Non-Aqueous Phase Liquids (LNAPL/DNAPL) & Source Elimination/Control

(*and update on LNAPL Guidance*)

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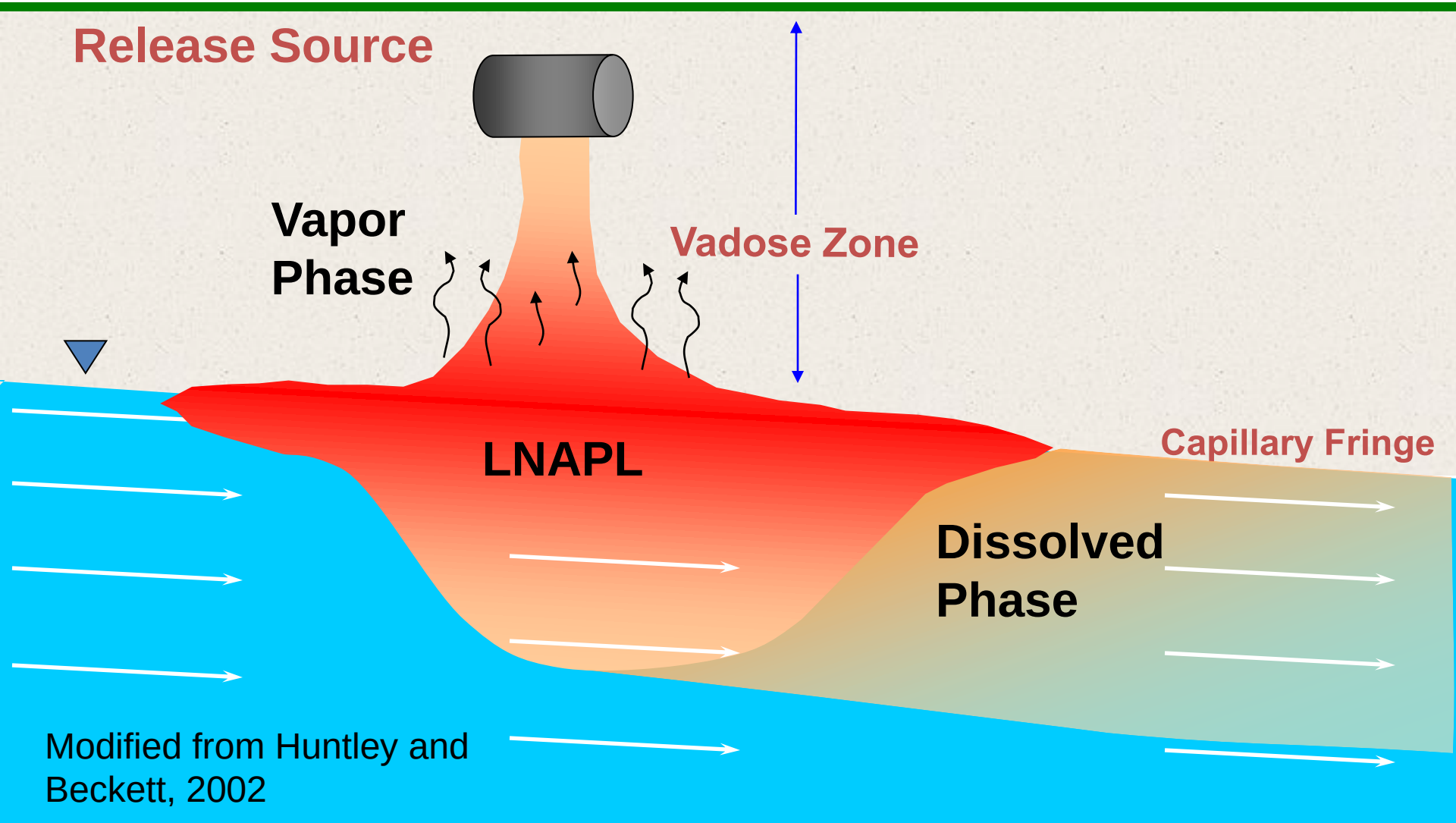
MCP Changes Made

