

North East BC Producers Society

Meeting in Fort St. John
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NAPL Mobility – Protocol 16

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Some slides were generously provided by:

- Golder Associates Ltd (Guy Patrick)
- BC Ministry of Environment (Peggy Evans)

The logo for GeoEnviroLogic, featuring the company name in a lowercase sans-serif font with a green underline beneath the text.

About Reidar and GeoEnviroLogic

Reidar is a transplanted Norwegian happily married in Canada and an environmental engineer, risk assessor and contaminated site expert with 30 years of Canadian and International consulting and teaching experience.

Reidar also organizes and teaches professional development seminars on contaminated sites through his company GeoEnviroLogic Professional Development.

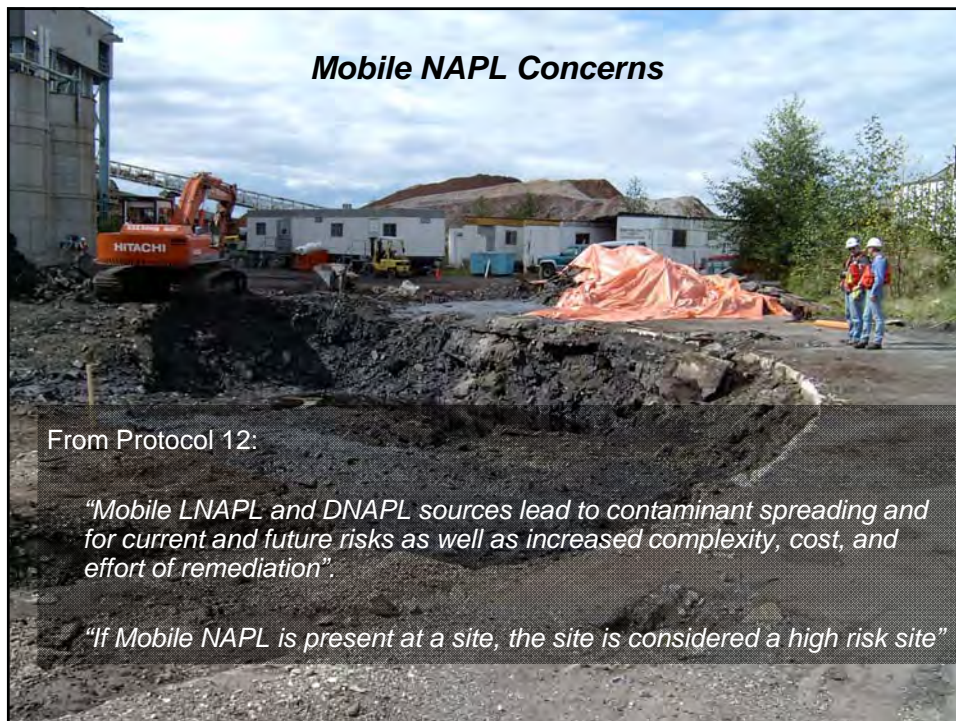
He has previously held two seminars in Fort St. John, and is planning a technical workshop here, on site investigation and risk assessment, for the Spring of 2010

The logo for GeoEnviroLogic, featuring the company name in a lowercase sans-serif font with a green underline beneath the text.

Outline - NAPL Mobility

1. Background:
 - Sources and issues
 - Regulatory development
2. Fundamentals: Principles of NAPL migration
3. Regulations: Protocol 16
 - NAPL presence
 - NAPL mobility
 - Exemptions
 - Links to other Protocols and requirements

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Protocol 16 Defines:

- LNAPL presence
- DNAPL presence
- Mobile LNAPL
- Mobile DNAPL
- Exemptions







Non-Aqueous Phase Liquids (NAPLs)

■ Light NAPLs (LNAPLs)

