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ENVIRONMENT

Mr. Kendall Marra
Bureau of Waste Site Cleanup
Massachusetts Department of Environmental Protection
One Winter Street
Boston, Massachusetts 02108

Subject:
Comments on MassDEP's draft Light Nonaqueous Phase Liquids (LNAPL) and the MCP: Guidance for Site Assessment and Closure
Policy #WSC-14-450

Date:
August 1, 2014

Contact:
Steven Gaito

Phone:
781.356.7300

Email:
steven.gaito@arcadis-us.com

:

Dear Mr. Marra:

ARCADIS appreciates the opportunity to provide comments on MassDEP's draft Light Nonaqueous Phase Liquids (LNAPL) and the MCP: Guidance for Site Assessment and Closure, Policy #WSC-14-450.

Overall, the approach outlined in the LNAPL guidance document is consistent with the current science and risk-based approach to LNAPL management which should facilitate permanent solutions of LNAPL sites. Attached are comments for your consideration.

We hope MassDEP will find these comments useful and we look forward to further opportunities to work with MassDEP on this important subject. Please contact me if you have any questions on the enclosed comments.

Sincerely,

ARCADIS U.S., Inc.

Steven Gaito
Senior Environmental Specialist

Enclosure

Page 2 – The MCP introduces new terms “non-stable NAPL” and “micro-scale mobility” to describe LNAPL conditions. In lieu of these new terms, it is suggested that the terms “migrating LNAPL” and “mobile NAPL” be adopted to be consistent with ITRC NAPL terminology.

Page 5/Figure 2 - The logic in Figure 2 appears to be inconsistent with the rest of the document – anything requiring 72 hour notification cannot achieve a permanent solution. Per section 3, ½-inch or greater LNAPL thickness in a monitoring well triggers a 72 hour notification. Per the flow chart it appears that any site with greater than ½-inch of LNAPL cannot achieve a permanent solution, which is inconsistent with the later part of the document.

Page 6/Figure 2 – the lower left box of the flow chart appears to be missing the end of the sentence.

Page 6 and 7 – The document uses the term LNAPL globule when discussing LNAPL plume morphology. An LNAPL globule is hydraulically disconnected NAPL (residual) as noted in the first paragraph on page 7. When discussing LNAPL movement in the subsurface, recommend replacing LNAPL globule, with LNAPL.

Page 11 – The guidance states: *“In general, the observed/apparent thickness of LNAPL in a well exaggerates the amount of LNAPL that is in fact mobile and recoverable, especially in fine-grained soils.”*

The apparent thickness has no relation to amount of recoverable LNAPL, i.e. it does not exaggerate it. What it does is create a perception of the relative degree of impact or recoverability that is not transferrable from site to site.

Page 12 – The guidance states: *“When installed correctly (e.g., screen intervals extending through the entire smear zone into the water table), monitoring wells may be representative of a much greater area/volume of a formation than discrete cores or soil samples obtained from within the same zone.”*

This is accurate for sites with unconfined LNAPL. At sites with confined LNAPL, it may be appropriate to screen the LNAPL monitoring wells below the groundwater potentiometric surface across the vertical interval where LNAPL is observed.

Page 18 - The guidance states: *“It is MassDEP’s position that the feasibility evaluations conducted at these and similar sites of high concern consider the full range of NAPL remedial options, including excavation and conventional (hydraulic/vacuum recovery) technologies as well as alternative/innovative technologies (e.g., ISCO, soil flushing, soil heating), and that remedial operations deemed to be feasible are maintained for as long as it is necessary to achieve MCP standards.”*

The full range of remedial options includes engineered barriers to prevent LNAPL movement and vapor barriers to protect occupied buildings and should be included in the feasibility evaluation.

Page 19 – The second paragraph discusses alternative/innovative technologies that may achieve a higher level of LNAPL recovery or control. The use of engineered barriers that control LNAPL should be included.

Pages 20 and 25 - The guidance states: *"Following a gauging event, at least one well volume of any LNAPL must be evacuated from the well and properly disposed or recycled."*

We recommend that LNAPL not be evacuated from wells to make sure that the formation is in static equilibrium before beginning LNAPL transmissivity testing, which is a high value metric in this guidance. Suggest that this be changed to a suggested practice rather than a mandate in order to facilitate LNAPL transmissivity testing. If communication with the formation is in question, the well should be developed or redeveloped.

Page 22 - The guidance states: *"Baring unavoidable site constraints, the spacing of a monitoring well network must be in the range of 15 to 30 feet within the core and at the perimeter of the LNAPL plume."*

Suggest that text be added that indicates that this spacing may be appropriate for a small scale site, e.g. < 1 acre, and that spacing at larger sites should be site specific based on the scale of the LNAPL plume and the judgment of the LSP.

Page 22 - The guidance states: *"At sites where Non-Stable LNAPL is present or potentially present, wells within and just downgradient of an identified LNAPL plume must be gauged on at least a monthly basis for a minimum of two years."*

This requirement conflicts with a statement on page 24 that requires quarterly gauging if thicknesses exceed "action levels" that are indicative of potentially non-stable LNAPL. The inconsistency should be rectified. Additionally, it should be noted that this requirement is for new releases. Older sites with many years of quarterly or semi-annual gauging data demonstrating LNAPL stability should not be required to collect a new set of data on a monthly basis.

Page 23 - The guidance states: *"A spill of a total of 10 or more gallons of oil/waste occurred or likely occurred at the site in the previous 10 years which was not promptly and adequately remediated via removal of the LNAPL, applied sorbents, and/or impacted soils;"* would indicate the likely presence of mobile NAPL and necessitate an evaluation of its mobility and recoverability

This is a very low threshold and seems unreasonable to assume a 10 gallon release would generate a mobile LNAPL plume that would persist for 10 years. A spill of 10 gallons in most cases is unlikely to even make it to the water table. Some site-specific consideration would be a better approach, perhaps use the 10,000 mg/kg threshold criteria and the release area (e.g., 10' x 10' observed surface staining) and depth to groundwater to calculate a site-specific volume that may lead to mobile LNAPL.

Page 23 - The guidance states: *"At sites at which a significant (>100 gallons) release of LNAPL had occurred within the previous 2 years, subsurface explorations must be undertaken to determine if the LNAPL plume is expanding."*

Spills on the order of a few thousand gallons of rail fuel from derailments generally produce a small mobile LNAPL footprint that does not continue to expand after a few days or months. The requirement to advance some soil borings to characterize is appropriate, but the presumption that a small volume such as 100 gallons is likely migrating creates an unnecessary data collection burden.

Page 23 - The guidance states: *"…LNAPL present in the subsurface shall be deemed Non-Stable if:*

- *It is discharging or periodically discharging to a Surface Water;*
- *It is discharging or periodically discharging into a building, including drainage sumps within such building;*
- *It is discharging or periodically discharging into a utility structure, including manholes, vaults, and piping/conduits;*
- *It is observed to be present within a preferred flow path, including in the pervious backfill of utility conduits or in bedrock fracture;"*

These four conditions are characteristic of stable LNAPL with micro scale mobility, and are technically inaccurate. We understand that the designation may be made to disallow sites with the first three conditions (periodic discharges to surface water, buildings, and utility structures), from achieving a permanent solution, but it is technically inaccurate. In these three cases, the surface water, building sump, or utility is no different than a monitoring well that may accumulate micro-mobile NAPL, but the fact that these discharges occur at a receptor makes the condition unacceptable. Consider revising the language to indicate that these conditions are not acceptable to a permanent closure and require additional evaluation.

Further, the presence of LNAPL in bedrock or pervious backfill of utility conduits is a different condition than the previous three bullets. Although this condition creates a more complex NAPL distribution, it does not demonstrate "LNAPL non-stability" and should not preclude a site from closure under the MCP. Suggest revising to indicate that the simplified approach in this guidance document may not be appropriate for LNAPL in bedrock or pervious backfill of utility conduits; however alternative evaluations can be conducted to demonstrate that LNAPL is not migrating and has been recovered to the extent feasible.

Page 25 - The guidance states: *"Only wells that straddle the groundwater fluctuation (smear) zone have relevance in this evaluation effort. "*

As stated above, this is accurate for sites where LNAPL is unconfined. Consider revising the language to account for unconfined, confined, and perched LNAPL conditions.

Page 25 – To conclude there is no current indication of Non-Stable LNAPL, the guidance states: *"Observed LNAPL thickness levels did not consistently or significantly increase in downgradient monitoring/sentinel wells."*

LNAPL thicknesses in monitoring wells fluctuate with groundwater levels as described in Section 7.1. Suggest revising this bullet into two bullets to summarize conditions at monitoring wells with previously measured LNAPL and sentinel wells as follows:

- Observed LNAPL thickness levels did not consistently or significantly increase in monitoring wells that is not attributable to seasonal water table fluctuations.

- No advancement of LNAPL across a portion of the monitoring well network previously lacking measureable LNAPL.

Page 25, Section 12.6 – General comment on the overall Simplified Approach

The use of LNAPL thickness, soil permeability, and oil viscosity to determine recoverability is preferential to using thickness alone. However, this approach is based on LNAPL recovery modeling that may not be transferrable to sites with complex geology.

We strongly advocate for use of LNAPL transmissivity as an alternative method to assess the feasibility of removing mobile LNAPL. This seems consistent with the use of LNAPL transmissivity in Section 12.7 that establishes a 0.8 ft^2/day criterion for recovery system shut down. LNAPL transmissivity in excess of 0.8 ft^2/day can be used to establish where recovery is feasible.

Page 25 - The guidance states that if conventional LNAPL recovery operations are deemed infeasible, *"Under the terms of this simplified approach, it is not possible to conclude that it is infeasible to recover LNAPL at sites where the maximum LNAPL thickness level is greater than 5 inches."*

This statement exemplifies the general comment above. Practical experience and LNAPL transmissivity data have established that LNAPL recovery may be infeasible even if feet of LNAPL accumulate in wells. This practical experience reinforces our recommendation to include LNAPL transmissivity as an acceptable method to establish recovery feasibility. Feasibility, or infeasibility, of LNAPL recovery should not be judged based on in-well LNAPL thickness alone.

Page 26 - The guidance states: *"At sites where conventional LNAPL recovery operations are being conducted to address stability, vapor, or other critical LNAPL concerns, such a finding would necessitate the need to evaluate and implement alternative/innovative technologies."*

Recommend revising this sentence by adding, "...if those LNAPL concerns are still present."

The list of technologies called out as alternative or innovative in Section 10.0 of the guidance is too limited for this statement. For example, LNAPL recovery via skimming may not be productive, but the dissolved phase and vapor concerns may be addressed by using a phase change technology such as air sparge/SVE.

From: Tim Nevins
Sent: Wednesday, October 29, 2014 9:06 AM
To: 'kendall.mara@state.ma.us'
Subject: Comment on draft LNAPL guidance

Hello Ken,

I hope I have not missed the deadline for comments.

I was wondering if the revision could include a section specifically addressing no. 6 oil and similar products. Due to the viscosity of these materials, it is not feasible to get an accurate measurement of the thickness of the NAPL in the environment or in a monitoring well. Consequently, it is not feasible to use the thickness measurements as outlined in the draft guidance to determine if the NAPL is non-stable.

I am wondering if the DEP could include a blanket statement to the effect that No. 6 oil and similar products are considered immobile or stable in the environment, absent a source of heat that could affect the viscosity of the oil. There is precedent for this blanket approach, as Table 9-1 of DEP Policy WSC-04-160 states that all petroleum compounds are considered non-persistent with the exception of No. 6 oil.

Sincerely,

Timothy F. Nevins, LSP
Project Manager

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November 3, 2014

Department of Environmental Protection
Bureau of Waste Site Cleanup
One Winter Street, 6th Floor
Boston, MA 02108

Subject: Comments to Draft LNAPL Guidance
Policy #WSC-14-450

Dear Kendall Marra,

This letter presents CDM Smith Inc.'s comments on the Public Review Draft, July 1, 2014 titled Light Nonaqueous Phase Liquids (LNAPL) and the MCP: Guidance for Site Assessment and Closure, Policy #WSC-14-450 (the Guidance).

Definition of Micro-scale Mobility

The Guidance begins by introducing two "new mobility terms" as defined at 310 CMR 40.0006 of the revised Massachusetts Contingency Plan (MCP). These are Non-Stable NAPL and NAPL with Micro-scale Mobility as presented on page 2. Based on these definitions, there is a broad spectrum for LNAPL mobility, ranging from any visible or detectable thickness of LNAPL in a monitoring well (Micro-scale Mobility) to a plume of LNAPL that has an expanding footprint (Non-Stable NAPL).

The aspect that any thickness of LNAPL measured or otherwise visible in a well is mobile is supported on page 12, within Section 7.1 which states that "the presence of measurable LNAPL, <u>regardless of thickness</u>, in an excavation, boring or monitoring well does have important meaning: It indicates OHM concentrations are high enough to exist as separate-phase OHM and <u>mobile enough</u> as a separate-phase to migrate at least a short distance." (underlines added).

This definition that any LNAPL in a monitoring well constitutes Micro-scale Mobility should be clarified with respect to requirements for Activity and Use Limitations (AULs) provided later in the Guidance. Section 11.0 states that "As required at 310 CMR 40.1012(2)(d), where the remaining LNAPL exhibits "Micro-scale Mobility", an AUL is required as part of the Permanent Solution." This statement and the corresponding regulation indicate that because any LNAPL in a monitoring well is mobile, any LNAPL in a monitoring well also requires an AUL. However, Section 11.0 later states that "It is MassDEP's position that the presence of LNAPL in a groundwater monitoring well at an observed thickness equal to or greater than ½ inch is evidence of NAPL with Micro-Scale (sic) Mobility, necessitating the implementation of an AUL. " This statement should be revised in

accordance with earlier definitions of Micro-scale Mobility to clarify that LNAPL at less than ½ inch in a monitoring well is also mobile, but does not require an AUL to support a Permanent Solution. This statement should also make clear that this policy does not completely agree with 310 CMR 40.1012(2)(d), which requires that all NAPL with Micro-scale Mobility, i.e. any measurable LNAPL in a well, requires an AUL. The need for this clarification also applies to similar occurrences within the Guidance in "Permanent and Temporary Solutions" on page 3 and in Section 12.8 on page 27. During the August 12, 2014 LNAPL Guidance pre-comment meeting, MassDEP stated that not all LNAPL with Micro-scale Mobility requires an AUL. At this time, MassDEP stated that they had developed a de minimis value of ½ inch for LNAPL with Micro-scale Mobility, thereby recognizing that LNAPL in a monitoring well at less than ½ inch is also mobile.

The early definition of two "new mobility terms" should also be clarified with respect to Section 12.4 on page 23. Section 12.4 states that "…an LNAPL is or is likely to be mobile if equal to or greater than 1/8 inch of LNAPL is identified (sic) any groundwater monitoring well or in any excavation at the site." This statement contradicts the earlier definition of Micro-scale Mobility introduced on page 2 of the Guidance and at 310 CMR 40.0006. That definition does not carry a minimum thickness as a condition of Micro-scale Mobility.

The definition of mobility should also be clarified in Section 12.3 of page 22. That section begins by stating that "Visual observation of any amount of oil or waste oil in a subsurface excavation or monitoring well, or seeping into a proximate surface water body or building structure, is proof of the presence of LNAPL at a disposal site." As this characterization describes not only the presence of LNAPL but more specifically mobile LNAPL, it should be so revised.

Distinction Between Mobility and Stability

In Section 8.2 page 15, the first paragraph states that Residual Concentration (C_{res}) is a valuable tool for "assessing LNAPL stability and recoverability". Given the definition of C_{res} and as illustrated on Figure 5, C_{res} should instead be used for assessing LNAPL <u>mobility</u> and recoverability.

In Section 8.3 page 15, the Guidance states that "While data from a low and high groundwater table condition may be sufficient to rule out a LNAPL <u>mobility</u> issue, an adequate sampling frequency to evaluate and document the <u>stability</u> of a significant LNAPL plume is generally…"(underlines added). This sentence confuses the terms mobility and stability. Based on the definitions of page 2 of the Guidance and at 310 CMR 40.0006 of the MCP, the very presence of LNAPL in a monitoring well constitutes some degree of mobility. At issue in this case is whether an LNAPL plume is stable, i.e. migrating along a preferred flow path, discharging into a sensitive structure or resource, or spreading.

Required Period of Monitoring

There is conflicting guidance regarding the suggested frequency of LNAPL monitoring. Section 8.3, page 15 states that the stability of a "significant" LNAPL plume should be assessed by sampling/gauging over a two year period of quarterly monitoring. This directive could be made more consistent with related guidance if it referred to an LNAPL plume at which the presence of Non-Stable NAPL was at least suspect, rather than the LNAPL plume being "significant".

Section 12.2 page 22 states that for sites where Non-Stable LNAPL is at least potentially present, gauging should be performed monthly for a minimum of two years. Where Non-Stable LNAPL is not present and not suspect, gauging should be performed quarterly for one year. The suggested frequency for monitoring for stability in this instance (monthly) does not agree with that provided at Section 8.3 (quarterly).

Section 12.5 page 24 states that in the event of potential Non-Stable LNAPL, an LNAPL plume should be monitored quarterly for two years. This agrees with Section 8.3 (quarterly) but does not agree with Section 12.2 (monthly).

Recovery Action Level

This term appears in Figure 7 but is not defined in the Guidance.

We appreciate the opportunity to comment on this important draft guidance. Please contact the undersigned if you have any questions.

Sincerely,

James H. Zigmont, LSP
Project Manager
CDM Smith Inc.

cc: Licensed Site Professional Association

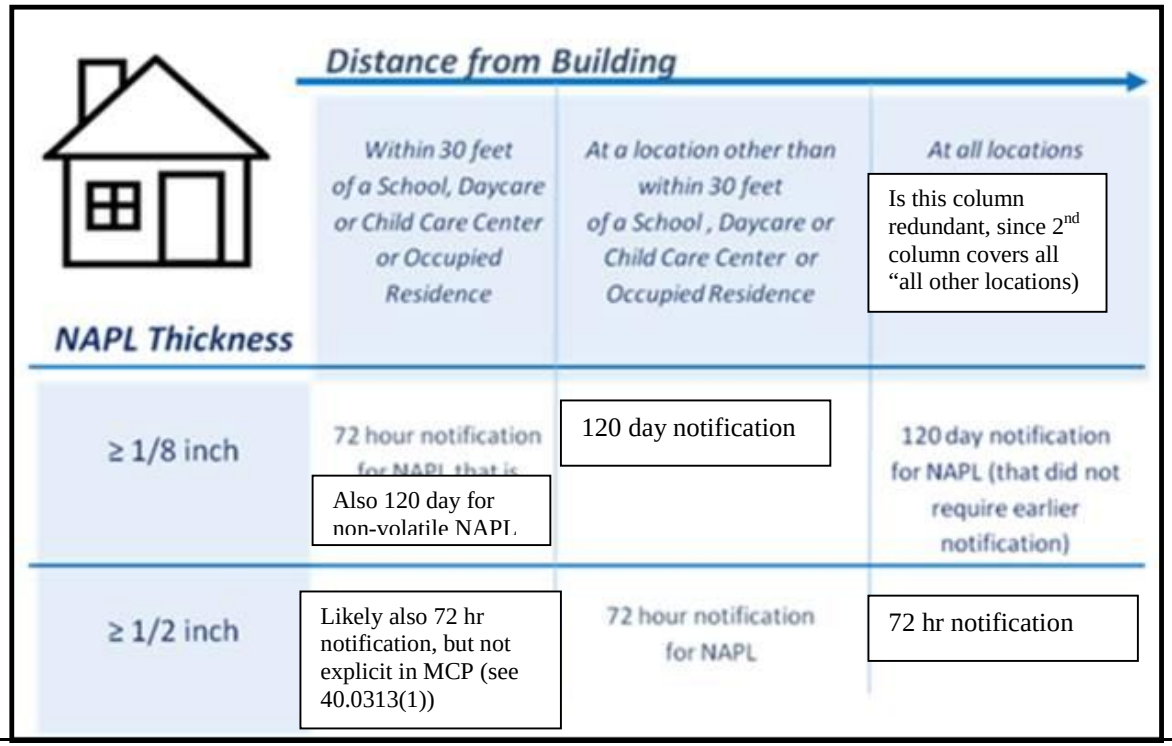
Attachment to LSPA Cover Letter: Compilation of Comments from the LSPA

Public Review Draft, July 1, 2014
LIGHT NONAQUEOUS PHASE LIQUIDS (LNAPL) AND THE MCP:
GUIDANCE for SITE ASSESSMENT AND CLOSURE
Policy #WSC-14-450

The following are collective comments from the LSPA. Page numbers refer to the Public Review Draft made available electronically in pdf. Every effort has been made to state the issue of concern, provide a specific example wherever possible and propose suggested language changes where appropriate.

LNAPL Draft Guidance		
Page No.	**Section**	**Comment**
1	**1.0**	To demonstrate the way in which this guidance presents "a simplified approach" it may be helpful to explain the analogy to MCP risk characterization methods 1, 2 and 3. The intent is analogous; to provide: 1) a simple but very conservative method that involves little or no specialized sampling, 2) a modification of #1 that includes some specialized sampling and site specific characteristics, and 3) a full site-specific characterization using transmissivity determination.
	General Comment	Use of LNAPL thickness measurements is not supported by ITRC or ASTM. LNAPL thickness is considered a poor metric that does not meaningfully correlate to any significant engineering, hydrogeologic or risk parameter. This guidance should reflect the actual state-of-the-art in LNAPL understanding. The presence of LNAPL in a monitoring well should be the appropriate notification guideline, and MassDEP should consider eliminating thickness based reporting requirements.
	General Comment	The guidance focuses strictly on technical feasibility with no discussion of cost/benefit of recovery of LNPL Micro-scale mobility. Is it MassDEP's intent to require attempts at LNAPL recovery in <u>all</u> cases other than LNAPL Transmissivity <0.8 ft2/day? That is the only off-ramp in Table 7 other than asymptotic or <1 gallon/ 3 month recovery rates.

		The guidance does not mention or seem to consider cost/benefit, except indirectly as it may relate to the level of technical investigation/evaluation. There is concern that the concept of cost versus benefit, especially incremental cost versus incremental benefit, is not addressed in the guidance, which could lead to significant problems as LSPs try to implement the guidance and as MassDEP staff try to evaluate response actions at LNAPL sites.
	General Comment	Guidance is needed as to what is required to demonstrate "control" of LNAPL with micro-scale mobility for purposes of a Temporary Solution as it seems micro-scale "control" is inherent in its definition, i.e. only macro-scale in LNAPL that is uncontrolled. Could the guidance so state that micro-scale LNAPL is controlled, absent some listed examples?
	General Comment	The guidance should recognize that potentially recoverable LNAPL at most sites is typically low (1% to 20%). Conversely, even good recovery systems may "leave behind" 80% to 99% of all LNAPL mass. The point of the guidance is to help identify when recovery should be used, and when it is not practicable. This clearly depends on the total volume of recoverable NAPL, and, a de minimus fraction and total volume would be helpful, particularly because most LNAPL sites are smaller sites (heating oil or gasoline/diesel releases).
1	**2.0**	The guidance is limited to LNAPL in porous media. Guidance on LNAPL in bedrock and DNAPL is also needed.
4	**3.0 – Figure 1**	Recommend revising the figure for clarity and to fill in empty cells. For example, see below:

<table>
<tr><td></td><td></td><td>


</td></tr>
<tr><td>4</td><td>3.0-
Figure 1</td><td>If LNAPL thickness is a poor metric, why bother having different thickness reporting conditions? Just simplify this to distances from sensitive receptors at any measureable thickness.