Eliminate ½ inch UCL

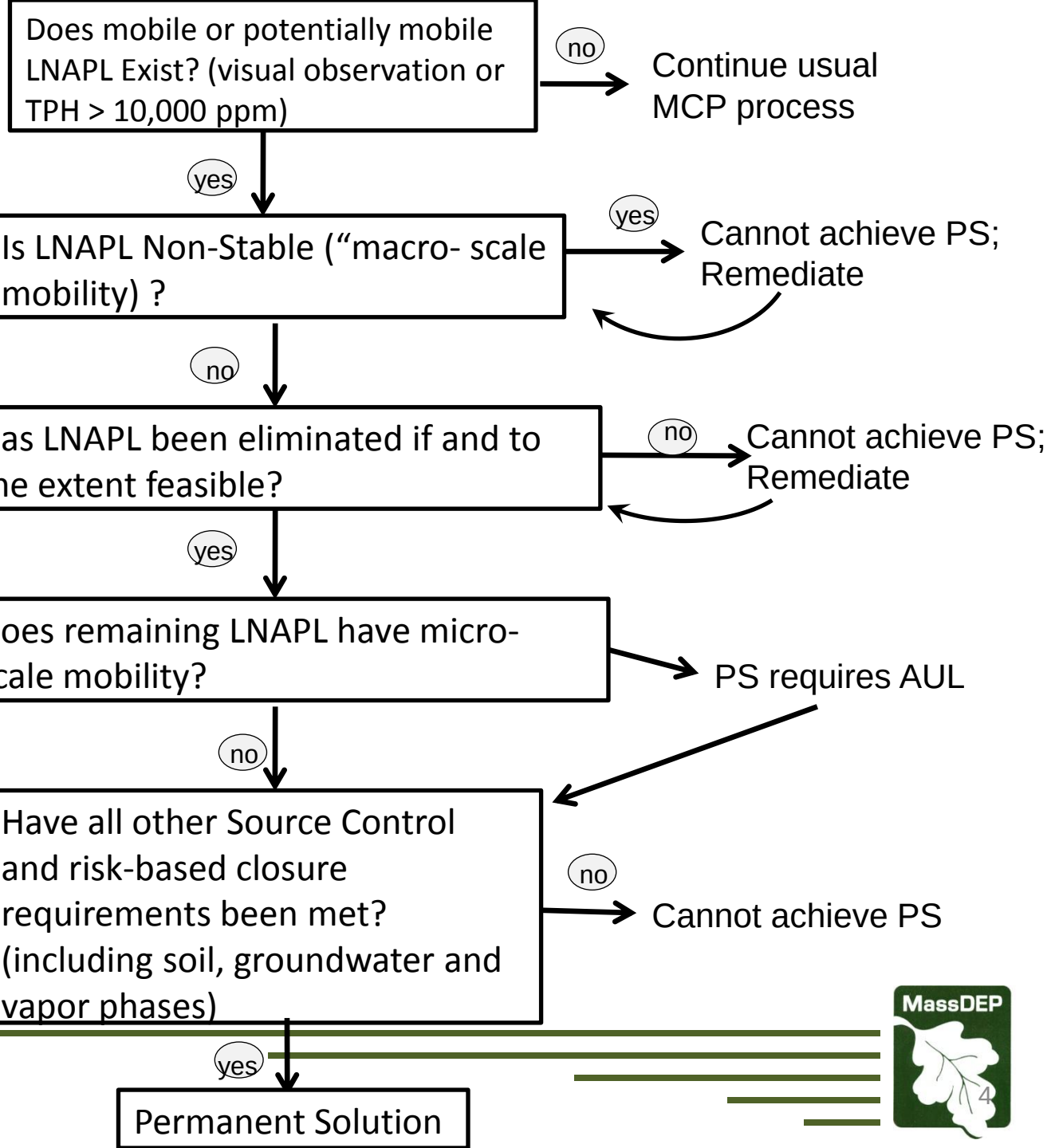
Replaced with better science, more reflective of NAPL behavior and risk

Simplified Subsurface LNAPL Processes (ITRC)



Modified from Huntley and Beckett, 2002

Evaluating Permanent Solutions at LNAPL Contaminated Sites



MCP Changes Made

- Correct NAPL definition (eliminate “continuous”)
- Define (L)CSM
- Define **“NAPL with Micro-Scale Mobility”** and **“Non-stable NAPL”**
- Reference LCSM principles (site characterization and **remediation “if and to the extent feasible”**)

➢ *Revised Source Elimination/Control Provisions addressing range of source issues, including NAPL and limiting exposure potential (e.g., vapor intrusion): SOURCE, MIGRATION, NAPL*

Definitions ...

Nonaqueous Phase Liquid and **NAPL** each means oil and/or hazardous material that is present in the environment as a separate phase liquid.

Dense Nonaqueous Phase Liquid and **DNAPL** each **means NAPL that has a specific gravity greater than one.**

Light Nonaqueous Phase Liquid and **LNAPL** each **means NAPL that has a specific gravity equal to or less than one.**

Definitions 310 CMR 40.0006

Conceptual Site Model or CSM means a site-specific description of how contaminants entered the environment, how contaminants have been and may be transported within the environment, and routes of exposure to human and environmental receptors that provides a dynamic framework for assessing site characteristics and risk, identifying and addressing data gaps and managing uncertainty, eliminating or controlling contaminant sources, developing and conducting response action strategies, and evaluating whether those strategies have been effective in achieving desired endpoints. **At sites at which NAPL is or may be present, this includes the body of fundamental scientific principles describing the behavior of fluid flow in porous media necessary to assess NAPL in subsurface strata.**

Definitions ...

NAPL with Micro-Scale Mobility means a NAPL with a **footprint that is not expanding**, but which is visibly present in the subsurface in sufficient quantities to migrate or potentially migrate as a separate phase over a short distance and visibly impact an excavation, boring or monitoring well.

