



# Deciding When to Use Environmental Sequence Stratigraphy (ESS), and Application to Per- and Polyfluoroalkyl Substances Sites

Simon Kline, P.G.  
April 16, 2019

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# Agenda

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- Overview of ESS
- Introduction of the ESS Decision Tree
- Examples encountered at decision points along tree pathways
- Desktop Case Study: Per- and Polyfluoroalkyl Substances Site

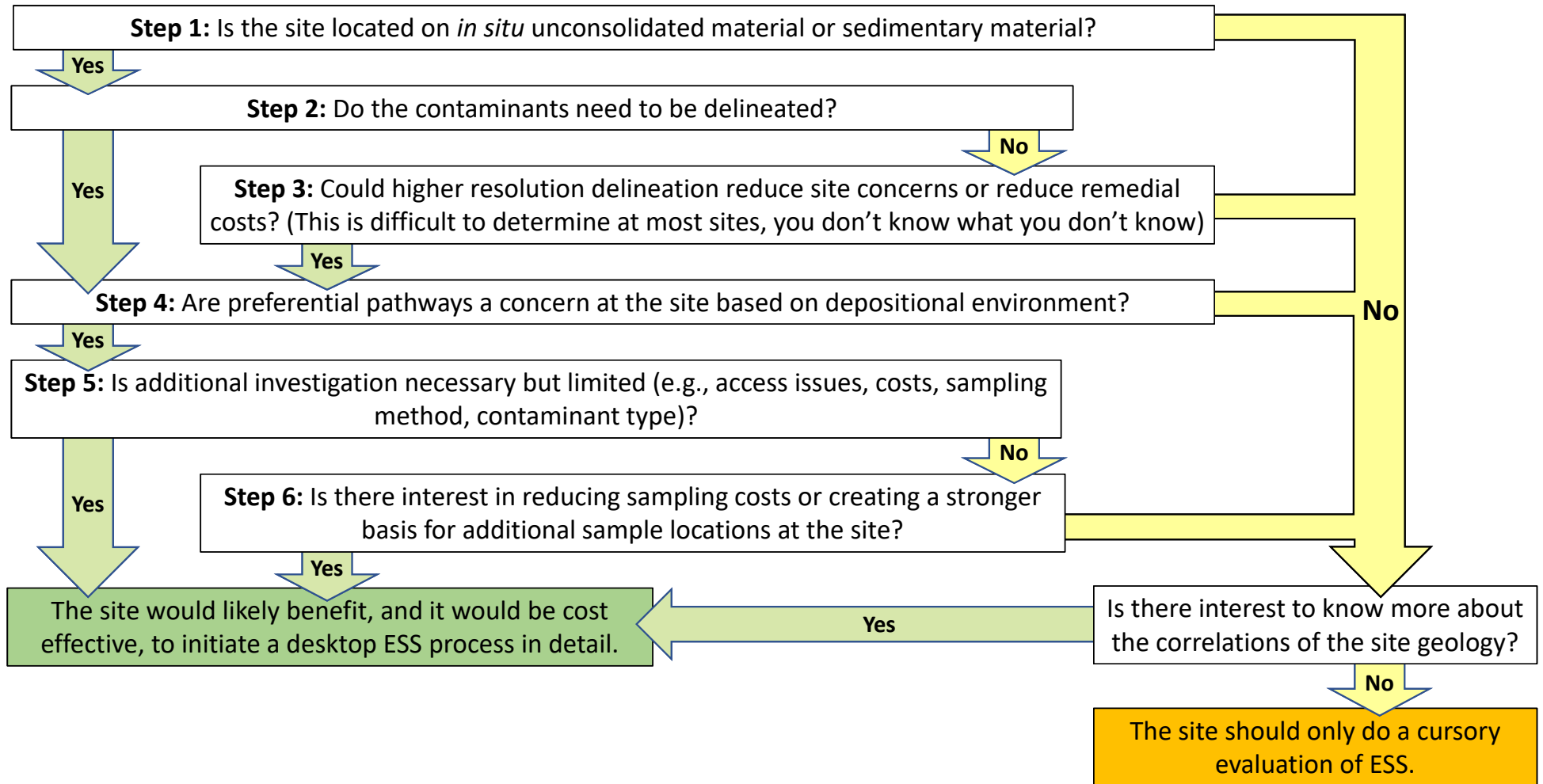


# ESS Overview

- Applying principles of sequence stratigraphy developed and practiced by the petroleum industry for decades
- Controls: Sea level (eustasy), tectonics, and magnitude/rate of deposition
- Produces repeated patterns (sequences) of depositional materials over spatial and temporal extents
- Same factors that provide hydrocarbon storage and transport applied to groundwater
- Scaled down to apply to environmental site investigations and Conceptual Site Models (CSMs)



# Should I Consider ESS For My Site?



# Is the site located on *in situ* unconsolidated material or sedimentary material?

Yes

No



Fluvial (River)



Lacustrine & Alluvial  
(Lake and loose sediment)



Marine & Aeolian  
(wind-blown)



Glacial



Man-Made  
(dredge deposits)



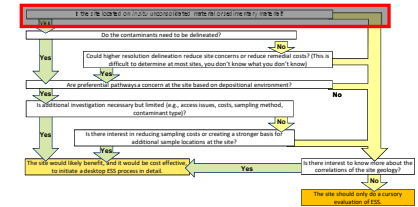
Fractured Igneous or High  
Grade Metamorphic Rocks



Exposed Rock with  
no Overburden



Karst



Stratigraphy is important to understanding consolidated sites, however the sites with above surface/subsurfaces utilize fields of larger scale structural geology

Unconsolidated materials are less massive and more prone to frequent variations and benefit from evaluation of ESS

