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Effective Use of Existing Data in Building Solid Conceptual Models

IPEC 2011

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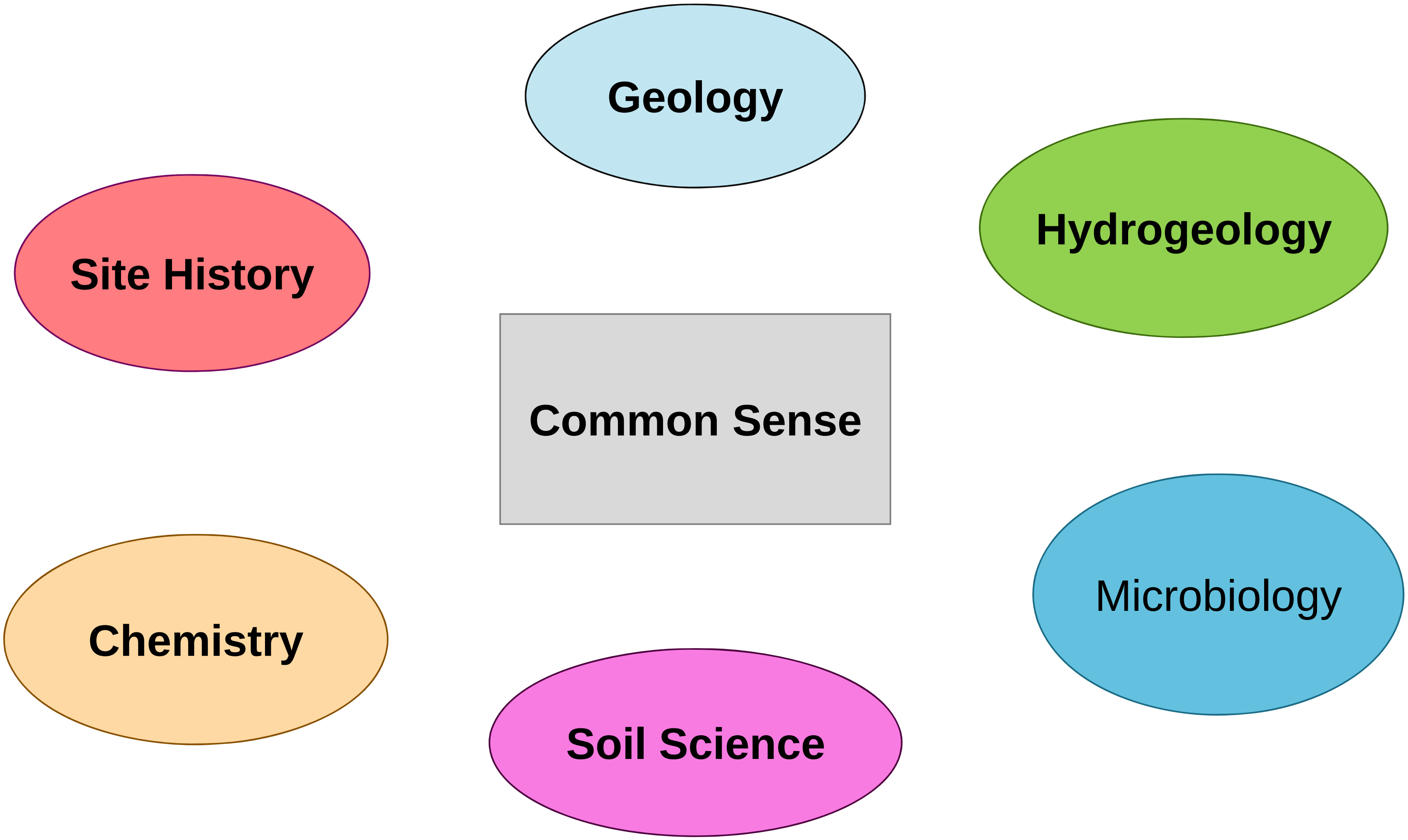
Good conceptual site models integrate multiple disciplines



Good LNAPL conceptual site models integrate multiple types of LNAPL data

LNAPL Release History

LNAPL Transmissivity

Common Sense

LNAPL Distribution

LNAPL Recovery History

Groundwater Elevation Changes

LNAPL Thickness Measurement

Sources of field data for an LNAPL conceptual site model

- Well Gauging Data (preferably at least 2 years)

How does LNAPL thickness change as the water table changes?

- Soil Core Data
  - Lithology
  - Staining
  - PID/FID readings

Detailed soil boring logs are fundamental to understanding LNAPL distribution.

- Chemical Characterization (unless its composition is known)
- Field Mobility Data
  - Baildown test (under equilibrium conditions)
  - Product recovery data
  - Pump test data
  - Water to LNAPL recovery rates in existing systems

Direct measurements of LNAPL transmissivity (recoverability) are much better than estimated from LNAPL thickness data alone.

