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NAPL MIGRATION AND PLUME GEOMETRY AT FORMER MGP SITES: Controlled By Depositional Environment of Site Stratigraphy

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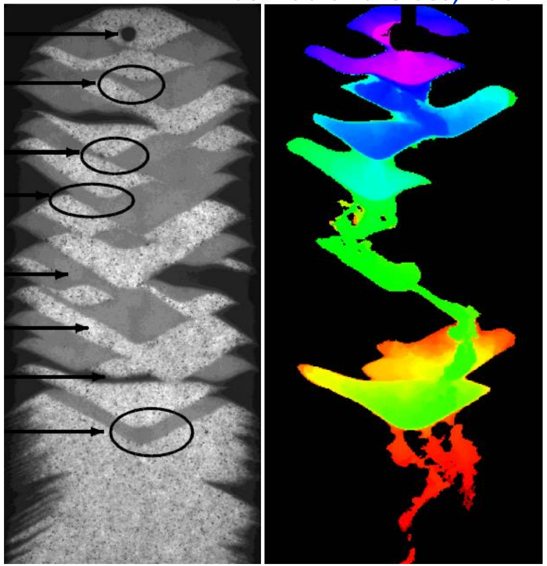
The Purpose of This Presentation

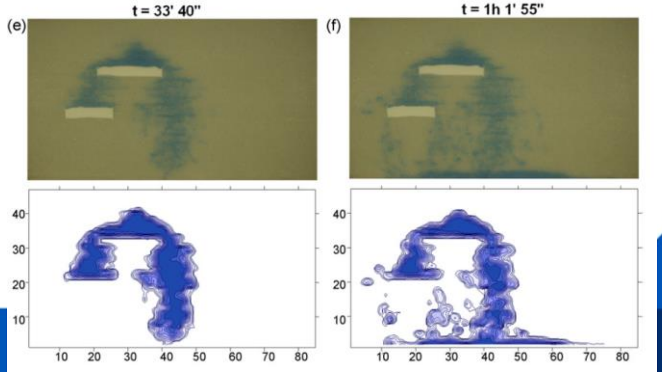
- Demonstrate the effect of commonly observed stratigraphic patterns on DNAPL migration in the saturated Zone
- Discuss the origins of these patterns and discuss why their scale and orientation is a knowable quantity
- Provide an approach to addressing uncertainty in the subsurface