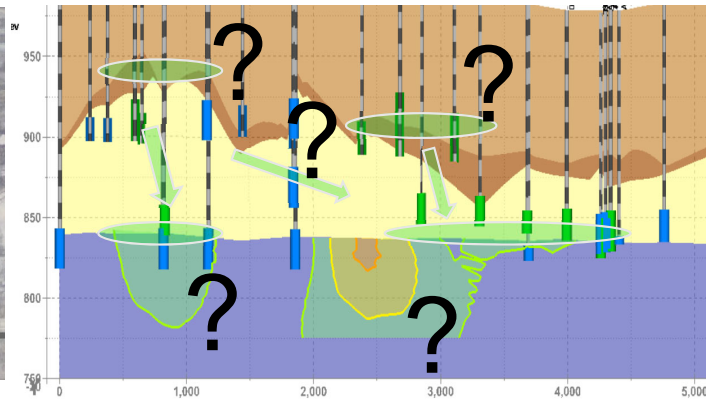
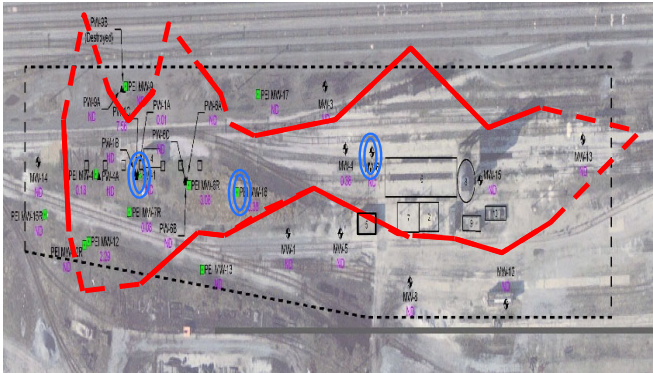
# Do the contaminants need to be delineated?

Yes

Laterally?

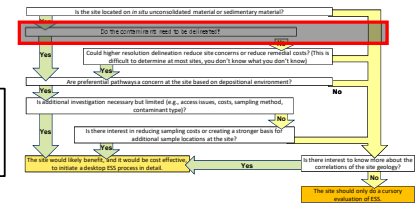
Vertically?

— Delineated      - - - Unknown Extent



If delineation data incomplete for one or both extents. ESS may provide delineation confidence without additional borings

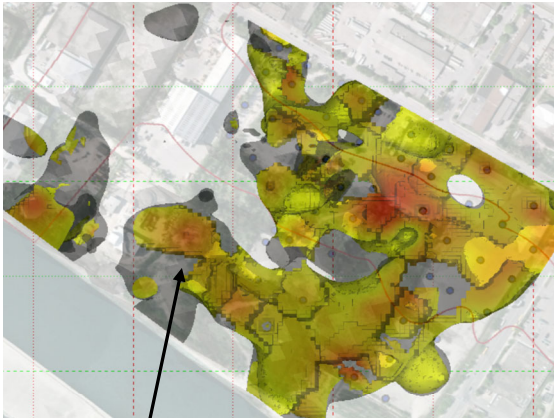
No



Could higher resolution delineation reduce site concerns or reduce remedial costs? (This is difficult to determine at most sites, you don't know what you don't know)

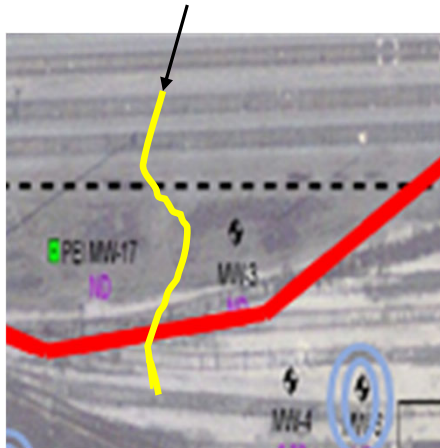
Yes

Delineation is relative to concerns.  
ESS can reduce the interpolated extent of contaminants.

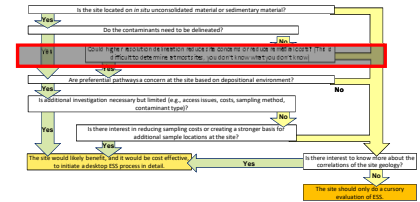


Gray areas removed based on additional data

What about this alluvial channel?

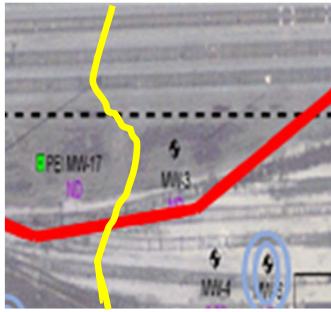


No

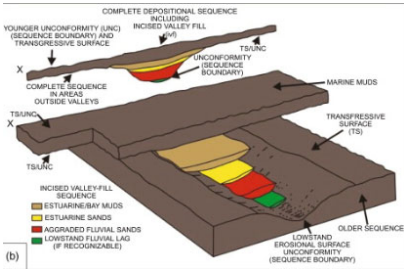


# Are preferential pathways a concern at the site based on depositional environment?

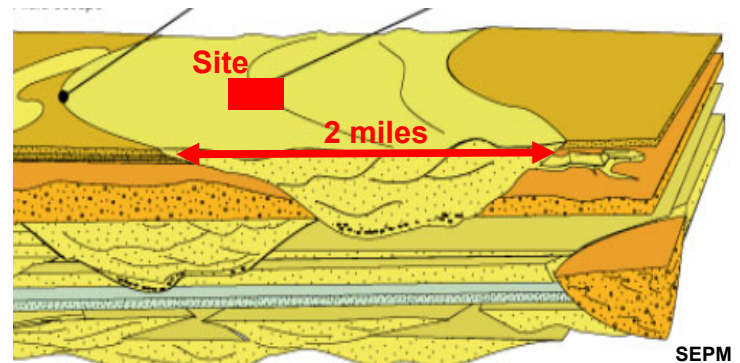
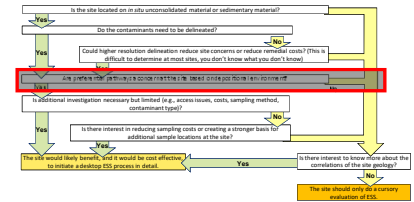
Yes



- Braided channel, fanglomerates, incised valleys, deltas...and many more
- Heterogeneity is the norm, not the exception



No

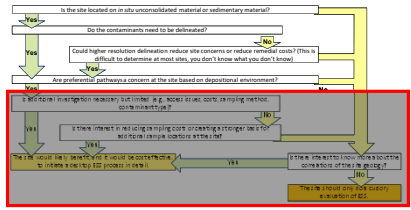


Some native deposits are just like having a thousand utility corridors running through your site.

Scale is important in ESS:  
If the size of the site is smaller than depositional changes ESS is less important



Is additional investigation necessary but limited (e.g., access issues, costs, sampling method, contaminant type)?



Areas that are inaccessible can benefit from ESS analysis (e.g., lack of preferential pathways and extrapolation of soil types)

No

Is there interest in reducing sampling costs or creating a stronger basis for additional sample locations at the site?