This begs the question what "any measureable thickness" means. Current interface probes used for measuring LNAPL thickness all appear to have a precision of 0.01 foot or 0.125 (1/8) inch. Using a variable term such as "any measurable thickness" is unwise as someone might develop an interface probe capable of a precision of 0.002 ft, for instance, and then it would depend on which probe was used.</td></tr>
<tr><td>6</td><td>4.0 –
Figure 2</td><td>Add a "No" box under "Does LNAPL with Micro-scale mobility remain at the site? If LNAPL is no longer present in wells after removal (or is less than ½ inch after removal), then the site qualifies for Permanent</td></tr>
</table>

		Solution without Conditions (i.e., no AUL).
7	**5.0**	This discussion of "pushing LNAPL" is unclear. Literature suggests that Cres is affected by maximum past LNAPL pressure. This is mostly a laboratory phenomenon. This is a concern about laboratory tests that use high back-pressure to saturate first with LNAPL before attempting to drive LNAPL out of the pore space. It is not clear that this is a significant concern for soil samples tested at field saturation values.
8	**5.0 – Figure 4**	Perhaps additional language should be added to clarify that this is an abstract simplification, and actual distribution will be highly site specific.
9	**6.1**	The discussion of Csat is not in line with the intended use in the LSPA White Paper. C_{sat} cannot be used as a mobility metric. Its value is limited to assessing LNAPL presence and extent. This is important in the context of establishing the extent of contamination (i.e. that LNAPL may be present as a source even if not measured in a groundwater monitoring well). In this regard Csat is valuable in delineating the extent of source zones. Rather than putting one number (i.e. 100 mg/kg) in the guidance, the table in the LSPA White Paper is valuable in showing the impact of solubility on Csat. Recommendation to not make TPH greater than or equal to 100 mg/kg in soil an indicator of the "likely presence of LNAPL". Absent other lines of evidence (site and release history, visual observations of LNAPL), this metric has the potential to make many sites "LNAPL sites" when the low level TPH can be attributable to many other sources, particularly in urban settings. TPH at 100 mg/kg is also well below NSR levels for unrestricted residential use. Guidance is requested as to a scenario in cases where soil concentrations are below S-1 standards, there is no observation of measurable LNAPL. LSPs want to know if the standard of practice has changed for such cases that would have been a simple A-2, Method 1 under the old regulation.
10-11	**6.3**	The guidance does not recognize the importance of confined aquifers and their impacts on LNAPL assessment and T_n measurements. As described by ANSR, confined LNAPL conditions can exist even when classically confined aquifers are not present (i.e. small permeability contrasts can create locally confined LNAPL conditions. This typically results in much higher LNAPL thicknesses than in similarly impacted unconfined aquifers).
10-11	**6.3**	Suggest that the guidance reference the context for the development of 0.8 ft2/day. From http://www.itrcweb.org/Guidance/GetDocument?documentID=48 , section 3.2.1.8 LNAPL Transmissivity,

		page 14.
11 - 12	**7.1**	The draft guidance presents many of the same approaches to characterizing and recovering LNAPL as ITRC has been recently promoting. However, Section 7.1 of the Guidance misconstrues the benefits of identifying LNAPL physical properties from monitoring wells. In their 2012 Conference Handbook, ITRC specifically stated that LNAPL thickness in monitoring wells "correlates unfavorably with LNAPL recoverability" and that monitoring well LNAPL data "does not account for soil and LNAPL properties, soil heterogeneity and LNAPL occurrence conditions" (pg. 228 of the 2012 Conference Handbook). It is not accurate for the guidance document to state that monitoring wells help characterize "LNAPL physical properties used in applying FFPM/LCSM principles" or that they are "representative of a much greater area/volume of a formation than discrete cores or soil samples obtained from within the same zone." (pg. 12 of the Guidance Document).
12	**7.1**	In the "Limitations" section, MassDEP should consider stressing the impact of seasonality and well diameter. 1" wells typically have 4 times the thickness of LNAPL compared to 2" wells, and similarly with 4-inch wells. While 2" wells used to be the "standard" well diameter, 1" Geoprobe wells are now common, as are 4" wells installed for conversion to recovery wells. LNAPL thickness references in graphs, charts and references should be annotated to reflect this significant impact on measured thickness. "Uncertainties continue to exist on the affects [*should be "effects"]* of well diameter and installation techniques on representativeness and data comparability." This statement might be expanded to indicate that while there appears to be an inverse relationship between LNAPL thickness and well diameter, there appears to be no reliable quantitative correlation.
12	**7.1**	Under last bullet of "Benefits" section, suggest removing "In the last several years" from intro, this will quickly become dated. Use actual dates.
13	**7.2**	MassDEP might consider allowing Integrated Sampling Methodology as an alternative, to try to more representatively characterize soils. No discussion of compositing and sub-sampling is included.
13	**7.2**	MassDEP might consider including a further discussion of screening tools in this section. Ex-situ and in-situ UVF/LIF are now very common tools for providing quality, inexpensive soil data. LIF has the capability of providing very fine vertical resolution, semi-qualitative forensic information, and clear vertical limits to contamination migration.
16	**8.3 –**	Cres is strongly influenced by soil type and product type, and there is no generally agreed upon method for

	Table 1	determining C_{res}, therefore it may not be a good idea to suggest using published C_{res} values. However, use of centrifugal tests to measure C_{res} for undisturbed soil samples is very conservative, and can be safely used for comparison to field saturation provided adequate site characterization has been performed. Assuming MassDEP agrees that published Cres values can't be typical of all soil types, then it is safe to assume that MassDEP is trying to provide a spectrum of options, analogous to MCP Methods 1, 2 and 3, to allow LSPs to evaluate their sites. The published Cres values are presented as *conservative* estimates of Cres, analogous to MCP Method 1. If the LSP can "screen out" their site using these published values, then that may be all they need to do, and this will be particularly helpful on smaller sites. But, if the LSP cannot "screen out" their site using published values, alternatives exist (analogous to Method 2 and Method 3), which they may still be able to use to demonstrate no non-stable NAPL.
18	**10.0**	MassDEP describes excavation as an effective corrective action for removal of LNAPL "hot spots". If feasible, excavation is a possibility for "removal of all LNAPL affected soil" (pg. 279 of the 2012 ITRC Conference Handbook). (Although it is recognized that if NAPL removal were feasible, the LSP would just do it and not need the guidance).
19	**11.0**	Provide clarification on when an AUL is not needed (such as any LNAPL below 15 feet/stable LNAPL below 15 feet/no micro-scale mobility below 15 feet). This is especially important now that MassDEP has decided that AUL conditions specific to LNAPL will reside in the LNAPL guidance and not the AUL guidance.
20	**12.2**	This section should clarify that bailing performed solely to investigate LNAPL mobility should be explicitly defined as not being remediation or a remedial activity.
20 and 25	**12**	The draft guidance states (p.20): "Following a gauging event, at least one well volume of any LNAPL must be evacuated from the well and properly disposed or recycled." Assuming MassDEP's intent is that, following gauging, all recoverable LNAPL should be removed from the well, so as not to be "maintaining a source of pollution" then perhaps better wording might be: "Following a gauging event, all recoverable LNAPL must be evacuated from the well, along with at least one well volume of groundwater, and properly disposed or recycled, in order to comply with the two MCP requirements listed at Section 9.0 (310 CMR 40.1003(7)(a)(2.), and 310 CMR 40.1003(7)(b)."

		This section should also clarify that removal of one well volume of LNAPL is not advisable after gauging, if prior to planned transmissivity testing. Suggest that this be changed to bail LNAPL as a "suggested assessment or maintenance practice" rather than a mandate, in order to facilitate LNAPL transmissivity testing.
21	**12.2 – Figure 7**	Consider replacing the term "mobile LNAPL" with "LNAPL?" What is the basis for the TPH >10K in soil indicating the presence of "Mobile LNAPL?" Consider replacing "LNAPL is Likely Present" and "Mobile LNAPL is Likely Present" with "The potential for LNAPL to be present must be evaluated." The terms used in Figure 7 should be the explicit terms of the regulation or refer to specific Tables in the guidance. This will assist with unifying the overall draft document.
22	**12.2**	The guidance states: "Baring unavoidable site constraints, the spacing of a monitoring well network must be in the range of 15 to 30 feet within the core and at the perimeter of the LNAPL plume." Recommend that text be changed to "Taking into account unavoidable site constraints and considering site-specific conditions, the spacing of a monitoring well network in the range of 15 to 30 feet, within the core and at the perimeter of the LNAPL plume, would seem appropriate for most smaller (<1-2 acre) sites such as service stations or residential fuel oil releases."
22	**12.2**	The draft guidance states: "At sites where Non-Stable LNAPL is present or potentially present, wells within and just downgradient of an identified LNAPL plume must be gauged on at least a monthly basis for a minimum of two years." This requirement conflicts with a statement on page 24 that requires quarterly gauging if thicknesses exceed "action levels" that are indicative of potentially non-stable LNAPL. Perhaps, it should be noted that this requirement is for new releases. Older sites with many years of quarterly or semi-annual gauging data demonstrating LNAPL stability should not be required to collect a new set of data on a monthly basis. Suggest changing to: "At sites where Non-Stable LNAPL is present or potentially present, wells within and

		just downgradient of an identified LNAPL plume must be gauged on at least a monthly basis for a minimum of two years, or until Non-Stable LNAPL has been determined not to be present."
23	**12.4**	The draft guidance states: "A spill of a total of 10 or more gallons of oil/waste occurred or likely occurred at the site in the previous 10 years which was not promptly and adequately remediated via removal of the LNAPL, applied sorbents, and/or impacted soils;" would indicate the likely presence of mobile NAPL and necessitate an evaluation of its mobility and recoverability. This is a very low threshold and seems unreasonable to assume a 10 gallon release would generate a mobile LNAPL plume that would persist for 10 years. Suggest changing to: "For the purposes of this approach, an evaluation for the presence of mobile LNAPL shall be conducted if:" We are assuming that this is to be used as a "rule out" approach, ie analogous to the EPA's "rule of thumb" that investigators evaluate for the presence of DNAPL if dissolved concentrations of compounds that could form DNAPL are detected at or above 1% of aqueous solubility. i. e., the proposed criterion is really a cutoff below which the LSP can rule out the presence of LNAPL, not an indication that LNAPL is actually present.
23	**12.5**	The guidance states: "…LNAPL present in the subsurface shall be deemed Non-Stable if:…" It is understand that the designation may be made to disallow sites with the first three conditions (periodic discharges to surface water, buildings, and utility structures), from achieving a permanent solution, but to call these conditions nonstable is technically inaccurate. In these three cases, the surface water, building sump, or utility is no different than a monitoring well that may accumulate micromobile NAPL, but the fact that these discharges occur at a receptor makes the condition unacceptable. Consider revising the language to indicate that these conditions are not acceptable to a permanent closure and require additional evaluation. Further, the presence of LNAPL in bedrock or pervious backfill of utility conduits is a different condition than the previous three bullets. Although this condition creates a more complex NAPL distribution, it does

		not demonstrate "LNAPL non-stability" and should not preclude a site from closure under the MCP. Suggest revising to indicate that the simplified approach in this guidance document may not be appropriate for LNAPL in bedrock "The scope of the guidance offered in this document is limited to the direct impacts related to the occurrence and bulk movement of LNAPL in and through porous media." As bedrock fractures are not porous media, this guidance is not applicable to LNAPL in bedrock fractures or pervious backfill of utility conduits; however alternative evaluations can be conducted to demonstrate that LNAPL is not migrating and has been recovered to the extent feasible.
23	**12.5**	Mobile NAPL includes both micro scale and macro scale ("Non-Stable") NAPL. What is being described here is LNAPL with macro-scale mobility i.e. "Non-Stable" LNAPL.
24	**12.5**	Most researchers believe that LNAPL at "most" sites is macro-stable, unless it is found to be discharging to a surface water body, provided the release is more than one or two years old. It is unclear how well data can be used to establish stability. Similarly, the basis behind Table 2 is suspect given the poor correlation of LNAPL thickness to engineering metrics.
26	**12.6 – Figure 8**	Figure 8: Is this figure specific to 2-inch wells? Does this matter? Our understanding of the purpose of Figure 8 is to provide LSPs a way to "screen out" their sites, not to imply that, if the conditions at their site indicate that LNAPL may be recoverable that it must be recovered. If Figure 8 allows an LSP to screen out their sites, good. If not, they have additional options to evaluate recoverability, including a transmissivity evaluation.
26	**12.7**	One gallon in a three month period is extremely conservative and would only be valuable for sites with *de minimus* quantities of recoverable LNAPL. This bullet should be removed as it is dependent on many factors unrelated to LNAPL recoverability.
27	**12.8**	A Permanent Solution should be achievable if it can be shown that recovery/removal is infeasible. Second bullet should be edited or a new bullet should be added to address economic infeasibility.
27	**12.8**	"In accordance with the provisions of 40.1012(2)(d), an Activity and Use Limitation (AUL) is required for sites where a Permanent Solution has been achieved and LNAPL with Micro-Scale Mobility is present. The presence of LNAPL with Micro-scale Mobility shall be assumed if the maximum observed thickness in any groundwater monitoring well was equal to or greater than ½ inch, at any time in the 12 months previous to

		the filing of the Permanent Solution, including during times of a low or falling water table." MassDEP should allow the flexibility to not require an AUL for a Permanent Solution for LNAPL that is isolated. While an AUL may be required on many smaller sites, on larger sites, such as existing oil terminals and larger industrial sites, it seems as though "Conditions" may be suitably informative to potential future owners. It seems reasonable to require AULs on residential and commercial properties, but the risk of micro-scale mobile LNAPL to receptors, especially where petroleum product use is continuing on a large scale (capacity >10,000 gallons?), the AUL is of little benefit.
32-33	**Appendix 1**	Providing the Lines of Evidence matrix is helpful, but there is concern that MassDEP audit staff will rely too heavily on this and the weighting, and not consider alternative or site specific information; this could result in contested Permanent Solution findings without cause. Additional clarity and training should be provided on the use of the Lines of Evidence checklist and matrix.

NAIOP
COMMERCIAL REAL ESTATE
DEVELOPMENT ASSOCIATION
MASSACHUSETTS

October 20, 2014

Benjamin J. Ericson
Assistant Commissioner
MassDEP
Bureau of Waste Site Cleanup
One Winter Street
Boston, MA 02108

Re: NAIOP Comments on Draft July 1, 2014 LNAPL Guidance Document

Dear Assistant Commissioner Ericson:

NAIOP Massachusetts, The Commercial Real Estate Development Association, appreciates the opportunity to comment on the draft Department of Environmental Protection (DEP) Bureau of Waste Site Cleanup guidance document titled *Light Nonaqueous Phase Liquids (LNAPL) and the MCP: Guidance for Site Assessment and Closure, Policy #WSC-14-450 (Draft LNAPL Guidance)*.

In both its recent June 20, 2014 updates to the Massachusetts Contingency Plan (MCP), 310 CMR 40.0000, and in the Draft LNAPL Guidance, DEP has made significant efforts to align investigation and clean-up parameters for LNAPL with current scientific standards. The removal of the historical ½-inch Upper Concentration Limit (UCL) limitation from the MCP represents a significant step forward in the evolution of waste site cleanup in Massachusetts. It acknowledges the scientific advances made with respect to the understanding of multi-phase fluid dynamics in the subsurface since the MCP was first promulgated.

We understand that DEP is working on draft vapor intrusion (VI) guidance, which inevitably will overlap to some degree with the Draft LNAPL Guidance and draft Activity and Use Limitation (AUL) guidance already issued for public comment in June and July 2014, respectively. We appreciate DEP's determination to issue new guidance addressing the recent MCP amendments as quickly as possible, but we caution DEP against finalizing any of these related guidance documents until public comments on all of the guidance documents have been received, considered together and adequately addressed.

In this letter, we have provided a summary of key comments on the Draft LNAPL Guidance. We also have provided suggested line-by-line edits to the Draft LNAPL Guidance in a redline format (attached).

Section 3.0 MCP Performance Standards for NAPL

Section 3.0 of the Draft LNAPL Guidance does not fully or accurately state the standards established in M.G.L. c. 21E for site clean-up. Chapter 21E, § 3A, clearly states that "permanent solutions" shall be implemented "to the extent feasible," and allows for "temporary solutions" to be implemented in situations where "permanent solutions" are not feasible.

Section 3.0 also references the two new significant MCP definitions intended to replace the historical MCP ½-inch Upper Concentration Limit (UCL): (1) Non-stable NAPL and (2) NAPL with Micro-scale Mobility. We believe it critical that the remainder of the guidance document use these terms consistently (e.g., "Macro-Scale Stability" is used in Section 5.0 and "Mobile LNAPL" is used in Section 12.0 rather than using the MCP terms).

Figure 1 in Section 3.0 does not include instances in which an LNAPL condition constitutes a 2-hour reporting condition. We recommend that DEP either change the title to specify "72 Hour and 120 Day" notification requirements OR, better yet, add a 2-Hour notification row in the table to reflect all three types of potential LNAPL notification requirements.

In addition, text was inadvertently omitted from Figure 2. The last text block needs to be expanded to show all text (e.g., "…an AUL must be filed to memorialize presence of remaining NAPL with Micro-scale Mobility unless ½-inch or less.").

Section 6.0 IMPORTANT TECHNICAL CONCEPTS, TERMS AND METRICS

We agree that discussion of the primary parameters associated with multi-phase fluid flow in porous media (FFPM) is appropriate. However, we recommend that DEP make clear in this Section that FFPM concepts assume and depend upon the existence of idealized homogeneous and isotropic soil conditions, and that such conditions in fact are uncommon in Massachusetts. Here, and in the "Simplified Approach" (Section 12.0), DEP should acknowledge that the Draft LNAPL Guidance is *not* intended to establish prescriptive requirements for assessment, characterization, and remediation of LNAPL sites because, among other reasons, soil conditions in New England are very often heterogeneous and anisotropic (e.g., urban fill and glacial till).

Section 8.0 LINES OF EVIDENCE FOR LNAPL OCCURANCE, MOBILITY, AND RECOVERABILITY

We recognize that monitoring wells will continue to play an important part in the MCP assessment and remediation process. However, we are concerned that the draft guidance places too much emphasis on the use of monitoring wells alone to assess LNAPL occurrence, mobility and recoverability. The LSPA LNAPL White Paper[1] approach is based

[1] *LNAPL and The Massachusetts Contingency Plan Part II*, prepared by LSPA Technical Practices Committee, dated July 2008.

on a scientifically established soil approach that has been peer reviewed and implemented effectively within the LSP community. Therefore, the LSPA LNAPL White Paper should be referenced more directly in this section as it already includes the White Paper's key concepts and is consistent with our proposed addition to Section 12.7 below.

Section 8.3 Product Thickness Measurements (Spatial and Temporal)

In this Section of the Draft LNAPL Guidance, DEP states, "…an adequate sampling frequency to evaluate and document the stability of a significant LNAPL plume is generally quarterly sampling/gauging over a two-year period…" As noted in Section 12.0 below, we agree that quarterly, not monthly, gauging is sufficient (compare fifth bullet in Section 12.2, recommending monthly gauging). Gauging for a minimum of two years is overly prescriptive. In addition, historical gauging events over longer periods of time and seasons should be acceptable evidence of plume stability.

We also note that Table 1 in this section, listing residual saturation values in soil, appears to have been cut and pasted from a Canadian source without sufficient consideration of whether and to what extent they are representative of soil conditions in Massachusetts. For example, "Ottawa sand" is a soil type unique to Canada. The table also includes several values listed as "NA," which is not explained. We recommend that the table be deleted or revised such that it is complete and relevant.

Section 10.0 LNAPL Recoverability

The title of this Section, "LNAPL Recoverability," is not broad enough to describe its content. We recommend changing the title to "LNAPL Recovery, Destruction or Control". This better reflects the overarching requirement to remove or control LNAPL to the extent feasible.

We recommend adding In-Situ Stabilization and Solidification (ISS) to the alternate technologies list as it has been demonstrated as an effective LNAPL control, especially where relatively fast and effective remediation is required (i.e., Brownfield redevelopments). We also recommend removal of Electrical Resistance/Radio Frequency Heating from the alternate technologies list as it is cost prohibitive and virtually never feasible as a remedial alternative to address LNAPL.

Section 11.0 Activity and Use Limitations (AULs)

This section establishes a residual Micro-scale Mobility AUL threshold as ½-inch of LNAPL observed in any monitoring well during the 12 months preceding filing of the Permanent Solution. We applaud DEP for establishing such a clear and tangible "bright line" threshold standard relating to the use of deed restrictions in support of LNAPL site closure.

Section 12.0 Recommended Simplified Approach For Petroleum LNAPL Sites

NAIOP understands that DEP has put significant research and effort into this section of the draft document. Nonetheless, we are concerned that the "Simplified Approach" will be misconstrued as prescribing requirements to be followed at all LNAPL sites. This is particularly problematic given that the Simplified Approach is largely predicated on the existence of homogeneous and isotropic soil conditions – conditions that are uncommon in Massachusetts. More generally, the Simplified Approach is overly rigid by nature and would prevent the LSP from exercising appropriate judgment and discretion in the site-specific waste site cleanup decision making process, which is in large part the function and role entrusted to LSPs under the MCP.

On an organizational level, we recommend that Section 12.0 be restructured. As drafted, it confuses the separate steps in the sequence of LNAPL discovery, assessment and remediation.

As noted within the earlier sections of the Draft LNAPL Guidance, and as borne out by the experience of the LSP community and the DEP, the majority of LNAPL sites either does not have or no longer has a condition of Non-Stable NAPL. LNAPL stability is commonly established within 1 to 2 years after a release where no other more immediate response actions are taken and, as such, the evaluation of site closure at the majority of LNAPL sites is most commonly limited to Micro-scale Mobility. Non-Stable LNAPL sites are often addressed with Immediate Response Action (IRA) cleanup activities approved by DEP, where achieving timely control of the release are both possible and appropriate given the recent nature of the release. For these reasons, NAIOP believes that the focus of a "Simplified Approach" for LNAPL closure should be directed primarily toward these sites, and should focus on Micro-scale Mobility (i.e., recoverability of LNAPL).

Section 12.2 Simplified Approach: Characterization Methods and Level of Effort

This section mixes the requirements for sites at different stages of the MCP assessment and closure continuum. We recommend that this be clarified by eliminating this section and moving the bullets to other portions of Section 12.0, as follows:

- Bullets 1, 2 and 3 relate to "Determining whether LNAPL is present" and therefore should be incorporated into Section 12.3 below

- Bullets 4 and 5 relate to sites where LNAPL has been identified as present and therefore should be incorporated into Section 12.5

- Bullet 6 relates to the use of soil concentration data to evaluate LNAPL recoverability and therefore should be moved to section 8.2

Further, several of the bullets are overly prescriptive. The additional level of effort and cost required to meet these proposed requirements is simply not justifiable in all cases

based on the minimal or nonexistent value that they would provide to support assessment data or risk reduction. The decision when and how to perform a Response Action (i.e., assessment, containment, or removal) needs to remain with the LSP-of-Record. Overly prescriptive proposed requirements include:

- At least one well volume of LNAPL be removed from the well following each gauging event
- Monitoring wells be installed in a range of 15 to 30 feet within and at the perimeter of the LNAPL plume
- Monthly gauging be performed for at least two years at Non-Stable or potential Non-Stable LNAPL sites

Section 12.3 Simplified Approach: Determining Whether LNAPL is Present

A TPH concentration of 100 mg/kg in soil (C_{sat}) is proposed to represent one line of evidence of the likely presence of LNAPL. Use of C_{sat} in this manner is overly conservative given that C_{res} , the concentration at which LNAPL only just becomes potentially mobile, is typically two orders of magnitude higher than C_{sat} itself. Even if the potential for mobility is removed from this decision process, such a low concentration is highly unlikely to represent a significant risk (e.g., the RCS-1 soil standard deemed safe for residential use is 1,000 mg/kg) and could even be attributable to interference from simple natural organic matter depending upon the nature of the soil. Urban fill may have a TPH concentration greater than 1,000 mg/kg with no evidence of LNAPL. In addition, the other straightforward and well established lines of evidence (i.e., discolored soil with petroleum odor, site storage history, credible evidence of an LNAPL release, and/or groundwater, soil vapor, or indoor air data exceeding MCP reporting thresholds) remain sufficient as indicators for the likely presence of LNAPL. For these reasons we believe that the use of C_{res} (100 mg/kg) in this manner should be removed entirely from the Draft LNAPL Guidance.

Section 12.4 Simplified Approach: Determining Whether Mobile LNAPL is Present

Mobile LNAPL is not an MCP term and should be clarified; consistent use of the promulgated MCP terms is critical to avoid confusion. We understand that this step was intended to initially evaluate whether Non-Stable LNAPL may be present. Therefore, we recommend incorporating this section into the first part of section 12.5 for determining if Non-Stable LNAPL is present.

Section 12.5 Simplified Approach: Determining Whether Mobile LNAPL is Non-Stable

It is our understanding that DEP coined the new term "Non-Stable NAPL" in the revised MCP to address the potential for NAPL areas to continue expanding (i.e., laterally or vertically) where it had been released within the previous two years. The proposed Stability Action Levels (Table 2) represent monitoring well thickness threshold values derived entirely from theoretical models[2]. The models considered LNAPL velocity and potential to displace pore entry pressure at the edge of the LNAPL plume. The models also assumed that "Mobility" in this context is analogous to "Non-Stable" as defined by the MCP. As these models were theoretical, they were intended to represent *preliminary* mobility potential for high versus low to moderate risk sites in the context of The British Columbia Ministry of Environment (MoE) draft BC MoE Protocol 12 titled *Classifying Site Risk Levels*.

As proposed, if a Stability Action Level is exceeded, a two year quarterly gauging requirement is required to evaluate if the NAPL is Non-Stable. Following two years of monitoring, it can be concluded that the LNAPL is not non-Stable if (1) there have been no discharges into surface waters or structures, and (2) LNAPL thicknesses did not increase consistently or significantly in downgradient/sentinel wells.