Non-Stable NAPL means a NAPL with a **footprint that is expanding laterally or vertically** by: (a) migrating along or within a preferred flow path; (b) discharging or periodically discharging to a building, utility, drinking water supply well, or surface water body; or (c) spreading as a bulk fluid through or from subsurface strata.

Notification

40.0313: Releases Which Require Notification Within 72 Hours

(1) a release to the environment indicated by the presence of Nonaqueous Phase Liquid (NAPL) in a groundwater monitoring well, excavation, or subsurface structure in which NAPL has come to be located at a measured thickness equal to or greater than **1/2 inch (0.04 feet) at a location greater than 30 feet from School, Daycare or Child Care Center or occupied Residential Dwelling**;

Notification

40.0315: Releases Which Require Notification Within 120 Days

(4) a release to the environment indicated by the presence of a subsurface Nonaqueous Phase Liquid (NAPL) in a groundwater monitoring well, excavation, or other subsurface structure in which NAPL has come to be located at-a measured thickness equal to or **greater than 1/8 inch (0.01 feet) and less than 1/2 inch (0.04 feet).**

Phase I & II Assessments

40.0483: Content of Phase I Report

(1)(e)5. information and details on NAPL, if present-or suspected, including **NAPL stability and the approximate horizontal and vertical extent of NAPL contamination**, as obtained from site investigations of scope and detail commensurate with release and site conditions.

40.0835: Phase II Report

(4)(f) Nature and Extent of Contamination, including a **characterization of the nature, and vertical and horizontal extent** of oil and/or hazardous material in the environment, including any and all source(s), **the presence, distribution, and stability of any NAPL**, tabulation of analytical testing results, and, where appropriate, a characterization of background concentrations of oil and/or hazardous material at the disposal site;

Risk Characterization – Method 3 UCL

40.0996 ~~**(6) The presence of non-aqueous phase liquids (NAPL) having a thickness equal to or greater than 1/2 inch in any environmental medium shall be considered a level which exceeds Upper Concentration Limits.**~~

Source Elimination/Control

Intent -

- Provide basic definition of “Source of OHM Contamination” that refers to the original OHM **release location** and/or **contaminated media from which OHM can migrate** as a bulk material.
- Source of OHM Contamination **shall be eliminated, if feasible.**
- If elimination is **not feasible**, then Source must be **controlled**; performance standards for “Source Control” are specified.

Source-Related Performance Standard

Divided into three parts/concerns at 40.1003 for Permanent and Temporary Solutions

- Source Elimination or Control
- Migration Control
- NAPL

Source of OHM Contamination

40.0006 Source of OHM Contamination means:

(a) a point of discharge of OHM into the environment that may include, without limitation:

1. leaking storage tanks, vessels, drums and other containers;
2. dry wells or wastewater disposal systems that are not in compliance with regulations governing discharges from those systems; or

(b) waste deposits, sludges, or impacted soil, sediment, or bedrock **at or near a point of discharge** or deposit of OHM into the environment containing sorbed OHM or NAPL that is **contaminating surrounding environmental media** via dissolution or volatilization processes;

Except that the downgradient leading edge of a plume of oil and/or hazardous material dissolved in and migrating with groundwater or as vapor-phase **shall not, in and of itself, be considered a Source of OHM Contamination.**

40.1003 General Provisions for Perm. & Temp. Solns.

(5) Source Elimination or Control. A Permanent or Temporary Solution shall not be achieved unless and until response actions are taken to adequately identify and address Sources of OHM Contamination at the disposal site. Such response actions shall ensure:

(a) for a **Permanent or Temporary Solution**, all unpermitted **releases** of OHM to the environment are **eliminated**;

(b) for a **Permanent Solution**, all **Sources** of OHM Contamination are **eliminated** or if they are not eliminated, they are **eliminated to the extent feasible and controlled**;

(c) for a **Temporary Solution**, all Sources of OHM Contamination are eliminated or controlled to the extent feasible.

40.1003 General Provisions for Perm. & Temp. Solns.

(6) Migration Control. A Permanent or Temporary Solution shall not be achieved unless and until response actions are taken to adequately assess and control the subsurface migration of OHM remaining at a disposal site. Such response actions shall ensure:

(a) for a **Permanent Solution**, **plumes** of dissolved OHM in **groundwater** and **vapor-phase** OHM in the Vadose Zone are **stable or contracting**;

(b) for a **Temporary Solution**, **plumes** of dissolved OHM in groundwater and vapor-phase OHM in the Vadose Zone are stable or contracting or **otherwise controlled or mitigated to the extent feasible**.