Inertia from client / consultant to engage with regulators on scope or sampling plan modifications



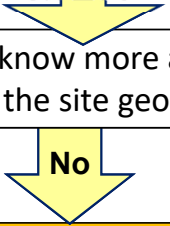
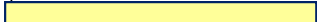
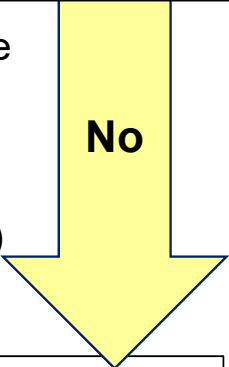
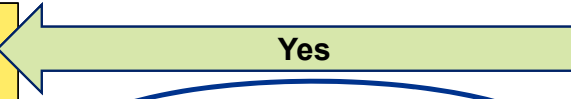
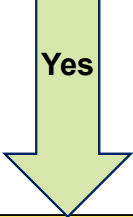
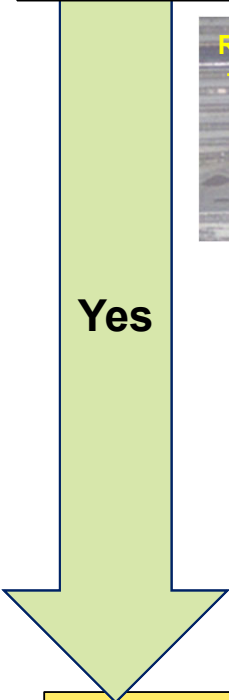
MEH

Is there interest to know more about the correlations of the site geology?

All our geology data is CPT logs, in a database, why not?

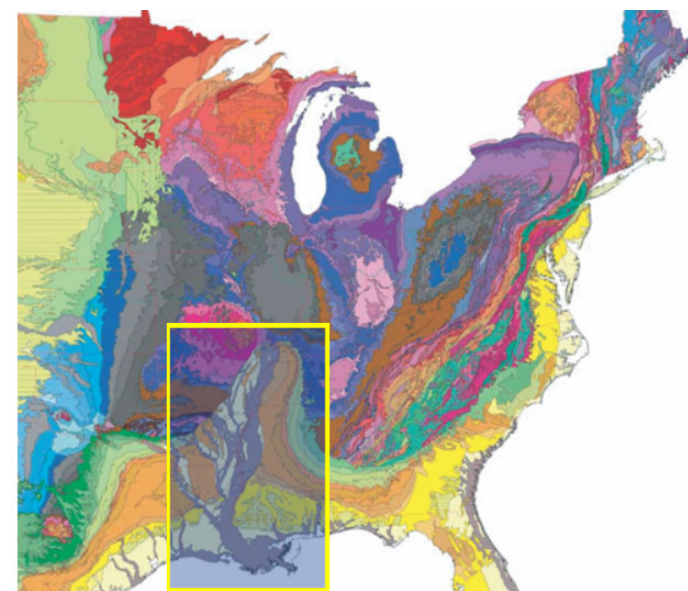
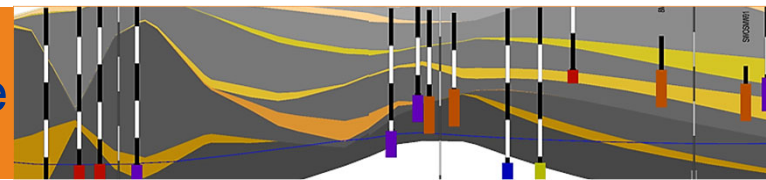
The site would likely benefit, and it would be cost effective, to initiate a desktop ESS process in detail.

The site should only do a cursory evaluation of ESS.



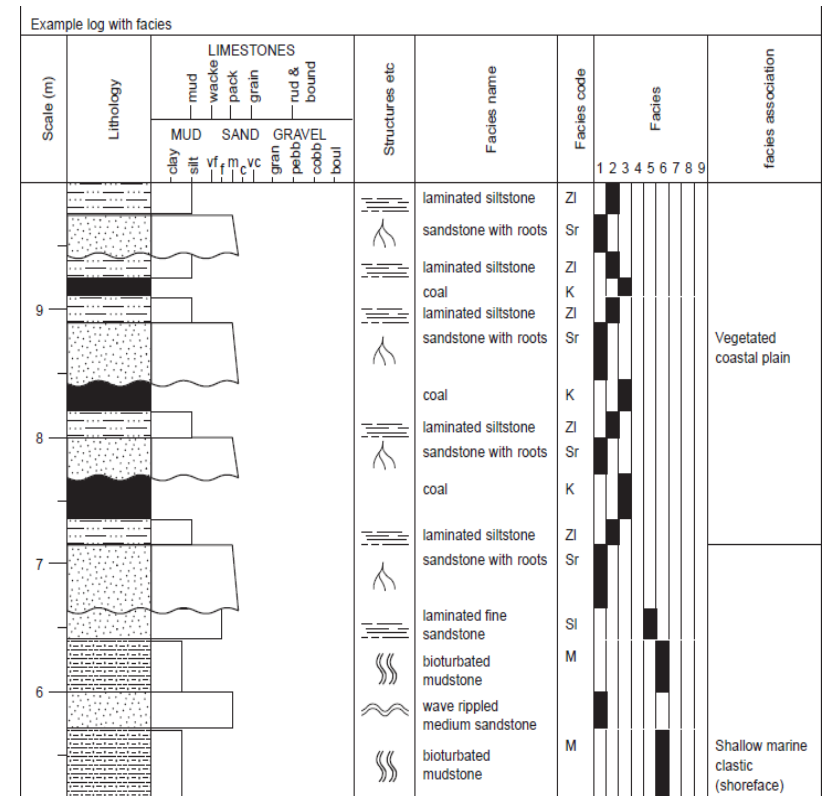
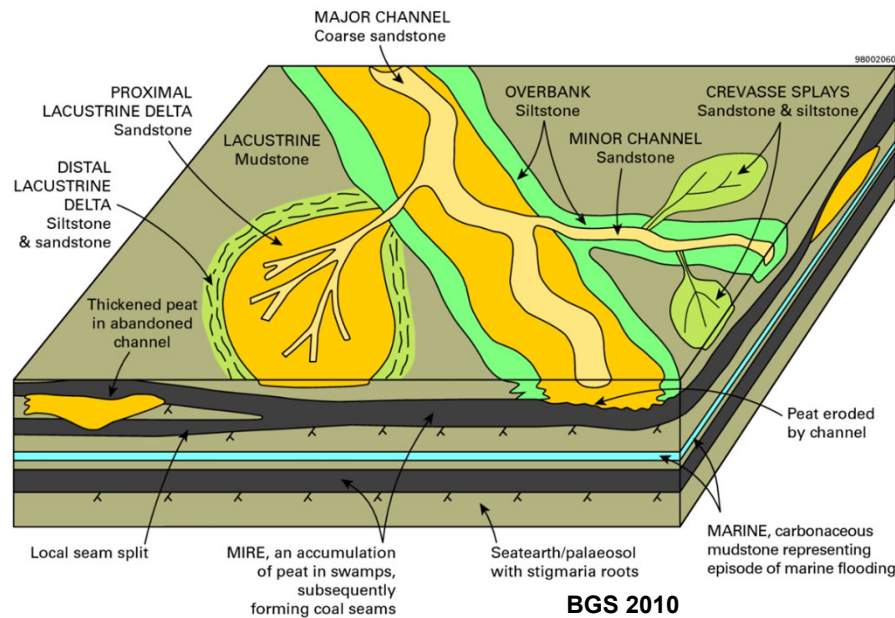
# Site - Regional Information