NAIOP agrees with these two proposed criteria for confirming Non-Stable NAPL. However, we take issue with the two-year prescription for monitoring duration. Given that the vast majority of LNAPL sites are not Non-Stable (as noted in Section 12.0 above) and the theoretical nature of the proposed Stability Action Level derivation, the minimum length of monitoring should be one year to remain consistent with historical MCP precedent, and to allow for the LSP to exercise judgment and discretion based on site specific lines of evidence.

Section 12.6 Simplified Approach: Determining the Feasibility of Removing or Containing Mobile LNAPL

In Figure 8, DEP proposes to adopt idealized values derived by API, in an entirely different context, and to use those to evaluate the feasibility of Mobile LNAPL recovery. The values in Figure 8 were derived theoretically by modeling the viscosity of the fluid and hydraulic conductivity of the porous media. The point at which recovery is infeasible was modeled for four different apparent monitoring well NAPL thicknesses[3]. While we support the use of clear criteria for determining feasibility of recovery, we note that the units on Figure 8 were transcribed incorrectly (i.e., feet in the API guidance was taken as inches in the draft guidance). If that transcription error is corrected, Figure 8 would allow up to 6 inches to 5 feet of residual NAPL to remain at a site that qualified for a Permanent Solution.

---

[2] *Guidance on Assessment of Light Non-Aqueous Phase Liquid Mobility for Site Classification Purposes in British Columbia*, prepared by Golder Associates Ltd., dated October 9, 2008.

[3] *API Interactive LNAPL Guide*, Version 2.0, dated July 2004.

As such, we propose that DEP remove Section 12.6/Figure 8 and condense the remaining portion of Section 12.6 (i.e., the last bullet citing 1/8-inch being categorically infeasible to recover) into Section 12.7. In other words, LNAPL recovery would generally be considered initially feasible (consistent with MCP current standard of care) ***unless or until*** one of the infeasibility metrics identified in Section 12.7 is achieved.

Section 12.7 Simplified Approach: Determining when it is No Longer Feasible to Continue Conventional LNAPL Recovery Operations

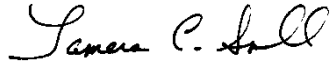
We support the multiple, mutually exclusive criteria proposed to determine when LNAPL recovery is no longer feasible. However, in recognition of the peer reviewed and scientifically established soil approach developed by the LSPA as noted in Section 8.2 (and already being implemented effectively within the LSP community), we recommend that another criterion be added to reflect the use of soil profiling and soil concentration data as another line of evidence to demonstrate lack of Micro-Scale Mobility.

Appendix I – LNAPL Screening Checklist and Lines of Evidence Matrix

We recommend inclusion of the LNAPL Receptors on the checklist and removal of the well spacing reference consistent with our comments above. We also recommend removal of the Lines of Evidence Matrix as overly simplistic and unnecessary. Rather than simply checking boxes, each LSP (and DEP) should rely instead on the guidance and, perhaps more importantly, good scientific judgment as applied to site-specific conditions.

Again, thank you for the opportunity to provide input on this important issue. We look forward to continuing to participate in the evolution of this important guidance document and to submitting comments on the AUL and VI guidance documents in the coming weeks.

Sincerely,
NAIOP Massachusetts, The Commercial Real Estate Development Association



Tamara C. Small
Senior Vice President, Government Affairs

Encl. Redline edits to draft guidance document

NAIOP MASSACHUSETTS COMMENTS – OCTOBER 20, 2014

LIGHT NONAQUEOUS PHASE LIQUIDS (LNAPL) AND THE MCP: GUIDANCE for SITE ASSESSMENT AND CLOSURE
Policy #WSC-14-450

This document provides guidance on investigating, assessing, understanding, and addressing the presence and migration of LNAPL at disposal sites regulated under the Massachusetts Contingency Plan (the "MCP" or 310 CMR 40.0000)

This document is intended solely as guidance. It does not create any substantive or procedural rights, and is not enforceable by any party in any administrative proceeding with the Commonwealth. This document provides guidance on approaches MassDEP considers acceptable for meeting the general requirements set forth in the MCP. Parties using this guidance should be aware that other acceptable alternatives may be available for achieving compliance with general regulatory requirements.

DRAFT

LNAPL AND THE MCP: GUIDANCE FOR SITE ASSESSMENT AND CLOSURE
Public Review Draft, July 1, 2014

NAIOP MASSACHUSETTS COMMENTS – OCTOBER 20, 2014

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NAIOP MASSACHUSETTS COMMENTS – OCTOBER 20, 2014

1.0 PURPOSE AND SCOPE

The purpose of this document is to provide general guidance and a simplified approach to evaluate and address Light Nonaqueous Phase Liquids (LNAPL) at contaminated sites, in accordance with the 2014 Amendments to Massachusetts Contingency Plan ("MCP" at 310 CMR 40.0000).

This document is designed for a wide range of MCP users, *especially* those whose professional expertise is *not* in hydrogeology or sub-surface engineering. In order to enable all such users to effectively and efficiently understand and implement relevant MCP provisions, this guidance:

- summarizes the new LNAPL provisions and performance standards of the MCP;
- provides a simplified description of the LNAPL Conceptual Site Model (LCSM);
- details the relevant fundamental principles of fluid flow in porous media (FFPM) consistent with the LCSM;
- outlines tools and metrics for the evaluation of LNAPL-contaminated sites using a *multiple lines of evidence* approach;
- presents a simplified approach that may be used, voluntarily and in appropriate circumstances, to demonstrate compliance with MCP LNAPL performance standards; and
- provides recommended technical references concerning LNAPL assessment and remediation.

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This guidance is not intended to limit or prevent use of alternative approaches based on good scientific analysis consistent with applicable MCP performance standards. The scope of the guidance offered in this document is limited to the direct impacts related to the occurrence and bulk movement of LNAPL *in and through* porous media. Beyond these direct impacts are secondary concerns related to the partitioning of LNAPL constituents into environmental media, including sorption onto/into soil organic carbon, dissolution into groundwater and volatilization into soil gas. Refer to other agency documents for guidance on these secondary impacts.

This document is intended solely as guidance. It does not create any substantive or procedural rights, and is not enforceable by any party in any administrative proceeding with the Commonwealth. This document provides guidance on approaches MassDEP considers acceptable for meeting the general requirements set forth in the MCP. Parties using this guidance should be aware that other acceptable alternatives may be available for achieving compliance with general regulatory requirements.

2.0 APPLICABILITY

This guidance applies to disposal sites regulated under the Massachusetts Contingency Plan where LNAPL is present in porous media. As defined in the MCP, LNAPL is any oil or hazardous material that is present in the environment as a separate phase liquid, and which has a specific gravity equal to or less than one.

This document does not address disposal sites in which LNAPL is present in non-porous media (e.g., bedrock fractures), or Dense Nonaqueous Phase Liquid (DNAPL).

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3.0 MCP PERFORMANCE STANDARDS FOR NAPL

Massachusetts General Law (MGL) c. 21E and the MCP address releases of "oil" and "hazardous materials" (OHM) to the environment. They require that at all sites impacted by such releases, one or more *Permanent Solutions* be implemented, to the extent feasible. A Permanent Solution is achieved when OHM at a site does not pose a Significant Risk to human health, safety, public welfare, or the environment, at present and for the foreseeable future. Where a Permanent Solution is not feasible, MGL c. 21E and the MCP require that one or more *Temporary Solutions* be implemented to the extent feasible. Such solutions must eliminate any Substantial Hazard to health, safety, public welfare, or the environment, and may include, but not be limited to, containment or removal of oil or hazardous materials. Both the statute and regulations also require that all releases of OHM be removed from the environment if and to the extent feasible.

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The presence of OHM in the environment as a separate phase – whether lighter or denser than water - is of special concern, with respect to these mandates, as:

- the mass of contaminants within NAPL is orders of magnitude higher than the "µg/L" levels of OHM dissolved in water, µg/m^{3}of OHM present in air, and mg/kg of OHM sorbed onto soil; and
- the presence of NAPL represents not only a direct and current exposure concern, but also a long-term/future risk via movement through the environment as a separate phase liquid and/or via inter-media mass transfer.

From 1993 to 2014, the MCP attempted to address these concerns by specifying an *Upper Concentration Limit* for NAPL, which precluded achieving a Permanent Solution if the average thickness of NAPL at a disposal site was "equal to or greater than ½ inch in any environmental medium." Evolving scientific knowledge in this area, along with difficulties in ascertaining compliance with the ½ inch standard, led MassDEP to address NAPL with a new approach in MCP amendments that became effective in June 2014.

These new provisions eliminate the ½ inch Upper Concentration Limit, and instead focus on NAPL movement and recoverability. Two new mobility terms have been defined in the MCP at 310 40.0006:

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

While not defined terms in the MCP, there are two additional types of sites with respect to the presence of NAPL (i.e., in addition to sites with Non-Stable NAPL and NAPL with Micro-scale Mobility):

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Sites at which some amount of NAPL is present, but where such NAPL does not have Non-Stable NAPL nor Micro-Scale Mobility*, due to its limited mass, its properties, and/or the properties of the porous environmental media; and*

Sites at which NAPL is not present *(i.e., all OHM are present in a sorbed, dissolved, or vapor state).*

Deleted: *at all*

Permanent and Temporary Solutions

The states of NAPL existence (or non-existence) and mobility have implications as to the type of closure that can be achieved under the MCP:

- Sites with **Non-Stable NAPL** cannot achieve a Permanent Solution, as specified at 40.1003(7)(a)(1.), but may qualify for a Temporary Solution, as specified at 40.1003(7)(b), if the Non-Stable NAPL and NAPL with Micro-Scale Mobility is removed and/or controlled to the extent feasible.
- Sites with **Micro-scale Mobility** may be able to achieve a Permanent Solution, but only after NAPL is removed or controlled to the extent feasible, as specified at 40.1003(7)(a)(2.), and all other MCP cleanup requirements relating to source and migration control and risk management are achieved. If remedial efforts are successful in removing all NAPL with Micro-Scale Mobility, there is no requirement to provide notice of the presence of any remaining NAPL with an Activity and Use Limitation (AUL). If NAPL with Micro-scale Mobility remains, an AUL is required, as specified at 40.1012(2)(d).
- Sites where NAPL is not/no longer present or where any remaining NAPL does not have Micro-Scale Mobility may be able to achieve a Permanent Solution, with no NAPL-related conditions or AUL.

While this document is focused on MCP performance standards in support of a Permanent or Temporary Solution for LNAPL disposal sites, other MCP requirements for notification and assessment specific to NAPL and LNAPL are important to note to ensure compliance with the MCP.

Notification

Two NAPL-related conditions require reporting to MassDEP within 2 hours:

- Oil or waste oil NAPL that constitutes a "sudden, continuous or intermittent release" that results in a sheen on a surface water (310 CMR 40.0311(5)); and
- NAPL that poses or could pose an Imminent Hazard (310 CMR 40.0311(7))

There are also two NAPL-related conditions that require reporting to MassDEP within 72 hours:

- **Equal to or greater than ½ inch** of NAPL in a groundwater monitoring well, excavation, or other subsurface structure **at any location** (310 CMR 40.0313(1)); and
- **Equal to or greater than 1/8 inch** of Volatile LNAPL in a groundwater monitoring well, excavation, or other subsurface structure **within 30 feet of a School, Daycare or Child Care Center or occupied residence** (310 CMR 40.0313(4)(f)3.).

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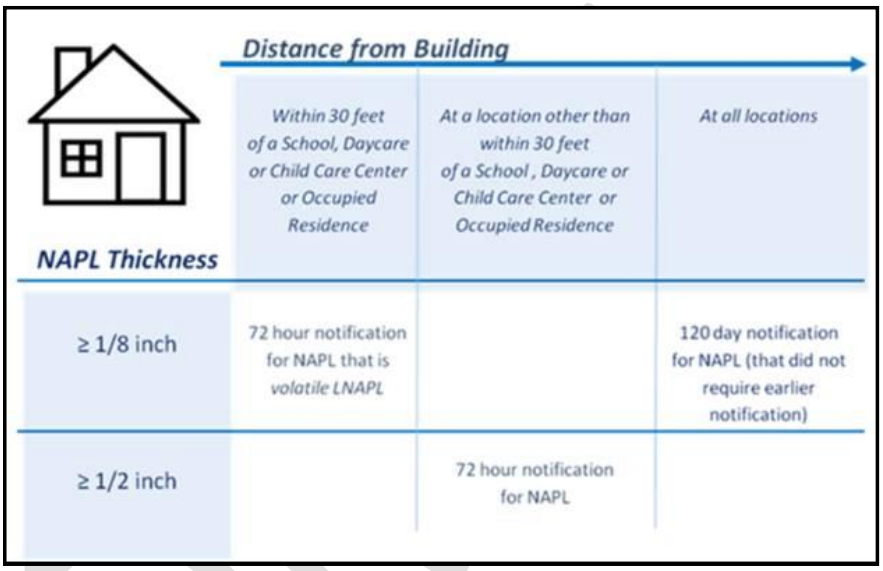
Lastly, there is one NAPL-related condition that requires reporting to MassDEP within 120 days:

> **Equal to or greater than 1/8 inch** of NAPL in a groundwater monitoring well, excavation, or other subsurface structure **at any location (310 CMR 40.0315(4))**.

As can be seen, the presence of subsurface NAPL equal to or greater than 1/8 inch can trigger a 120 day or 72 hour reporting obligation, depending on its proximity to sensitive receptors and on its volatility, as summarized in Figure 1.



NAPL Thickness	Distance from Building: Within 30 feet of a School, Daycare or Child Care Center or Occupied Residence	At a location other than within 30 feet of a School, Daycare or Child Care Center or Occupied Residence	At all locations
≥ 1/8 inch	72 hour notification for NAPL that is *volatile LNAPL*		120 day notification for NAPL (that did not require earlier notification)
≥ 1/2 inch		72 hour notification for NAPL	

Figure 1 – Notification Requirements for NAPL in the Subsurface

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In those cases where a NAPL condition triggers a 2- or 72-hour notification obligation, an Immediate Response Action must be conducted to assess the NAPL and, as appropriate, to implement immediate measures to contain the NAPL and prevent or mitigate exposures.

Conceptual Site Model (CSM) and Assessment

Conceptual Site Model development as a tool for organizing and analyzing information about disposal site conditions and designing and implementing sampling and remedial plans has become standard practice by environmental professionals and regulators on the state and national level. Use of the CSM is particularly important for understanding and successfully managing more complex sites, such as sites with potential vapor intrusion or NAPL. The MCP provides a CSM definition (310 CMR 40.0006) that includes a specific reference to sites where "NAPL is or may be present." **Section 6** provides further discussion of CSM at LNAPL sites.

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In addition to the CSM definition, there are requirements to document the preliminary CSM at the conclusion of a Phase I Initial Site Investigation (310 CMR 40.0483(1)(h)); base the Conceptual Phase II Scope of Work on the preliminary CSM developed in Phase I (310 CMR 40.0834(2)(a)); and provide an updated CSM at the conclusion of the Phase II Comprehensive Site Assessment (310 CMR 40.0835(4)(i)). A succinct summary of the CSM must also be provided in support of a Permanent or Temporary Solution (310 CMR 40.1056(2)(b) and 310 CMR 40.1057(2)(b), respectively). Each of these provisions makes specific reference to NAPL sites and, as applicable, specifies requirements to document the presence, distribution and stability of NAPL.

Other MCP references to CSM relevant to LNAPL include the provision at 310 CMR 40.1003(7) related to evaluating the feasibility of removing NAPL with Micro-Scale Mobility "based upon consideration of CSM principles."

> 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.***

A flowchart summarizing these MCP Performance Standards for NAPL is provided in **Figure 2**.

4.0 COMPLYING WITH MCP PERFORMANCE STANDARDS FOR LNAPL

Any scientifically justified approach may be used to demonstrate compliance with the LNAPL mobility and recoverability standards in the MCP, as long as it is based upon and/or consistent with the fundamental principles of Fluid Flow in Porous Media (FFPM) and the LNAPL Conceptual Site Model.

Many organizations have published excellent comprehensive technical documents for assessing LNAPL behavior in the sub-surface, and MassDEP's preferred and recommended references in this regard are provided in Section 13.0 with Internet Hyperlinks for ready access. Repeating the extensive technical details from these works is beyond the scope of this document. However, familiarity with these references is recommended and sometimes necessary.

Regardless of the approach used, of paramount concern is the level of effort and amount of data needed to adequately demonstrate compliance with MCP provisions. While decisions of this nature are inherently site-specific and involve professional judgment, as a general rule, data needs will be greatest for sites:

- where the LNAPL is gasoline or another material with significant toxicity, mobility, solubility, and/or volatility;

- where the LNAPL is located in complex fill or geological conditions; and/or
- where the LNAPL is proximate to drinking water supplies, homes, schools, surface waters and/or other sensitive receptors.

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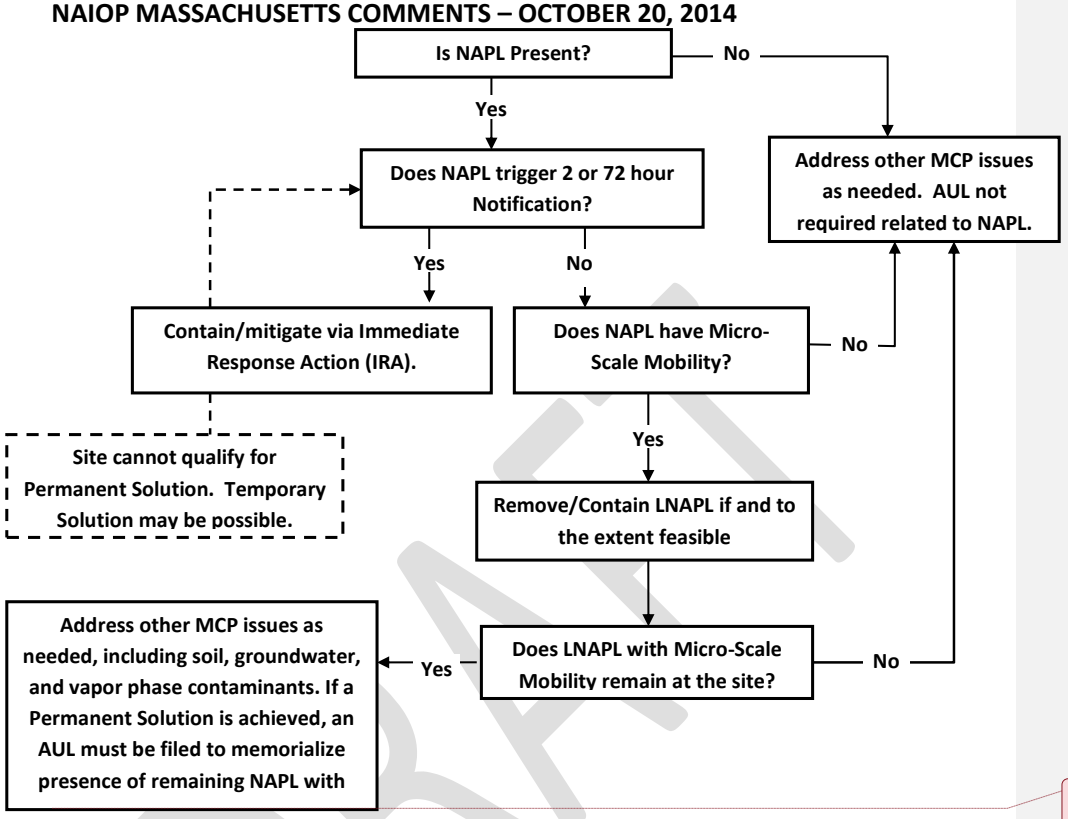

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Figure 2: MCP Performance Standards for LNAPL

5.0 SIMPLIFIED CONCEPTUAL SITE MODEL FOR LNAPL

Soil is a porous media. At uncontaminated sites, above the water table (the *Vadose Zone*), the void (*pore*) spaces between soil particles are filled with a mixture of air and water. Below the water table (the *Saturated Zone*), void spaces are completely filled with water.

LNAPL (e.g., gasoline, fuel oils, and certain chemical products) spilled onto or into the ground travels downward due to the force of gravity, moving through the void spaces in the Vadose Zone. The LNAPL will follow the path(s) of least resistance, preferentially following any interconnected air-space "finger" structures that may be present. Water droplets present in larger pore areas may be dislodged by the migrating LNAPL globules, but the water present in smaller pore areas will be held tightly in place by capillary forces, forcing the LNAPL globules to travel in a different direction (see Figure 3).

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Some of the LNAPL traveling downward through the Vadose Zone gets "stuck" in the pore spaces, leaving behind a trail of LNAPL globules (*Residual Saturation*). If enough LNAPL has been spilled, globules will eventually reach the water table, where void spaces between the soil particles are completely filled with water. At this point, the (less dense) LNAPL will initially not be able to "push" the water out of the void spaces in the Saturated Zone, and further downward movement of the LNAPL ceases, at least temporarily.

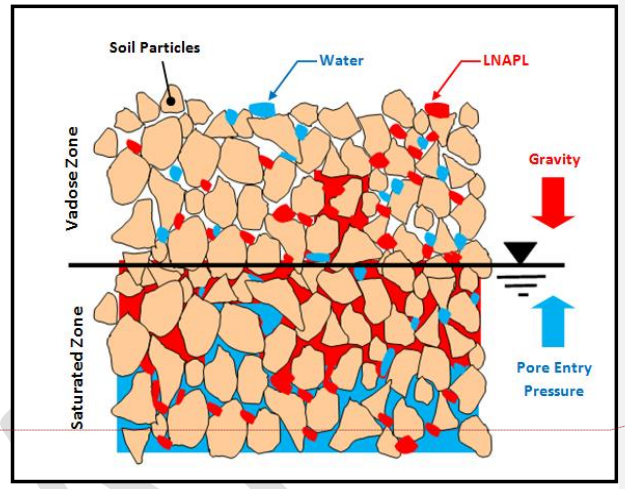

Figure 3: NAPL Movement through Porous Media

If additional LNAPL continues to travel downward to the water table, its collective mass will eventually become large enough to create a gravitational force that is greater than the opposing density/capillary forces (*Pore Entry Pressure*), and some LNAPL will enter into the pore, displacing some (but not all) of the water. Additional transport of LNAPL to the water table interface will continue to push more LNAPL into the Saturated Zone pore spaces, vertically and laterally, based upon these force dynamics.

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In theory, an equilibrium condition would be reached when further transport of LNAPL to the water table is halted (i.e., the spill/release of LNAPL is terminated). In reality, a continuously rising and falling water table will alter pore and LNAPL forces and pressure conditions, resulting in the ongoing movement of LNAPL and water in and out of pore spaces. However, absent preferred flow paths, a quasi-equilibrium condition will generally become established within 1 to 2 years after the LNAPL spill, in that the overall footprint of the LNAPL globules will cease to expand laterally and vertically, even though some movement of globules will continue within this footprint. At this point, the LNAPL is considered to be no longer Non-Stable.

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In previous decades, it was theorized that LNAPL that made its way to the water table would displace all water in the impacted Saturated Zone void spaces, creating a so-called "pancake" of pure LNAPL at the water table. This is now known to be incorrect, and a gross oversimplification of a complex process and condition, in which pore spaces at and below the water table are in fact filled with a mixture of LNAPL and water, while the pore spaces above the water table are filled with a mixture of LNAPL, water, and air – with most of the LNAPL eventually becoming concentrated in the area just above and below the water table (*Smear Zone*).

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Although the exact shape and nature of this dynamic multi-phase condition is complex, variable, and site-specific, it is often visualized as a "shark fin", straddling the water table interface in a perpendicular orientation (see **Figure 4**).

In this model, the outline of the shark fin represents the percentage of soil void spaces filled with LNAPL. The tip of the fin occurs near the water table interface (i.e., where the largest accumulation of LNAPL occurs). Pore LNAPL saturation sharply decreases with distance above and below the water table interface, until it reaches zero percent at the lower extent of the Smear Zone (in the Saturated Zone), and approaches Residual Saturation levels in the upper extent of the Smear Zone (in the Vadose Zone). In coarse soils (with large pore spaces), up to 70% of the void spaces at and just below the water table interface could be filled with LNAPL, with the remaining 30% filled with water that could not be "pushed out" by the migrating LNAPL globules. In finer grained soils, the maximum LNAPL saturation value will be less than 70%, as water present in smaller void spaces is more closely held in place via capillary forces, making it harder for migrating LNAPL globules to dislodge.