Research In DNAPL Migration

Conrad and Glass, 2002

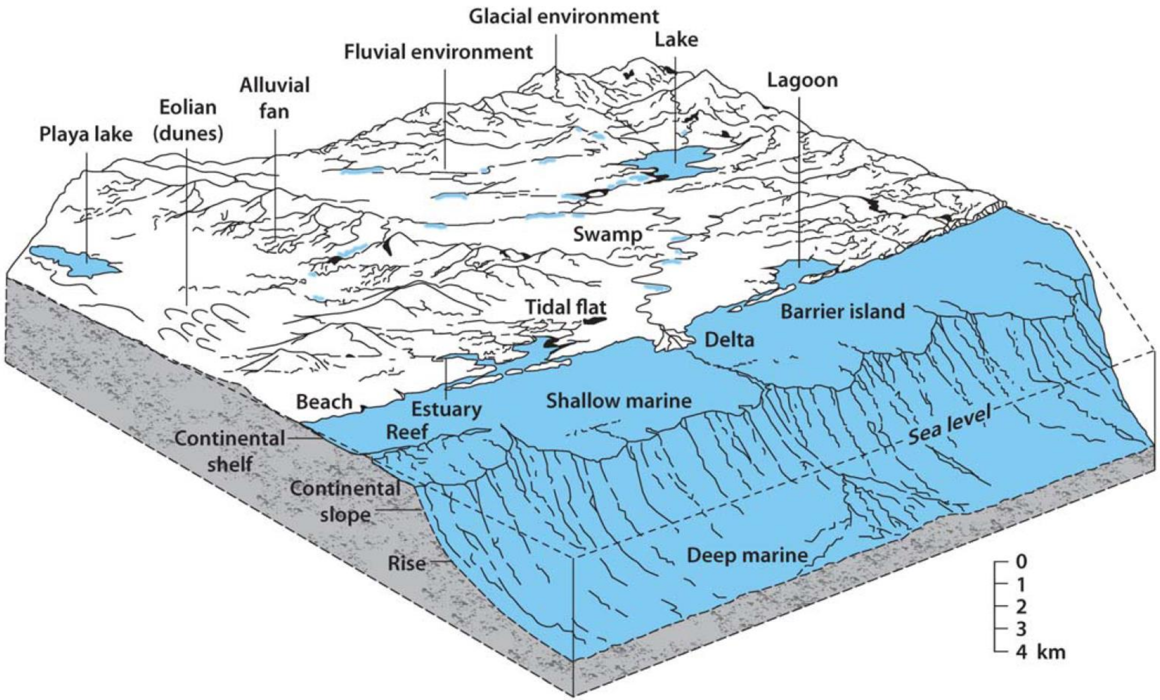


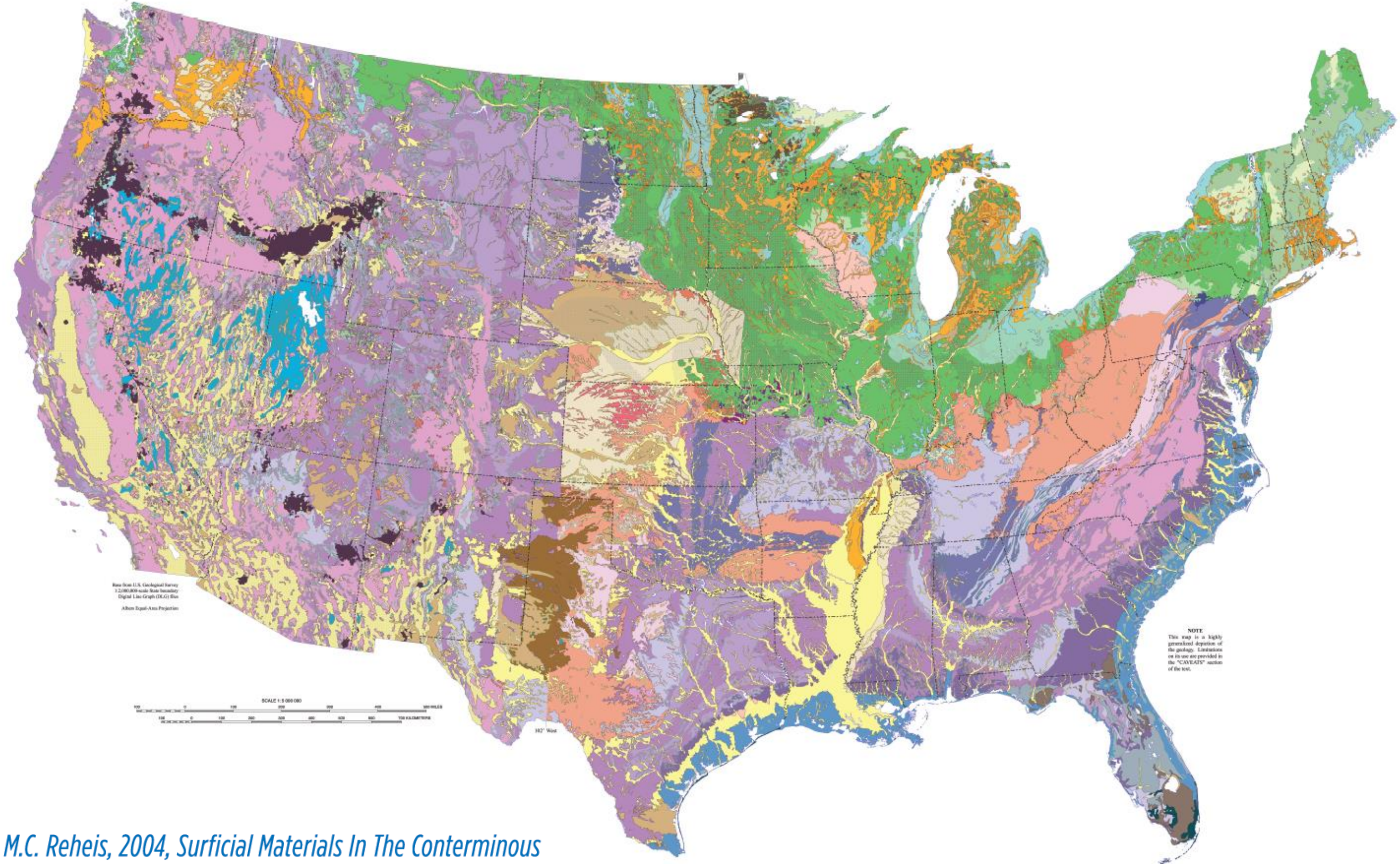
- …heterogeneity causes pooling at multiple scales. This controls extent and will critically influence remediation attempts
- "Variations in texture can have a profound effect on migration"
- "We may never have enough geologic detail to use deterministic simulations to aid in finding DNAPL"



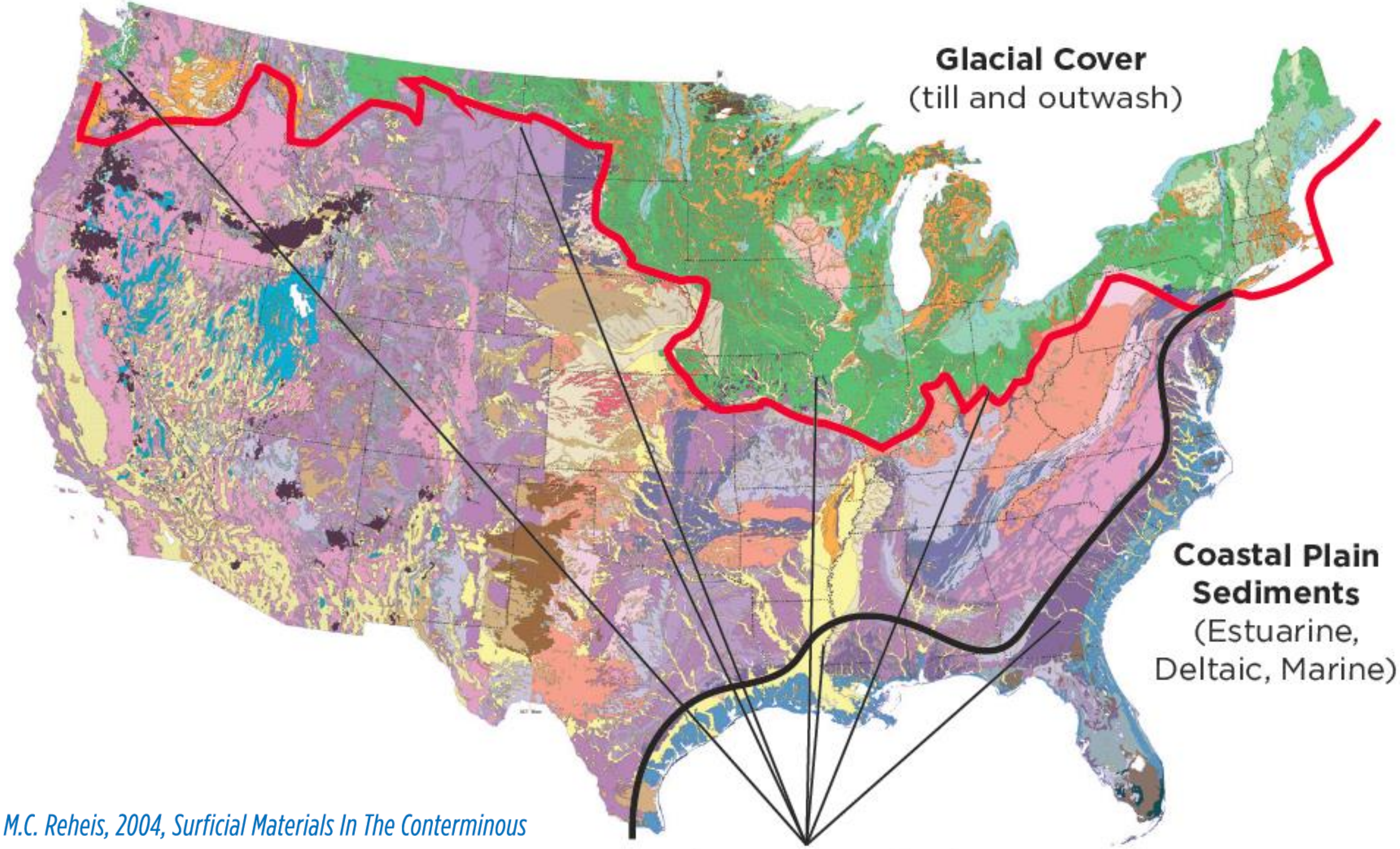
Luciano et al, 2010

What Controls The Heterogeneity of the Subsurface? The Depositional Environment.