- Located in Coastal Plain of Mississippi and is part of the Mississippi Embayment
- Lithology Group - Mix of marine and alluvial/deltaic deposits from cyclical transgressing and regressing seas
- Local surficial geology composed primarily of:
  - Finer-grained soil (clay and silt) represent overbank and lagoonal settings
  - Lignite deposits from vegetation in lagoon settings
  - Coarser-grained soil (sand) represent channels and sandy mouth bars



# Site Depositional Environment

- River-dominated deltas selected as depositional environment for ESS study
- Based on regional information, descriptions of depositional environments, and site data

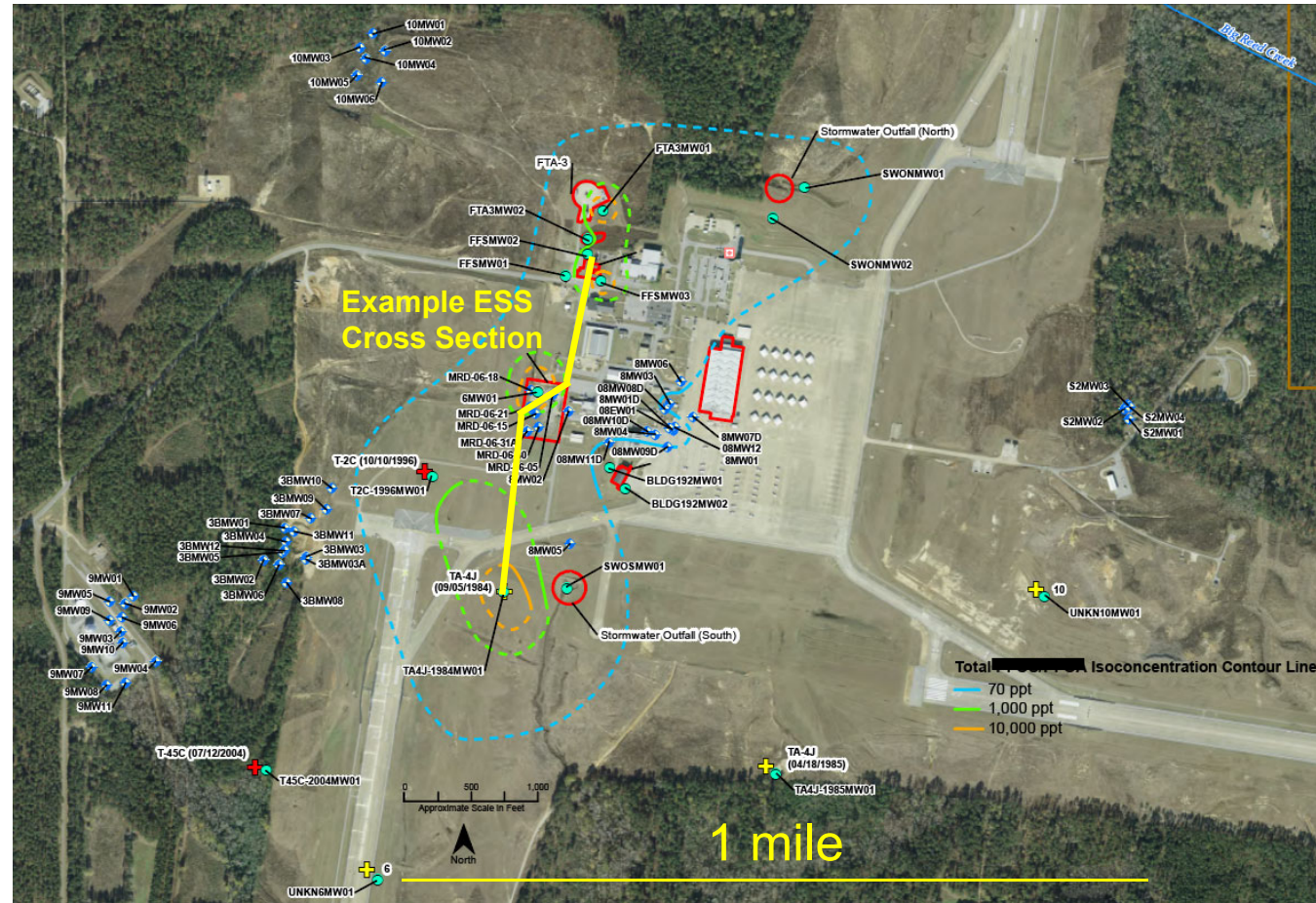


Example Stratigraphic Column for Deltaic Environment (Nichols 2009)

# Site Per- and Polyfluoroalkyl Substances ESS Desktop Study

## Summary

- Geology presents a complex system of highly variable hydraulic conductivity layers including organic clays (lignite) that may affect per- and polyfluoroalkyl substances transport
- Variability in field sample descriptions contribute to uncertainty
- Flow paths towards base boundaries (lateral and vertical) need refinement – data gaps exist
- Data Gaps
- Objectives
- Refine understanding of preferential pathways and reduce stratigraphic material description uncertainty
- Refine understanding of the lateral and vertical extent of per- and polyfluoroalkyl substances