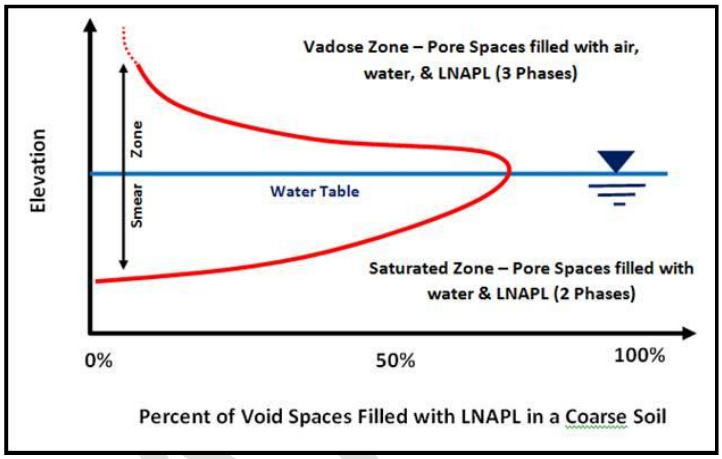

Figure 4: LNAPL Saturation at Water Table Interface

Theoretical and empirical methods and models have been developed to qualitatively and quantitatively evaluate this phenomenon on a semi-generic and/or site-specific nature, based upon the properties of the LNAPL (e.g., specific gravity, viscosity), the properties of the porous media (e.g., porosity, grain size distribution), and the resulting interactions (e.g., interfacial forces).

While addressing Non-Stable NAPL is an important milestone in controlling contaminant migration at a site, it may only be the first step. Even after the bulk movement of the separate phase OHM is halted, additional migration of contaminants can occur as constituents within the LNAPL (e.g., benzene in gasoline) partition out of the LNAPL globule. This includes sorption onto/ into soil organic carbon, dissolution into groundwater and volatilization into soil gas. Of particular concern is the subsequent migration of these constituents in groundwater and soil gas, which can impact drinking water supplies and indoor air.

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6.0 IMPORTANT TECHNICAL CONCEPTS, TERMS AND METRICS

Subsurface LNAPL behavior in soils is governed by the fundamental principles of multi-phase fluid flow in porous media (or "FFPM," which includes Darcy's Law) used for decades in the oil industry, which have been developed and used in recent years in environmental applications. A number of states and regulatory authorities have published guidelines based heavily on FFPM concepts to more accurately describe the nature, extent and behavior of LNAPL contamination in the subsurface. The foundation of this work is commonly called the LNAPL Conceptual Site Model (or "LCSM"). Although there is value to the science of multi-phase FFPM and the LCSM, it is important to note that these concepts are based on idealized homogeneous and isotropic soil conditions which are very often not present at sites in Massachusetts. It is important that any assessment concerning the nature, extent and behavior of LNAPL contamination in the subsurface take into account actual site conditions.

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While a detailed description and discussion of all technical concepts, terms, and metrics in this area is beyond the scope of this document, certain items warrant mention:

6.1 Soil Saturation Concentration or "C_{sat}"

OHM within LNAPL released to the environment will partition into soil organic carbon, soil pore water, and soil air spaces, based upon the properties of the OHM and the soil. Eventually, an equilibrium condition will be established. Mathematical models and empirical data can be used to calculate/estimate this equilibrium condition, and resultant concentration levels. These equilibrium levels represent a "saturation" concentration, in that no additional contaminant molecules can be accommodated in the soil organic carbon, soil pore water, or soil air space. Accordingly, a measured concentration in excess of these saturation levels is suggestive of the presence of an LNAPL (i.e., a separate phase of OHM not sorbed/dissolved/vaporized).

For most LNAPL sites, the most important data set in this regard is for the concentration of hydrocarbons (or other LNAPL materials) in soil, as this is the media compartment where most of the partitioned mass will generally reside. Soil Saturation Concentration values (C_{sat}) have been developed by researchers for a number of common LNAPL materials and soils. A helpful summary tool in this regard published by th ndicates that for most common s) in soil above about 100 mg/l

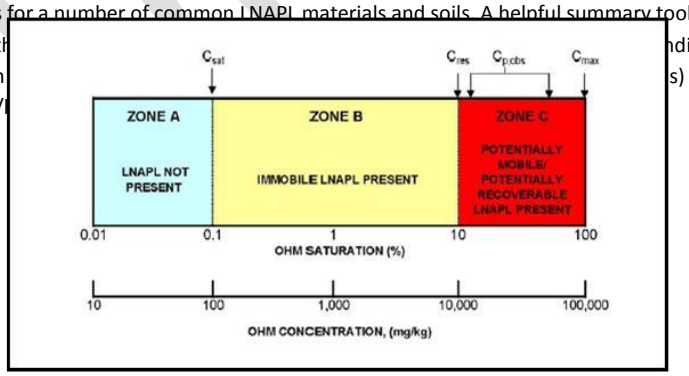

Figure 5: LNAPL in Soil (LSPA, 2008)

The idea that LNAPL can be present in a soil with as little as 100 mg/kg (or less) of hydrocarbons may come as a surprise to many people who have traditionally understood LNAPL to be present only if it is visually observed as droplets in soil or groundwater.

6.2 LNAPL Saturation and Residual Saturation

LNAPL Saturation refers to the amount of LNAPL contained in a volume of subsurface porous media at a given point in time, usually measured as the percent of void space filled. In the near-term aftermath of a significant release of LNAPL to the environment, this value will generally be no more than 70% for coarse, pervious soils, and significantly less in fine grain soils.

An important sub-universe of LNAPL Saturation is *LNAPL Residual Saturation*. Similar to LNAPL Saturation, it is expressed in terms of percent, but can also be converted to units of mg/kg, to express an *LNAPL Residual Concentration* value. It is important to note, however, that there appear to be subtle variations in the exact meaning, measurement, and application of this term and metric in available literature.

Basically, LNAPL Residual Saturation/Concentration is meant to describe the amount of LNAPL that will be immobile in subsurface soils, and, by implication/extension:

- the *maximum* level of LNAPL that can exist in soil and not be mobile; and
- the *minimum* level of LNAPL that will remain in soil after the completion of conventional remedial recovery efforts (i.e., it is theoretically not possible to get the site any cleaner using these technologies).

Various researchers have published values for these metrics. It can however be difficult to ascertain the assumptions and conditions inherent in these presentations to ensure an "apples to apples" comparison. Of particular concern are:

- whether the data/values apply to the Vadose Zone or the Saturated Zone (some researchers have maintained that these values are somewhat or even substantially higher in the Saturated Zone);
- the amount of LNAPL that was present or was assumed at a site (large amounts of LNAPL – as observed in the oil industry – will "push" LNAPL deep into soil void spaces, which will result in high LNAPL Residual Saturation values not relevant to environmental LNAPL applications).

6.3 LNAPL Transmissivity (T_n)

LNAPL Transmissivity (or T_n) is a measure of how much and how quickly LNAPL can flow through soil, and it has become a popular metric as an indicator of LNAPL "recoverability." T_n values, expressed in units of

ft^2/day, are determined on a site-specific basis using recovery/bail-down data from wells installed through an LNAPL smear zone. Results can vary with seasonal water table fluctuations, and familiarity with hydrogeology or sub-surface engineering may be necessary to obtain and apply these data in a competent manner.

The LNAPL Transmissivity metric provides a discrete numerical value that: (1) has nationwide regulatory precedent and acceptance; (2) has been confirmed and/or endorsed by a number of researchers; and (3) can indicate a point at which recovery (or further recover) of LNAPL may be considered "infeasible". The API and ASTM T_n methods listed in Section 13.0 – which include a method for direct-push micro-wells - are among the more recognized for determining LNAPL Transmissivity.

Regulatory programs in a number of states have closed or granted no further action status to sites that have demonstrated or achieved a T_n value of between 0.1 and 0.8 ft^2/day.

7.0 APPROACHES TO EVALUATE THE OCCURRENCE/MOBILITY OF LNAPL

The simplest indicators of the presence of LNAPL are visual observations of LNAPL/LNAPL discharge in structures, utilities, excavations, water bodies and/or wells. While such observations can confirm the existence of mobile LNAPL at a site or portion of a site, they cannot rule out the existence of mobile or potentially mobile LNAPL in other areas. To accomplish this objective, proactive steps must be taken to search for LNAPL. Traditional approaches in this regard typically focus on the advancement of subsurface borings, followed by the installation of monitoring wells and/or retrieval and subsequent evaluation of core samples. While many practitioners rely upon on monitoring wells to detect and evaluate LNAPL, others, concerned with perceived anomalies in well gauging data, advocate an approach focused primarily on the testing of soil/core samples.

Each approach has its own benefits and limitations, however, *both* can and usually do add value to characterizing LNAPL sites and assessing LNAPL behavior using LCSM/FFPM principles.

7.1 Use of Monitoring Well/Groundwater Data

Monitoring wells have been used for decades to document and evaluate the presence of LNAPL at contaminated sites. Until recently, however, these data have been widely misunderstood and misapplied.

Most researchers now believe that while observed/apparent LNAPL thickness in a well provides an approximation of the amount of *potentially* mobile LNAPL in the surrounding formation, this metric – in and of itself - is not a reliable indicator of the *actual* amount, mobility, or recoverability of LNAPL. In general, the observed/apparent thickness of LNAPL in a well exaggerates the amount of LNAPL that is in fact mobile and recoverable, especially in fine-grained soils.

Further complicating matters are fluctuating groundwater levels, which often lead to increased LNAPL thickness in wells during a low or falling water table condition. Some researchers have suggested that this effect is more pronounced in coarser-grained soils, because LNAPL drains more freely from larger

pore spaces when transitioning from a two phase LNAPL-water system to a three phase LNAPL-water-air system.

The utility and limitations of monitoring well data are further summarized below:

Benefits

- While LNAPL well thickness measurements are not a reliable indicator of the amount, mobility, or recoverability of the LNAPL at a site, the presence of measurable LNAPL, regardless of thickness, in an excavation, boring or monitoring well does have important meaning: It indicates OHM concentrations are high enough to exist as separate-phase OHM and mobile enough as a separate-phase to migrate at least a short distance. Monitoring well installation is common, cost-effective, and necessary in any event at virtually all sites to characterize groundwater quality (e.g., dissolved phase contamination) as well as some LNAPL specific physical properties used in applying FFPM/LCSM principles (e.g., LNAPL density, and viscosity). Moreover, permanent monitoring well installations allow for temporal monitoring programs over time to better characterize dynamic conditions (e.g., seasonal water table fluctuations).
- Monitoring well installations can be used to evaluate and/or institute LNAPL recovery (e.g., one time or long-term multiphase extraction efforts).
- When installed correctly (e.g., screen intervals extending through the entire smear zone into the water table), monitoring wells may be representative of a much greater area/volume of a formation than discrete cores or soil samples obtained from within the same zone.
- In the last several years, a number of regulatory agencies and other organizations have begun to publish guidelines on LNAPL characterization based upon LCSM/FFPM principles, most notably Texas, Alaska, British Columbia, ITRC, API, ASTM, among others listed in Section 13.0. All involve the use of LNAPL measurements in monitoring wells.

Limitations

- Many monitoring wells may not have been properly installed, developed, or maintained, which can lead to erroneous or unreliable results.
- Using well data and testing results for some of the more detailed analyses and determinations (e.g., recoverability and saturation distribution profiling) often involve complex calculations and/or computer modeling.
- LNAPL thicknesses may differ significantly in neighboring wells, possibly due to the inherent heterogeneities that limit any approach, and/or issues with well construction and maintenance.
- Uncertainties continue to exist on the affects of well diameter and installation techniques on representativeness and data comparability.

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7.2 Use of Soil Borings/Core Samples/OHM Concentration Data

Similar to groundwater monitoring wells, soil borings have also been used for decades to evaluate LNAPL contaminated sites. Traditionally, these LNAPL characterization efforts have focused on obtaining and examining core samples and/or obtaining and quantifying LNAPL or LNAPL constituents in soil samples. The development of specialized direct push technologies incorporating Laser Induced Fluorescence (LIF), Membrane Interface Probes (MIPs), and Cone Penetrometer Technology (CPT) have added further capabilities in this area, as have approaches to more fully characterize undisturbed core samples to obtain site-specific information on LNAPL saturation and mobility.

The biggest limitations with the use of soil cores and/or samples are concerns over representativeness. Even at sites without fill and with relatively uniform soil conditions, heterogeneities and macro-features can create LNAPL "fingers" which are detectable only by a robust boring program. The relatively small volume and representativeness of soil cores are further reduced in cases where characterization relies upon OHM soil concentration data, given the small size of soil samples that are analyzed (e.g., typically only 10 grams), as depicted in **Figure 6**.

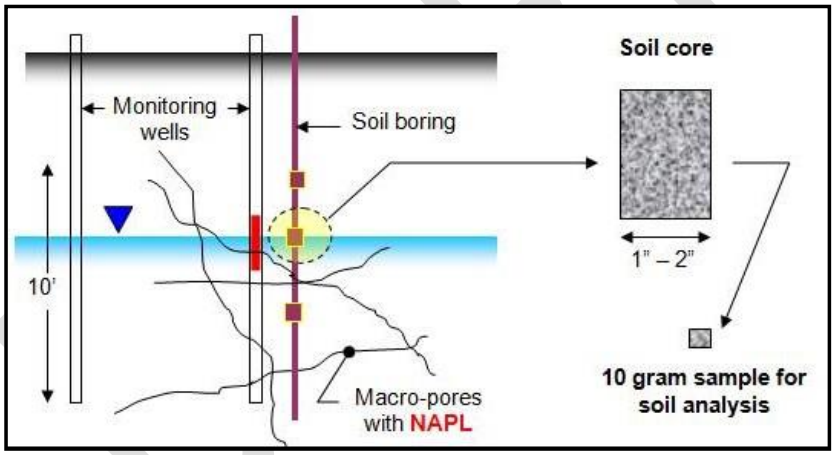

Figure 6: Representativeness Concerns for Soil Samples

The utility and limitations of approaches that rely on soil borings are further summarized below:

Benefits

- Actual site-specific soil data (e.g., TPH) often have already been obtained (and hence are available at no additional cost).
- Inexpensive and reliable field test methods are available to test for common LNAPL constituents (e.g., TPH).

- Soil data can provide a direct vertical profile of LNAPL saturation which exists in zones of variable saturation throughout the vertical column, including the Vadose Zone and the smear (or fluctuating) zone within the water table itself, where the highest LNAPL saturations usually exist.
- Soil sampling can provide a direct measure of physical soil properties necessary for applying FFPM/LCSM principles (e.g., porosity, grain size distribution and density).
- Comparing soil data to residual saturation is a simple indicator of potential LNAPL mobility.

Limitations

- A substantial amount of core/soil data may be needed to adequately characterize a site.
- Soil boring/sample data is specific to a point in time, and cannot be used to monitor variations in LNAPL conditions over time, which can be a key issue in the evaluation of mobility.
- Representative core samples for quantitatively evaluating LNAPL saturation conditions (particularly in the Saturated Zone) can be difficult and costly to obtain.

8.0 LINES OF EVIDENCE FOR LNAPL OCCURRENCE, MOBILITY, AND RECOVERABILITY

In Massachusetts, the fundamental nature of FFPM science combined with our tens of thousands of heterogeneous LNAPL sites - usually having shallow and seasonally varying groundwater elevations and/or decades-old urban development remnants - creates an unavoidable degree of complexity and uncertainty. Therefore, in many cases, *there may be no single definitive compliance criterion*. Rather, *the best evaluation of environmental protection* using this science often *depends on multiple lines of evidence*, which collectively form an improved and more informed professional opinion.

Below are summaries of the most widely acknowledged and simplest Lines of Evidence with regulatory precedent which can and should be used to assess LNAPL behavior for MCP-specific purposes. References for all of these Lines of Evidence (as well as others that also are suitable but more complex) are provided in Section 13.0, and familiarity with these references is recommended. The LSPA White Paper II provides a detailed section (Section 6.0, LNAPL Mobility Evaluation; LSPA 2008) describing several scientific lines of evidence to assess LNAPL Mobility and these approaches: (1) Weight of Evidence, (2) Comparison to residual Saturation or Residual Concentration, (3) Site Specific LNAPL Mobility Evaluation, and (4) Inherent Mobility Based on Baildown testing form a very useful reference for practitioners to address site specific decision making.

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8.1 Release Date and Volume, LNAPL type, soil type

Basic and easily available information can provide a Line of Evidence in the evaluation of LNAPL occurrence and mobility/stability:

Release Date and Volume: Most LNAPL releases generally approach a condition of Macro-scale stability (often for both the LNAPL plume as well as the dissolved groundwater plume) within 1 to 2 years from when the release was terminated, absent preferred flow paths. It is informative to know the date of the release termination, at least to the extent of whether the release is

"new" (e.g., less than two years) or "old" (e.g., more than five years). In addition, all other factors being equal, larger releases spread and migrate more than smaller releases.

LNAPL Type: LNAPL viscosity is inversely proportional to its mobility (a principle of Darcy's Law.) Therefore, more viscous LNAPLs such as No. 4 and No. 6 oil are less mobile than diesel or gasoline in similar soils under similar conditions.

Soil Type: Because soil permeability is proportional to grain size, LNAPL flows more easily through larger grained soils than smaller grained soils. Therefore, absent preferred flow paths, LNAPL releases to low permeability/fine grained soils, such as clay, will migrate less than identical releases to coarse sand under the same conditions. Soil type also significantly affects pore entry pressures and residual saturation. Soil grain size testing (ASTM sieve analysis) and classification (Unified Soil Classification System or USCS) are usually inexpensive and should be considered, as appropriate.

8.2 Soil Concentration Data

In concept, if the concentration of OHM in soil does not exceed its Soil Saturation Concentration (C_{sat}), LNAPL will not be present. Even if LNAPL is present, it will not, in theory, be mobile if the LNAPL concentration (e.g., TPH) in soil is less than its Residual Concentration (C_{res}) value. When used properly, this comparison can be an inexpensive and valuable line of evidence for assessing LNAPL stability and recoverability.

One of the most widely referenced collections of C_{sat} and C_{res} data is by Brost et. al., in API Soil and Groundwater Bulletin No. 9, June, 2000. A summary table from this publication is reproduced, in part, in Table 1. As can be seen, C_{res} values reported in literature can vary significantly, even for the same petroleum product in similar soil types. This is reflective of the various assumptions/parameters/test conditions used to develop these values.

Reported values for Residual LNAPL Saturation often over-estimate values seen at MCP LNAPL sites, sometimes by orders of magnitude. This happens because Residual Saturation is directly proportional to Initial LNAPL Saturation, and many of the literature values reflect conditions in oilfield petroleum reservoirs where depths, pressures and initial oil (or LNAPL) saturations far exceed those at typical shallow environmental LNAPL sites.

For this reason, absent definitive knowledge on the origin and relevance of a published metric, only the most conservative values should be used when applying these data to MCP sites. Moreover, even when applying the most conservative values, it is important to carefully consider the representativeness of existing site data, given site/soil heterogeneity issues, sampling procedures, and small (e.g., 10 gram) sample sizes.

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For the purpose of obtaining soil data for comparison to Residual Soil Concentration metrics, the use of a GC/FID "Total Petroleum Hydrocarbon (TPH)" test method is acceptable for non-gasoline LNAPLs, as long as the chromatographic integration is to baseline, and the carbon range covered is at least C_9 through C_{24} for diesel/#2 Fuel, and C_9 thorough $_{36}$ for heavier oils. A "TPH" value can also be obtained by

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summation of Target Analytes and hydrocarbon ranges in the Massachusetts Extractable Petroleum Hydrocarbon (EPH) method.

Although soil concentration data alone may not be sufficient to rule out the presence of mobile LNAPL, a robust data set coupled with soil concentration levels well below conservative Residual Concentration values would be a significant line of evidence in support of such a finding.

8.3 Product Thickness Measurements (Spatial and Temporal)

Defining the LNAPL "footprint" and demonstrating that it is not expanding are requirements in the 2014 MCP amendments. Valid use of these data as a Line of Evidence depends on: (1) proper well installation techniques (e.g., well screen intervals extending through the entire smear zone into the lowest water table elevation); (2) an adequate number and spatial distribution of wells to surround and define the "footprint" boundary; and (3) adequate sampling/gauging frequency to account for seasonal groundwater table fluctuations, which can affect the measured thicknesses (and the occurrence) of LNAPL significantly.

While data from a low and high groundwater table condition may be sufficient to rule out a LNAPL mobility issue, an adequate sampling frequency to evaluate and document the stability of a significant LNAPL plume is generally quarterly sampling/gauging over a minimum of a one-year period, with events occurring at

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Table 1: C_{sat} and Residual Saturation (C_{res}) Values in Soil (API, 2000)

LNAPL	Soil Type	Theoretical	Measured	
		$C_{sat.\ soil}$ (mg/kg)	S_r (cm^3/cm^3)	$C_{res.\ soil}$ (mg/kg)
Gasoline	coarse gravel	57	0.01	1,000
Gasoline	coarse sand and gravel	102	0.01	1,697
Gasoline	medium to coarse	143	0.02	3,387
Gasoline	fine to medium sand	215	0.03	5,833
Gasoline	silt to fine sand	387	0.05	10,000
Middle distillates	coarse gravel	2	0.02	2,286
Middle distillates	coarse sand and gravel	4	0.02	3,879
Middle distillates	medium to coarse	5	0.04	7,742
Middle distillates	fine to medium sand	9	0.06	13,333
Middle distillates	silt to fine sand	18	0.1	22,857
Fuel oils	coarse gravel	2	0.04	5,143
Fuel oils	coarse sand and gravel	4	0.05	8,727
Fuel oils	medium to coarse	6	0.08	17,419
Fuel oils	fine to medium sand	9	0.1	30,000
Fuel oils	silt to fine sand	18	0.2	51,429
Light oil & gasoline	soil	9	0.18	40,800
Diesel & light fuel oil	soil	-	0.15	34,000
Lube & heavy fuel oil	soil	-	0.2	53,067
Gasoline	coarse sand	106	0.15 to 0.19	24,954 to 31,609
Gasoline	medium sand	106	0.12 to 0.27	19,767 to 44,476
Gasoline	fine sand	106	0.19 to 0.6	31,065 to 98,100
Gasoline	graded fine-coarse	106	0.46 to 0.59	80,500 to 103,250
Mineral oil	Ottawa sand	3	0.11	20,116
Mineral oil	Ottawa sand	3	0.14	25,602
Mineral oil	Ottawa sand	3	0.172	31,454
Mineral oil	Ottawa sand	3	0.235	42,975
Mineral oil	glacial till (NA)	3	0.15 to 0.28	13,500 to 25,200
Mineral oil	glacial till	3	0.12 to 0.21	10,800 to 18,900
Mineral oil	alluvium (NA)	3	0.19	61,071
Mineral oil	alluvium	3	0.19	61,071
Mineral oil	loess (NA)	3	0.49 to 0.52	154,000 to 163,800
Paraffin oil	coarse sand	-	0.12	27,000
Paraffin oil	fine sediments	-	0.52	147,086
Paraffin oil	Ottawa sand	-	0.11 to 0.23	20,382 to 42,618
O-Xylene	coarse sand	143	0.01	1,936
Gasoline	sandy loam	-	0.42 to 0.59	94,500 to 132,750

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both high and low water table conditions. Determining adequate spatial coverage depends on the quality of site characterization and the site Conceptual Site Model, including the presence of heterogeneities and/or preferred flow paths.

8.4 Pore Entry Pressure Correlations

A well-known and referenced correlation is the relationship between soil type, LNAPL type, and "pore entry pressure" (which equates to the height of a column of LNAPL). Exceeding this pressure (or measured height of LNAPL) can indicate potential LNAPL migration. While "real world" site conditions are variable, this theory is sound and its use (with appropriate caution) as a Line of Evidence is simple and has regulatory precedent. Examples and applications of this approach have been published by Golder Associates (2008).

8.5 Recovery Decline Curve Analysis

Decline Curve Analysis is a formal and systematic method of recording and interpreting LNAPL well removal quantities over time (by bailing or pumping) to estimate the limit of recoverability. LNAPL recovery rates typically decline over time, as the volume of LNAPL in the ground decreases and its saturation approaches Residual Saturation. Eventually, an asymptotic limit of recovery or "point of diminishing returns" can be observed by graphs of: (1) recovery rate versus time; or (2) recovery rate versus cumulative recovery. Random periodic bailing of small quantities of LNAPL from a monitoring well may not generate enough data to perform this analysis, but if a trend can be observed, it could provide a valuable Line of Evidence.

Appendix I provides a LNAPL Screening Checklist,

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9.0 FEASIBILITY EVALUATIONS

The 2014 Amendments to the MCP have established two new NAPL-related feasibility requirements:

- Per 310 CMR 40.1003(7)(a)(2.), in order to achieve a Permanent Solution, all NAPL with Micro-scale Mobility at a site must be removed if and to the extent feasible.
- In cases where a Permanent Solution cannot be achieved due to the presence of Non-Stable NAPL, in order to achieve a Temporary Solution, all Non-Stable NAPL and NAPL with Micro-scale Mobility at a site must be removed and/or controlled if and to the extent feasible (310 CMR 40.1003(7)(b)).

In both cases, feasibility evaluations must be conducted in accordance with the provisions of 310 CMR 40.0860, which specifies the procedures and criteria used to conduct feasibility evaluations at all MCP sites. Under this process and paradigm, a feasibility evaluation considers technical practicability *and* economics, integrated into a benefit/cost evaluation.