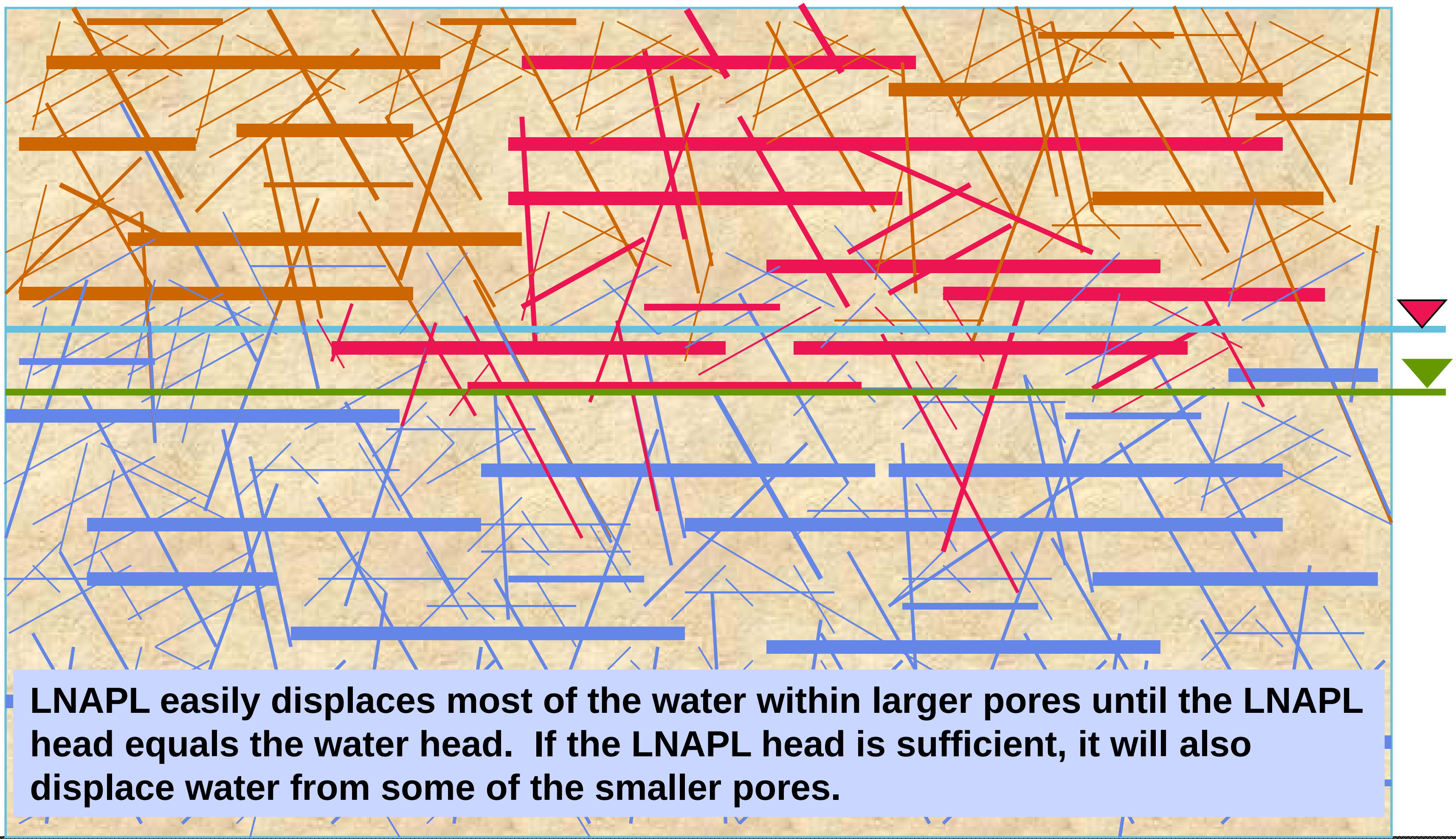
- Published Values and Relationships

Components of a conceptual site model for an LNAPL site

- **Site setting:** size of impacted area; location of potential receptors, history of known or suspected releases, probable timing and volume of releases
- **Exposure pathways**: LNAPL, dissolved phase, vapor phase, surface water
- **LNAPL properties**: chemical composition, physical properties, known or suspected past sources, known or likely future sources, plume stability
- **Physical setting**: geology (top 30 ft; 10 m), depth to groundwater, seasonal and historic fluctuations in water level, depth to top and bottom of LNAPL impacts, gradients, seepage velocity, hydraulic conductivity, hydraulic influences (extraction wells, recharge areas, etc.), presence of man-made corridors (utility backfill, wells, foundations, etc.)
- **Confining layers:** the presence, continuity, and slope of lower permeability lenses/layers