# Per- and Polyfluoroalkyl Substances (PFAS) Characterization Challenges

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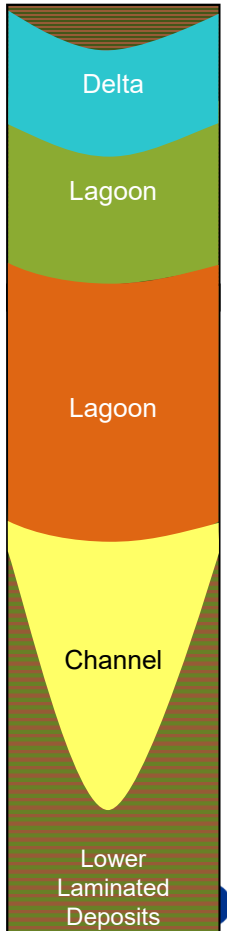
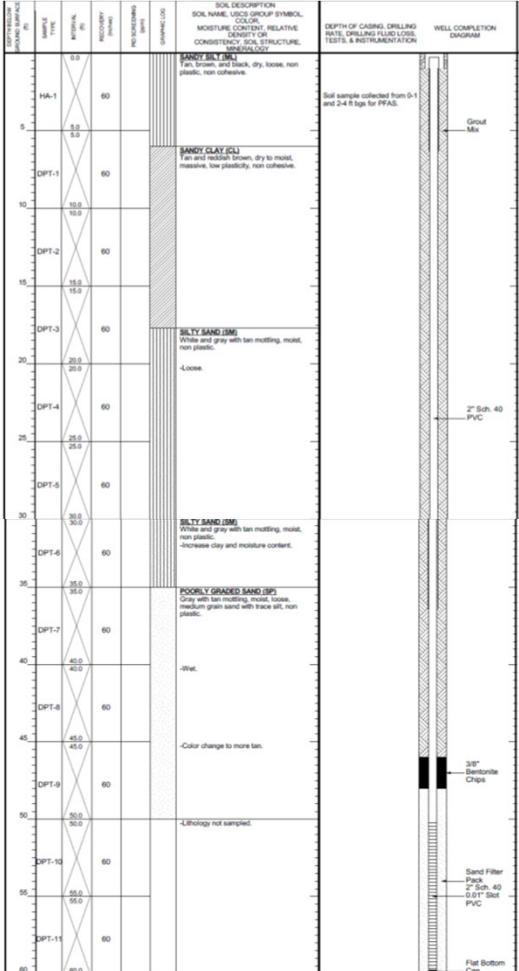
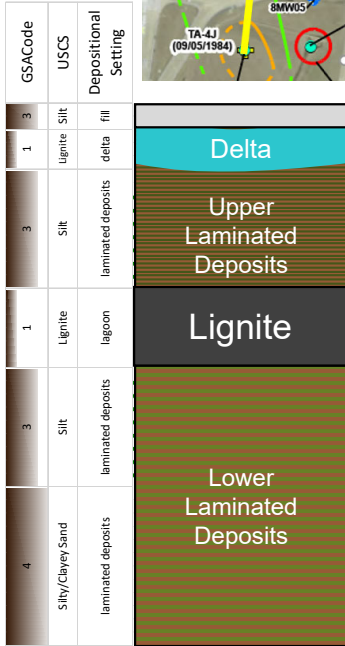
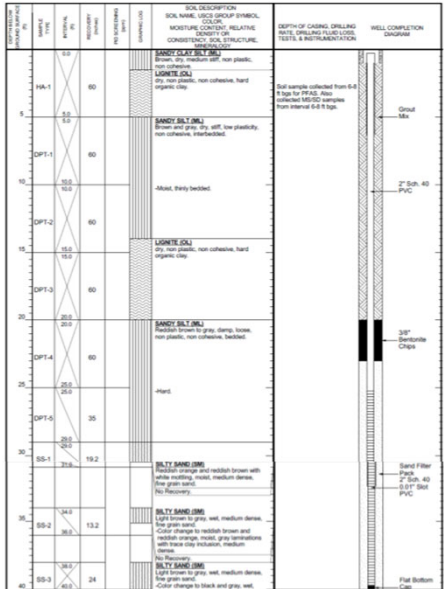
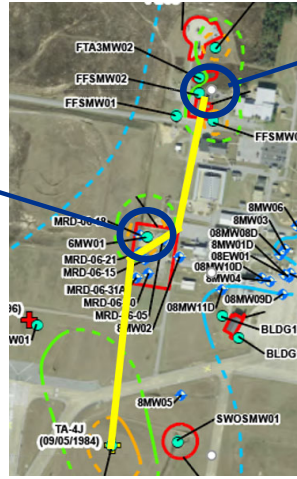
- Varied behavior amongst different PFAS requires assessment of all media present (soil, sediment, groundwater, surface water, NAPL)
- Some PFAS are sorbed in source areas, others mobile in groundwater
- Some PFAS (precursors) start immobile and end up mobile
- Preferential pathways and heterogeneities as important as for other soluble COCs
- Surfactant behavior causes accumulation at surfaces/transitions:
  - Air/water, air/NAPL, NAPL/water
  - Clays/sands, sands/gravels (understanding the CSM is critical)
- No field screening method
- Very persistent, requires following possible migration routes FOREVER