40.1003 General Provisions for Perm. & Temp. Solns.

(7) NAPL. A **Permanent or Temporary Solution** shall not be achieved … unless and until response actions are taken to adequately **assess the nature, extent, and mobility** of the NAPL, and, **where necessary, remedial actions are taken to adequately contain or remove such NAPL**. Such response actions **shall ensure:**

…

40.1003 General Provisions for Perm. & Temp. Solns.

(a) **for a Permanent Solution**, (i) **Non-Stable NAPL is not present** under current site conditions and for the foreseeable future, and (ii) **all NAPL with Micro-Scale Mobility is removed if and to the extent feasible** based upon consideration of CSM principles;

(b) **for a Temporary Solution**, all Non-Stable NAPL and NAPL with Micro-Scale Mobility **is removed and/or controlled if and to the extent feasible**.

40.1012: Activity and Use Limitations

(2) Except as provided in 310 CMR 40.1012(3) and 310 CMR 40.1013, Activity and Use Limitations shall be required:

…

(d) At disposal sites for which a Permanent Solution is achieved and **NAPL with Micro-Scale Mobility is present.**

LNAPL Guidance

LNAPL and the MCP: Guidance for Site Assessment and Closure

310 CMR 40.0996:

"The presence of non-aqueous phase liquids (**NAPL**) having a thickness equal to or greater than ***½ inch*** in any environmental medium is considered to be a level which exceeds Upper Concentration Limits (UCLs)" and hence which ***prohibits the attainment of a Permanent Solution***.

310 CMR 40.0006:

This thickness is “as a ***continuous separate phase*** as measured in a groundwater ***monitoring well*** or ***otherwise observed in the environment***.”

Multi-Phase Fluid Flow in Porous Media or LNAPL Conceptual Site Model (LCSM)

Fundamental

More accurate

Not necessarily simple – usually needs ***multiple lines of evidence***

MULTIPLE (not singular) Lines of Evidence

Guiding Principles

- Keep it simple (*as possible*)
  "Tiered" Approach
- Focus on MCP and PS
- Clear, established, peer-reviewed, published works

LNAPL Guidance: Key Resources & References

- ITRC
- API
- ASTM
- Other agencies (British Columbia, Alaska, Texas)

NOTE: ***These methods INCLUDE the use of WELL data, in addition to SOIL data***

LNAPL Guidance Resources & References (cont.)

Interstate Technology & Regulatory Council (ITRC)

Archived On-Line Classes:

LNAPL Training Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface - State of Science vs. State of Practice (last uploaded March 4, 2014)
http://www.itrcweb.org/Training#LNAPLPart1

LNAPL Training Part 2: LNAPL Characterization and Recoverability - Improved Analysis - Do you know where the LNAPL is and can you recover it? (last uploaded March 6, 2014)
http://www.itrcweb.org/Training#LNAPLPart2

LNAPL Training Part 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
http://www.itrcweb.org/Training#LNAPLpart3 (last uploaded Sept 24, 2013)

Tech/Reg Guidance Document:

Evaluating LNAPL Remedial Technologies for Achieving Project Goals; December 2009.
http://www.itrcweb.org/Documents/LNAPL-2.pdf

American Petroleum Institute (API)

Brost et al.; *Non-Aqueous Phase Liquid (NAPL) Mobility Limits in Soil*; API Bulletin No. 9; June 2000.
http://www.api.org/ehs/groundwater/upload/09_bull.pdf

Light Non-Aqueous Phase Liquid (LNAPL) Resource Center (including: *Interactive LNAPL Guide; LNAPL Distribution and Recovery Model (LDRM); and LNAPL Transmissivity Workbook - Calculation of LNAPL Transmissivity from Baildown Test Data.)*
http://www.api.org/environment-health-and-safety/clean-water/ground-water/lnapl

LNAPL Guidance Resources & References (cont.)

American Society for Testing and Materials (ASTM International)

ASTM E2856-13 *Standard Guide for Estimation of LNAPL Transmissivity* (revised 2013)
http://www.astm.org/Standards/E2856.htm

ASTM D7242/D7242M-06(2013)e1 *Standard Practice for Field Pneumatic Slug (Instantaneous Change in Head) Tests to Determine Hydraulic Properties of Aquifers with Direct Push Groundwater Samplers* (revised 2006, re-approved 2013)
http://www.astm.org/Standards/D7242.htm

Adamski, Mark, P.G.

Adamski, Mark, Kremesec, Victor, and Charbeneau, Randall, Charbeneau *Residual Saturation: What is it? How is it Measured? How Should We Use it?*, National Ground Water Association and American Petroleum Institute, 20th Conference, Petroleum Hydrocarbons and Organic Chemicals in Groundwater, 2003.

Adamski, et. al., *LNAPL in Fine-Grained Soils: Conceptualization of Saturation, Distribution, Recovery, and Their Modeling*, Groundwater Monitoring and Remediation, Vol 25, no.1, Winter 2005 pages 100–112.

LNAPL Guidance Resources & References (cont.)

