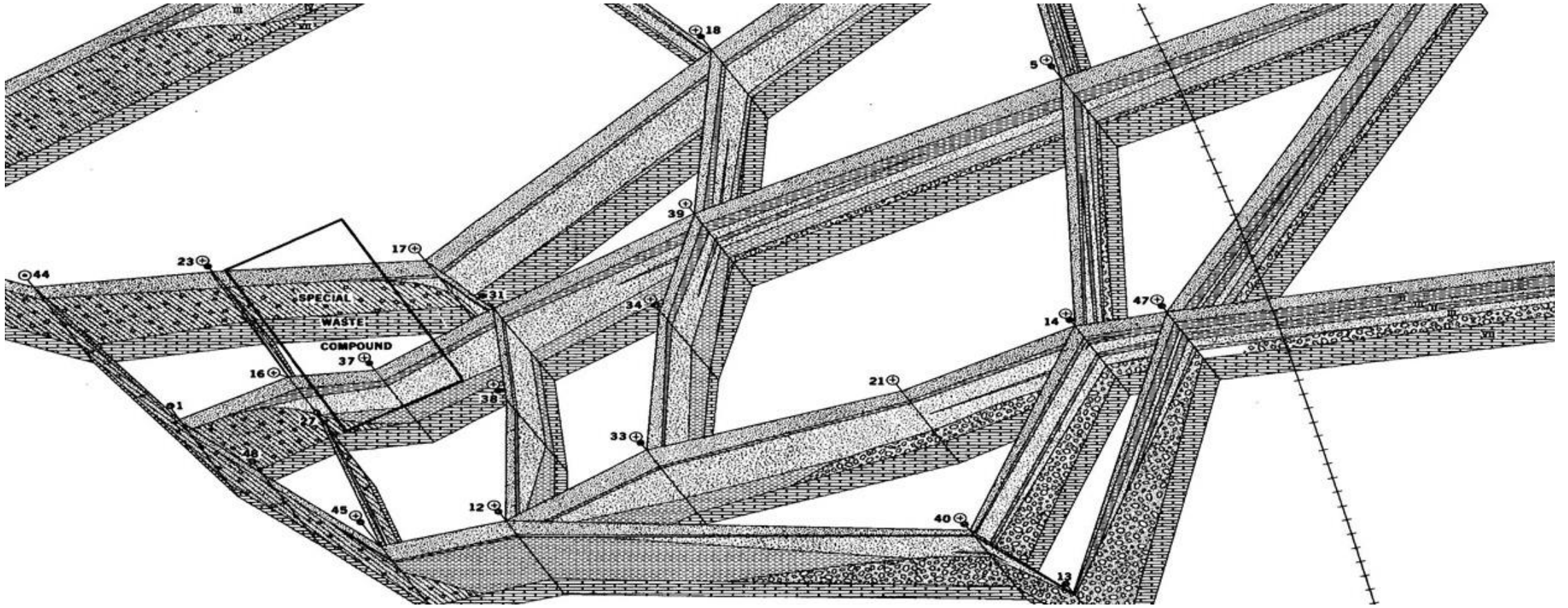
Future Work



Future Work

- Further characterization of the site
 - Current MIP/HPT survey
 - Multi-level wells within the upper portion of the deep aquifer (Unit C)
 - Wells in portions of the shallow aquifer that have not been studied extensively
- Updating the 3D model to optimize remediation in a targeted manner
- Communication of the results
 - Decisions about remedial endpoints





Summary



Summary

- The CSM for the site has evolved over a number of decades
- 3D CSM provides a useful evaluation and communication tool
- Software package provides a central location for project investigation data
- Refinement of the CSM allows tracking of remediation progress



Acknowledgements

- Henry Hecky, P. Geo. for his contributions to the understanding of the site
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Approvisionnement Canada



Jonathan Coakley Ph.D.

Senior Environmental Scientist/Remediation Specialist



Phone: (905) 385-3234

Email: Jonathan.Coakley@stantec.com

Thank You – Questions?