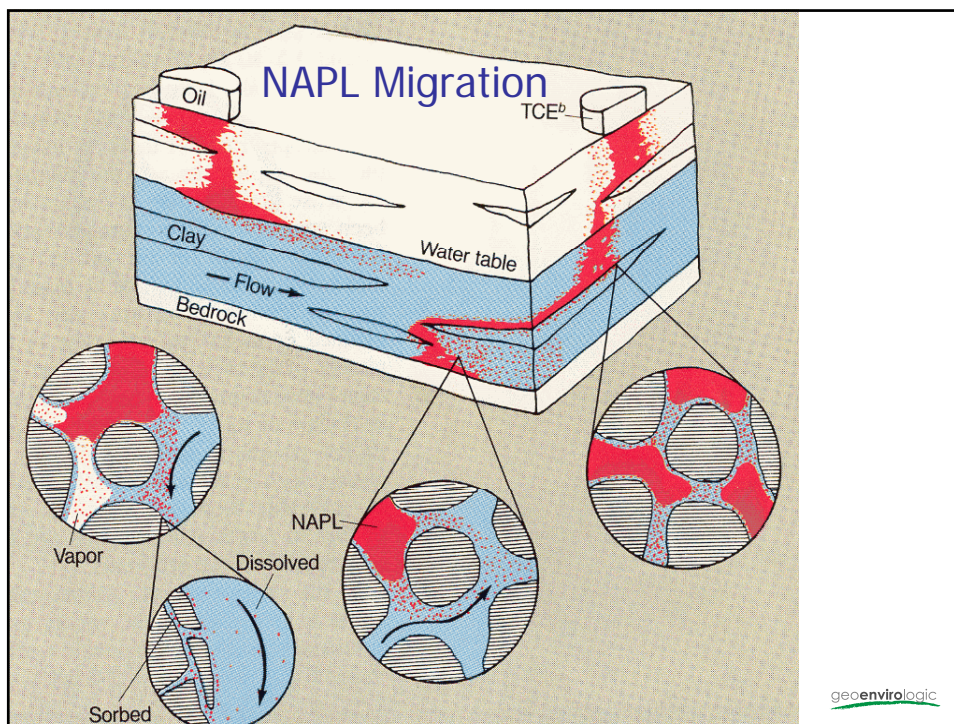
- Most of the petroleum hydrocarbons
- e.g., gasoline (petrol), middle distillates (diesel or gasoil, kerosene), heavy oils (e.g., motor oil)

■ Dense NAPLs (DNAPLs)

- Most of the chlorinated solvents (e.g., TCE)
- PCBs
- Coal tar, creosote
- Some pesticides
- Mercury

We can classify NAPLs according to their **behaviour** in the subsurface: **“floaters”** and **“sinkers”**

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LNAPL Can Exist Below Water Table

Hydrodynamic case –
Pour in olive oil first,
chase with water

Funnel →
Water
Olive oil
Tubing

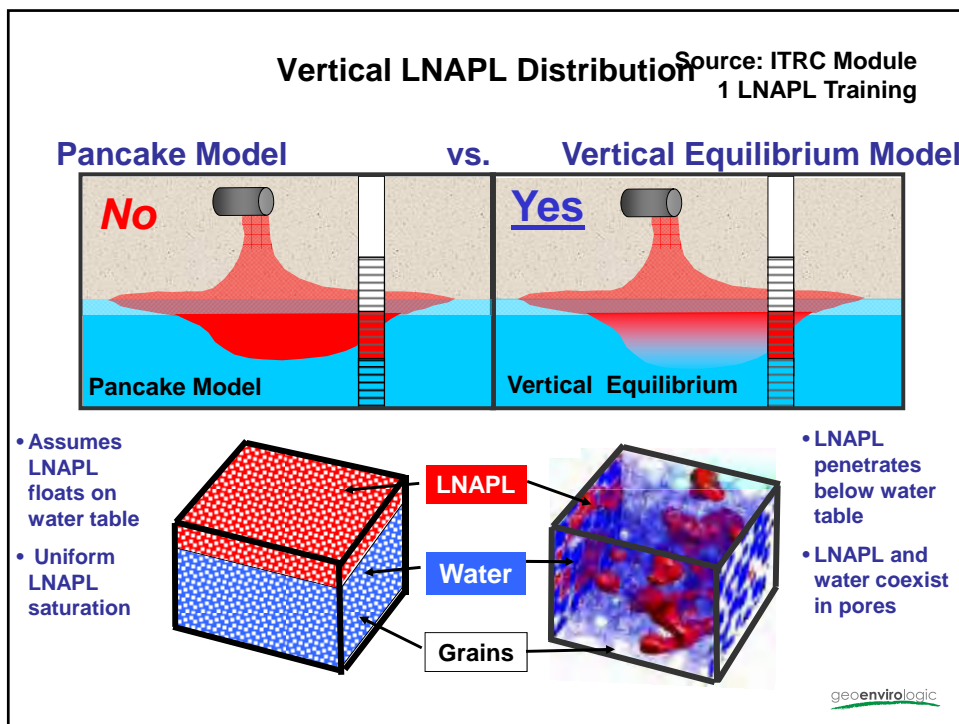
Hydrostatic case –
LNAPL is like an iceberg