British Columbia Ministry of Environment

PROTOCOL 16 FOR CONTAMINATED SITES: Determining the Presence and Mobility of Nonaqueous Phase Liquids and Odorous Substances; May 2010.
http://www.env.gov.bc.ca/epd/remediation/policy_procedure_protocol/protocols/pdf/protocol-16.pdf

Report on: Approaches and Methods for Evaluation of Light non-Aqueous – Hydrogeological Assessment Tools Project; Submitted to: Ministry of Environment; February 2006.
http://www.sabcs.chem.uvic.ca/LNAPL%20Guidance%2002-15-06%20rev.pdf

Alaska Department of Environmental Conservation (ADEC)

Maximum Allowable Concentration, Residual Saturation, and Free-Product Mobility Technical Background Document and Recommendations; Prepared for Alaska Statement of Cooperation Working Group; September 2006.
http://dec.alaska.gov/spar/csp/docs/soc/4_max_allow_conc.pdf

Texas Commission on Environmental Quality

Risk-Based NAPL Management; RG-366/TRRP-32; Revised July 2013.
http://www.tceq.texas.gov/publications/rg/rg-366_trrp_32.html/at_download/file

Saturation versus Residual Saturation (ITRC)

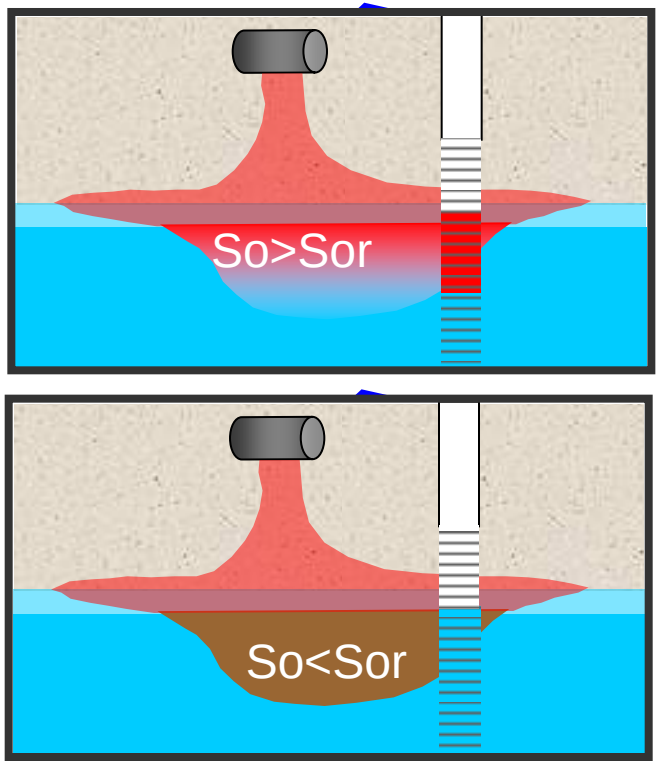
When LNAPL *Saturation* in the ground exceeds LNAPL *Residual Saturation*

LNAPL Saturation (So)

Fraction of pore space occupied by LNAPL

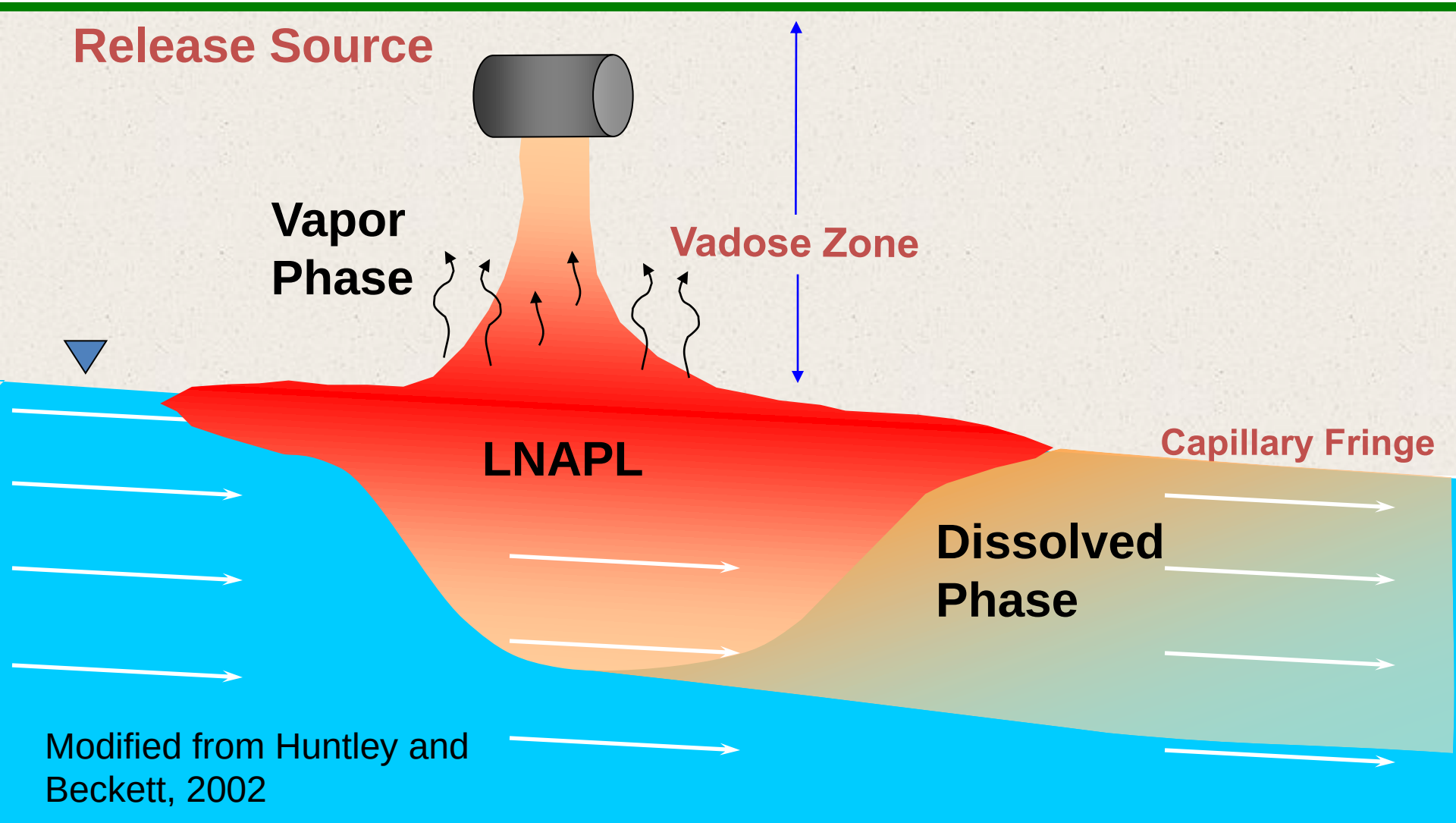
Residual LNAPL Saturation (Sor)