The benefits involved in removing LNAPL from the environment are clear: eliminating or reducing the possibility of future separate-phase mobility, eliminating or mitigating a potential source/continuing source of groundwater, soil gas, and indoor air contamination; eliminating or mitigating risks to human and ecological receptors. However, the costs of achieving these objectives can be high and at times

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disproportionate to the benefit, as documented by historic examples of costly LNAPL recovery systems that were only able to extract a few gallons of petroleum.

While acknowledging the inherent difficulties and uncertainties in these areas, under certain conditions, the need and benefit of attempting and continuing LNAPL recovery are high, and outweigh even significant costs. This includes sites where LNAPL:

- Is Non-Stable and/or
- is creating a vapor pathway that presents a significant risk of harm to human health, safety, or public welfare.

It is MassDEP's position that the feasibility evaluations conducted at these and similar sites of high concern should duly consider the full range of NAPL remedial options and their comparative costs, including excavation and conventional (hydraulic/vacuum recovery) technologies as well as alternative/innovative technologies (e.g., ISCO, soil flushing, soil solidification and stabilization), and that remedial operations deemed to be feasible are maintained for as long as it is necessary to achieve MCP standards.

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In contrast to the above, many sites contain relatively small quantities of "oil" as LNAPL, where (i) the LNAPL has Micro-scale Mobility (only), (ii) the LNAPL is not creating vapor pathways of concern nor posing any other significant exposure threats, and (iii) the Source Elimination and Migration Control requirements of the MCP have otherwise been achieved. When these lesser concerns are combined with the long-term biodegradation potential of petroleum LNAPLs, the benefit/cost considerations are significantly altered. At these sites, it is MassDEP's position that:

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- Feasibility evaluations may be limited to excavation of hot spots and conventional hydraulic/vacuum extraction technologies, although parties are encouraged to consider alternative techniques, where appropriate, for effectiveness and cost-effectiveness. Moreover, these recovery operations need not be attempted at sites where the amount and type of petroleum products and hydraulic conductivity of site soils suggest that only *a de minimis* quantity of LNAPL is likely to be recovered.
- Where instituted, remedial operations at these sites may be terminated when LNAPL Transmissivity decreases to a de minimis level and/or when asymptotic recovery conditions are observed and documented.

10.0 LNAPL RECOVERY, DESTRUCTION OR CONTROL

Conventional LNAPL recovery systems typically involve hydraulic and/or vacuum extraction technology with standardized "off the shelf" modular components. These include:

- Floating LNAPL Extraction/Skimming
- Dual Pump Liquid Extraction
- Soil Vapor Extraction

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- Dual/Multi-phase Extraction

Excavation of "hot spots" can also be an effective conventional approach, especially for more viscous oils.

The selection of any particular system/combination of systems is dependent on a number of factors, including LNAPL fluid properties, soil properties, site conditions, remedial timeframes, and site/logistical constraints. There are many excellent references available on the evaluation/design/operation of these systems, including those cited in Section 13.0.

In addition to these conventional approaches are a number of alternative/innovative technologies that often rely upon chemical transformations and/or modifications of LNAPL or media properties to enhance and maximize LNAPL recovery, destruction or control. These include:

- Soil Flushing;
- Steam/Hot Air Injection
- In-Situ Stabilization and Solidification (ISS);In-Situ Chemical Oxidation (ISCO).

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11.0 ACTIVITY AND USE LIMITATIONS (AULs)

A Permanent Solution may be achieved at a disposal site where some NAPL remains in the environment, provided a level of No Significant Risk has been achieved, Non-Stable LNAPL is not present (i.e., the overall LNAPL footprint is not expanding) and all LNAPL with Micro-Scale Mobility has been removed to the extent feasible. As required at 310 CMR 40.1012(2)(d), where the remaining LNAPL exhibits "Micro-scale Mobility", an AUL is required as part of the Permanent Solution.

The purpose of the AUL where there is NAPL with Micro-scale Mobility is to provide notice to the current and future property owners about the presence of NAPL so that appropriate measures can be taken to manage future exposure to the NAPL (e.g., to protect construction workers and/or to establish management plans for any NAPL that may flow into future excavations in the event of construction activities in the area of the NAPL that exhibits Micro-scale Mobility).

If LNAPL is observed in a groundwater monitoring well at a thickness less than ½ inch, it is MassDEP's position that Micro-Scale Mobility is not present for the purposes of determining whether an AUL is required under the MCP. This ½ inch metric applies to the maximum observed thickness in any monitoring well at a site during the 12 month period preceding the filing of a Permanent Solution, particularly during a period of a low or falling groundwater table.

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At those sites where Micro-scale Mobility does not exist, an AUL could still be necessary to address other exposure/risk concerns related or unrelated to any LNAPL remaining at the site.

12.0 RECOMMENDED SIMPLIFIED APPROACH FOR PETROLEUM LNAPL SITES

The vast majority of LNAPL sites in Massachusetts are petroleum, with the most common petroleum spills being gasoline, diesel/#2 fuel oil, jet fuel, #4-#6 fuel oil, (automotive) waste oil, and lubricating oil.

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all of which constitute "oil" as defined in 310 CMR 40.0006. A relatively small number of LNAPL sites are chemical in nature (e.g., toluene). The simplified approach described in this section pertains only to oil LNAPL. This approach is intended to provide a "short cut" that may be used to satisfy MCP performance standards to assess and address LNAPL mobility and recoverability at relatively simple NAPL sites. This simplified approach may only be used as appropriate, in the judgment and discretion of the Licensed Site Professional of Record, based on site specific conditions. In outlining parameters for a simplified approach, it is not DEP's intention to limit or prevent use of alternative approaches based on good scientific analysis consistent with applicable MCP performance standards.

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12.1 Simplified Approach: Basis and Limitations

The recommended simplified approach consists of a series of investigatory and/or remedial steps with specified levels of efforts, data needs, and evaluation metrics. All decisions and conclusions shall be based on a preponderance of the evidence, i.e., that a condition is more likely than not.

To maximize its utility and application, the specific procedures and metrics incorporated into this simplified approach are designed to be applicable and protective at the vast majority of LNAPL sites. However, there may be unusual site conditions where these guidelines may not be sufficiently protective. The Department may, upon review of the use of this approach in such cases, require additional documentation and/or response actions to demonstrate that the requirements of the MCP are met.

The overall approach is summarized in **Figure 7**. Additional details on individual elements are provided below in Sections 12.2 though 12.8.

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Deleted: 12.2 Simplified Approach: Characterization Methods and Level of Effort¶
The simplified approach relies upon site history research, observations, LNAPL thickness in groundwater monitoring wells, and conservative metrics obtained or adapted from other regulatory agencies and researchers.¶

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Deleted: Site history information must be obtained for the area under investigation, including information and data on past storage or uses of petroleum products and petroleum spills.¶ The installation of semi-permanent monitoring wells is required to allow repeated gauging over time. These monitoring wells must be screened across the groundwater fluctuation zone in overburden unconfined formations. After installation, all groundwater monitoring wells must be thoroughly developed.

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Deleted: <#>LNAPL thickness measurements must be made using an oil/water interface probe to eliminate accuracy concerns associated with measuring the thickness of LNAPL observed in a bailer. Each time a well is gauged for LNAPL thickness, the elevation of the groundwater/LNAPL interface must be observed and recorded, to ensure that the well screen is not above the groundwater table. Following a gauging event, at least one well volume of any LNAPL must be evacuated from the well and properly disposed or recycled.¶

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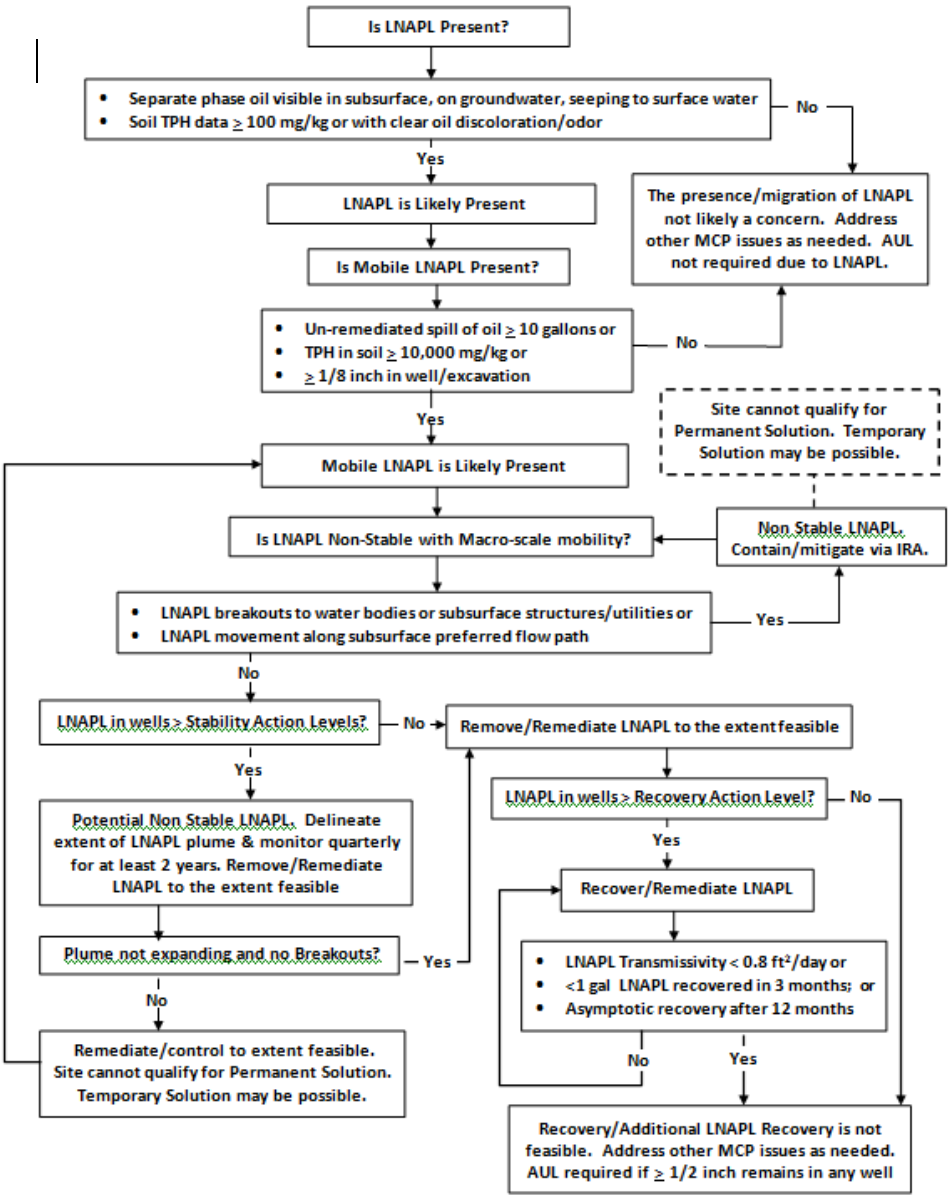

12.3 Simplified Approach: Determining Whether LNAPL is Present

Visual observation of any amount of oil or waste oil in a subsurface excavation or monitoring well, or seeping into a proximate surface water body or building structure, is

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2. Reduce quarterly monitoring to one year when determining if NAPL is Non-Stable.

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Commented [A10]: As bullet 6 relates to the issue of use of soil concentration data to evaluate recoverability, recommend moving to section 8.2

Deleted: <#>Baring unavoidable site constraints, the spacing of a monitoring well network must be in the range of 15 to 30 feet within the core and at the perimeter of the LNAPL plume. The placement of wells shall reflect the existence of sensitive LNAPL receptors, which include surface waters and buildings, sumps, utilities/subsurface structures within the groundwater fluctuation/LNAPL smear zone. ¶
<#>At sites where Non-Stable LNAPL is present or potentially present, wells within and just downgradient of an identified LNAPL plume must be gauged on at least a monthly basis for a minimum of two years. At sites where Non-Stable LNAPL is not present or potentially present, wells within and just downgradient of an identified LNAPL plume must be gauged on at least a quarterly basis for a minimum of one year.¶

Deleted: For the purpose of obtaining soil data for comparison to Residual Soil Concentration metrics, the use of a GC/FID "Total Petroleum Hydrocarbon (TPH)" test method is acceptable for non-gasoline LNAPLs, as long chromatographic integration is to baseline, and the carbon range covered is at least C_9 through C_{24} for diesel/#2 Fuel, and C_9 thorough $_{36}$ for heavier oils. A "TPH" value can also be obtained by summation of Target Analytes and hydrocarbon ranges in the Massachusetts Extractable Petroleum Hydrocarbon (EPH) method.¶

Figure 7: Recommended LNAPL Simplified A

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proof of the presence of LNAPL at a disposal site. At sites where LNAPL is not visually observed, proactive steps should be taken to determine its possible presence if:

- soils at the site are discolored with a clear petroleum odor;
- the site was previously used to store more than household quantities of petroleum products or other site history information suggests potential petroleum impacts (i.e., quantities of petroleum use and storage beyond a home heating oil tank, and gasoline/oil used for lawn/yard/car maintenance);
- credible evidence exists that a release of an LNAPL occurred or likely occurred at the site; or
- available groundwater, soil gas, or indoor air data at the site exceed MCP reporting thresholds for petroleum constituents.

These proactive investigatory steps may include soil borings, test pits, groundwater monitoring wells, and/or soil cores/samples. The level of effort in this regard should reflect the nature and quantities of petroleum products of interest, site complexity, and presence of sensitive receptors, consistent with the Conceptual Site Model.

The installation of semi-permanent monitoring wells is required to allow repeated gauging over time. These monitoring wells must be screened across the groundwater fluctuation zone in overburden unconfined formations. After installation, all groundwater monitoring wells must be thoroughly developed.

LNAPL thickness measurements must be made using an oil/water interface probe to eliminate accuracy concerns associated with measuring the thickness of LNAPL observed in a bailer. Each time a well is gauged for LNAPL thickness, the elevation of the groundwater/LNAPL interface must be observed and recorded, to ensure that the well screen is not above the groundwater table.

If it is determined that LNAPL is not present at a site, other MCP concerns and requirements must be addressed as applicable.

12.5 Simplified Approach: Determining Whether LNAPL at a Site is Non-Stable

At sites where LNAPL is present or likely present, for the purpose of this approach, LNAPL may *initially* be considered Non-Stable or likely to be Non-Stable if:

- A spill of a total of 10 or more gallons of oil occurred or likely occurred at the site in the previous 10 years which was not promptly and adequately remediated via removal of the LNAPL, applied sorbents, and/or impacted soils;
- Total hydrocarbons in soil exceed 10,000 mg/kg (via a TPH test method or via the summation of fractions and Target Analytes from a VPH or EPH test method); or
- Equal to or greater than 1/8 inch of LNAPL is identified in any groundwater monitoring well or in any excavation at the site.

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At sites where LNAPL is present or likely present, investigatory actions must taken to ascertain its potential mobility. For the purposes of this approach, an LNAPL is or is likely to be mobile if:¶
<#>A spill of a total of 10 or more gallons of oil/waste occurred or likely occurred at the site in the previous 10 years which was not promptly and adequately remediated via removal of the LNAPL, applied sorbents, and/or impacted soils;¶
<#>Total hydrocarbons in soil exceed 10,000 mg/kg (via a TPH test method or via the summation of fractions and Target Analytes from a VPH or EPH test method); or¶
<#>Equal to or greater than 1/8 inch of LNAPL is identified any groundwater monitoring well or in any excavation at the site.¶
A finding that mobile LNAPL is present or likely present at a site necessitates an evaluation of its mobility per Section 12.5 and recoverability per Section 12.6¶

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At sites where LNAPL is *initially* considered Non-Stable or likely to be Non-Stable, initial investigatory actions must be promptly taken to confirm whether it is Non-Stable.

These initial efforts shall focus on proactive and systematic observations in proximate (< 50 – 100 feet) buildings, utilities, and surface water bodies. At sites at which a significant (>100 gallons) release of LNAPL had occurred within the previous 2 years, subsurface explorations must be undertaken to determine if the LNAPL plume is expanding. These explorations must include, as appropriate, the advancement of soil borings, installation of groundwater monitoring wells, and/or excavation of test pits with the following level of assessment required:

- Baring unavoidable site constraints, the spacing of a monitoring well network must be within the core and at the perimeter of the LNAPL plume. The placement of wells shall reflect the existence of sensitive LNAPL receptors, which include surface waters and buildings, sumps, utilities/subsurface structures within the groundwater fluctuation/LNAPL smear zone.
- Wells within and just downgradient of an identified LNAPL plume must be gauged on at least a quarterly basis for a minimum of one year.

As a result of these efforts, or any other available observational/site assessment data, an LNAPL present in the subsurface shall be deemed Non-Stable if:

- It is discharging or periodically discharging to a Surface Water;
- It is discharging or periodically discharging into a building, including drainage sumps within such building;
- It is discharging or periodically discharging into a utility structure, including manholes, vaults, and piping/conduits;
- It is observed to be present within a preferred flow path, including in the pervious backfill of utility conduits or in bedrock fracture; and/or
- Its footprint is expanding as described below.

For the purposes of this approach, "periodically" means any discharge that occurs one or more times within a 12 month period.

Even when LNAPL is not actively discharging to surface waters or other receptor of concern, it may still meet the MCP definition of Non-Stable if it is moving as a separate phase through subsurface porous media (i.e., the LNAPL footprint is expanding, and Macro-Scale stability has not been achieved). This is most likely to occur when the amount of oil/waste oil within a subsurface LNAPL plume is sufficient to overcome pore entry pressures within adjacent impacted media. While not a perfect instrument, the measured thicknesses of LNAPL in a monitoring well network is generally the most readily available surrogate to judge whether this condition may exist, and researchers have developed well thickness criteria as a means to evaluate this concern.

Accordingly, for the purposes of this approach, a condition of Non-Stable LNAPL may exist at a site if, during the course of investigating an LNAPL spill or obtaining data for other site assessment purposes,

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LNAPL is observed/measured in any boring, excavation, or groundwater monitoring well at any time at a thickness equal to or greater than the Stability Action Levels contained in **Table 2**.

Table 2: Stability Action Levels (Golder Associates, 2008)

Soil Type*	Characteristic Fraction	Percent Fines (silt and clay)	LNAPL Thickness (inches)
Coarse sand or gravel	> 20% Coarse sand	< 3	**1.2 inch**
Coarse sand or gravel	> 20% Coarse sand	3-10	**2 inches**
Medium sand	Medium sand	< 10	**4 inches**
Fine sand	Fine sand	< 10	**8 inches**
Silty sand	Sand	> 10	**12 inches**

*If soil at a site does not match any of the listed types, judgment shall be used to select an available category and metric that is a reasonably conservative approximation.

- If an appropriate Stability Action Level in Table 2 is exceeded, at least one year of quarterly monitoring is required to determine whether a condition of Non-Stable LNAPL is present.

LNAPL above the notification threshold at 310 CMR 40.0311(5) shall be reported to MassDEP within 2 hours and above the notification thresholds at 310 CMR 40.0313(1) or (4)(f)3. within 72 hours. All such notifications require the implementation of Immediate Response Actions to assess the condition and, as appropriate, to implement immediate measures to contain the LNAPL and prevent or mitigate exposures. See the Summary of LNAPL-related notification requirements in **Section 3**.0.

Following this one-year monitoring program, it can be concluded that there is no current indication of Non-Stable LNAPL if:

- Subsurface LNAPL did not discharge to surface waters, buildings, building sumps, or subsurface utility conduits and/or structures; and
- Observed LNAPL thickness levels did not consistently or significantly increase in downgradient monitoring/sentinel wells.

12.7 Simplified Approach: Determining when it is Not Feasible to Recover LNAPL

A feasibility evaluation must be conducted in accordance with the provisions of 310 CMR 40.860, as further discussed in Section 9.0.

Thickness levels in a groundwater monitoring well less than 1/8 (0.125) inch are deemed to be infeasible to recover for all petroleum products in all media. Further, LNAPL recovery is considered feasible unless and until one of the following infeasibility metrics is achieved:

- The LNAPL Transmissivity value (T_n) in all recovery wells is shown to be less than 0.8 ft^2/day; or
- The total volume of LNAPL recovered at a site is less than 1 gallon in any 3 month period; or

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<#>a thickness value is exceeded by more than a factor of 2 in any well/excavation within 50 feet of a potential subsurface LNAPL receptor if no additional wells are already present in this zone, with potential subsurface LNAPL receptors defined as Surface Waters and building/building sumps and utility structures located within the groundwater fluctuation (LNAPL smear) zone; or¶
one or more key monitoring wells in the area of interest are not screened over the water table fluctuation (smear) zone.

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In addition to gauging monitoring wells, assessment efforts shall also include the inspection of potential subsurface receptors within 50 feet of the presumed edge of the LNAPL plume.¶

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Deleted: **12.6 Simplified Approach: Determining the Feasibility of Removing or Containing Mobile LNAPL¶**
A feasibility evaluation must be conducted in accordance with the provisions of 310 CMR 40.860, as further discussed in Section 9.0. ¶
In applying this simplified approach at sites where the feasibly evaluation is appropriately limited to conventional hydraulic/vacuum LNAPL recovery technologies, the graph contained in **Figure 8** may be used to conclude that such LNAPL recovery efforts are infeasible. ¶
In applying the criteria in **Figure 8**:¶
<#>The Hydraulic Conductivity value selected for the site shall be based upon the most pervious/ transmissive soils present within the LNAPL plume. Conservative (i.e., more permeable) values shall be assumed at sites where this determination is based upon soil type, not site-specific testing data.**<object><object>¶**
<#>The Dynamic Viscosity value (C_p) value may be selected on the basis of the type of oil/waste oil present, with conservative (lower) values assumed when a mixture of products is present or when the identity of the LNAPL is not conclusively established. ¶
<#>The maximum observed thickness of LNAPL in any monitoring wells over a 1-2 year gauging cycle shall be determined and be used as the basis for determining the thickness level in the graph. ¶
<#>Values between the indicated inches may be extrapolated, within the range of 0.125 to 5.0 inches. **<object>¶**
<#>A condition of infeasibility may be assumed in cases where the intersection of the Hydraulic Conductivity (cm/sec) and Dynamic Viscosity (cP) values is above the indicated or extrapolated thickness line. ¶
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- A decline curve analysis of at least one year of cumulative LNAPL recovery data demonstrates an asymptotic condition; or
- A sufficient line of evidence using soil profiling and soil concentration data demonstrates a lack of LNAPL with Micro-Scale Mobility consistent with the alternate LSPA approach (outlined by the LSPA, July 2008).

At all sites, such a finding may allow the achievement of a Permanent Solution, assuming all other (non-LNAPL) MCP requirements and standards have been satisfied.

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At sites where conventional LNAPL recovery operations are being conducted to address stability, vapor, or other critical LNAPL concerns, such a finding would necessitate the need to evaluate and implement alternative/innovative technologies.¶

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12.8 Simplified Approach: Achieving a Permanent Solution

An LNAPL site can achieve a Permanent Solution if:

- Non-Stable LNAPL is not or no longer present, as articulated in Section 12.5;
- LNAPL has been recovered or removed to the extent feasible, as articulated in Section 12.6; and
- all other MCP requirements and standards have been met, including those related to Source Elimination or Control, Migration Control, site characterization and risk assessment.

In accordance with the provisions of 40.1012(2)(d), an Activity and Use Limitation (AUL) is required for sites where a Permanent Solution has been achieved and LNAPL with Micro-Scale Mobility is present. The presence of LNAPL with Micro-scale Mobility shall be assumed if the maximum observed thickness in any groundwater monitoring well was equal to or greater than ½ inch, at any time in the 12 months previous to the filing of the Permanent Solution, including during times of a low or falling water table.

13.0 RECOMMENDED SUPPORTING TECHNICAL REFERENCES

MassDEP's Recommended Supporting Technical References for some of the more comprehensive detailed and technically sound works from other regulatory agencies, organizations and experts are listed below. Familiarity with these references is recommended and may be necessary to properly assess complex LNAPL sites. While MassDEP does not necessarily or explicitly endorse (or even agree with) each and every single conclusion or thesis in these works, collectively they clearly represent "accurate and up-to-date methods, standards and practices, equipment and technologies which are appropriate, available and generally accepted by the professional and trade communities conducting response actions in accordance with M.G.L. c. 21E and 310 CMR 40.0000 under similar circumstances" as articulated by the MCP's Response Action Performance Standard 310 CMR 40.0191(2)(b).

MassDEP LNAPL Workgroup
http://www.state.ma.us/dep

Licensed Site Professionals Association (LSPA)
LNAPL and The Massachusetts Contingency Plan Part II; Prepared by: LSPA Technical Practices Committee; July, 2008.
http://www.LSPA.org

MassDEP:

Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the VPH/EPH Approach; Policy #WSC-02-411; October 31, 2002.