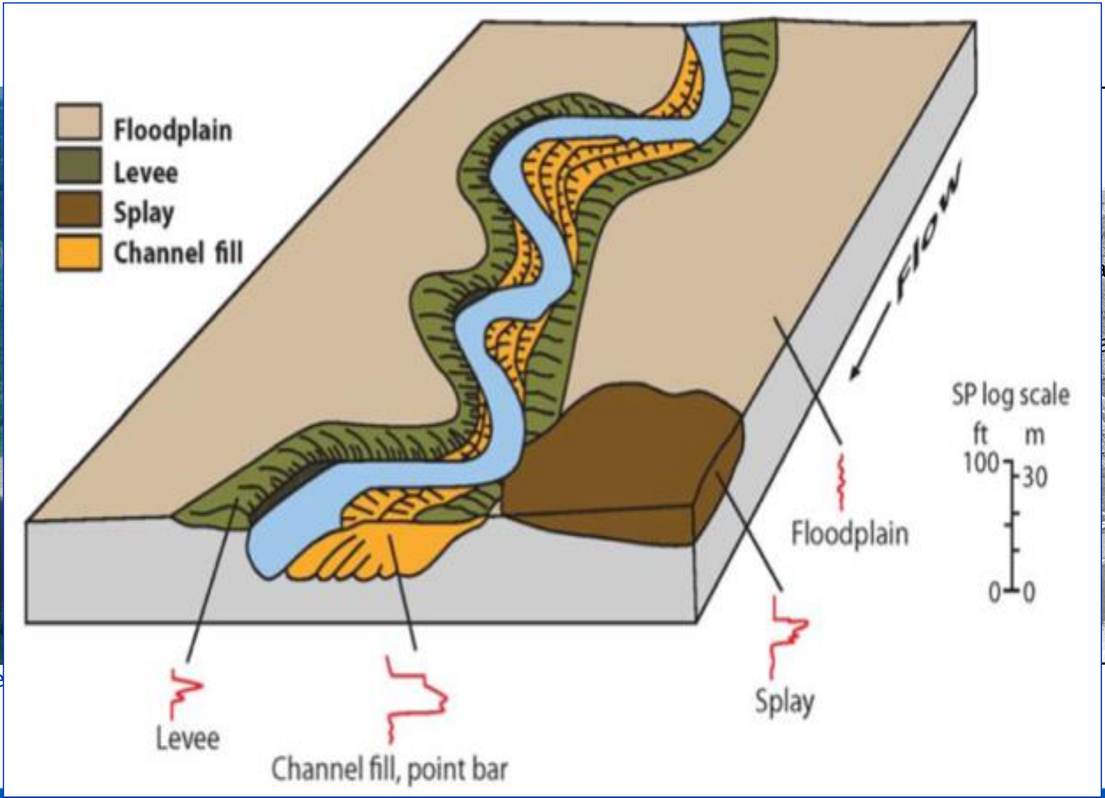
Soller, D.R. and M.C. Reheis, 2004, Surficial Materials In The Conterminous United States. U.S. Geological Survey Open-File Report OFR-03-275

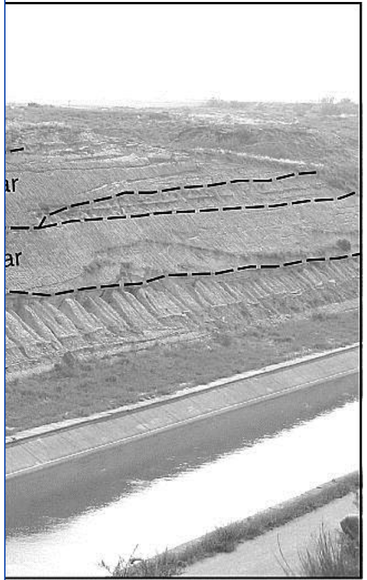


Soller, D.R. and M.C. Reheis, 2004, Surficial Materials In The Conterminous United States. U.S. Geological Survey Open-File Report OFR-03-275