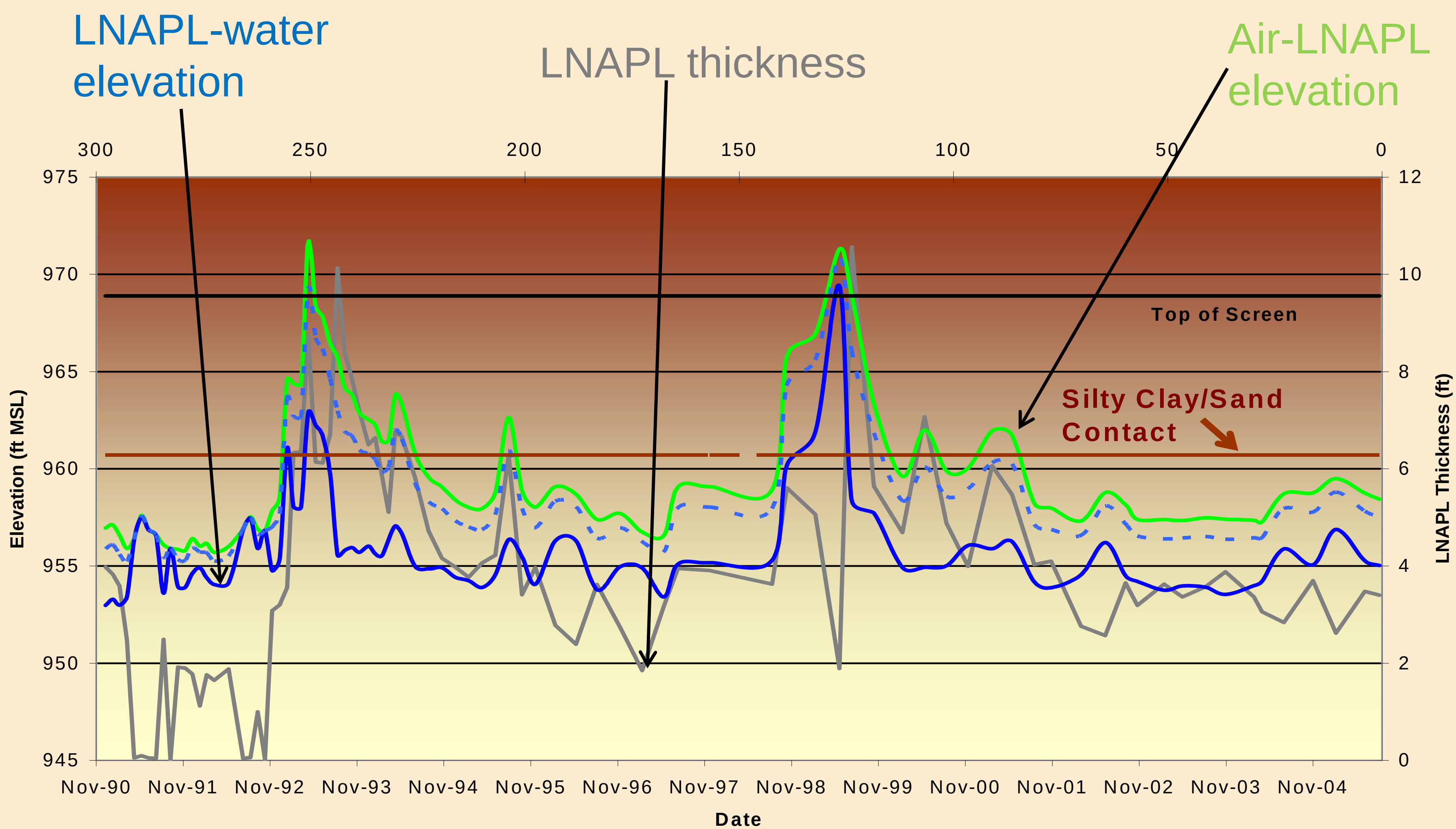
LNAPL distribution is a function of release history and lithology

Blue lines contain water – red represent LNAPL (hydrocarbon)



LNAPL easily displaces most of the water within larger pores until the LNAPL head equals the water head. If the LNAPL head is sufficient, it will also displace water from some of the smaller pores.

LNAPL Conceptual Site Model validation



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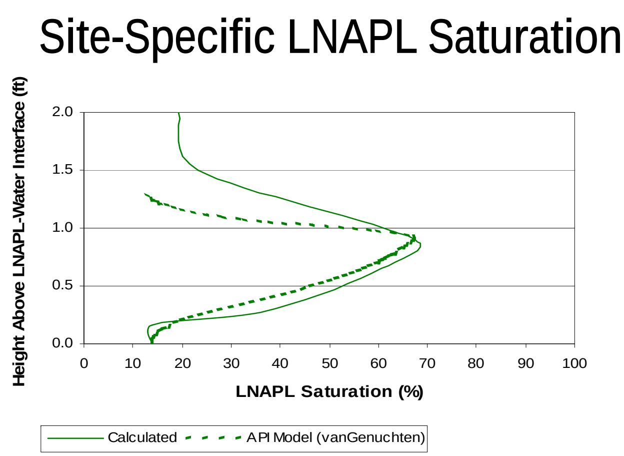
Conditions that can lead to misleading interpretation of LNAPL thickness (in well) data

- LNAPL present above or below the screened portion of the monitoring well
- Confined hydraulic conditions
- Perched water table conditions or other complex lithologies
- Rapidly changing groundwater elevations or other factors that inhibit achieving horizontal equilibrium between the formation and the monitoring well
- Continuing releases, either from the surface or from the unsaturated zone
- Flow controlled by secondary porosity such as is present in fine grained sediments

In summary, any time the LNAPL in the well and the LNAPL in the formation is not in vertical equilibrium, LNAPL thickness must be interpreted with extreme caution.