Interstate Technology & Regulatory Council (ITRC)

Archived On-Line Classes: http://cluin.org/live/archive/default.cfm?display=all&group=itrc#

LNAPL Training Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface - State of Science vs. State of Practice
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?
http://www.itrcweb.org/Training#LNAPLPart2

LNAPL Training Part 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
http://www.itrcweb.org/Training#LNAPLpart3

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

New England Interstate Water Pollution Control Commission (NEIWPCC)

UST and LUST/Corrective Action Training
http://neiwpcc.org/ust.asp
http://neiwpcc.org/lust-correctiveaction.asp

American Petroleum Institute (API)

Brost et al.; *Non-Aqueous Phase Liquid (NAPL) Mobility Limits in Soil*; API Bulletin No. 9; June 2000. (API changing web site, use their search box with "Bulletin 9")
http://www.api.org/ehs/groundwater/upload/09_bull.pdf
http://www.clu-in.org/conf/itrc/iuLNAPL/030513_residual.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

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NAIOP MASSACHUSETTS COMMENTS – OCTOBER 20, 2014

American Society for Testing and Materials (ASTM International)

ASTM E2856-13 *Standard Guide for Estimation of LNAPL Transmissivity*
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
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.
http://www.clu-in.org/conf/itrc/iuLNAPL/030513_residual.pdf

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

Johnston, C., Adamski, M., 2005, Relationship Between Initial and Residual LNAPL Saturation for Different Soil Types, 2005 Petroleum Hydrocarbons and Organics Chemicals in Ground Water Conference, Costa Mesa, CA, August 18-19, 2005, Proceedings.
http://www.ngwa.org/_bdc/http___www_ngwa_org/GWOL%20Data_1.aspx?RecordID=653494

Applied NAPL Science Review **"***Applied NAPL Science Review* (ANSR) is a scientific ejournal that provides insight into the science behind the characterization and remediation of non-aqueous phase liquids (NAPLs) using plain English"; Hawthorne, Adamski, Charbeneau, Garg, Johnson, Kirkman, Malander.
http://www.h2altd.com/ansr

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

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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

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APPENDIX I
LNAPL SCREENING CHECKLIST & LINES OF EVIDENCE MATRIX

NAIOP MASSACHUSETTS COMMENTS – OCTOBER 20, 2014

LNAPL SCREENING CHECKLIST

Date/age of release:
LNAPL type:
LNAPL volume:
Soil Type:
Max Soil TPH range

- ☐ Do monitoring wells adequately cover the LNAPL footprint?
  Potential LNAPL Receptors (e.g., surface waters, building/building sumps and utility structures)
  Temporally: _____ sampling events over _____ years
  Represent both High and Low water Table elevations
  Well completion/screen through entire smear zone into GW table?

- ☐ Existing soil TPH Data:
  Spatially: _____ locations over _____ SF
  Vertically: sample depth intervals_____
  Samples in Vadose Zone? Smear Zone? GW table?

- ☐ Have CSM requirements (including LNAPL CSM) been met?

- ☐ Is the LNAPL plume stable?
  Based on what Line(s) of Evidence?

- ☐ Has LNAPL been "removed if and to the extent feasible?"
  Based on what Line(s) of Evidence?

- ☐ Does LNAPL with Micro-scale mobility remain?
  Based on what Line(s) of Evidence?

- ☐ Is an AUL Required?

- ☐ Have all other MCP Source Control and risk-based closure requirements been met (including soil, groundwater and vapor phases)?

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LINES OF EVIDENCE ...

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November 3, 2014

Liz Callahan, Acting Division Director for Policy and Program Development
MassDEP, Bureau of Waste Site Cleanup
One Winter Street
Boston, MA 02108

Subject: LSPA Comments on Public Review Draft, July 1, 2014, Light Nonaqueous Phase Liquids (LNAPL) and the MCP: Guidance for Site Assessment and Closure, Policy #WSC-14-450

Dear Ms. Callahan:

The LSP Association (LSPA), a professional non-profit association of nearly 900 LSPs and other environmental professionals, appreciates the opportunity to provide comments on the above-referenced draft guidance document. As is typical, the LSPA formed a workgroup to consider the draft guidance, and solicited and vetted comments and suggestions from LSPA members. As is also typical, there was consensus that areas of the guidance need clarification and further consideration. What was more of a challenge for the workgroup and LSPA leadership was reaching agreement on fundamental assumptions in the draft guidance, such as LNAPL thickness as a metric, and the use of transmissivity in estimating LNAPL.

This cover letter summarizes the overall LSPA concerns and comments on the draft guidance. The attached matrix of comments is a compilation of specific LSPA comments on the draft guidance; the matrix identifies areas needing additional clarification, notes areas of inconsistency, and suggests specific language changes where appropriate.

Provided below are the LSPA's general comments on the draft guidance.

- While simplified guidance is welcomed and the intent of Figure 7 is appreciated, there is concern that the flowchart will become a de facto performance standard. LNAPL sites will have differing levels of complexity and risk, and therefore each site may have a different but acceptable approach to assessing LNAPL mobility and the risks posed. The LSPA is concerned that the draft guidance is too prescriptive and doesn't allow an LSP sufficient flexibility to make practical decisions.

- There is concern that while some of the provisions in the guidance are designed to help LSPs "rule out" the presence of "Non-Stable NAPL" at their sites, there is concern that some may misinterpret these provisions and/or apply them incorrectly. For example, the LSPA interprets the reference to the soil TPH<100 mg/kg criterion as allowing LSPs to conclude that if their soil

has <100 mg/kg TPH, they can "rule out" "Non-Stable NAPL" at their site. However, there is concern that MassDEP may say, if your soil concentration exceeds 100 mg/kg TPH, then you must assume that "Non-Stable NAPL" is present unless you can prove it is not, thereby suggesting that one must prove a negative.

The LSPA thinks it was the intent of the LNAPL guidance to present a series of "tests" (hypotheses) and criteria that would demonstrate that "Non-Stable NAPL" was present, to determine whether these hypotheses were true. If the tests fail (the hypothesis is not proven) one could then conclude that the alternative is true and that "Non-Stable NAPL" does not exist. However this is not clearly explained in the Draft LNAPL guidance, leaving the "tests" and procedures contained in the guidance subject to misinterpretation, and misuse.

- The guidance document needs a set of internally consistent terms and definitions for: mobile LNAPL, LNAPL with macroscale mobility, LNAPL with microscale mobility, Non-stable LNAPL, and Stable LNAPL. To assist with clarity, the LSPA recommends that any time the term "mobile" is used, it should be modified with the term "micro" or "macro."

- There are also a number of interchangeable terms in the document such as: oil/waste oil, petroleum, LNAPL, NAPL, separate phase OHM, oil or waste oil NAPL (See MCP), "certain chemical products", and the listed fuels. These should be defined at the outset of the guidance and used consistently.

- The guidance is lacking a summary of the different "triggers" that result in reporting, assessing macroscale mobility, microscale mobility, feasibility of remediation, when remediation needs to be conducted, when remediation can be stopped, and when an AUL is necessary. This includes clarification when remediation/recovery does not need to be initiated. The LSPA LNAPL workgroup is attempting to draft a summary table that includes the above; we hope to have it ready in advance of the yet-unscheduled BWSC meeting on this topic in December. The guidance needs this type of summary.

- It would be helpful if the document were reorganized to better segregate assessment for the presence of LNAPL, macroscale mobility, and microscale mobility. Currently, it is difficult to identify what type of assessment and techniques are being discussed. In addition the guidance appears to blend together characterization/assessment and feasibility of recovery.

- The guidance is heavily weighted to well data; it should encourage equal support for use of soil data. Both well and soil data have strengths and limitations and LSPs should understand the applicability and be able to rely on both.

- While the LSPA acknowledges that the guidance states that consideration of DNAPL is beyond its scope, we do think that LNAPL in bedrock should be included and discussed. There are sites with minor and periodic LNAPL in bedrock that are assessed over long periods of time illustrating both stability of LNAPL and dissolved phase contamination, as well as assessment of the risk associated for current and future uses of the property.

- The draft guidance needs to be completed in conjunction with the AUL Guidance document so that a read can better understand when an AUL is required. In addition, it is overly conservative to require the filing of an AUL in all cases when LNAPL has been present in a monitoring well in the preceding 12-month period regardless of frequency, thickness, and depth. The LSPA appreciates and understands that a change to this requirement would require a regulatory change in the MCP.

- The performance standard of 2-years of monthly gauging as evidence of Stable LNAPL and specification of well spacing is overly conservative. The guidance should recognize:
    - Site conditions are different and more or less gauging may be warranted.
    - Generally 1 year of quarterly monitoring may be sufficient.
    - Very mature LNAPL sites with years or decades of monitoring, may not require any additional gauging to illustrate LNAPL stability.
    - Figure 8 illustrating feasibility of LNAPL recovery is incorrect and should be removed or corrected.

We look forward to continuing to work with MassDEP on further clarifying and refining this draft guidance. Thank you again for the opportunity to provide comments.

Sincerely,

LSP Association, Inc.

Paul McKinlay, LSP
President

Wendy Rundle
Executive Director

Attachment: November 3, 2014 Compilation of Comments from the LSPA

EnvironmentalSafetyHealthGeotechnical

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November 3, 2014

Mr. Ken Marra, P.E.
MassDEP – BWSC
1 Winter Street
Boston, MA 01208

Re: LNAPL Draft Gudance Document
Policy # WSC-14-450

Dear Mr. Marra:

I appreciate the effort you and others have put into the draft guidance document for assessment and closure of LNAPL Sites. I feel MCP feasibility guidance documents have been the most challenging guidance to develop. In the absence of significant risk, how does an LSP, MassDEP and responsible parties properly weigh high costs of remediation to reduce mass or concentrations of contaminants in cases of negligible risk benefits? In my opinion, while adequate in areas of assessment, the guidance document needs a section dealing with cost benefit feasibility evaluations to properly guide LSP Site closure opinions, as outlined below.

No parties should conclude LNAPL recovery is not merited in cases of Macro mobility or when LNAPL poses a significant risk. Such cases do not require feasibility guidance. The guidance should recognize that potentially recoverable LNAPL at most sites is typically low (1% to 20%). Conversely, even good recovery systems will “leave behind” 80% to 99% of all LNAPL mass. The key guidance needed by LSPs is: “when is recovery warranted when we are dealing only with micro-scale mobility, No Significant Risk (NSR) and at best we can get 20 % out of ground”?

In my view, the guidance document is lacking for the above scenario, which is typical of the majority of LNAPL sites that remain in the system. The only “cost” off-ramp in Table 7 of the draft guidance appears to be when oil recovery is less than one gallon/quarter. The implication is that this recovery rate and associated costs is an economic tipping point. A quarterly manual recovery of 1 gallon per month would likely cost $10,000 in combined field efforts, reporting and fees. Is MassDEP suggesting $2,500 per gallon of recovered oil per year is an acceptable cost in the case of micro-scale mobility and NSR? In my view, the guidance should identify when recovery of micro-scale mobile LNAPL (posing NSR) should be performed, and when it is not economically practicable. Alternately, if it is MassDEP’s position that cost considerations (as opposed to technical considerations) do not play a significant role in LNAPL closure decisions, the guidance should state this explicitly.

Closure guidance is needed for requirements to demonstrate “control” of LNAPL with micro-scale mobility for purposes of a Temporary Solution. It seems “control” is inherent in the definition of micro-scale mobility. If not, we ask that the guidance be expanded to list some examples of “uncontrolled” NAPL with micro-scale mobility.

Guidance is also requested for a scenario in cases where soil concentrations are below risk based standards, and there is no observation of measurable LNAPL. LSPs want to know if Remedial Action Performance Standard (RAPs) has changed for such cases that would have been a simple A-2 RAO under the former regulations.

Thanks you for your efforts to date. Feel free to contact me if I can be of assistance to you or your work group.

O'Reilly, Talbot & Okun Associates, Inc.
Very truly yours,

Kevin J. O'Reilly, LSP
Principal

Hi Ken,

I have been through the guidance a few times and thought I would send you my initial thoughts.

Attached my current comments.

I am a little concerned about the way the Guidance gives you the impression that LNAPL Transmissivity is the way to compliance. Having read the Guidance many times, I asked the question "What is the way to close out an LNAPL site following this guidance?" My conclusion was to document the history of the site and run LNAPL Transmissivity bail down tests in monitoring wells and show values less than the 0.8 Ft2/day provided in the Guidance.

The potential reliance on LNAPL Transmissivity bail down test has some significant issues; all surround the assumptions and conditions that need to be recognized to apply the evaluation process, including:

· The models used to derive the analytical evaluation of data collected assume that the LNAPL thickness in the well is the same thickness as the LNAPL impacted soil thickness in the formation.
Huntly (2000) is the basis of most of the bail down testing approaches and he states that at the LNAPL/water interface the NAPL saturation in the soil is zero (no LNAPL) and the soil saturation increases as one approaches the water table. In my experience soil data shows that this is seldom the case at the type of sites generally seen in the MCP. The LNAPL thickness is generally substantially less than the LNAPL saturation zone.

· The well construction and geometries, especially the screen placement and pack thickness, significantly influence data evaluation, and needs to be recognized.

· Huntly says to use the Bower-Rice approach to calculate LNAPL Transmissivity the water transmissivity be much greater than the LNAPL Transmissivity

· LNAPL thicknesses need to be at least 0.5 feet, and some recommend more than 1.0 feet, to apply the methods. Only the LNAPL should be removed from the well during the conduct of the test. These conditions may not be met by those applying the method and at these lower limits, most likely do not reflect the LNAPL zone in the soil.

· Long stabilization times, measured in months, are recommended before the tests are conducted and long recovery times, also measured in months, sometimes are recommended after the tests are conducted.

I suggest that the Department add much more information on what the PRP needs demonstrate to use data derived from applying this approach.
At a minimum, there needs to be soil data to support LNAPL thickness measurements demonstrating that the theory is applicable.

I also think that the guidance needs to be developed more to help LSPs with the larger, more complex sites. Little help is given as to how and where to find and execute analytical methods and approaches.

I am available to discuss in more detail, if you wish,

Wes

LIGHT NONAQUEOUS PHASE LIQUIDS (LNAPL) AND THE MCP: GUIDANCE for SITE ASSESSMENT AND CLOSURE
Policy #WSC-14-450

Comment [WS1]: Comments provided by Wesley Stimpson

This document provides guidance on investigating, assessing, understanding, and addressing the presence and migration of LNAPL at disposal sites regulated under the Massachusetts Contingency Plan (the "MCP" or 310 CMR 40.0000)

This document is intended solely as guidance. It does not create any substantive or procedural rights, and is not enforceable by any party in any administrative proceeding with the Commonwealth. This document provides guidance on approaches MassDEP considers acceptable for meeting the general requirements set forth in the MCP. Parties using this guidance should be aware that other acceptable alternatives may be available for achieving compliance with general regulatory requirements.

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1.0 PURPOSE AND SCOPE

The purpose of this document is to provide general guidance and a simplified approach to evaluate and address Light Nonaqueous Phase Liquids (LNAPL) at contaminated sites, in accordance with the 2014 Amendments to Massachusetts Contingency Plan ("MCP" at 310 CMR 40.0000).

This document is designed for a wide range of MCP users, *especially* those whose professional expertise is *not* in hydrogeology or sub-surface engineering. In order to enable all such users to effectively and efficiently understand and implement relevant MCP provisions, this guidance:

- summarizes the new LNAPL provisions and performance standards of the MCP;
- provides a simplified description of the LNAPL Conceptual Site Model (LCSM);
- details the relevant fundamental principles of fluid flow in porous media (FFPM) consistent with the LCSM;
- outlines tools and metrics for the evaluation of LNAPL-contaminated sites using a *multiple lines of evidence* approach;
- presents a simplified approach that may be voluntarily used to demonstrate compliance with MCP LNAPL performance standards; and
- provides recommended technical references for parties who elect to demonstrate compliance with MCP LNAPL performance standards using an alternative and/or more rigorous site-specific approach.

The scope of the guidance offered in this document is limited to the direct impacts related to the occurrence and bulk movement of LNAPL *in and through* porous media. Beyond these direct impacts are secondary concerns related to the partitioning of LNAPL constituents into environmental media, including sorption onto/into soil organic carbon, dissolution into groundwater and volatilization into soil gas. Refer to other agency documents for guidance on these secondary impacts.

This document is intended solely as guidance. It does not create any substantive or procedural rights, and is not enforceable by any party in any administrative proceeding with the Commonwealth. This document provides guidance on approaches MassDEP considers acceptable for meeting the general requirements set forth in the MCP. Parties using this guidance should be aware that other acceptable alternatives may be available for achieving compliance with general regulatory requirements.

2.0 APPLICABILITY

This guidance applies to disposal sites regulated under the Massachusetts Contingency Plan where LNAPL is present in porous media. As defined in the MCP, LNAPL is any oil or hazardous material that is present in the environment as a separate phase liquid, and which has a specific gravity equal to or less than one.

This document does not address disposal sites in which LNAPL is present in non-porous media (e.g., bedrock fractures), or Dense Nonaqueous Phase Liquid (DNAPL).

3.0 MCP PERFORMANCE STANDARDS FOR NAPL

Massachusetts General Law (MGL) c. 21E and the MCP address releases of oil and hazardous materials (OHM) to the environment, and require that all sites impacted by such releases achieve a *Permanent Solution*. A Permanent Solution is achieved when OHM at a site does not pose a Significant Risk to human health, safety, public welfare, or the environment, at present and for the foreseeable future. Both the statute and regulations also require that all releases of OHM be removed from the environment if and to the extent feasible.

Comment [WS2]: I don't believe this is the case. Isn't it only if response actions are undertaken that additional removable needs to be evaluated. The statutes use of the term "Permanent Solution" implies that response actions are needed to achieve a level of NSR. Section 3A(g) talks about "implementing a Permanent Solution". The end point is NSR.

The presence of OHM in the environment as a separate phase – whether lighter or denser than water - is of special concern, with respect to these mandates, as:

- the mass of contaminants within NAPL is orders of magnitude higher than the "µg/L" levels of OHM dissolved in water, µg/m^{3}of OHM present in air, and mg/kg of OHM sorbed onto soil; and
- the presence of NAPL represents not only a direct and current exposure concern, but also a long-term/future risk via movement through the environment as a separate phase liquid and/or via inter-media mass transfer.

From 1993 to 2014, the MCP attempted to address these concerns by specifying an *Upper Concentration Limit* for NAPL, which precluded achieving a Permanent Solution if the average thickness of NAPL at a disposal site was "equal to or greater than ½ inch in any environmental medium." Evolving scientific knowledge in this area, along with difficulties in ascertaining compliance with the ½ inch standard, led MassDEP to address NAPL with a new approach in MCP amendments that became effective in June 2014.

These new provisions eliminate the ½ inch Upper Concentration Limit, and instead focus on NAPL movement and recoverability. Two new mobility terms have been defined in the MCP at 310 40.0006:

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

Comment [WS3]: Visibly?

While not defined terms in the MCP, there are two additional types of sites with respect to the presence of NAPL (i.e., in addition to sites with Non-Stable NAPL and NAPL with Micro-scale Mobility):

> ***Sites at which some amount of NAPL is present, but where such NAPL does not have Micro-Scale Mobility****, due to its limited mass, its properties, and/or the properties of the porous environmental media; and*
>
> ***Sites at which NAPL is not present at all*** *(i.e., all OHM are present in a sorbed, dissolved, or vapor state).*

Permanent and Temporary Solutions

The states of NAPL existence (or non-existence) and mobility have implications as to the type of closure that can be achieved under the MCP:

- Sites with **Non-Stable NAPL** cannot achieve a Permanent Solution, as specified at 40.1003(7)(a)(1.), but may qualify for a Temporary Solution, as specified at 40.1003(7)(b), if the Non-Stable NAPL and NAPL with Micro-Scale Mobility is removed and/or controlled to the extent feasible.
- Sites with **Micro-scale Mobility** may be able to achieve a Permanent Solution, but only after NAPL is removed or controlled to the extent feasible, as specified at 40.1003(7)(a)(2.), and all other MCP cleanup requirements relating to source and migration control and risk management are achieved. If remedial efforts are successful in removing all NAPL with Micro-Scale Mobility, there is no requirement to provide notice of the presence of any remaining NAPL with an Activity and Use Limitation (AUL). If NAPL with Micro-scale Mobility remains, an AUL is required, as specified at 40.1012(2)(d).
- Sites where NAPL is not/no longer present or where any remaining NAPL does not have Micro-Scale Mobility may be able to achieve a Permanent Solution, with no NAPL-related conditions or AUL.

While this document is focused on MCP performance standards in support of a Permanent or Temporary Solution for LNAPL disposal sites, other MCP requirements for notification and assessment specific to NAPL and LNAPL are important to note to ensure compliance with the MCP.

Notification

Two NAPL-related conditions require reporting to MassDEP within 2 hours:

- Oil or waste oil NAPL that constitutes a "sudden, continuous or intermittent release" that results in a sheen on a surface water (310 CMR 40.0311(5)); and
- NAPL that poses or could pose an Imminent Hazard (310 CMR 40.0311(7))

There are also two NAPL-related conditions that require reporting to MassDEP within 72 hours:

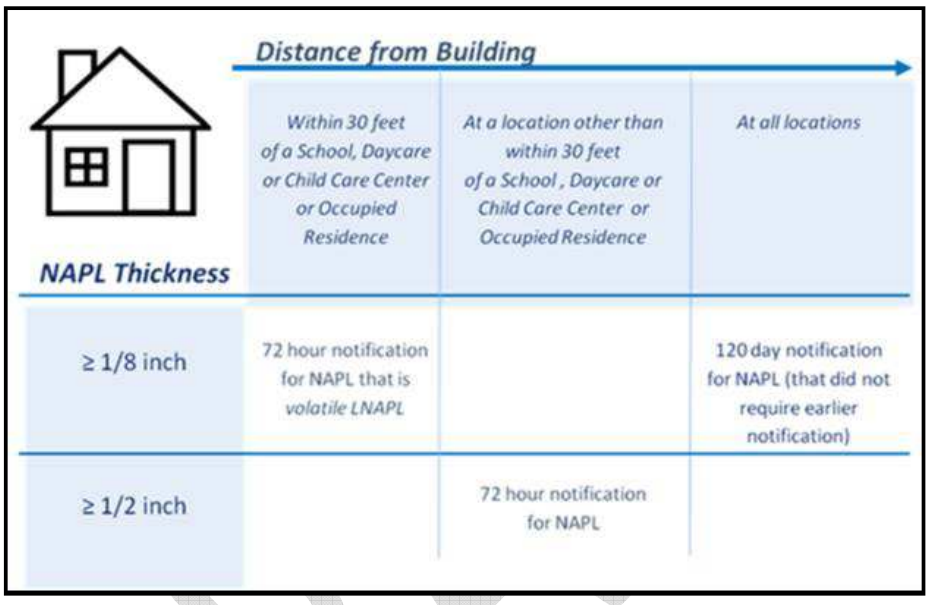
- **Equal to or greater than ½ inch** of NAPL in a groundwater monitoring well, excavation, or other subsurface structure **at any location** (310 CMR 40.0313(1)); and
- **Equal to or greater than 1/8 inch** of Volatile LNAPL in a groundwater monitoring well, excavation, or other subsurface structure **within 30 feet of a School, Daycare or Child Care Center or occupied residence** (310 CMR 40.0313(4)(f)3.).

Comment [WS4]: Needs to be defined.

Lastly, there is one NAPL-related condition that requires reporting to MassDEP within 120 days:

Equal to or greater than 1/8 inch of NAPL in a groundwater monitoring well, excavation, or other subsurface structure **at any location (310 CMR 40.0315(4))**.

As can be seen, the presence of subsurface NAPL equal to or greater than 1/8 inch can trigger a 120 day or 72 hour reporting obligation, depending on its proximity to sensitive receptors and on its volatility, as summarized in Figure 1.



NAPL Thickness	Distance from Building: Within 30 feet of a School, Daycare or Child Care Center or Occupied Residence	At a location other than within 30 feet of a School, Daycare or Child Care Center or Occupied Residence	At all locations
≥ 1/8 inch	72 hour notification for NAPL that is *volatile LNAPL*		120 day notification for NAPL (that did not require earlier notification)
≥ 1/2 inch		72 hour notification for NAPL	

Figure 1 – Notification Requirements for NAPL in the Subsurface

In those cases where a NAPL condition triggers a 2- or 72-hour notification obligation, an Immediate Response Action must be conducted to assess the NAPL and, as appropriate, to implement immediate measures to contain the NAPL and prevent or mitigate exposures.

Conceptual Site Model (CSM) and Assessment

Conceptual Site Model development as a tool for organizing and analyzing information about disposal site conditions and designing and implementing sampling and remedial plans has become standard practice by environmental professionals and regulators on the state and national level. Use of the CSM is particularly important for understanding and successfully managing more complex sites, such as sites with potential vapor intrusion or NAPL. The MCP provides a CSM definition (310 CMR 40.0006) that includes a specific reference to sites where "NAPL is or may be present." **Section 6** provides further discussion of CSM at LNAPL sites.