Fluvial Depositional Environments

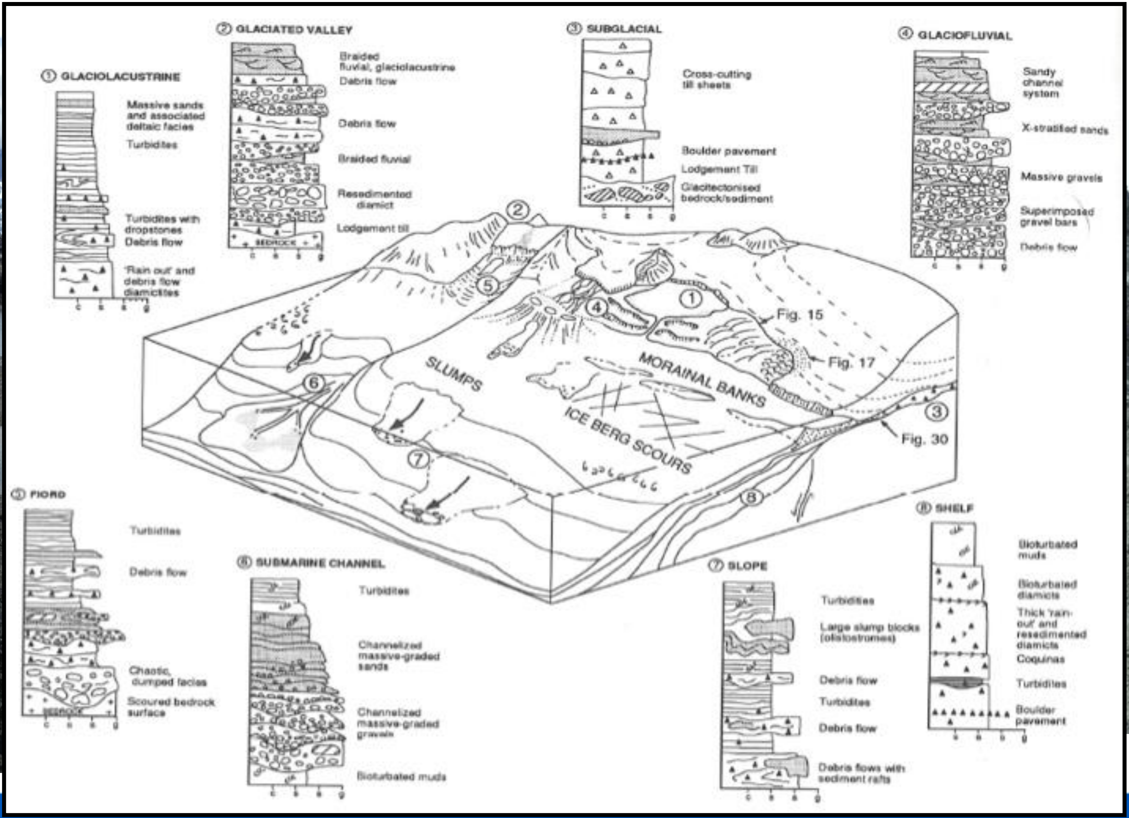
U.S. Fish and Wildlife Service





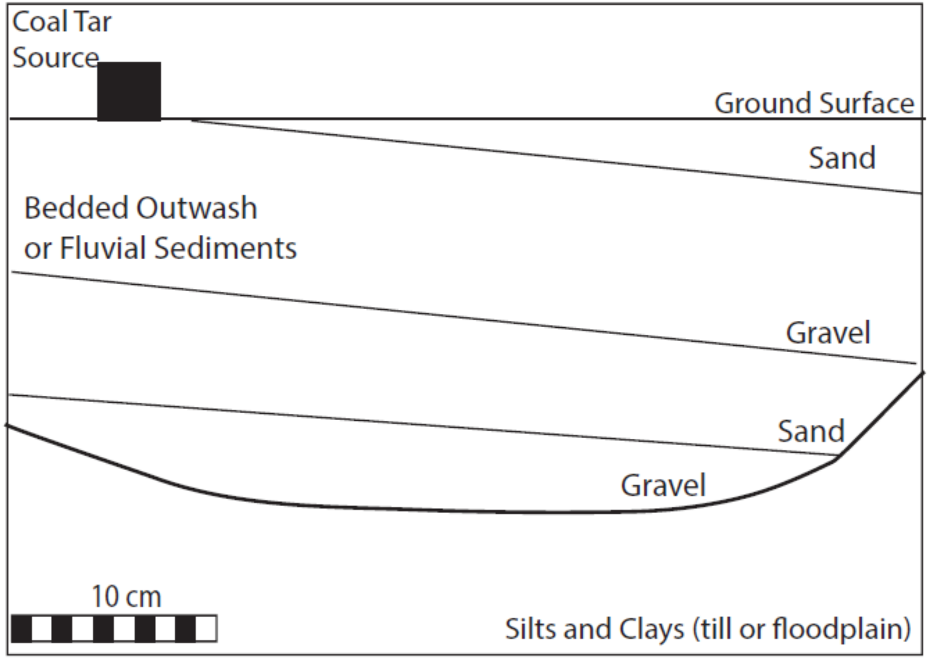

250 m
10 m

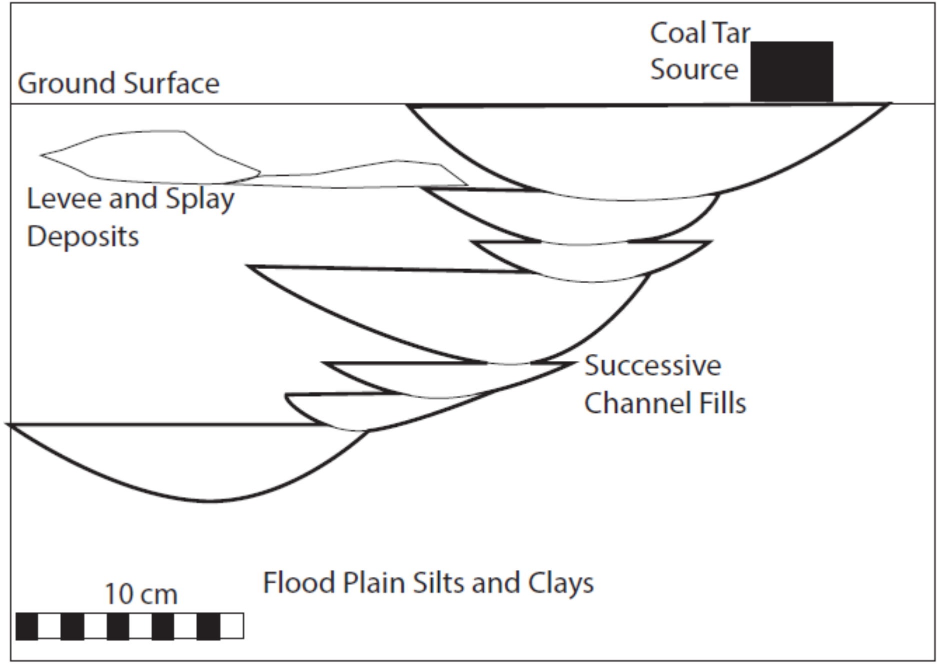
Glacial Depositional Environments



Indiana geological survey

Tank Stratigraphy





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Tanks For The Memories

- Two 6 gallon tanks
- 3 grainsizes
  - Silt, Coarse Sand (.5-2mm), and Gravel
- Coal Tar: 1.2 g/cm^3, 500csk
- Time Lapse Camera at 5 minute interval for 16 hours
- 2 stratigraphic scenarios