API models can help identify inconsistencies in the LNAPL CSM



Soil Properties: porosity, residual moisture, pore size distribution

Matrix Properties: alpha and beta correlation factors

LNAPL Properties: density, viscosity, surface tension, interfacial tension

Endpoint Criteria

LNAPL Mobility Model correlates NAPL thickness in a well and NAPL mobility

API LNAPL Recoverability Model – example output

Free-Product Recovery System Analysis

$t_{recovery}$ [yr] =	40
R_c [ft] =	25
μ_o [cp] =	2.45
K_w [ft/d] =	15.5
r_w [ft] =	0.333
K_o [ft/d] =	0.02887

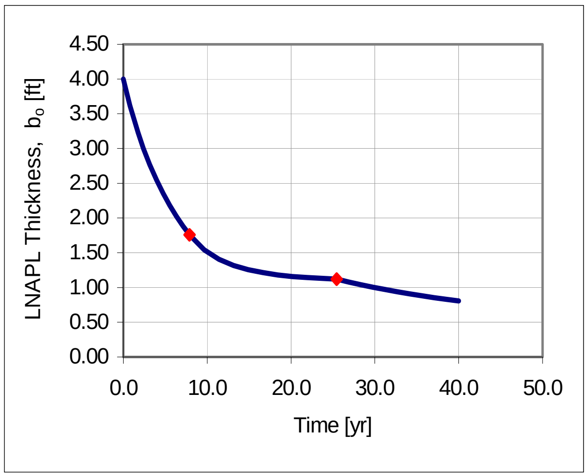
Water Enhanced	
Q_w [gpm] =	5
b_w [ft] =	9
R_I [ft] =	40
s_w [ft] =	5.26

Vacuum Enhanced	
(-) p_w [atm] =	0.000
L_{well} [ft] =	2
k_{ra} =	1
Q_a [gpm] =	0.0
h_w [ft] =	0.00

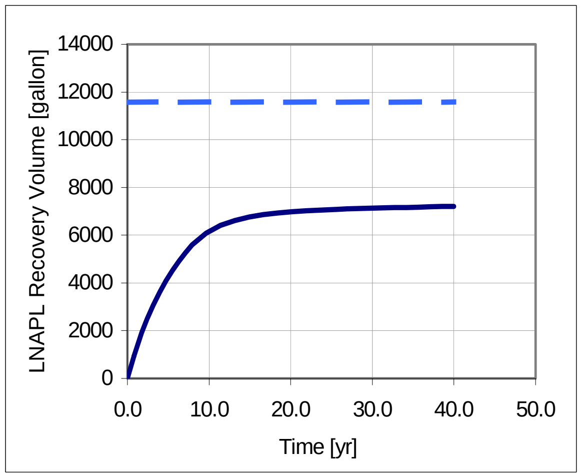
0.0

Skimmer Well

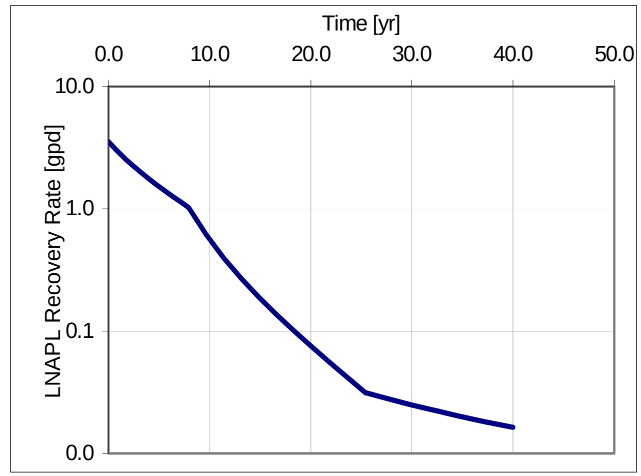
If $Q_w = 0$ and $p_w = 0$ then
a skimmer well is assumed