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The diagram illustrates two scenarios for LNAPL. The "Hydrodynamic case" shows a funnel pouring olive oil into a tube, with water being chased behind it. The "Hydrostatic case" is compared to an iceberg, where the visible part is above the water table and the larger part is below. A photograph of an iceberg is provided for visual reference. The date "12/3/2010" and the number "15" are also present. The logo "geoenvirollogic" is in the bottom right corner.



Properties of Immiscible Contaminants

Important properties of NAPLs are:

- *Interfacial tension*
- *Capillary pressure*
- *Viscosity*

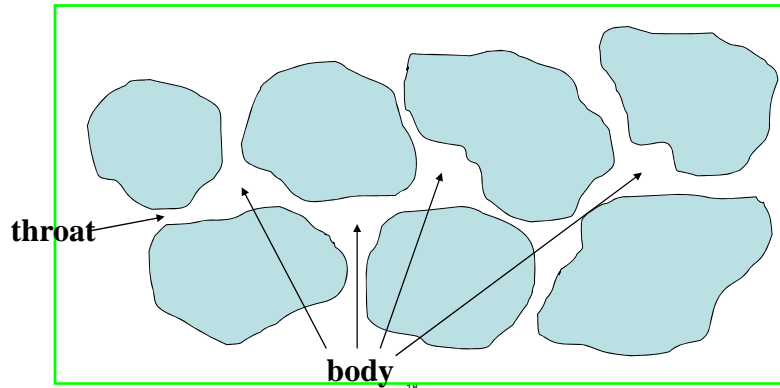
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Capillary Pressure in Soil

Pore space in soils can be split into “throats” and “bodies”. The pore space is the “volume” of the box minus the volume of the sand grains.

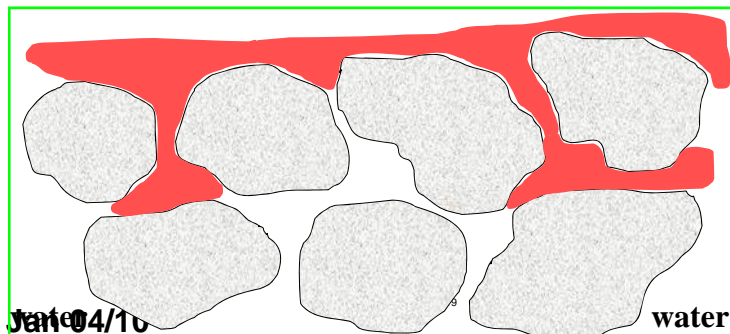


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Displacement Pressure

- The capillary pressure at which the non-wetting fluid first forms a *connected pathway* is termed the **displacement pressure**
- With increasing NAPL thickness and weight (NAPL head), more NAPL will penetrate pore “throats”.