Fraction of pore space occupied by LNAPL that cannot be mobilized under an applied gradient



When So < Sor, non-multiphase flow fate-and-transport decision frameworks (dissolved phase or vapor phase) work well (e.g., RBCA)

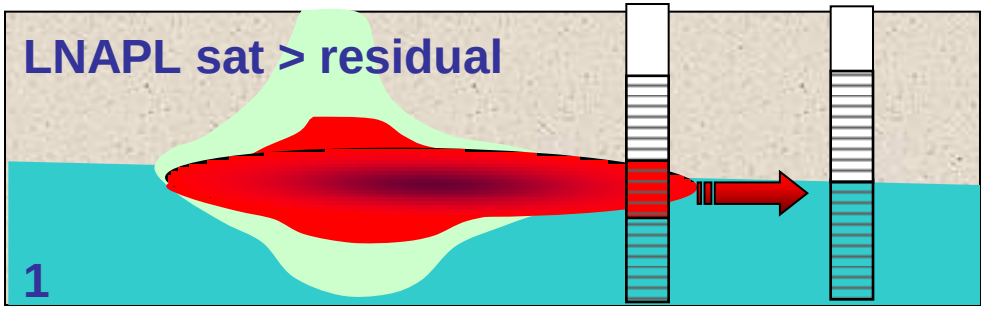
Simplified Subsurface LNAPL Processes (ITRC)



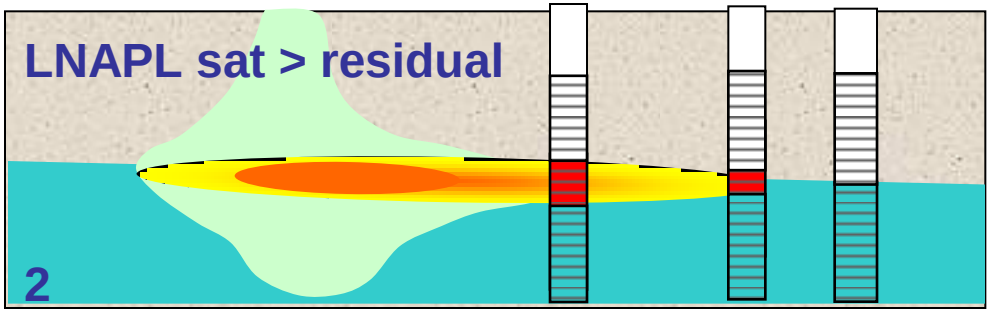
Modified from Huntley and Beckett, 2002

"Macro-" and "Micro-scale" Mobility?