In addition to the CSM definition, there are requirements to document the preliminary CSM at the conclusion of a Phase I Initial Site Investigation (310 CMR 40.0483(1)(h)); base the Conceptual Phase II Scope of Work on the preliminary CSM developed in Phase I (310 CMR 40.0834(2)(a)); and provide an updated CSM at the conclusion of the Phase II Comprehensive Site Assessment (310 CMR 40.0835(4)(i)).

A succinct summary of the CSM must also be provided in support of a Permanent or Temporary Solution (310 CMR 40.1056(2)(b) and 310 CMR 40.1057(2)(b), respectively). Each of these provisions makes specific reference to NAPL sites and, as applicable, specifies requirements to document the presence, distribution and stability of NAPL.

Other MCP references to CSM relevant to LNAPL include the provision at 310 CMR 40.1003(7) related to evaluating the feasibility of removing NAPL with Micro-Scale Mobility "based upon consideration of CSM principles."

> 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.***

A flowchart summarizing these MCP Performance Standards for NAPL is provided in **Figure 2**.

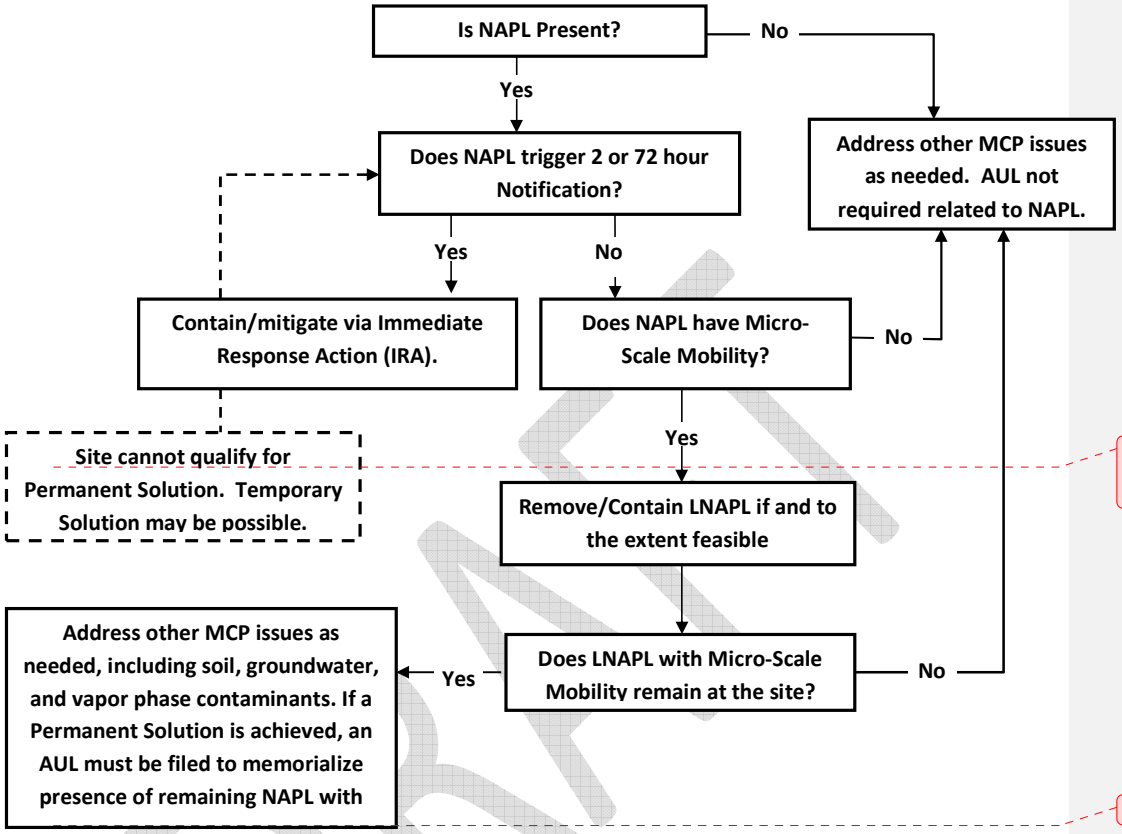
4.0 COMPLYING WITH MCP PERFORMANCE STANDARDS FOR LNAPL

Any scientifically justified approach may be used to demonstrate compliance with the LNAPL mobility and recoverability standards in the MCP, as long as it is based upon and/or consistent with the fundamental principles of Fluid Flow in Porous Media (FFPM) and the LNAPL Conceptual Site Model.

Many organizations have published excellent comprehensive technical documents for assessing LNAPL behavior in the sub-surface, and MassDEP's preferred and recommended references in this regard are provided in Section 13.0 with Internet Hyperlinks for ready access. Repeating the extensive technical details from these works is beyond the scope of this document. However, familiarity with these references is recommended and sometimes necessary.

Regardless of the approach used, of paramount concern is the level of effort and amount of data needed to adequately demonstrate compliance with MCP provisions. While decisions of this nature are inherently site-specific and involve professional judgment, as a general rule, data needs will be greatest for sites:

- where the LNAPL is gasoline or another material with significant toxicity, mobility, solubility, and/or volatility;
- where the LNAPL is located in complex fill or geological conditions; and/or
- where the LNAPL is proximate to drinking water supplies, homes, schools, surface waters and/or other sensitive receptors.



Comment [WS5]: Doesn't there need to be a step in here that evaluates for the presence of Non-stable NAPL?

Comment [WS6]: Missing some words

Figure 2: MCP Performance Standards for LNAPL

5.0 SIMPLIFIED CONCEPTUAL SITE MODEL FOR LNAPL

Soil is a porous media. At uncontaminated sites, above the water table (the *Vadose Zone*), the void (*pore*) spaces between soil particles are filled with a mixture of air and water. Below the water table (the *Saturated Zone*), void spaces are completely filled with water.

LNAPL (e.g., gasoline, fuel oils, and certain chemical products) spilled onto or into the ground travels downward due to the force of gravity, moving through the void spaces in the Vadose Zone. The LNAPL will follow the path(s) of least resistance, preferentially following any interconnected air-space "finger" structures that way be present. Water droplet present in larger pore areas may be dislodged by the migrating LNAPL globules, but the water present in smaller pore areas will be held tightly in place by capillary forces, forcing the LNAPL globules to travel in a different direction (see Figure 3).

Some of the LNAPL traveling downward through the Vadose Zone gets "stuck" in the pore spaces, leaving behind a trail of LNAPL globules (*Residual Saturation*). If enough LNAPL has been spilled, globules will eventually reach the water table, where void spaces between the soil particles are completely filled with water. At this point, the (less dense) LNAPL will initially not be able to "push" the water out of the void spaces in the Saturated Zone, and further downward movement of the LNAPL ceases, at least temporarily.

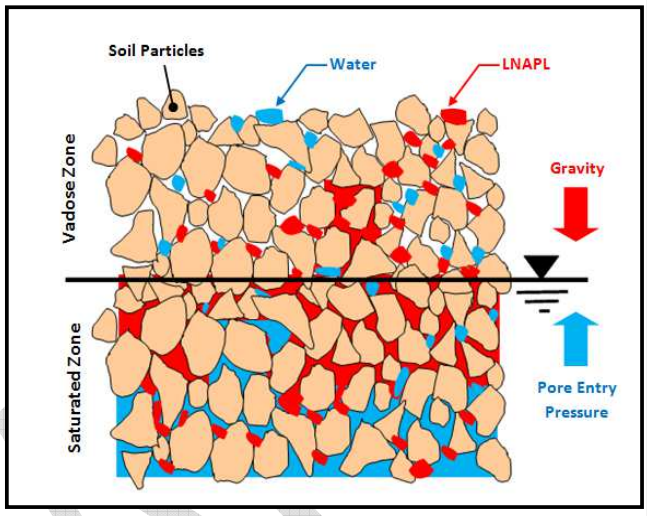


Figure 3: NAPL Movement through Porous Media

If additional LNAPL continues to travel downward to the water table, its collective mass will eventually become large enough to create a gravitational force that is greater than the opposing density/capillary forces (*Pore Entry Pressure*) arresting the movement of the globules, and some LNAPL will enter into the pore, displacing some (but not all) of the water. Additional transport of LNAPL to the water table interface will continue to push more LNAPL into the Saturated Zone pore spaces, vertically and laterally, based upon these force dynamics.

In theory, an equilibrium condition would be reached when further transport of LNAPL to the water table is halted (i.e., the spill/release of LNAPL is terminated). In reality, a continuously rising and falling water table will alter pore and LNAPL forces and pressure conditions, resulting in the ongoing movement of LNAPL and water in and out of pore spaces. However, absent preferred flow paths, a quasi-equilibrium condition will generally become established within 1 to 2 years after the LNAPL spill, in that the overall footprint of the LNAPL globules will cease to expand laterally and vertically, even though some movement of globules will continue within this footprint. At this point, the LNAPL is considered to be in a state of *Macro-Scale Stability*.

Comment [WS7]: This is not an MCP term and you should relate it to an MCP term or not use it

In previous decades, it was theorized that LNAPL that made its way to the water table would displace all water in the impacted Saturated Zone void spaces, creating a so-called "pancake" of pure LNAPL at the water table. This is now known to be incorrect, and a gross oversimplification of a complex process and condition, in which pore spaces at and below the water table are in fact filled with a mixture of LNAPL and water, while the pore spaces above the water table are filled with a mixture of LNAPL, water, and air – with most of the LNAPL eventually becoming concentrated in the area just above and below the water table (*Smear Zone*).

Although the exact shape and nature of this dynamic multi-phase condition is complex, variable, and site-specific, it is often visualized as a "shark fin", straddling the water table interface in a perpendicular orientation (see **Figure 4**).

In this model, the outline of the shark fin represents the percentage of soil void spaces filled with LNAPL. The tip of the fin occurs near the water table interface (i.e., where the largest accumulation of LNAPL occurs). Pore LNAPL saturation sharply decrease with distance above and below the water table interface, until it reaches zero percent at the lower extent of the Smear Zone (in the Saturated Zone), and approaches Residual Saturation levels in the upper extent of the Smear Zone (in the Vadose Zone). In coarse soils (with large pore spaces), up to 70% of the void spaces at and just below the water table interface could be filled with LNAPL, with the remaining 30% filled with water that could not be "pushed out" by the migrating LNAPL globules. In finer grained soils, the maximum LNAPL saturation value will be less than 70%, as water present in smaller void spaces is more closely held in place via capillary forces, making it harder for migrating LNAPL globules to dislodge.

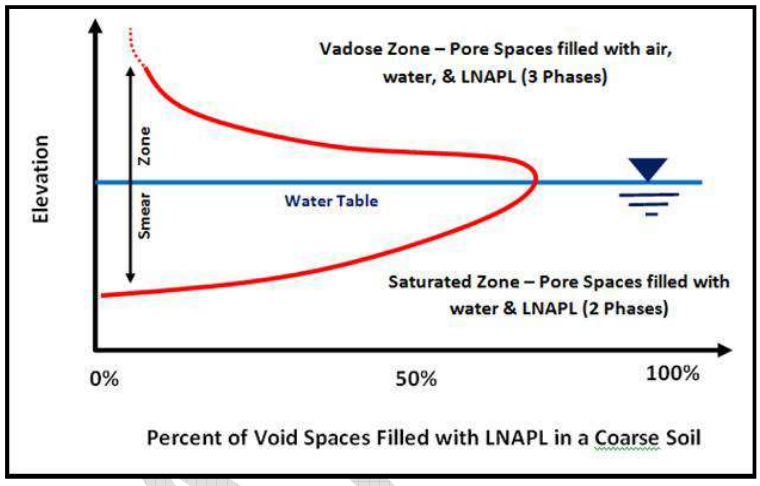


Figure 4: LNAPL Saturation at Water Table Interface

Theoretical and empirical methods and models have been developed to qualitatively and quantitatively evaluate this phenomenon on a semi-generic and/or site-specific nature, based upon the properties of the LNAPL (e.g., specific gravity, viscosity), the properties of the porous media (e.g., porosity, grain size distribution), and the resulting interactions (e.g., interfacial forces).

While achievement of a state of LNAPL Macro-Scale Stability is an important milestone in controlling contaminant migration at a site, it may only be the first step. Even after the bulk movement of the separate phase OHM is halted, additional migration of contaminants can occur as constituents within the LNAPL (e.g., benzene in gasoline) partition out of the LNAPL globule. This includes sorption onto/ into soil organic carbon, dissolution into groundwater and volatilization into soil gas. Of particular concern is the subsequent migration of these constituents in groundwater and soil gas, which can impact drinking water supplies and indoor air.

Comment [WS8]: See comment above

6.0 IMPORTANT TECHNICAL CONCEPTS, TERMS AND METRICS

Subsurface LNAPL behavior in soils is governed by the fundamental principles of multi-phase fluid flow in porous media (or "FFPM," which includes Darcy's Law,) used for decades in the oil industry, which have been developed and used in recent years in environmental applications. A number of states and regulatory authorities have published guidelines based heavily on FFPM concepts to more accurately describe the nature, extent and behavior of LNAPL contamination in the subsurface. The foundation of this work is commonly called the LNAPL Conceptual Site Model (or "LCSM").

While a detailed description and discussion of all technical concepts, terms, and metrics in this area is beyond the scope of this document, certain items warrant mention:

6.1 Soil Saturation Concentration or "C_{sat}"

OHM within LNAPL released to the environment will partition into soil organic carbon, soil pore water, and soil air spaces, based upon the properties of the OHM and the soil. Eventually, an equilibrium condition will be established. Mathematical models and empirical data can be used to calculate/estimate this equilibrium condition, and resultant concentration levels. These equilibrium levels represent a "saturation" concentration, in that no additional contaminant molecules can be accommodated in the soil organic carbon, soil pore water, or soil air space. Accordingly, a measured concentration in excess of these saturation levels is suggestive of the presence of an LNAPL (i.e., a separate phase of OHM not sorbed/dissolved/vaporized).

For most LNAPL sites, the most important data set in this regard is for the concentration of hydrocarbons (or other LNAPL materials) in soil, as this is the media compartment where most of the partitioned mass will generally reside. Soil Saturation Concentration values (C_{sat}) have been developed by researchers for a number of common LNAPL materials and soils. A helpful summary tool in this regard published by the Massachusetts LSP Association is provided in **Figure 5**. This graphic indicates that for most common LNAPLs, a concentration of OHM (e.g., Total Petroleum Hydrocarbons) in soil above about 100 mg/kg (C_{sat}) indicates the likely presence of LNAPL.

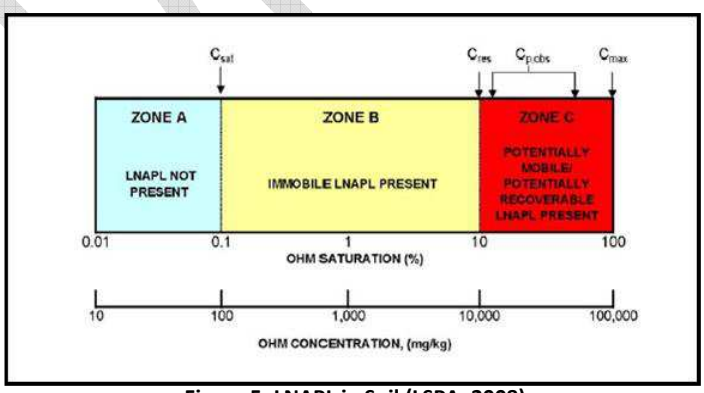


Figure 5: LNAPL in Soil (LSPA, 2008)

The idea that LNAPL can be present in a soil with as little as 100 mg/kg (or less) of hydrocarbons may come as a surprise to many people who have traditionally understood LNAPL to be present only if it is visually observed as droplets in soil or groundwater.

6.2 LNAPL Saturation and Residual Saturation

LNAPL Saturation refers to the amount of LNAPL contained in a volume of subsurface porous media at a given point in time, usually measured as the percent of void space filled. In the near-term aftermath of a significant release of LNAPL to the environment, this value will generally be no more than 70% for coarse, pervious soils, and significantly less in fine grain soils.

An important sub-universe of LNAPL Saturation is *LNAPL Residual Saturation*. Similar to LNAPL Saturation, it is expressed in terms of percent, but can also be converted to units of mg/kg, to express an *LNAPL Residual Concentration* value. It is important to note, however, that there appear to be subtle variations in the exact meaning, measurement, and application of this term and metric in available literature.

Comment [WS9]: Why doesn't the guidance go into more detail as to the options available to determine a site specific residual concentration value(s)? Literature gives a lot of weight to this parameter and the guidance appears to downplay it, suggesting using look up values that are very conservatively compared to soil data.

Basically, LNAPL Residual Saturation/Concentration is meant to describe the amount of LNAPL that will be immobile in subsurface soils, and, by implication/extension:

- the *maximum* level of LNAPL that can exist in soil and not be mobile; and
- the *minimum* level of LNAPL that will remain in soil after the completion of conventional remedial recovery efforts (i.e., it is theoretically not possible to get the site any cleaner using these technologies).

Various researchers have published values for these metrics. It can however be difficult to ascertain the assumptions and conditions inherent in these presentations to ensure an "apples to apples" comparison. Of particular concern are:

- whether the data/values apply to the Vadose Zone or the Saturated Zone (some researchers have maintained that these values are somewhat or even substantially higher in the Saturated Zone);
- the amount of LNAPL that was present or was assumed at a site (large amounts of LNAPL – as observed in the oil industry – will "push" LNAPL deep into soil void spaces, which will result in high LNAPL Residual Saturation values not relevant to environmental LNAPL applications).

6.3 LNAPL Transmissivity (T_n)

Comment [WS10]: See comments in transmitting email.

LNAPL Transmissivity (or T_n) is a measure of how much and how quickly LNAPL can flow through soil, and it has become a popular metric as an indicator of LNAPL "recoverability." T_n values, expressed in units of ft^2/day, are determined on a site-specific basis using recovery/bail-down data from wells installed through an LNAPL smear zone. Results can vary with seasonal water table fluctuations, and familiarity with hydrogeology or sub-surface engineering may be necessary to obtain and apply these data in a competent manner.

The LNAPL Transmissivity metric provides a discrete numerical value that: (1) has nationwide regulatory precedent and acceptance; (2) has been confirmed and/or endorsed by a number of researchers; and (3) can indicate a point at which recovery (or further recover) of LNAPL may be considered "infeasible. The API and ASTM T_n methods listed in Section 13.0 – which include a method for direct-push micro-wells - are among the more recognized for determining LNAPL Transmissivity.

Comment [WS11]: ASTM E2856 assumes the tests are conducted in 2 to 4 inch diameter wells. Section 5.2.7.4?

Regulatory programs in a number of states have closed or granted no further action status to sites that have demonstrated or achieved a T_n value of between 0.1 and 0.8 ft^2/day.

Comment [WS12]: These values apply to gravity systems and you might want to caution that they may not be appropriate for site settings warranting considerations of more aggressive approaches discussed in Section 10.0.

7.0 APPROACHES TO EVALUATE THE OCCURRENCE/MOBILITY OF LNAPL

The simplest indicators of the presence of LNAPL are visual observations of LNAPL/LNAPL discharge in structures, utilities, excavations, water bodies and/or wells. While such observations can confirm the existence of mobile LNAPL at a site or portion of a site, they cannot rule out the existence of mobile or potentially mobile LNAPL in other areas. To accomplish this objective, proactive steps must be taken to search for LNAPL. Traditional approaches in this regard typically focus on the advancement of subsurface borings, followed by the installation of monitoring wells and/or retrieval and subsequent evaluation of core samples. While many practitioners rely upon on monitoring wells to detect and evaluate LNAPL, others, concerned with perceived anomalies in well gauging data, advocate an approach focused primarily on the testing of soil/core samples.

Each approach has its own benefits and limitations, however, *both* can and usually do add value to characterizing LNAPL sites and assessing LNAPL behavior using LCSM/FFPM principles.

7.1 Use of Monitoring Well/Groundwater Data

Monitoring wells have been used for decades to document and evaluate the presence of LNAPL at contaminated sites. Until recently, however, these data have been widely misunderstood and misapplied.

Most researchers now believe that while observed/apparent LNAPL thickness in a well provides an approximation of the amount of *potentially* mobile LNAPL in the surrounding formation, this metric – in and of itself - is not a reliable indicator of the *actual* amount, mobility, or recoverability of LNAPL. In general, the observed/apparent thickness of LNAPL in a well exaggerates the amount of LNAPL that is in fact mobile and recoverable, especially in fine-grained soils.

Further complicating matters are fluctuating groundwater levels, which often lead to increased LNAPL thickness in wells during a low or falling water table condition. Some researchers have suggested that this effect is more pronounced in coarser-grained soils, because LNAPL drains more freely from larger pore spaces when transitioning from a two phase LNAPL-water system to a three phase LNAPL-water-air system.

Comment [WS13]: Also discuss well diameter influence?

The utility and limitations of monitoring well data are further summarized below:

Benefits

- While LNAPL well thickness measurements are not a reliable indicator of the amount, mobility, or recoverability of the LNAPL at a site, the presence of measurable LNAPL, regardless of thickness, in an excavation, boring or monitoring well does have important meaning: It indicates OHM concentrations are high enough to exist as separate-phase OHM and mobile enough as a separate-phase to migrate at least a short distance. Monitoring well installation is common, cost-effective, and necessary in any event at virtually all sites to characterize groundwater quality (e.g., dissolved phase contamination) as well as LNAPL physical properties used in applying FFPM/LCSM principles (e.g., density, viscosity). Moreover, permanent monitoring well installations allow for temporal monitoring programs over time to better characterize dynamic conditions (e.g., seasonal water table fluctuations).
- Monitoring well installations can be used to evaluate and/or institute LNAPL recovery (e.g., one time or long-term multiphase extraction efforts).
- When installed correctly (e.g., screen intervals extending through the entire smear zone into the water table), monitoring wells may be representative of a much greater area/volume of a formation than discrete cores or soil samples obtained from within the same zone.
- In the last several years, a number of regulatory agencies and other organizations have begun to publish guidelines on LNAPL characterization based upon LCSM/FFPM principles, most notably Texas, Alaska, British Columbia, ITRC, API, ASTM, among others listed in Section 13.0. All involve the use of LNAPL measurements in monitoring wells.

Limitations

- Many monitoring wells may not have been properly installed, developed, or maintained, which can lead to erroneous or unreliable results.
- Using well data and testing results for some of the more detailed analyses and determinations (e.g., recoverability and saturation distribution profiling) often involve complex calculations and/or computer modeling.
- LNAPL thicknesses may differ significantly in neighboring wells, possibly due to the inherent heterogeneities that limit any approach, and/or issues with well construction and maintenance.
- Uncertainties continue to exist on the affects of well diameter and installation techniques on representativeness and data comparability.

7.2 Use of Soil Borings/Core Samples/OHM Concentration Data

Similar to groundwater monitoring wells, soil borings have also been used for decades to evaluate LNAPL contaminated sites. Traditionally, these LNAPL characterization efforts have focused on obtaining and examining core samples and/or obtaining and quantifying LNAPL or LNAPL constituents in soil samples. The development of specialized direct push technologies incorporating Laser Induced Fluorescence (LIF), Membrane Interface Probes (MIPs), and Cone Penetrometer Technology (CPT) have

added further capabilities in this area, as have approaches to more fully characterize undisturbed core samples to obtain site-specific information on LNAPL saturation and mobility.

The biggest limitations with the use soil cores and/or samples are concerns over representativeness. Even at sites without fill and with relatively uniform soil conditions, heterogeneities and macro-features can create LNAPL "fingers" which are detectable only by a robust boring program. The relatively small volume and representativeness of soil cores are further reduced in cases where characterization relies upon OHM soil concentration data, given the small size of soil samples that are analyzed (e.g., typically only 10 grams), as depicted in **Figure 6**.

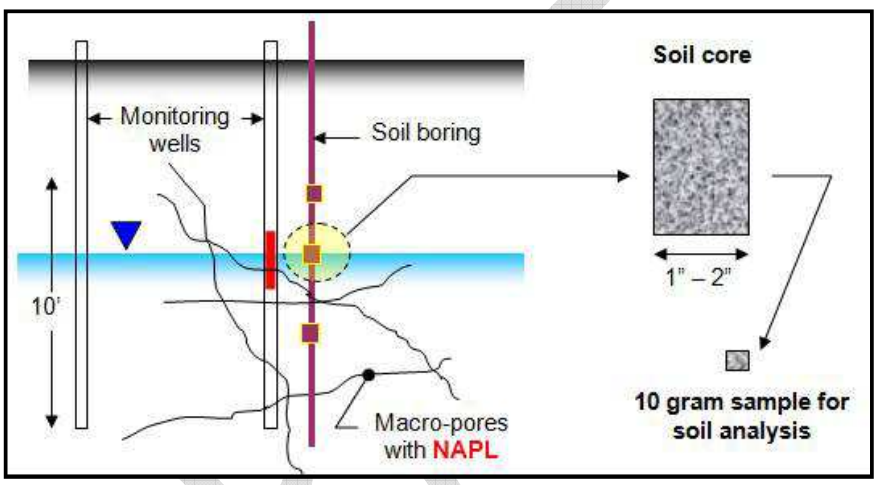


Figure 6: Representativeness Concerns for Soil Samples

The utility and limitations of approaches that rely on soil borings are further summarized below:

Benefits

- Actual site-specific soil data (e.g., TPH) often have already been obtained (and hence are available at no additional cost).
- Inexpensive and reliable field test methods are available to test for common LNAPL constituents (e.g., TPH).
- Soil data can provide a direct vertical profile of LNAPL saturation which exists in zones of variable saturation throughout the vertical column, including the Vadose Zone and the smear (or fluctuating) zone within the water table itself, where the highest LNAPL saturations usually exist.
- Soil sampling can provide a direct measure of physical soil properties necessary for applying FFPM/LCSM principles (e.g., porosity, grain size distribution and density).
- Comparing soil data to residual saturation is a simple indicator of potential LNAPL mobility.