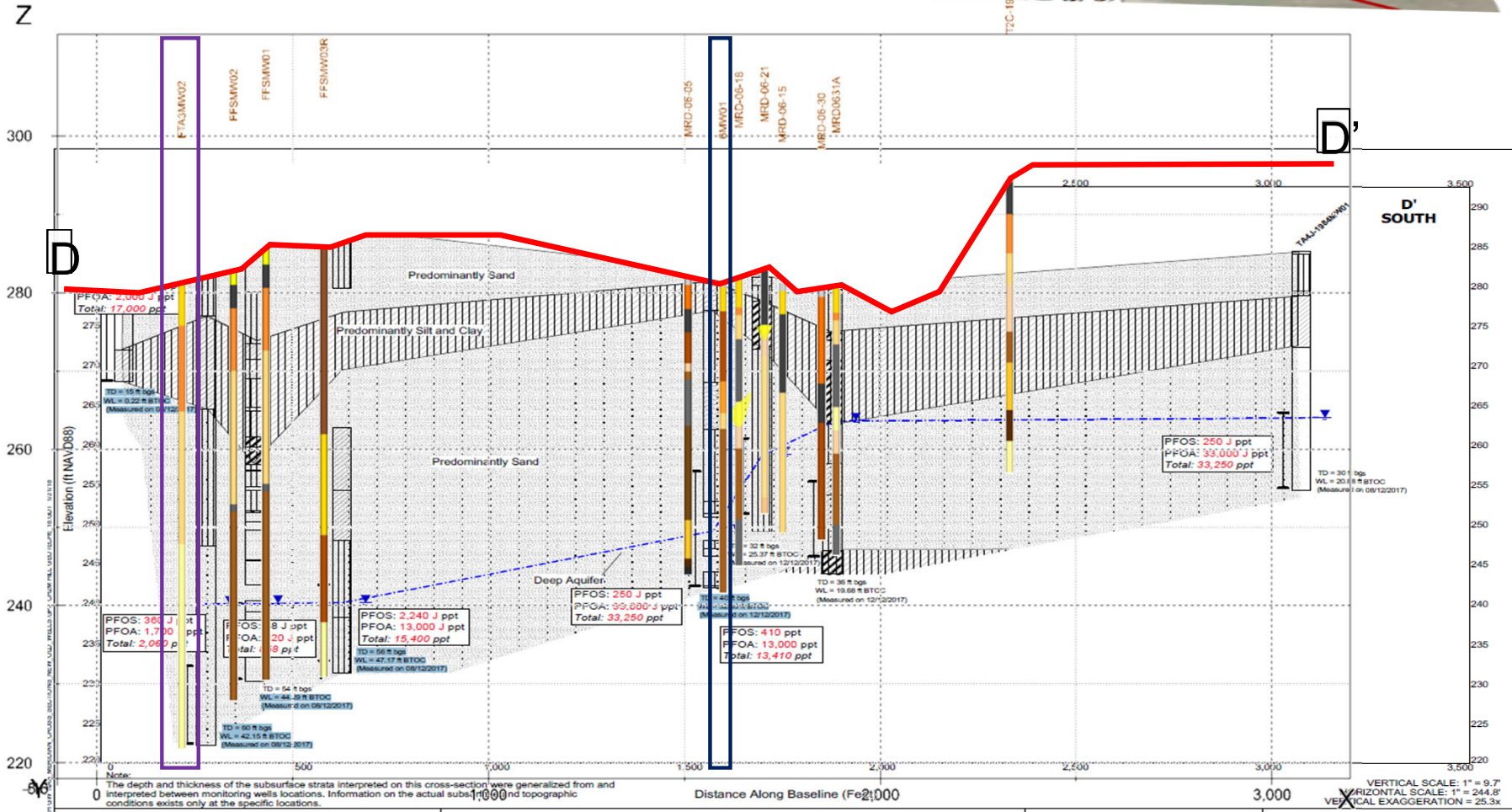
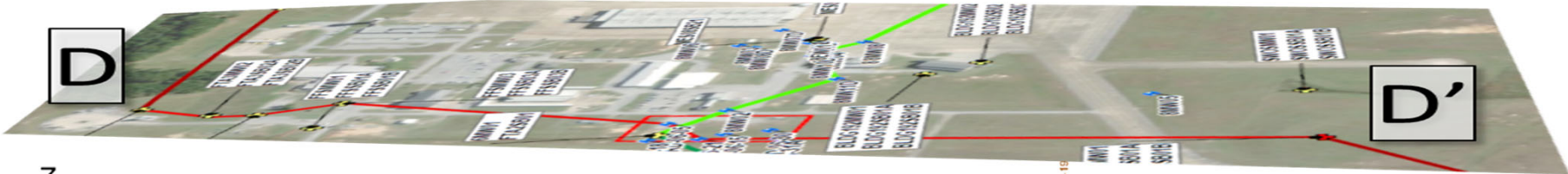
# Example ESS Borings

- 6MW01- Example of primary and low energy lagoonal deposits

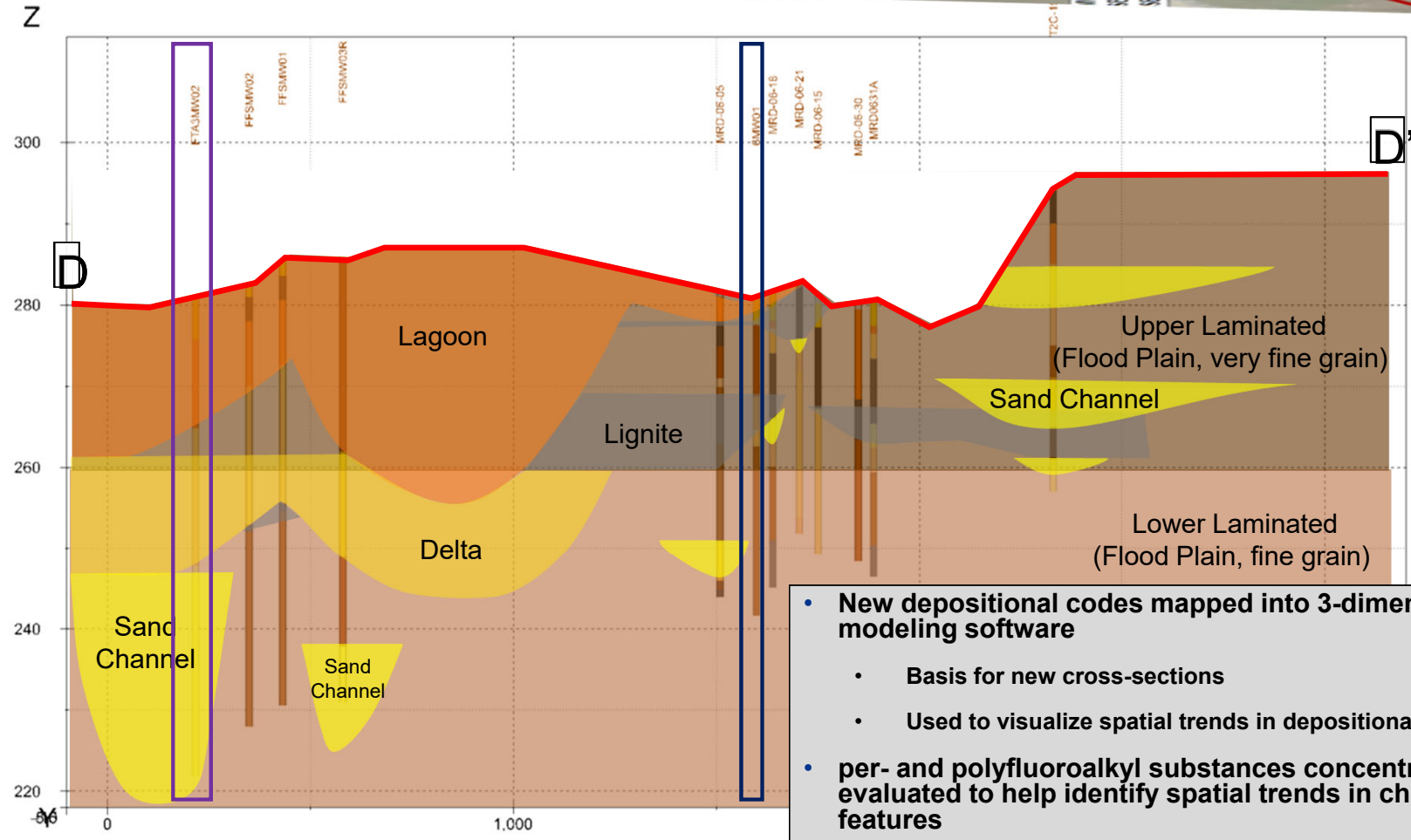
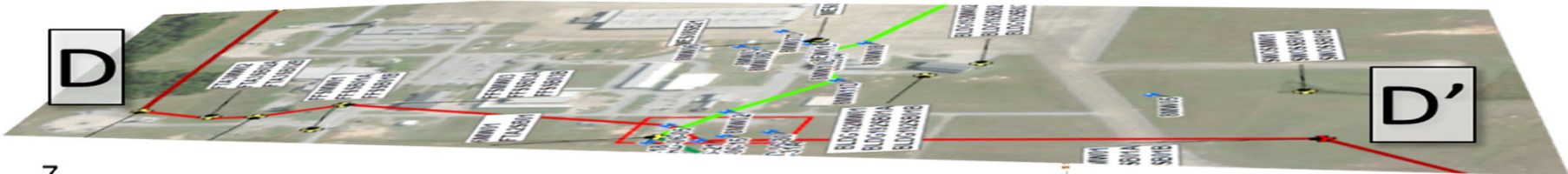
- FTA3SB02 – Secondary cutting depositional environment