LNAPL thickness vs time

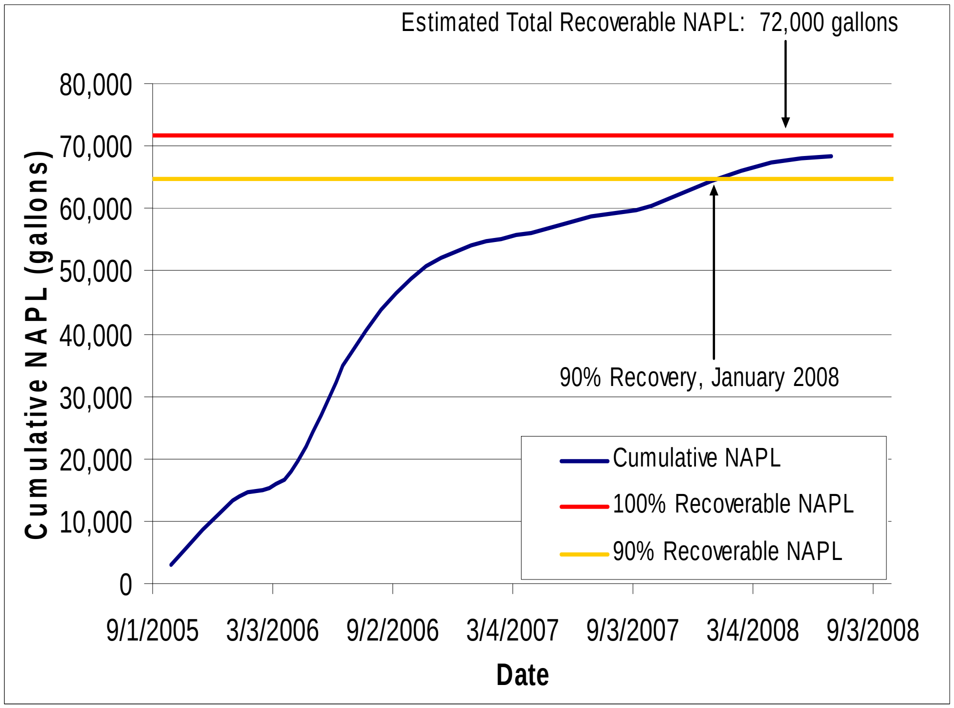


Recovery volume vs time



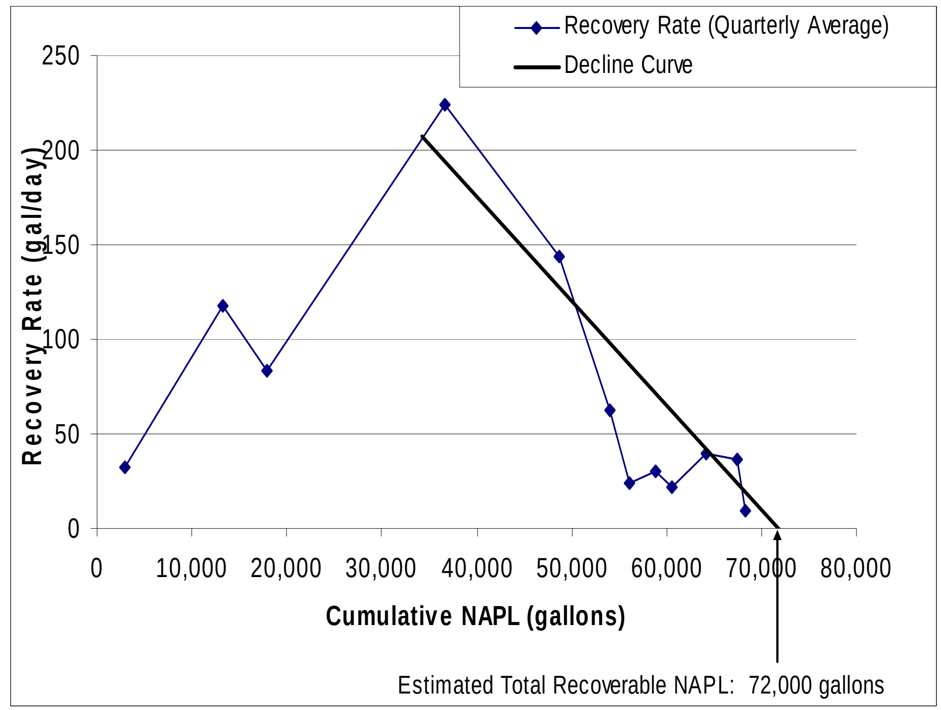
Recovery rate vs time

Decline curves from an LNAPL recovery well - former refinery



Cumulative LNAPL recovery versus Time