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Displacement Pressures

Since larger capillary pressures are needed to enter smaller pores, soils with **smaller pores** have **larger displacement pressures**

Soil	Displacement Pressure (m of TCE)
Gravel	0.02
Sand	0.15
Silt	1.5

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LNAPL Migration

- Released LNAPL migrates vertically downward through unsaturated zone, under gravity gradient.
- If LNAPL reaches the water table it will spread radially.
- LNAPL will come to a stable configuration and cease to spread when resistive capillary forces balance the driving forces (LNAPL head)
- **Case studies and modeling indicate LNAPL plumes tend to come to stable configuration over relatively short time frames**
- Vertical LNAPL distribution varies and is non-uniform

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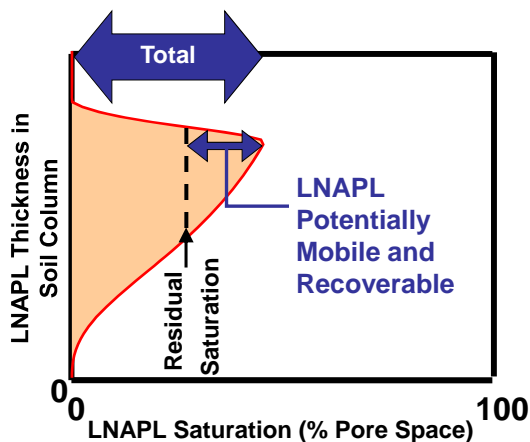
Prediction of Residual

- The amount of non-wetting-phase residual that gets trapped in a porous medium depends on:
 - The medium
 - The fluid
 - The maximum achieved non-wetting-phase saturation on drainage
- Residual will range between 5% and 50% in common soils
- Higher LNAPL saturations occur in coarse-grained than fine-grained soils (can lead to very significant differences in predicted volumes)

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Potentially Mobile Fraction of the LNAPL Distribution

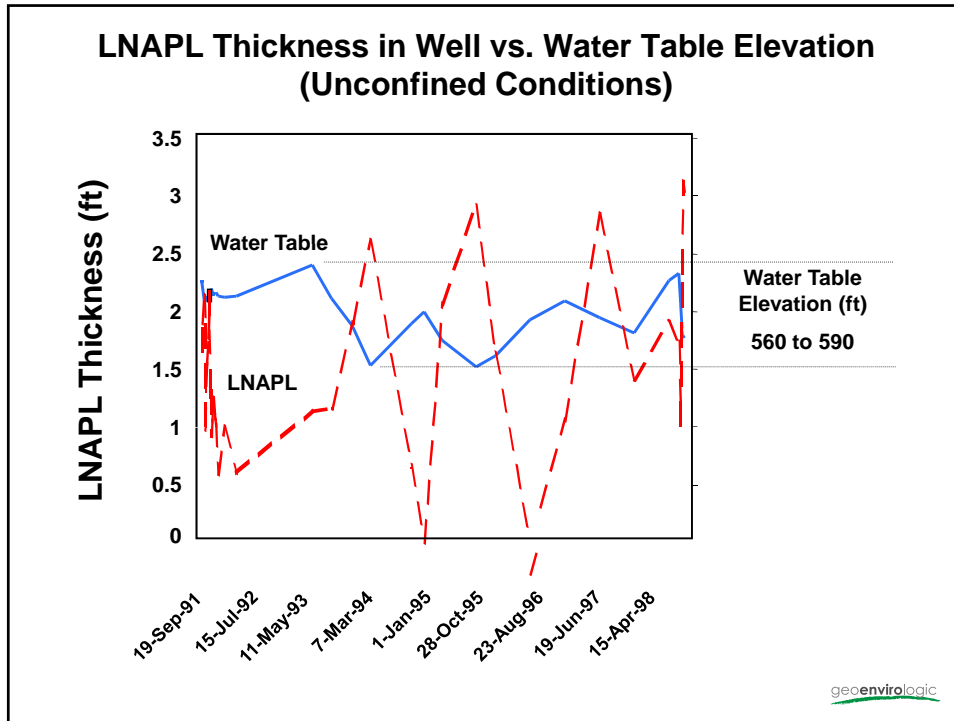


Key Point:

LNAPL potentially mobile only if the saturation exceeds residual saturation

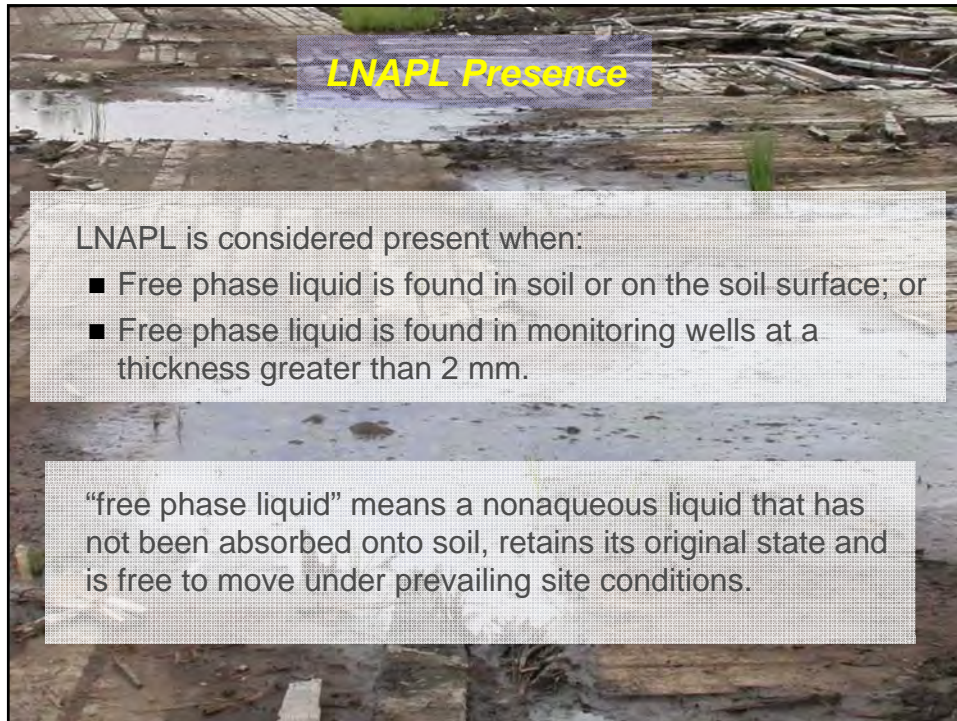
Source: ITRC Module 1 LNAPL Training (S. Garg)

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Protocol 16

- Provides NAPL definition for CSR “not present” and for P12 and P13:
 - LNAPL presence
 - DNAPL presence
 - Mobile LNAPL
 - Mobile DNAPL
 - Exemptions