# D-D' Old Section



# D-D' New Section

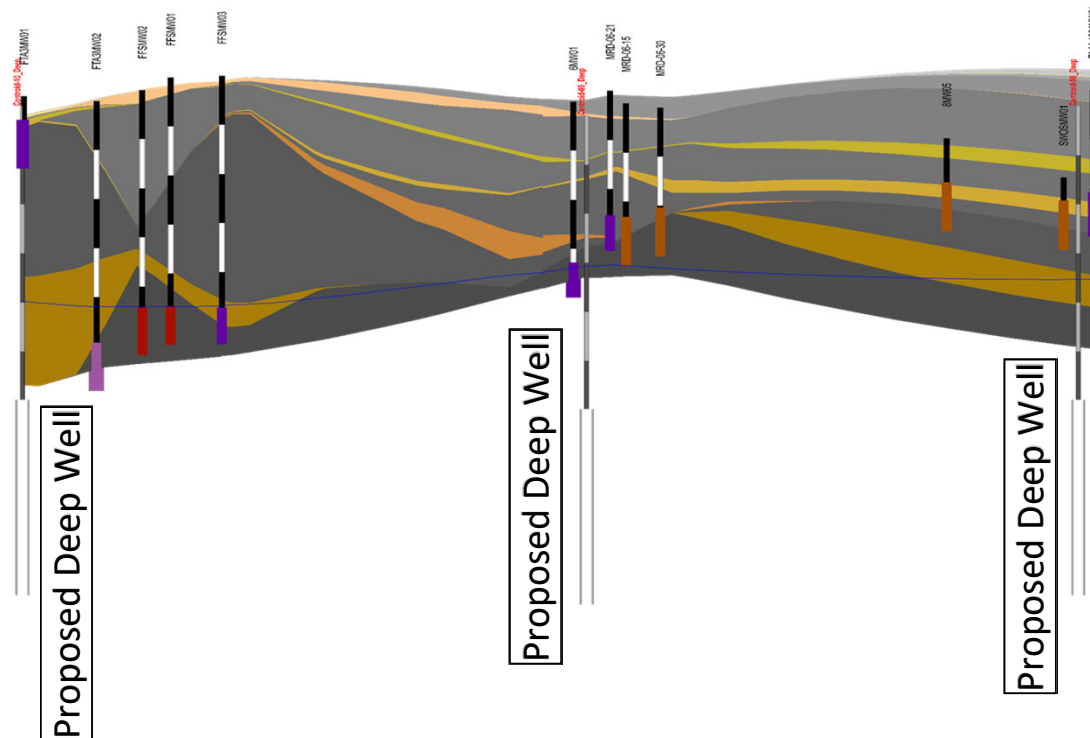


- **New depositional codes mapped into 3-dimensional (3D) modeling software**
  - Basis for new cross-sections
  - Used to visualize spatial trends in depositional features
- **per- and polyfluoroalkyl substances concentration data evaluated to help identify spatial trends in channel features**

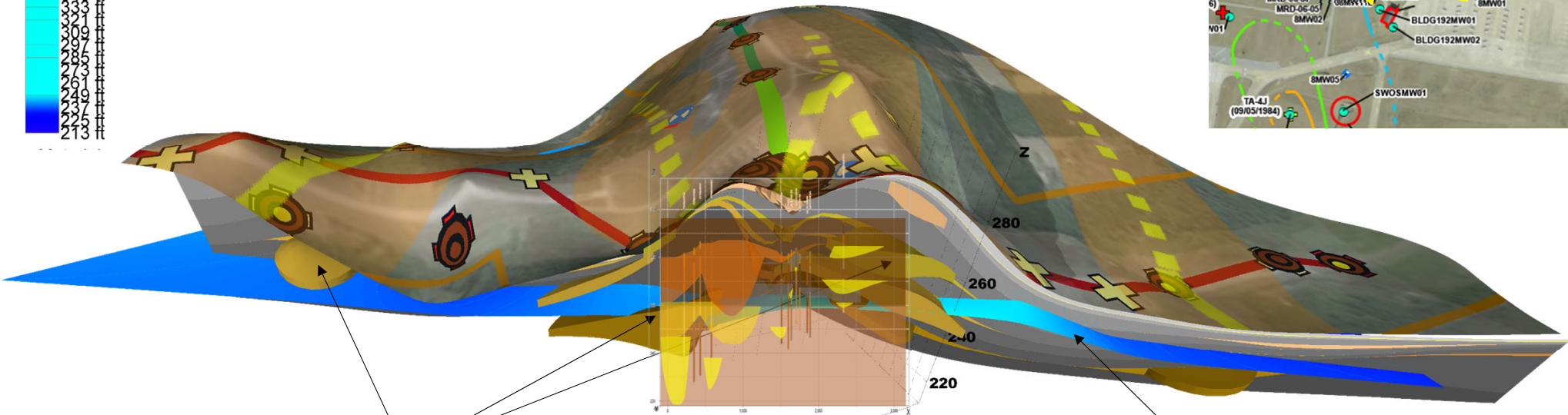
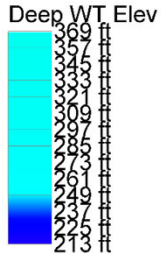