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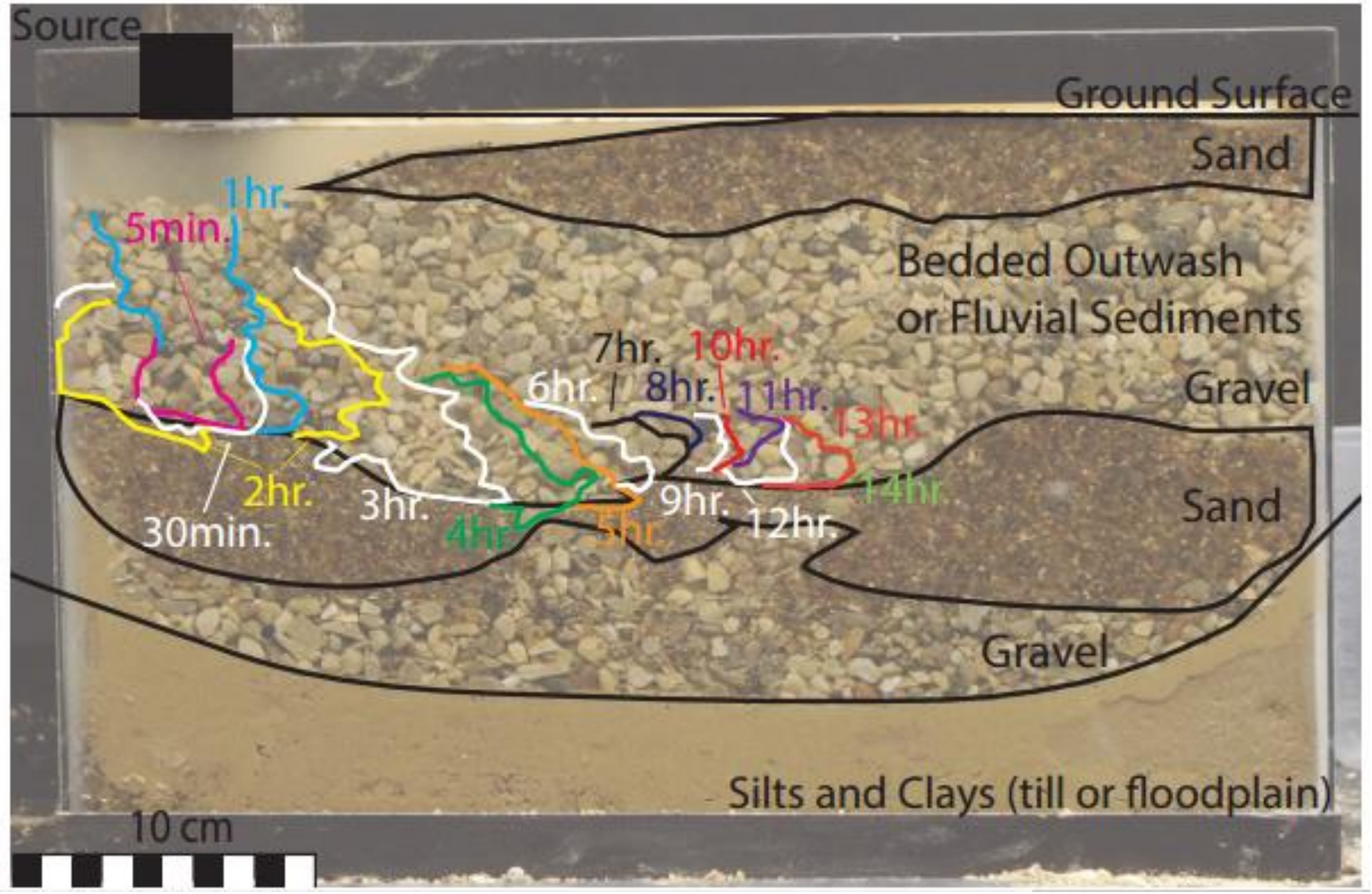
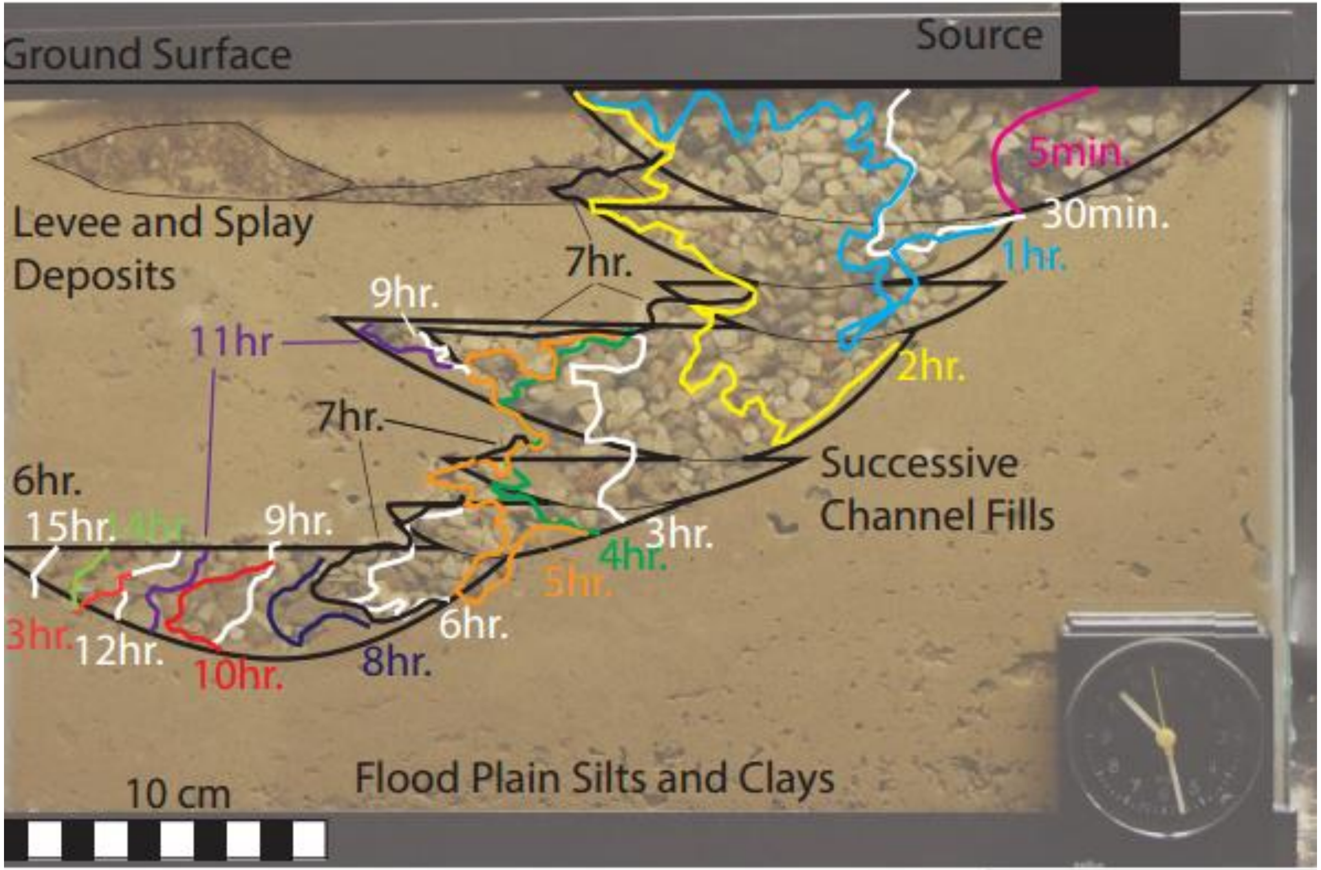
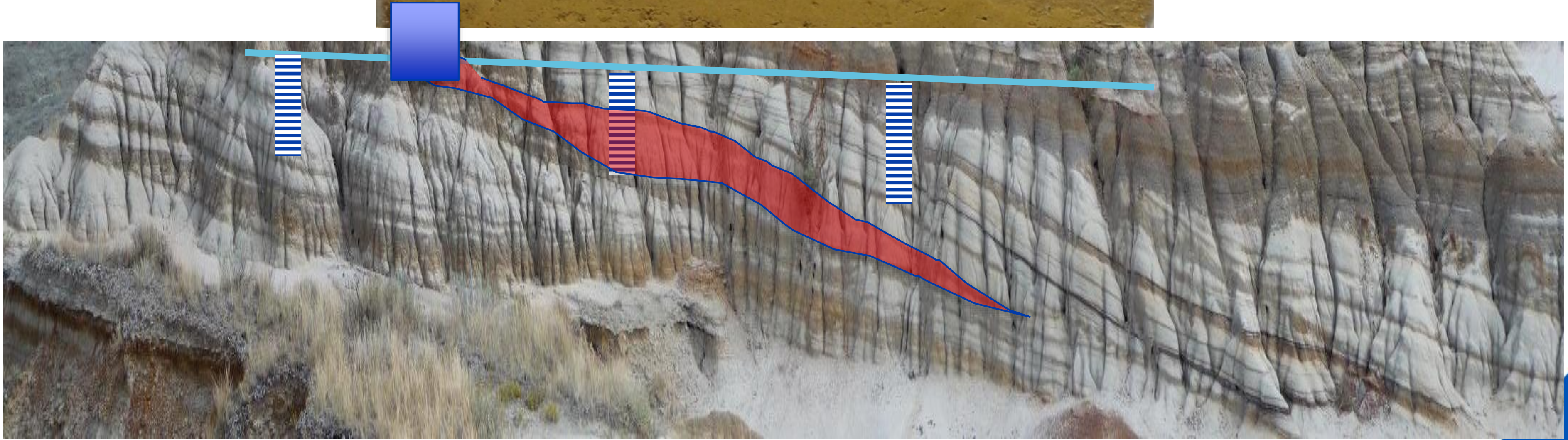