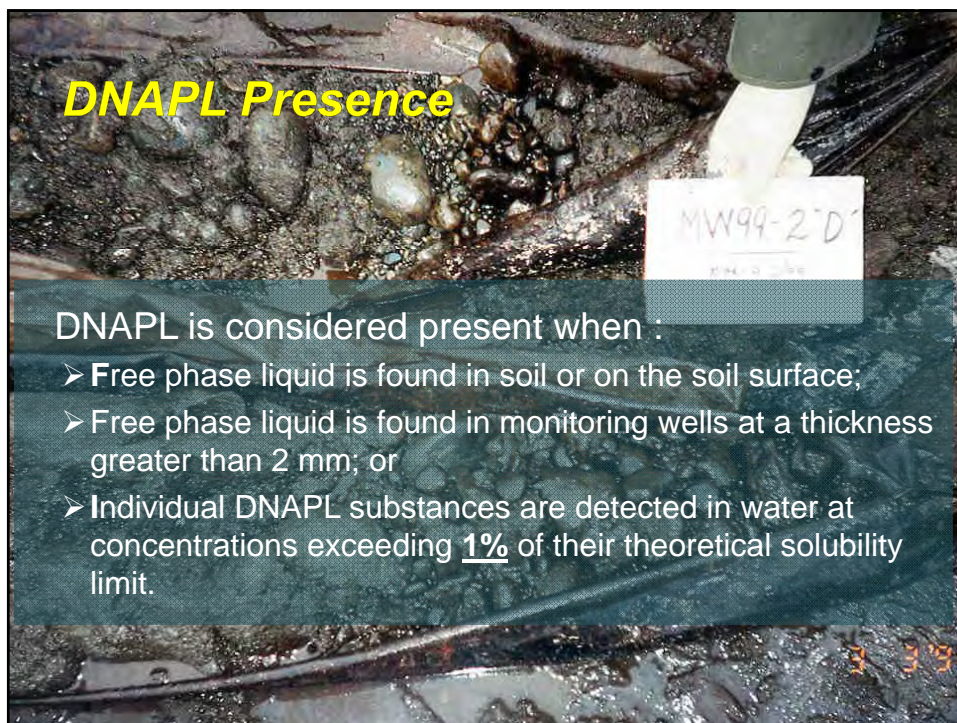


LNAPL Presence

LNAPL is considered present when:

- Free phase liquid is found in soil or on the soil surface; or
- Free phase liquid is found in monitoring wells at a thickness greater than 2 mm.

“free phase liquid” means a nonaqueous liquid that has not been absorbed onto soil, retains its original state and is free to move under prevailing site conditions.



DNAPL Presence

DNAPL is considered present when :

- Free phase liquid is found in soil or on the soil surface;
- Free phase liquid is found in monitoring wells at a thickness greater than 2 mm; or
- Individual DNAPL substances are detected in water at concentrations exceeding 1% of their theoretical solubility limit.

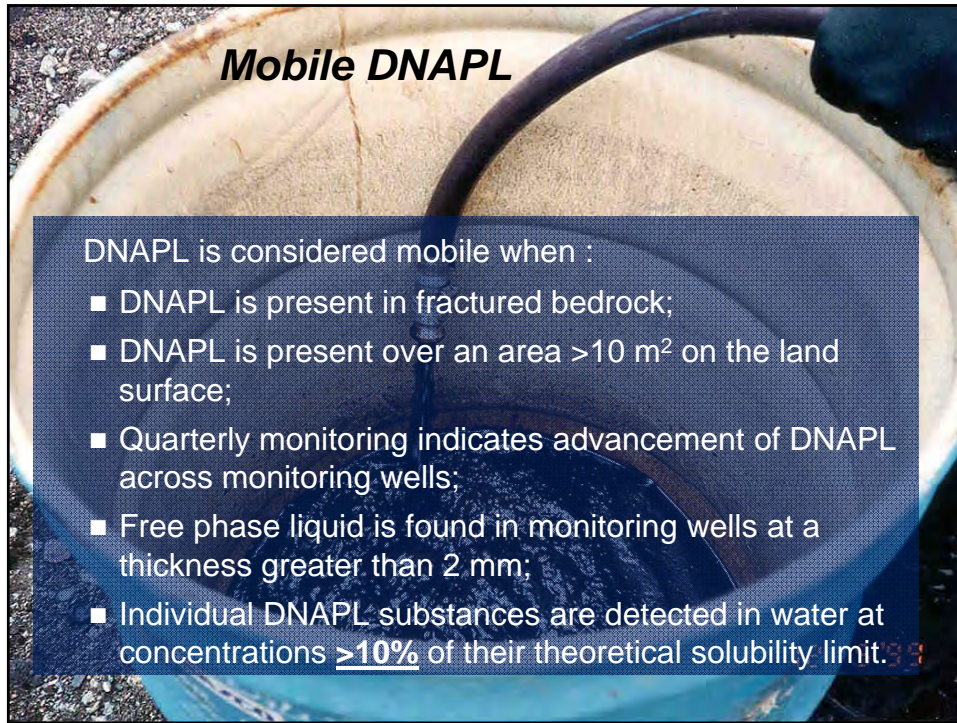
Protocol 16: Mobile LNAPL Definition

LNAPL is defined as mobile when:

- Present in fractured bedrock;
- Present over an area >10 m² on the land surface;
- Quarterly monitoring indicates increasing thickness in monitoring wells;
- Quarterly monitoring indicates advancement across monitoring wells;
- Present over an area >50 m² and one of following applies:
 - Seasonal water table fluctuations exceed 1 m;
 - Hydraulic gradients exceed 0.01 m/m;
 - Preferential pathways intersect LNAPL zones;
- Present over an area >50 m² at thicknesses exceeding values in Table 1.