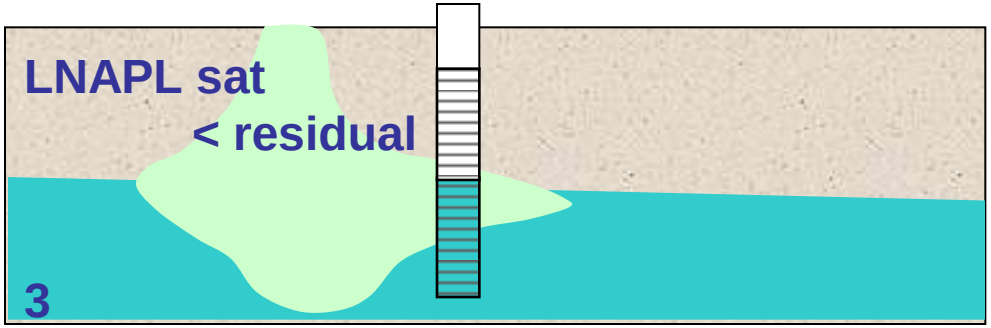
The Three Basic LNAPL Site Scenarios (ITRC)



Condition: LNAPL in wells, mobile
Driver: LNAPL saturation
MassDEP: NON-STABLE "Macro-scale" Mobility



Condition: LNAPL in wells, mobile, not migrating
Driver: LNAPL composition, saturation
MassDEP: STABLE "Micro-scale" Mobility



Condition: No LNAPL in wells
Driver: LNAPL composition

"Non-Stable" or "Macro-Scale" Mobility

LNAPL footprint expands or moves as a bulk mass

Source is not Controlled and **No Permanent Solution** if Non-Stable LNAPL remains, **even after removal to extent feasible**

"Micro-Scale" Mobility

LNAPL footprint does not move, but LNAPL must be removed if and to the extent feasible to meet LNAPL source control requirements

BUT....

LNAPL Phase

LNAPL may still move within the LNAPL footprint, e.g., into a well

Dissolved Phase

Soluble LNAPL constituents may still contaminate groundwater

Vapor Phase

Volatile LNAPL constituents may still migrate towards the surface

MULTIPLE (not singular) Lines of Evidence

LNAPL Removal "if and to the extent feasible"

- Decline Curve Analysis
- Transmissivity (ASTM)
- Residual Saturation Tables

Other Lines of Evidence to Assess LNAPL Behavior

- Seasonal/areal well monitoring data (including "pore entry pressure" well thickness)
- Vertical/areal soil type and TPH data
- Site-specific residual saturation testing

LNAPL Pore Entry “well thickness

TABLE 2
Example NAPL Thickness Necessary to Overcome Water Displacement Pressure for Selected Soil Textures (From Charbeneau et.al., 1999)

		NAPL Specific Gravity	
		0.775	0.85
Soil Texture	Air-Water Bubbling Pressure or Pore Entry Pressure (feet of water)	Monitoring Well LNAPL Thicknesses to Overcome Water Displacement Pressures (feet of oil)	
Sand	0.23	0.7	1.0
Loamy Sand	0.27	0.8	1.3
Sandy Loam	0.43	1.4	2.1
Loam	0.92	2.8	3.6
Sandy Clay Loam	0.56	2.3	3.0
Silt Loam	1.64	4.1	5.2
Silt	2.03	4.8	5.9
Clay Loam	1.74	4.4	5.7
Sandy Clay	1.21	3.9	4.9
Silty Clay Loam	3.28	6.1	8.2
Clay	4.10	6.6	9.5
Silty Clay	6.56	8.7	13.8