Source
Ground Surface
Sand
1hr.
5min.
Bedded Outwash
or Fluvial Sediments
7hr.
10hr.
6hr.
8hr.
11hr.
Gravel
13hr.
14hr.
2hr.
3hr.
9hr.
12hr.
Sand
30min.
4hr.
5hr.
Gravel
Silts and Clays (till or floodplain)
10 cm


Ground Surface
Source
Levee and Splay
Deposits
5min.
30min.
1hr.
7hr.
9hr.
11hr
2hr.
7hr.
Successive
Channel Fills
6hr.
15hr.
14hr.
9hr.
3hr.
4hr.
5hr.
13hr.
12hr.
10hr.
8hr.
6hr.
10 cm
Flood Plain Silts and Clays

Implications of Tank Demonstration

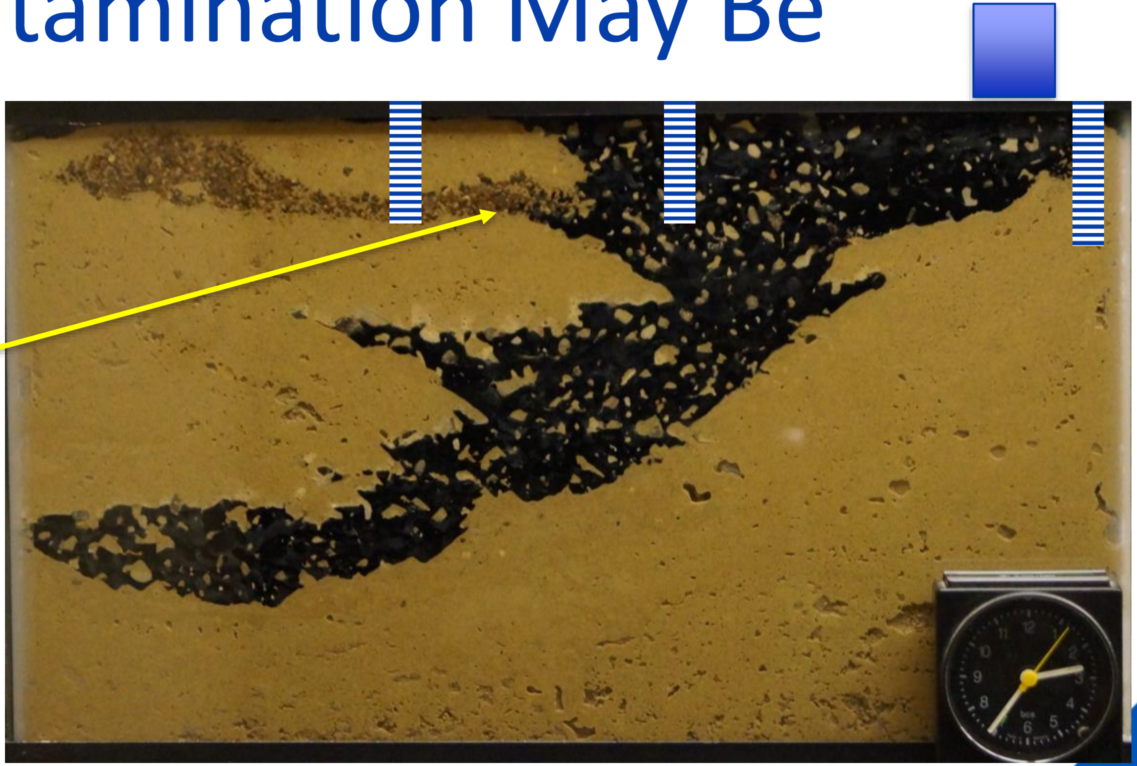
Understand
Your Source Area's
Position Relative
To Features of
Depositional Env.

Understand
Your Source Area's
Position Relative
To Depositional
Dip



Use Facies Relationships to Infer Where Deeper Contamination May Be

Levee deposit deeper than
A channel succession implies
more channels at depth



EPA Issue Paper

- Environmental Sequence Stratigraphy (ESS)
- A Methodology For Using a Depositional Systems Approach

EPA/600/R-17/293
September 2017

EPA United States Environmental Protection Agency **Groundwater Issue**

Best Practices for Environmental Site Management:

A Practical Guide for Applying Environmental Sequence Stratigraphy to Improve Conceptual Site Models

Michael R. Shultz[1], Richard S. Cramer[1], Colin Plank[1], Herb Levine[2], Kenneth D. Ehman[3]

CONTENTS

This document was prepared under the U.S. Environmental Protection Agency National Decontamination Team Decontamination Analytical And Technical Service (DATS) II Contract EP-W-12-26 with Consolidated Safety Services, Inc. (CSS), 10301 Democracy Lane, Suite 300, Fairfax, Virginia 22030

[1]Burns & McDonnell
[2]U.S. EPA
[3]Chevron Energy Technology Company

BACKGROUND

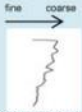
This issue paper was prepared at the request of the Environmental Protection Agency (EPA) Ground Water Forum. The Ground Water, Federal Facilities, and Engineering Forums were established by professionals from the United States Environmental Protection Agency (USEPA) in the ten Regional Offices. The Forums are committed to the identification and resolution of scientific, technical, and engineering issues impacting the remediation of Superfund and RCRA sites. The Forums are supported by and advise Office of Solid Waste and Emergency Response's (OSWER) Technical Support Project, which has established Technical Support Centers in laboratories operated by the Office of Research and Development (ORD), Office of Radiation Programs, and the Environmental Response Team. The Centers work closely with the Forums providing state-of-the-science technical assistance to USEPA project managers. A compilation of issue papers on other topics may be found here:

http://www.epa.gov/superfund/remedytech/tsp/issue.htm

The purpose of this issue paper is to provide a practical guide on the application of the geologic principles of sequence stratigraphy and facies models (see "Definitions" text box, page 2) to the characterization of stratigraphic heterogeneity at hazardous waste sites.