Incremental Versus Cumulative LNAPL Recovery



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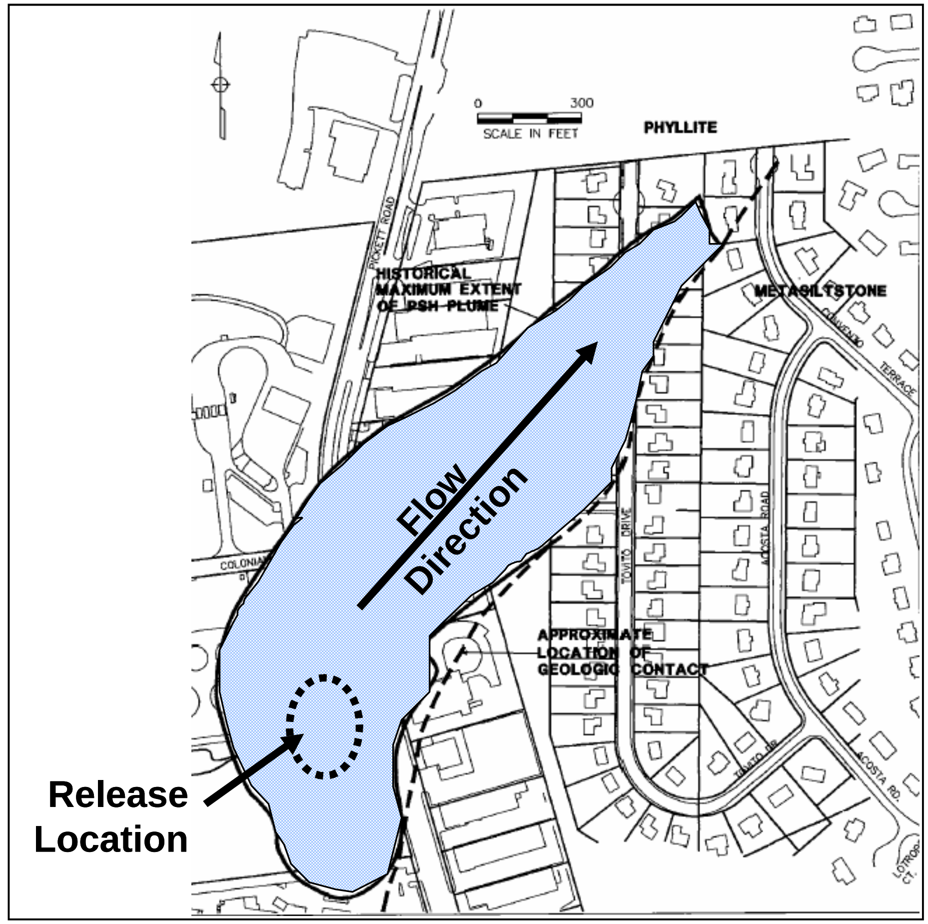
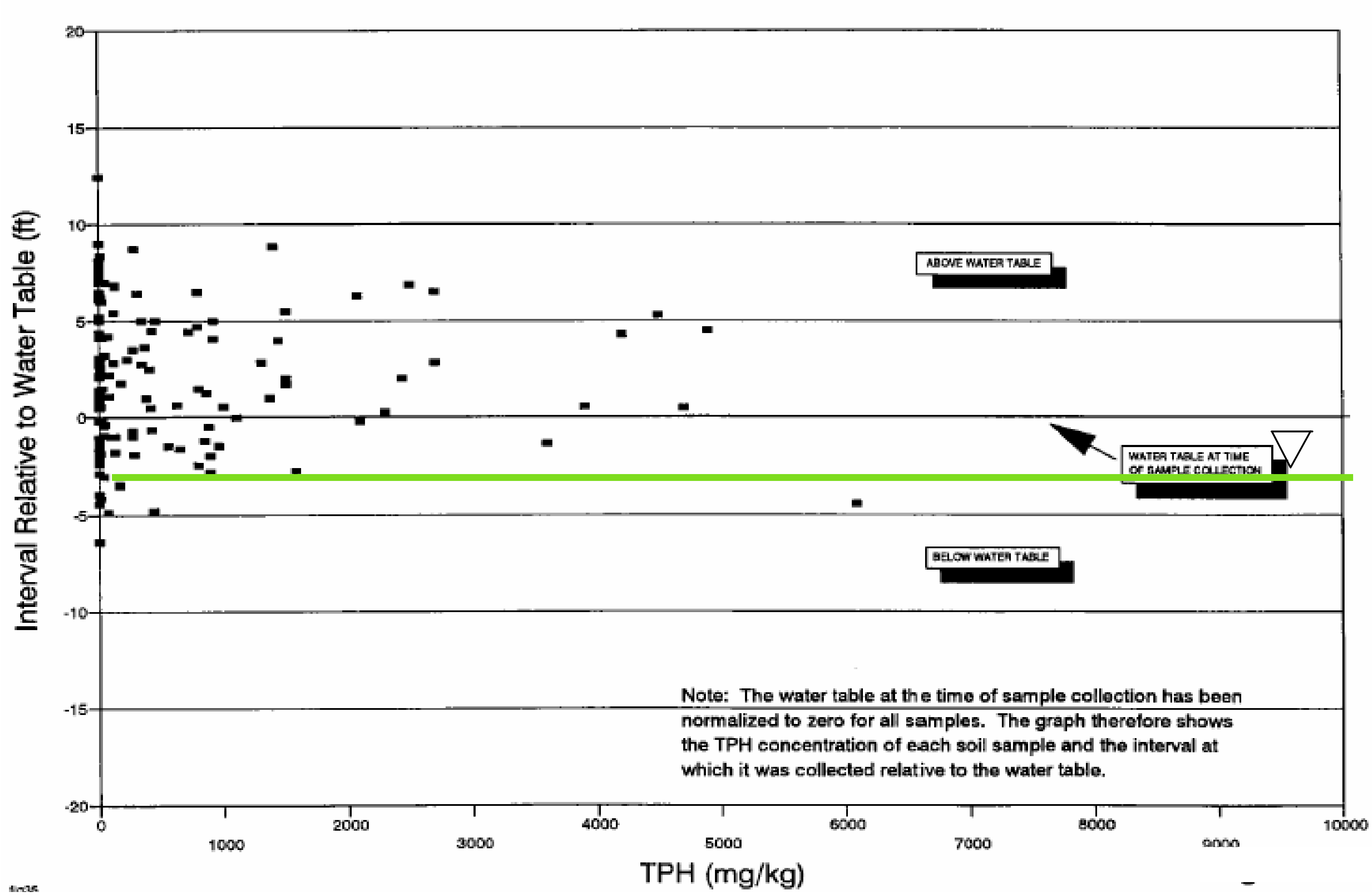
Case Study: LNAPL Release at a Petroleum Distribution Facility