Table 1: Mobile LNAPL Thickness (based on gasoline)

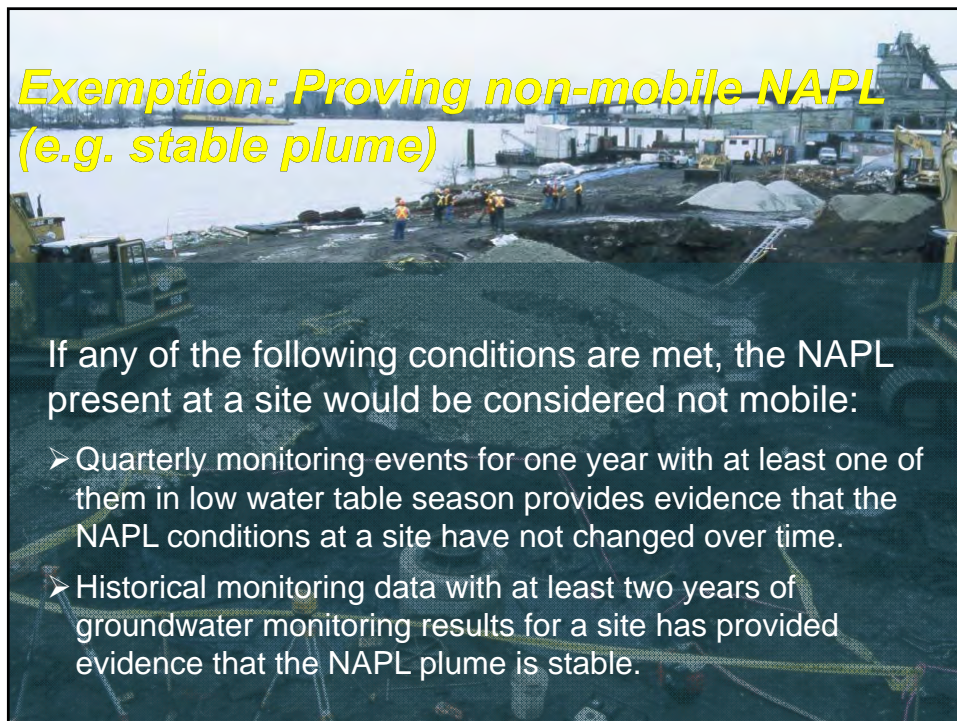
Soil Type	Characteristic Fraction	Percent Fines (silt and clay)	LNAPL Thickness (m)
coarse sand or gravel	> 20% coarse sand	< 3	0.03
coarse sand or gravel	> 20% coarse sand	3-10	0.05
medium sand	medium sand	< 10	0.1
fine sand	fine sand	< 10	0.2
silty sand	sand	> 10	0.3



Mobile DNAPL

DNAPL is considered mobile when :

- DNAPL is present in fractured bedrock;
- DNAPL is present over an area $>10 \text{ m}^2$ on the land surface;
- Quarterly monitoring indicates advancement of DNAPL across monitoring wells;
- Free phase liquid is found in monitoring wells at a thickness greater than 2 mm;
- Individual DNAPL substances are detected in water at concentrations $\geq 10\%$ of their theoretical solubility limit.



Exemption: Proving non-mobile NAPL (e.g. stable plume)

If any of the following conditions are met, the NAPL present at a site would be considered not mobile:

- Quarterly monitoring events for one year with at least one of them in low water table season provides evidence that the NAPL conditions at a site have not changed over time.
- Historical monitoring data with at least two years of groundwater monitoring results for a site has provided evidence that the NAPL plume is stable.

QUESTIONS?

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