# Development of ESS-Based CSM

- Detailed ESS Environments Divided into Sand Channels (coarser grain, more continuous preferential pathways) and everything else (Finer grain, laminated deposits/floodplain), lignite, etc.)
- Updated simplified depositional geology expanded to 3D geological model
- There will be discrepancies between idealized cross sections and interpolation of 3D data. The model provides conceptual semi-quantitative understanding of sand channel distribution
- Basis for new cross-sections and correlation with other site data (analytical, groundwater surfaces, etc.)
- Used to visualize spatial trends in depositional features



# Updated Geology (Sand Channel Focused) Looking East to West (DD-DD' Oblique)



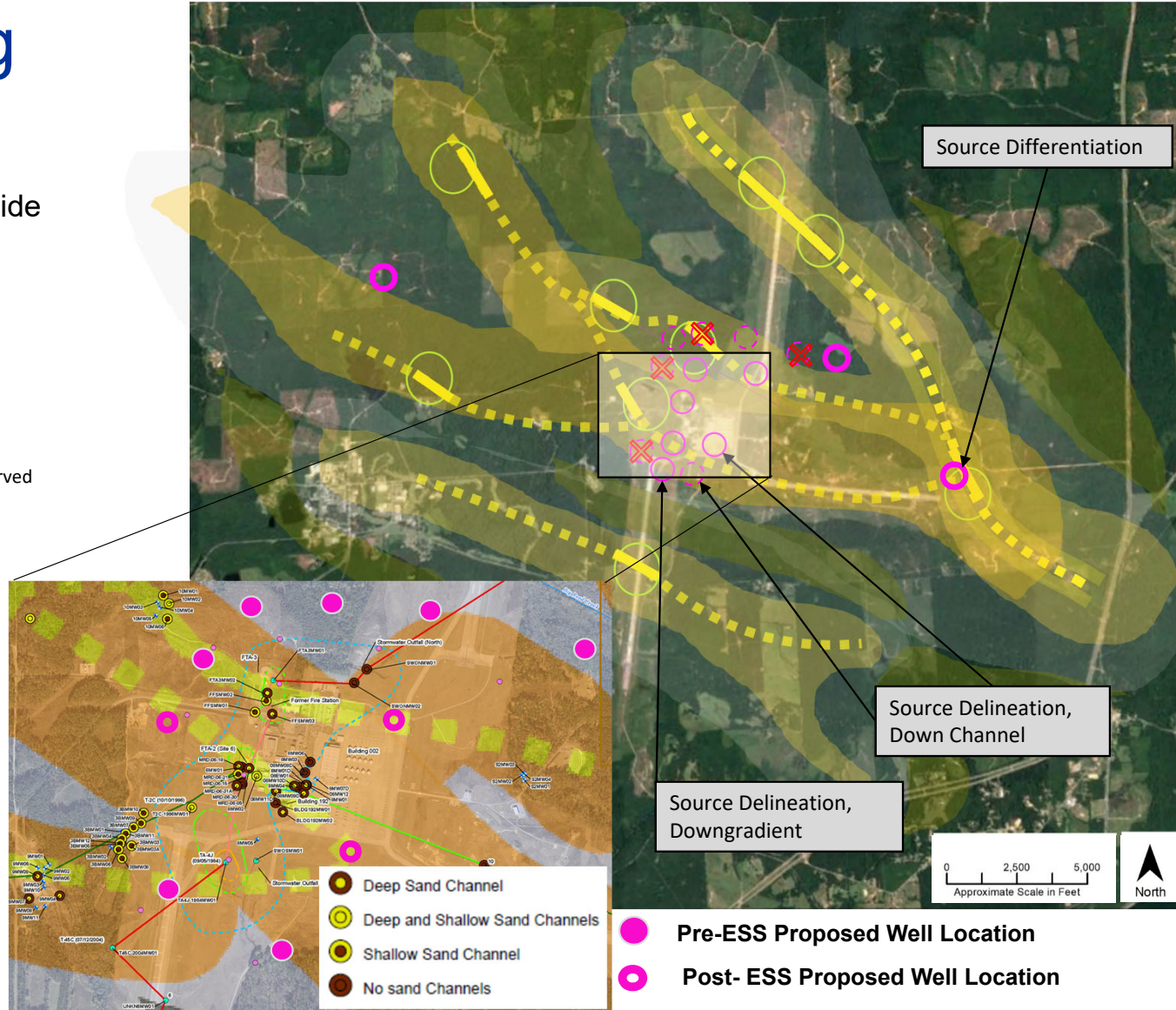
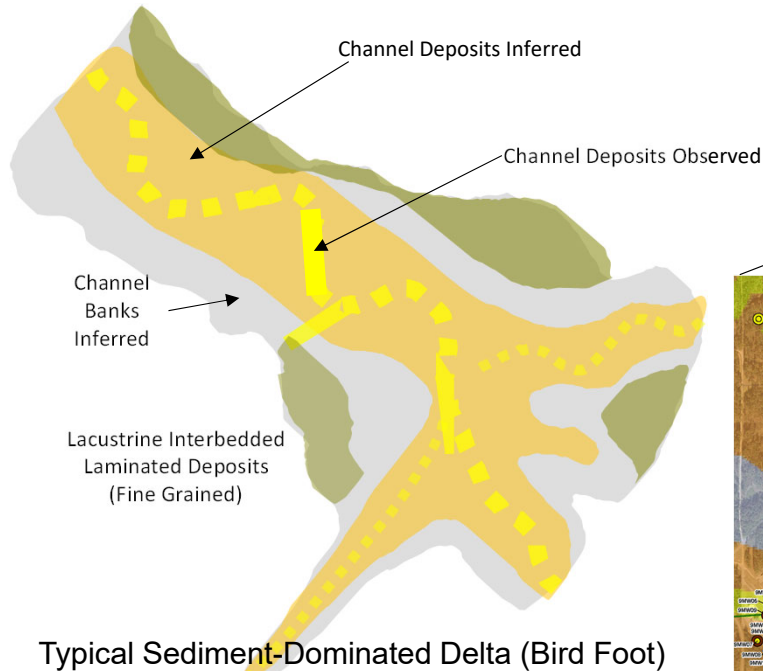
Sand Channels  
NW-SE Alignment

Deep GW



# ESS Aerial Mapping of Sand Channels

- Using the desktop ESS Study for drill guide for further Perfluorinated Compounds delineation along preferential pathways (channel deposits)



Thank You

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