TPH distribution in smear zone



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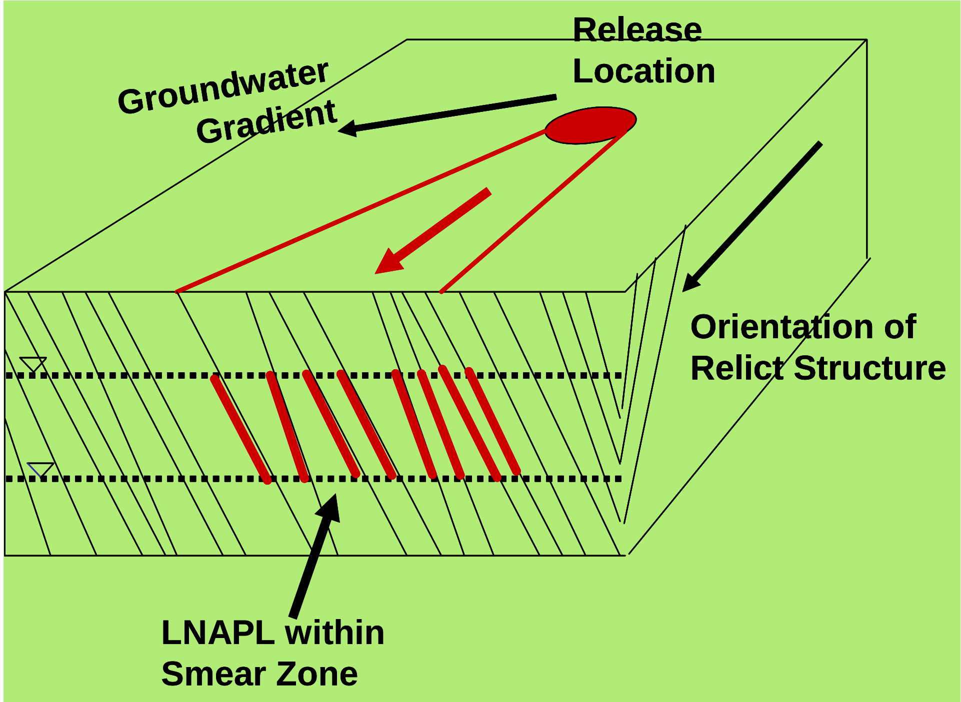
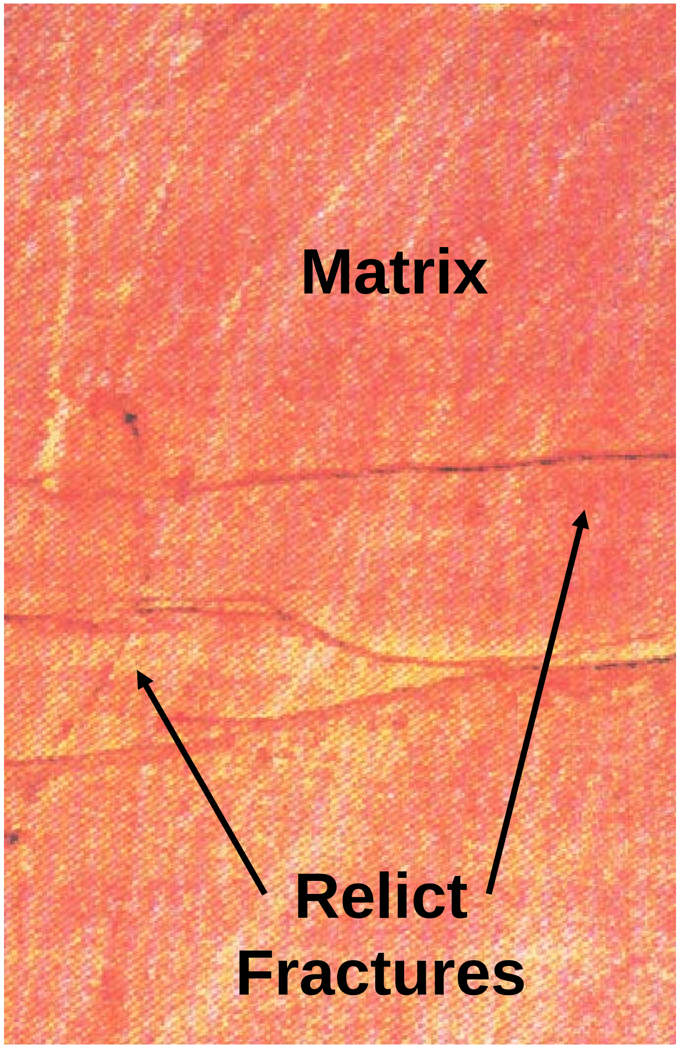
Saprolite