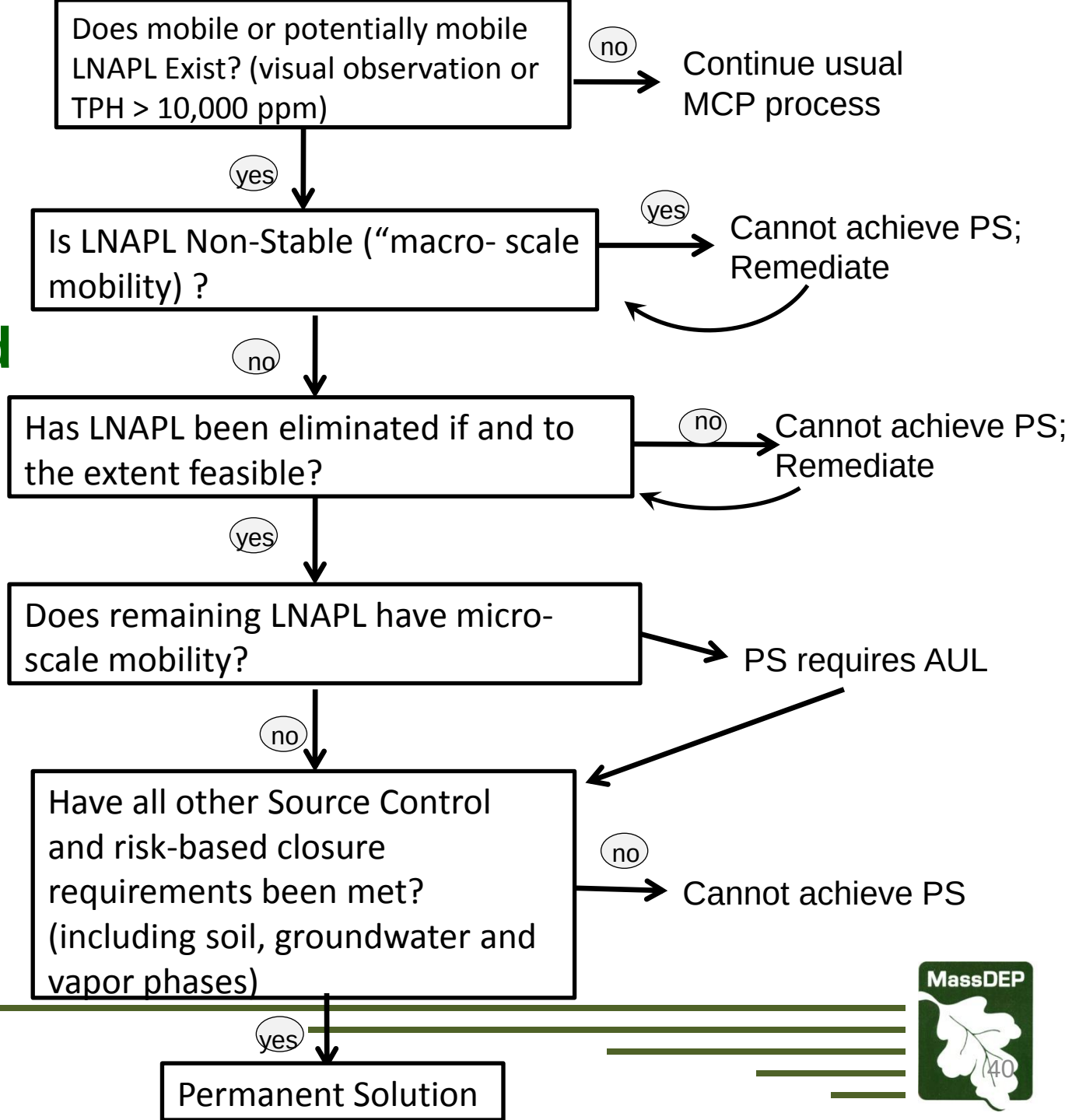
Table From Charbeneau et. al. (1999)
All Soil Textures Based on USDA/ Soil Conservation Service Soil Classifications
Soil Property Data from Carsel and Parish (1988)

Residual Saturation Tables

Table 2. Summary values of residual NAPL concentration in soil, $C_{res,soil}$, residual NAPL volume fraction, θ_o, and residual NAPL fraction in the voids, S_r. Calculated values for soil saturation limit, $C_{sat,soil}$, are also shown. Parameters for the calculations are shown in the second part of the table.

	NAPL	Soil Type	Ref	Measured S_r (cm^3/cm^3)	Measured $1000 \cdot \theta_o$ (cm^3/cm^3)	Measured $C_{res,soil}$ (mg/kg)	$C_{sat,soil}$ (mg/kg)
1.	Gasoline	coarse gravel	1	*0.01*	2.5	1,000	57
2.	Gasoline	coarse sand and gravel	1	*0.01*	4	1,697	102
3.	Gasoline	medium to coarse	1	*0.02*	7.5	3,387	143
4.	Gasoline	fine to medium sand	1	*0.03*	12.5	5,833	215
5.	Gasoline	silt to fine sand	1	*0.05*	20	10,000	387
6.	Middle distillates	coarse gravel	1	*0.02*	5	2,286	2
7.	Middle distillates	coarse sand and gravel	1	*0.02*	8	3,879	4
8.	Middle distillates	medium to coarse	1	*0.04*	15	7,742	5
9.	Middle distillates	fine to medium sand	1	*0.06*	25	13,333	9
10.	Middle distillates	silt to fine sand	1	*0.1*	40	22,857	18
11.	Fuel oils	coarse gravel	1	*0.04*	10	5,143	2
12.	Fuel oils	coarse sand and gravel	1	*0.05*	16	8,727	4
13.	Fuel oils	medium to coarse	1	*0.08*	30	17,419	6
14.	Fuel oils	fine to medium sand	1	*0.1*	50	30,000	9
15.	Fuel oils	silt to fine sand	1	*0.2*	80	51,429	18
16.	Light oil & gasoline	soil	2	0.18	*72*	40,800	9 (a)
17.	Diesel & light fuel oil	Soil	2	0.15	*60*	34,000	NE (b)
18.	Lube & heavy fuel oil	Soil	2	0.2	*80*	53,067	NE
19.	Gasoline	coarse sand	3	0.15 to 0.19	*61 to 77*	24,954 to 31,609	106
20.	Gasoline	medium sand	3	0.12 to 0.27	*48 to 109*	19,767 to 44,476	106
21.	Gasoline	fine sand	3	0.19 to 0.6	*76 to 240*	31,065 to 98,100	106
22.	Gasoline	Graded fine-coarse	3	0.46 to 0.59	*184 to 236*	80,500 to 103,250	106
23.	Mineral oil	Ottawa sand	4	0.11	*39*	20,116	3

Evaluating Permanent Solutions at LNAPL Contaminated Sites



Questions?

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