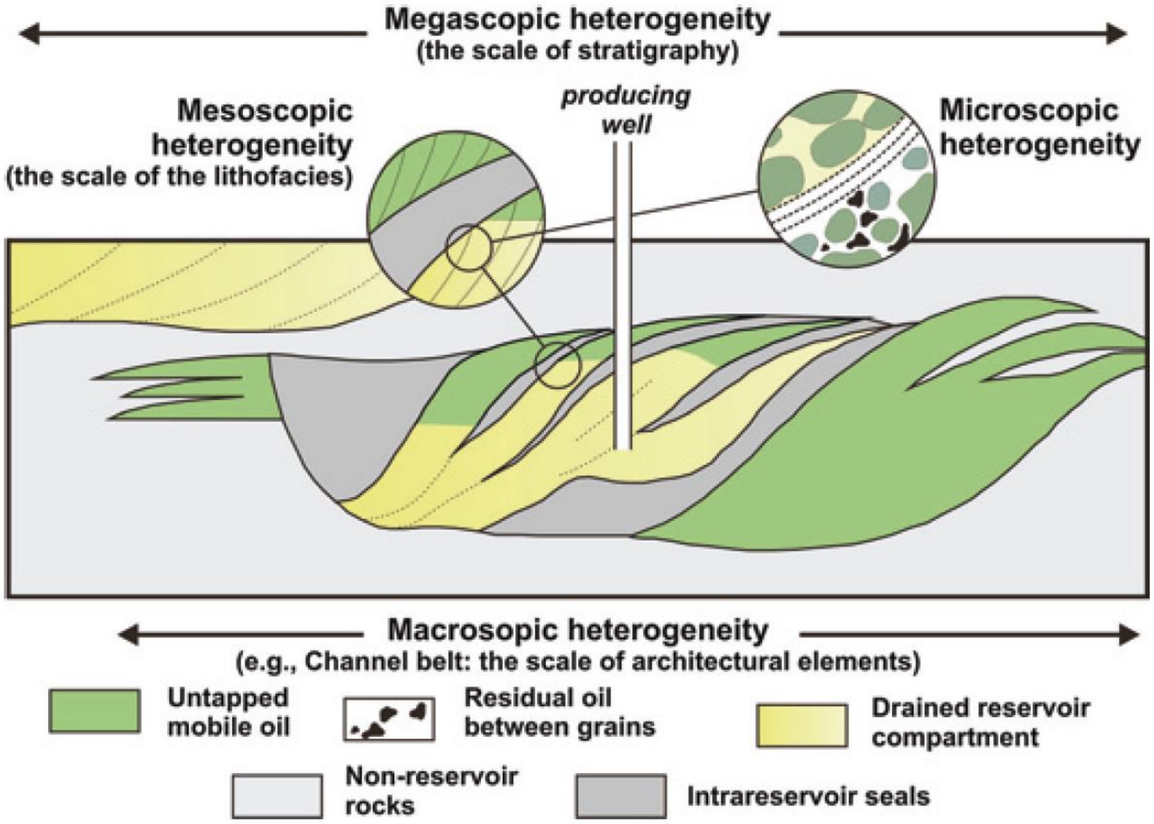
Application of the principles and methods presented in this issue paper will improve Conceptual Site Models (CSM) and provide a basis for understanding stratigraphic flux and associated contaminant transport. This is fundamental to designing monitoring programs as well as selecting and implementing remedies at contaminated groundwater sites. EPA recommends re-evaluating the CSM while completing the site characterization and whenever new data are collected. Updating the CSM can be a critical component of a 5 year review or a remedy optimization effort.

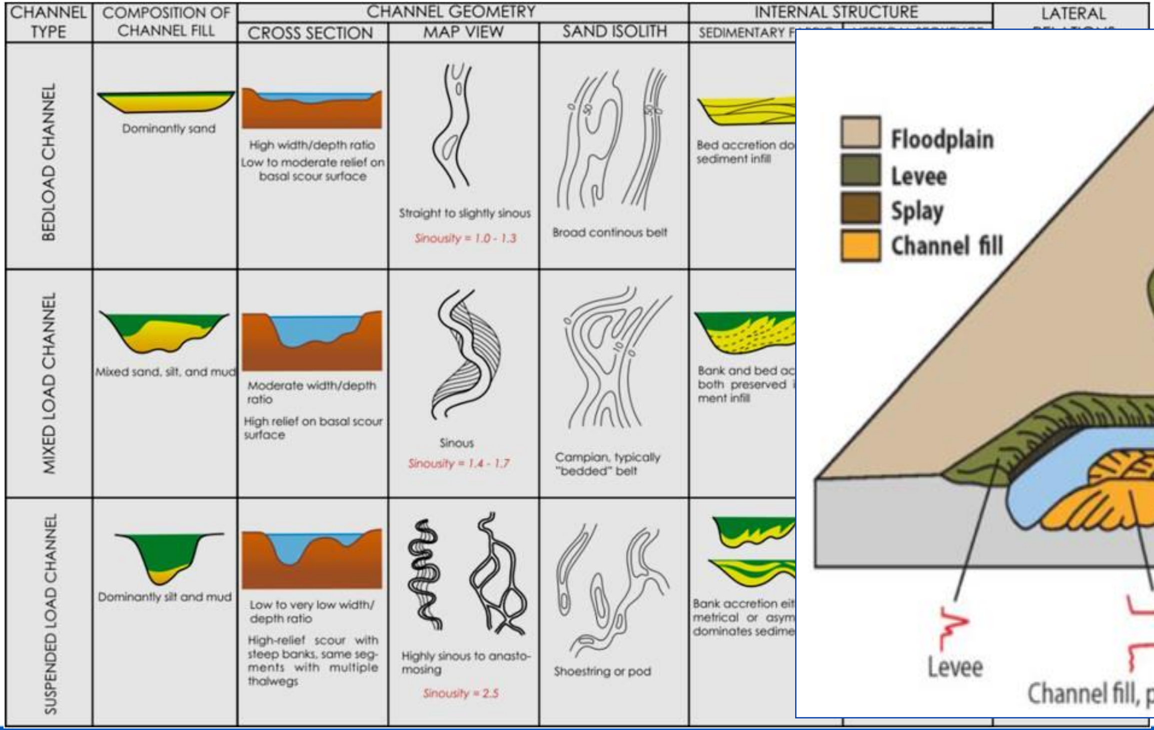
Table 1. Table showing vertical grain size profiles typical of a variety of depositional environments, major aquifer and aquitard elements and their common dimensions, impact on CSMs, and implications for required data resolution for characterization of groundwater remediation sites.