1.2 inches

LNAPL recovery end-point analysis at a railroad maintenance facility

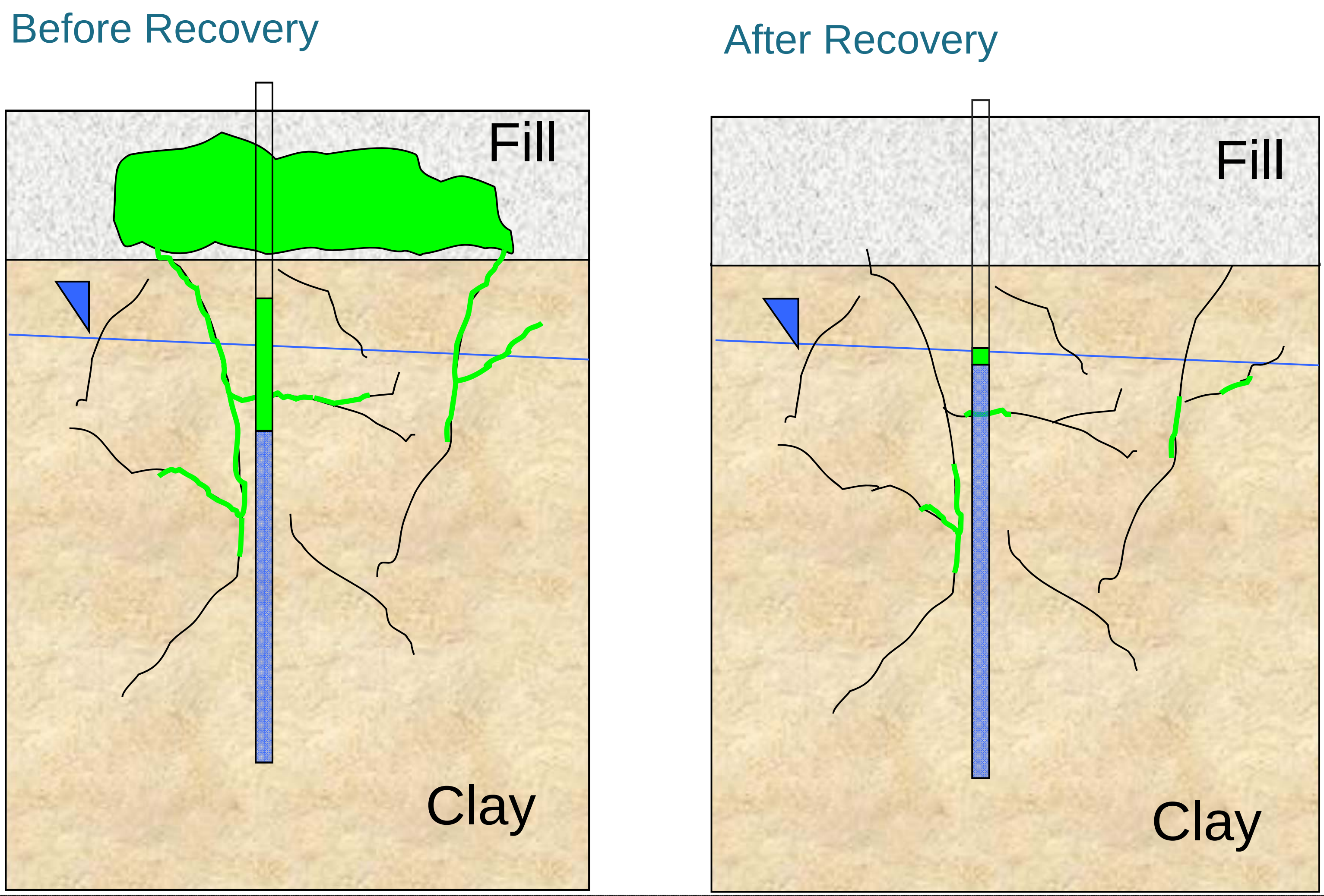
Problem: Developing An Appropriate Endpoint to Terminate LNAPL Recovery

- Full service fueling and maintenance yard
- Multiphase Extraction with mobile unit
  - 2001 to 2003
  - 2200 equivalent gallons of NAPL removed
  - Reduced thickness from 6-feet to 0.06-feet
- LNAPL still present in wells at the site, at an irregular frequency

Default Remediation Criteria

- Monthly gauging and removal
- Thickness in wells must decrease to less than 0.01 feet

Fractured flow can lead to unusual LNAPL distribution and recovery patterns



Critical review of data can lead to important insights

- Reviewing hydrographs along with soil type, well screen elevation
- Explaining unusual LNAPL behavior is often the key to understanding the potential mobility and/or recoverability of LNAPL.
- Direct measurement of LNAPL transmissivity can help resolve uncertainties in the CSM.
  - Bail-down testing
  - Calculating water-to-LNAPL recovery ratios
- Irregularities in LNAPL recovery decline curves may reflect a new or continuing LNAPL release.

Thank you for your attention

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