Depositional environment and typical grain size profile	Major aquifer elements and their common dimensions	Major aquitard elements and their common dimensions	Impact on CSM	Data resolution needs
Alluvial Fan  coarsening-upward	Proximal fan channels, mid-fan sheet sands, distal fringe sands X: 10^2 m – 10^4 m Y: 10^1 m – 10^3 m Z: 10^{-1} m – 10's m	Playa lake deposits or paleosol formations commonly vertically separate fans. Debris-flow deposits also commonly clay-rich. X: 10^2 m – 10^3 m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10's m	Laterally extensive paleosol or playa lake deposits may be thin (10's of cm to meters), but can vertically compartmentalize aquifers. Such thin aquitards may not be recognized by non-continuous sampling methods due to their thin nature. Fans have a primary stratigraphic dip basinward at 1-6 degrees, and are laterally offset stacked ("shingled"). Fans are constructed primarily by channels encased in sheet-flood deposits. Channels are radial from a point source and represent permeable pathways. Channel density decreasing down-fan.	High in vertical sense, need for lateral resolution decreases down-fan where channels are less predominant.
Meandering Fluvial  fining-upward	Channel axial fill, point bar, crevasse splays X: 1 m – 10's m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10 m	Floodplain deposits, levee deposits, clay drapes on lateral accretion surfaces, plugs filling abandoned channels. X: 10^2 m – 10^3 m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10's m	Channel and point-bar deposits are encased in fine-grained floodplain deposits and represent the groundwater flow pathways. Traditional potentiometric surface maps are poor predictors of specific groundwater flow paths and contaminant migration pathways. Coarse-grained "lags" at the bases of channels and point bars represent high-permeability pathways. Lateral accretion drapes can form "shingled" aquifer units. Clay plugs filling abandoned channels ("oxbow lakes") common and provide barriers to groundwater flow and contaminant fate and transport.	High both laterally and vertically
Braided Fluvial  blocky	Channel axial fill, bar complex X: 1 m – 10^1 m Y: 10^1 m – 10^2 m Z: 10^{-1} m – 10^1 m	Floodplain deposits, silt and clay plugs filling abandoned channels. X: 10^2 m – 10^3 m Y: 10^1 m – 10^2 m Z: 10^{-1} m – 1's m	Low-sinuosity high-permeability streaks encased within an overall permeable matrix may dominate groundwater flow and contaminant migration. Laterally discontinuous silt and clay units may be significant at the plume scale, and are more continuous in the down-channel direction compared to the cross-channel direction.	High both laterally and vertically, greater lateral resolution required perpendicular to depositional axis (i.e., cross-channel transects) versus parallel to depositional axis (down-channel)
Marine or Lacustrine  symmetrical or bow	Offshore bar, shelf, transgressive sand X: 10^1 m – 10^2 m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10 m	Fair-weather fine-grained draping shales X: 10^1 m – 10^2 m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10 m	Gradational base and top related to shifting sea-level or environment. High degree of lateral continuity. Interbedded storm deposits (coarser grained) with fair-weather deposits (finer-grained) lead to high degree of vertical heterogeneity and "layer cake" stratigraphy.	Low in lateral sense, high in vertical
Near-shore, Deltaic  coarsening-upward	Shoreface (beach), distributary channels in upper part, prodelta in lower part X: 10^1 m – 10^2 m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10 m	Marine flooding shales capping sequences, interdistributary fluvial overbank in upper parts X: 10^1 m – 10^2 m Y: 10^2 m – 10^3 m Z: 10^{-1} m – 10 m	Laterally extensive, sand-rich near-shore units in upper parts of sequences and delta-plain channels. High degree of interbedding of coarse and fine-grained units in lower parts. Silt and clay flooding shales capping sequences dip basinward, may lead to erroneous correlations at distances of hundreds of meters to kilometers.	Low in lateral sense, high in vertical. Higher resolution required in upper parts of sequences due to the presence of distributary channels.

Why Concepts of Depositional Environment Matter

- Stratigraphy is the plumbing of the subsurface
- Sediment geometry influences the location of contaminant mass in the subsurface
- Directly affects recoverability and remediation efficiency
- Understanding helps provide a predictive framework for addressing delineation concerns and issues of uncertainty impacting site closure


Megascopic heterogeneity
(the scale of stratigraphy)
Mesoscopic heterogeneity
(the scale of the lithofacies)
producing well
Microscopic heterogeneity
Macrosopic heterogeneity
(e.g., Channel belt: the scale of architectural elements)
Untapped mobile oil
Residual oil between grains
Drained reservoir compartment
Non-reservoir rocks
Intrareservoir seals



CHANNEL TYPE	COMPOSITION OF CHANNEL FILL	CHANNEL GEOMETRY: CROSS SECTION	CHANNEL GEOMETRY: MAP VIEW	CHANNEL GEOMETRY: SAND ISOLITH	INTERNAL STRUCTURE: SEDIMENTARY F...	LATERAL ...
BEDLOAD CHANNEL	Dominantly sand	High width/depth ratio Low to moderate relief on basal scour surface	Straight to slightly sinous Sinousity = 1.0 - 1.3	Broad continous belt	Bed accretion do... sediment infill	
MIXED LOAD CHANNEL	Mixed sand, silt, and mud	Moderate width/depth ratio High relief on basal scour surface	Sinous Sinousity = 1.4 - 1.7	Campian, typically "bedded" belt	Bank and bed ac... both preserved i... ment infill	
SUSPENDED LOAD CHANNEL	Dominantly silt and mud	Low to very low width/depth ratio High-relief scour with steep banks, same segments with multiple thalwegs	Highly sinous to anastomosing Sinousity = 2.5	Shoestring or pod	Bank accretion eit... metrical or asym... dominates sedime...