Limitations

- A substantial amount of core/soil data may be needed to adequately characterize a site.
- Soil boring/sample data is specific to a point in time, and cannot be used to monitor variations in LNAPL conditions over time, which can be a key issue in the evaluation of mobility.
- Representative core samples for quantitatively evaluating LNAPL saturation conditions (particularly in the Saturated Zone) can be difficult and costly to obtain.

Comment [WS14]: Add another bullet saying that it is difficult to get LNAPL properties.

8.0 LINES OF EVIDENCE FOR LNAPL OCCURRENCE, MOBILITY, AND RECOVERABILITY

In Massachusetts, the fundamental nature of FFPM science combined with our tens of thousands of heterogeneous LNAPL sites - usually having shallow and seasonally varying groundwater elevations and/or decades-old urban development remnants - creates an unavoidable degree of complexity and uncertainty. Therefore, in many cases, *there may be no single definitive compliance criterion*. Rather, *the best evaluation of environmental protection* using this science often *depends on multiple lines of evidence*, which collectively form an improved and more informed professional opinion.

Below are summaries of the most widely acknowledged and simplest Lines of Evidence with regulatory precedent which can and should be used to assess LNAPL behavior for MCP-specific purposes. References for all of these Lines of Evidence (as well as others that also are suitable but more complex) are provided in Section 13.0, and familiarity with these references is recommended.

8.1 Release Date and Volume, LNAPL type, soil type

Basic and easily available information can provide a Line of Evidence in the evaluation of LNAPL occurrence and mobility/stability:

Release Date and Volume: Most LNAPL releases generally approach a condition of Macro-scale stability (often for both the LNAPL plume as well as the dissolved groundwater plume) within 1 to 2 years from when the release was terminated, absent preferred flow paths. It is informative to know the date of the release termination, at least to the extent of whether the release is "new" (e.g., less than two years) or "old" (e.g., more than five years). In addition, all other factors being equal, larger releases spread and migrate more than smaller releases.

LNAPL Type: LNAPL viscosity is inversely proportional to its mobility (a principle of Darcy's Law.) Therefore, more viscous LNAPLs such as No. 4 and No. 6 oil are less mobile than diesel or gasoline in similar soils under similar conditions.

Soil Type: Because soil permeability is proportional to grain size, LNAPL flows more easily through larger grained soils than smaller grained soils. Therefore, absent preferred flow paths, LNAPL releases to low permeability/fine grained soils, such as clay, will migrate less than identical releases to coarse sand under the same conditions. Soil type also significantly affects pore entry pressures and residual saturation. Soil grain size testing (ASTM sieve analysis) and

classification (Unified Soil Classification System or USCS) are usually inexpensive and should be considered, as appropriate.

Comment [WS15]: Add "using a standard system

8.2 Soil Concentration Data

In concept, if the concentration of OHM in soil does not exceed its Soil Saturation Concentration (C_{sat}), LNAPL will not be present. Even if LNAPL is present, it will not, in theory, be mobile if the LNAPL concentration (e.g., TPH) in soil is less than its Residual Concentration (C_{res}) value. When used properly, this comparison can be an inexpensive and valuable line of evidence for assessing LNAPL stability and recoverability.

One of the most widely referenced collections of C_{sat} and C_{res} data is by Brost et. al., in API Soil and Groundwater Bulletin No. 9, June, 2000. A summary table from this publication is reproduced, in part, in Table 1. As can be seen, C_{res} values reported in literature can vary significantly, even for the same petroleum product in similar soil types. This is reflective of the various assumptions/parameters/test conditions used to develop these values.

Reported values for Residual LNAPL Saturation often over-estimate values seen at MCP LNAPL sites, sometimes by orders of magnitude. This happens because Residual Saturation is directly proportional to Initial LNAPL Saturation, and many of the literature values reflect conditions in oilfield petroleum reservoirs where depths, pressures and initial oil (or LNAPL) saturations far exceed those at typical shallow environmental LNAPL sites.

For this reason, absent definitive knowledge on the origin and relevance of a published metric, only the most conservative values should be used when applying these data to MCP sites. Moreover, even when applying the most conservative values, it is important to carefully considered the representativeness of existing site data, given site/soil heterogeneity issues, sampling procedures, and small (e.g., 10 gram) sample sizes.

Although soil concentration data alone may not be sufficient to rule out the presence of mobile LNAPL at most sites, a robust data set with all soil concentration levels well below conservative Residual Concentration values would be a significant line of evidence in support of such a finding.

8.3 Product Thickness Measurements (Spatial and Temporal)

Possibly the most direct, reliable and simplest tool for demonstrating LNAPL (and dissolved phase) plume stability is with the use of groundwater monitoring wells. Defining the LNAPL "footprint" and demonstrating that it is not expanding are requirements in the 2014 MCP amendments. Valid use of these data as a Line of Evidence depends on: (1) proper well installation techniques (e.g., well screen intervals extending through the entire smear zone into the lowest water table elevation); (2) an adequate number and spatial distribution of wells to surround and define the "footprint" boundary; and (3) adequate sampling/gauging frequency to account for seasonal groundwater table fluctuations, which can affect the measured thicknesses (and the occurrence) of LNAPL significantly.

While data from a low and high groundwater table condition may be sufficient to rule out a LNAPL mobility issue, an adequate sampling frequency to evaluate and document the stability of a significant LNAPL plume is generally quarterly sampling/gauging over a two-year period, with events occurring at

Table 1: C_{sat} and Residual Saturation (C_{res}) Values in Soil (API, 2000)

LNAPL	Soil Type	Theoretical	Measured	
		$C_{sat.\ soil}$ (mg/kg)	S_r (cm^3/cm^3)	$C_{res.\ soil}$ (mg/kg)
Gasoline	coarse gravel	57	0.01	1,000
Gasoline	coarse sand and gravel	102	0.01	1,697
Gasoline	medium to coarse	143	0.02	3,387
Gasoline	fine to medium sand	215	0.03	5,833
Gasoline	silt to fine sand	387	0.05	10,000
Middle distillates	coarse gravel	2	0.02	2,286
Middle distillates	coarse sand and gravel	4	0.02	3,879
Middle distillates	medium to coarse	5	0.04	7,742
Middle distillates	fine to medium sand	9	0.06	13,333
Middle distillates	silt to fine sand	18	0.1	22,857
Fuel oils	coarse gravel	2	0.04	5,143
Fuel oils	coarse sand and gravel	4	0.05	8,727
Fuel oils	medium to coarse	6	0.08	17,419
Fuel oils	fine to medium sand	9	0.1	30,000
Fuel oils	silt to fine sand	18	0.2	51,429
Light oil & gasoline	soil	9	0.18	40,800
Diesel & light fuel oil	soil	-	0.15	34,000
Lube & heavy fuel oil	soil	-	0.2	53,067
Gasoline	coarse sand	106	0.15 to 0.19	24,954 to 31,609
Gasoline	medium sand	106	0.12 to 0.27	19,767 to 44,476
Gasoline	fine sand	106	0.19 to 0.6	31,065 to 98,100
Gasoline	graded fine-coarse	106	0.46 to 0.59	80,500 to 103,250
Mineral oil	Ottawa sand	3	0.11	20,116
Mineral oil	Ottawa sand	3	0.14	25,602
Mineral oil	Ottawa sand	3	0.172	31,454
Mineral oil	Ottawa sand	3	0.235	42,975
Mineral oil	glacial till (NA)	3	0.15 to 0.28	13,500 to 25,200
Mineral oil	glacial till	3	0.12 to 0.21	10,800 to 18,900
Mineral oil	alluvium (NA)	3	0.19	61,071
Mineral oil	alluvium	3	0.19	61,071
Mineral oil	loess (NA)	3	0.49 to 0.52	154,000 to 163,800
Paraffin oil	coarse sand	-	0.12	27,000
Paraffin oil	fine sediments	-	0.52	147,086
Paraffin oil	Ottawa sand	-	0.11 to 0.23	20,382 to 42,618
O-Xylene	coarse sand	143	0.01	1,936
Gasoline	sandy loam	-	0.42 to 0.59	94,500 to 132,750

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both high and low water table conditions. Determining adequate spatial coverage depends on the quality of site characterization and the site Conceptual Site Model, including the presence of heterogeneities and/or preferred flow paths.

8.4 Pore Entry Pressure Correlations

A well-known and referenced correlation is the relationship between soil type, LNAPL type, and "pore entry pressure" (which equates to the height of a column of LNAPL). Exceeding this pressure (or measured height of LNAPL) can indicate potential LNAPL migration. While "real world" site conditions are variable, this theory is sound and its use (with appropriate caution) as a Line of Evidence is simple and has regulatory precedent. Examples and applications of this approach have been published by Golder Associates (2008).

8.5 Recovery Decline Curve Analysis

Decline Curve Analysis is a formal and systematic method of recording and interpreting LNAPL well removal quantities over time (by bailing or pumping) to estimate the limit of recoverability. LNAPL recovery rates typically decline over time, as the volume of LNAPL in the ground decreases and its saturation approaches Residual Saturation. Eventually, an asymptotic limit of recovery or "point of diminishing returns" can be observed by graphs of: (1) recovery rate versus time; or (2) recovery rate versus cumulative recovery. Random periodic bailing of small quantities of LNAPL from a monitoring well may not generate enough data to perform this analysis, but if a trend can be observed, it could provide a valuable Line of Evidence.

Appendix I provides a LNAPL Screening Checklist and a Lines of Evidence Matrix that indicates the applicability of the different Lines of Evidence to evaluating the MCP LNAPL requirements for a Permanent or Temporary Solution.

9.0 FEASIBILITY EVALUATIONS

The 2014 Amendments to the MCP have established two new NAPL-related feasibility requirements:

- Per 310 CMR 40.1003(7)(a)(2.), in order to achieve a Permanent Solution, all NAPL with Micro-scale Mobility at a site must be removed if and to the extent feasible.
- In cases where a Permanent Solution cannot be achieved due to the presence of Non-Stable NAPL, in order to achieve a Temporary Solution, all Non-Stable NAPL and NAPL with Micro-scale Mobility at a site must be removed and/or controlled if and to the extent feasible (310 CMR 40.1003(7)(b)).

Comment [WS16]: I am still struggling with this phrase. Get the if feasible part. I don't understand the extent part. Does extent mean the amount to which something is or is believed to be feasible or is it partial removal? Do you first evaluate if it is feasible to remove it all and if it isn't do you evaluate if it is feasible to remove some? It is always going to be feasible to remove some. Or if it isn't feasible to remove it all you are done evaluating?

In both cases, feasibility evaluations must be conducted in accordance with the provisions of 310 CMR 40.0860, which specifies the procedures and criteria used to conduct feasibility evaluations at all MCP sites. Under this process and paradigm, a feasibility evaluation considers technical practicability *and* economics, integrated into a benefit/cost evaluation.

The benefits involved in removing LNAPL from the environment are clear: eliminating or reducing the possibility of future separate-phase mobility, eliminating or mitigating a potential source/continuing source of groundwater, soil gas, and indoor air contamination; eliminating or mitigating risks to human

and ecological receptors. However, the costs of achieving these objectives can be high and at times disproportionate to the benefit, as documented by historic examples of costly LNAPL recovery systems that were only able to extract a few gallons of petroleum.

While acknowledging the inherent difficulties and uncertainties in these areas, under certain conditions, the need and benefit of attempting and continuing LNAPL recovery are high, and outweigh even significant costs. This includes sites where LNAPL:

- Is Non-Stable and/or
- is creating a vapor pathway that presents a significant risk of harm to human health, safety, or public welfare.

It is MassDEP's position that the feasibility evaluations conducted at these and similar sites of high concern consider the full range of NAPL remedial options, including excavation and conventional (hydraulic/vacuum recovery) technologies as well as alternative/innovative technologies (e.g., ISCO, soil flushing, soil heating), and that remedial operations deemed to be feasible are maintained for as long as it is necessary to achieve MCP standards.

In contrast to the above, many sites contain relatively small quantities of oil or waste oil LNAPL, where (i) the LNAPL has Micro-scale Mobility (only), (ii) the LNAPL is not creating vapor pathways of concern nor posing any other significant exposure threats, and (iii) the Source Elimination and Migration Control requirements of the MCP have otherwise been achieved. When these lesser concerns are combined with the long-term biodegradation potential of petroleum LNAPLs, the benefit/cost considerations are significantly altered. At these sites, it is MassDEP's position that:

- Feasibility evaluations may be limited to excavation of hot spots and conventional hydraulic/vacuum extraction technologies, although parties are encouraged to consider alternative techniques, where appropriate, for effectiveness and cost-effectiveness. Moreover, these recovery operations need not be attempted at sites where the amount and type of petroleum products and hydraulic conductivity of site soils suggest that only *a de minimis* quantity of LNAPL is likely to be recovered.
- Where instituted, remedial operations at these sites may be terminated when LNAPL Transmissivity decreases to a de minimis level and/or when asymptotic recovery conditions are observed and documented.

Comment [WS17]: This may not be a good criteria for non-gravity system end point. How will this be determined other than by reduced recovery?

10.0 LNAPL RECOVERY

Conventional LNAPL recovery systems typically involve hydraulic and/or vacuum extraction technology with standardized "off the shelf" modular components. These include:

- Floating LNAPL Extraction/Skimming
- Dual Pump Liquid Extraction
- Soil Vapor Extraction

- Dual/Multi-phase Extraction

Excavation of "hot spots" can also be an effective conventional approach, especially for more viscous oils.

The selection of any particular system/combination of systems is dependent on a number of factors, including LNAPL fluid properties, soil properties, site conditions, remedial timeframes, and site/logistical constraints. There are many excellent references available on the evaluation/design/operation of these systems, including those cited in Section 13.0

In addition to these conventional approaches are a number of alternative/innovative technologies that often rely upon chemical transformations and/or modifications of LNAPL or media properties to enhance and maximize LNAPL recovery or destruction. These include:

- Soil Flushing;
- Steam/Hot Air Injection
- Electrical Resistance/Radio Frequency Heating
- In-Situ Oxidation (ISCO);

While often (though not always) more costly than conventional systems, these technologies can generally achieve a higher level of LNAPL recovery or control.

11.0 ACTIVITY AND USE LIMITATIONS (AULs)

A Permanent Solution may be achieved at a disposal site where some NAPL remains in the environment, provided a level of No Significant Risk has been achieved, Non-Stable LNAPL is not present (i.e., the overall LNAPL footprint is not expanding) and all LNAPL with Micro-Scale Mobility has been removed to the extent feasible. As required at 310 CMR 40.1012(2)(d), where the remaining LNAPL exhibits "Micro-scale Mobility", an AUL is required as part of the Permanent Solution.

Comment [WS18]: If and to the extent feasible

The purpose of the AUL where there is NAPL with Micro-scale Mobility is to provide notice to the current and future property owners about the presence of NAPL so that appropriate measures can be taken to manage future exposure to the NAPL (e.g., to protect construction workers and/or to establish management plans for any NAPL that may flow into future excavations in the event of construction activities in the area of the NAPL that exhibits Micro-scale Mobility).

It is MassDEP's position that the presence of LNAPL in a groundwater monitoring well at an observed thickness equal to or greater than ½ inch is evidence of NAPL with Micro-Scale Mobility, necessitating the implementation of an AUL. This ½ inch metric applies to the maximum observed thickness in any monitoring well at a site during the 12 month period preceding the filing of a Permanent Solution, particularly during a period of a low or falling groundwater table.

At those sites where Micro-scale Mobility does not exist, an AUL could still be necessary to address other exposure/risk concerns related or unrelated to any LNAPL remaining at the site.

12.0 RECOMMENDED SIMPLIFIED APPROACH FOR PETROLEUM LNAPL SITES

The vast majority of LNAPL sites in Massachusetts are petroleum, with the most common petroleum spills being gasoline, diesel/#2 fuel oil, jet fuel, #4-#6 fuel oil, (automotive) waste oil, and lubricating oil. A relatively small number of LNAPL sites are chemical in nature (e.g., toluene). The simplified approach described in this section pertains only to oil and waste oil LNAPL. While voluntary, absent unusual site-specific factors, this approach will satisfy MCP performance standards to assess and address LNAPL mobility and recoverability. Parties electing to use other approaches are required to demonstrate that such techniques are scientifically valid.

12.1 Simplified Approach: Basis and Limitations

The recommended simplified approach consists of a series of investigatory and/or remedial steps with specified levels of efforts, data needs, and evaluation metrics. All decisions and conclusions shall be based on a preponderance of the evidence, i.e., that a condition is more likely than not.

To maximize its utility and application, the specific procedures and metrics incorporated into this simplified approach are designed to be applicable and protective at the vast majority of LNAPL sites. However, there may be unusual site conditions where these guidelines may not be sufficiently protective. The Department may, upon review of the use of this approach in such cases, require additional documentation and/or response actions to demonstrate that the requirements of the MCP are met.

The overall approach is summarized in **Figure 6**. Additional details on individual elements are provided below in Sections 12.2 though 12.8.

12.2 Simplified Approach: Characterization Methods and Level of Effort

The simplified approach relies upon site history research, observations, LNAPL thickness in groundwater monitoring wells, and conservative metrics obtained or adapted from other regulatory agencies and researchers.

- Site history information must be obtained for the area under investigation, including information and data on past storage or uses of petroleum products and petroleum spills.
- The installation of semi-permanent monitoring wells is required to allow repeated gauging over time. These monitoring wells must be screened across the groundwater fluctuation zone in overburden unconfined formations. After installation, all groundwater monitoring wells must be thoroughly developed.
- LNAPL thickness measurements must be made using an oil/water interface probe to eliminate accuracy concerns associated with measuring the thickness of LNAPL observed in a bailer. Each time a well is gauged for LNAPL thickness, the elevation of the groundwater/LNAPL interface must be observed and recorded, to ensure that the well screen is not above the groundwater table. Following a gauging event, at least one well volume of any LNAPL must be evacuated from the well and properly disposed or recycled.

Comment [WS19]: Are you saying you remove a volume equal to the area of the cross section of the well times the LNAPL thickness as a volume or are you looking for the more traditional volume of oil and water contained within the entire well length?

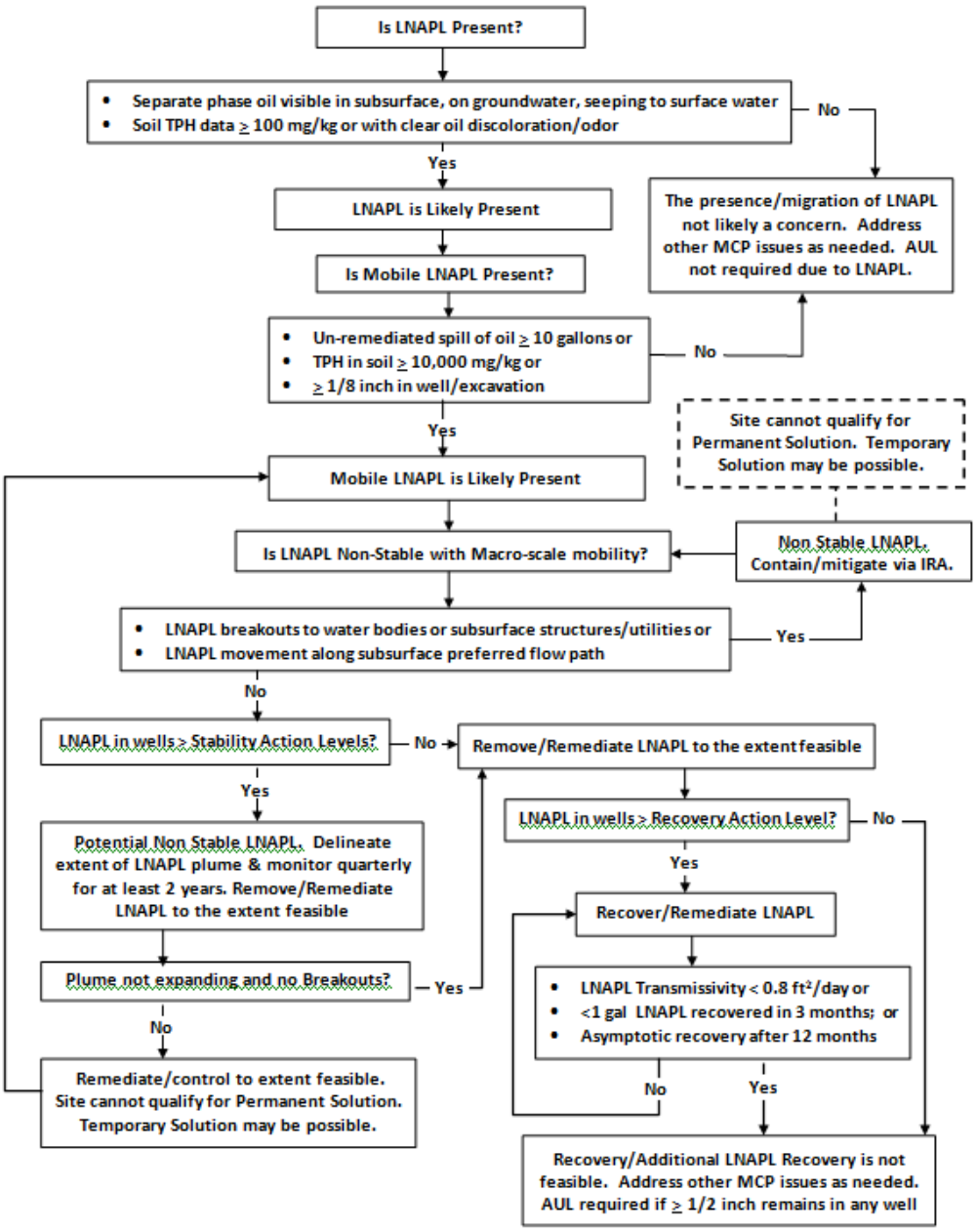

Figure 7: Recommended LNAPL Simplified Approach

- Baring unavoidable site constraints, the spacing of a monitoring well network must be in the range of 15 to 30 feet within the core and at the perimeter of the LNAPL plume. The placement of wells shall reflect the existence of sensitive LNAPL receptors, which include surface waters and buildings, sumps, utilities/subsurface structures within the groundwater fluctuation/LNAPL smear zone.
- At sites where Non-Stable LNAPL is present or potentially present, wells within and just downgradient of an identified LNAPL plume must be gauged on at least a monthly basis for a minimum of two years. At sites where Non-Stable LNAPL is not present or potentially present, wells within and just downgradient of an identified LNAPL plume must be gauged on at least a quarterly basis for a minimum of one year.
- For the purpose of obtaining soil data for comparison to Residual Soil Concentration metrics, the use of a GC/FID "Total Petroleum Hydrocarbon (TPH)" test method is acceptable for non-gasoline LNAPLs, as long chromatographic integration is to baseline, and the carbon range covered is at least C_9 through C_{24} for diesel/#2 Fuel, and C_9 thorough $_{36}$ for heavier oils. A "TPH" value can also be obtained by summation of Target Analytes and hydrocarbon ranges in the Massachusetts Extractable Petroleum Hydrocarbon (EPH) method.

Comment [WS20]: On center? Should it be a function of the size of the release area impacted? Really don't need that close a spacing if you have a large impacted area.

Comment [WS21]: As long as

12.3 Simplified Approach: Determining Whether LNAPL is Present

Visual observation of any amount of oil or waste oil in a subsurface excavation or monitoring well, or seeping into a proximate surface water body or building structure, is proof of the presence of LNAPL at a disposal site. Additionally, for the purposes of complying with this approach, a concentration of total hydrocarbons in soil in excess of 100 mg/kg (dry weight) shall be assumed to constitute proof of the likely presence of LNAPL.

At sites where LNAPL is not visually observed, proactive steps should be taken to determine its possible presence if:

- soils at the site are discolored with a clear petroleum odor;
- the site was previously used to store more than household quantities of petroleum products (i.e., quantities of petroleum use and storage beyond a home heating oil tank, and gasoline/oil used for lawn/yard/car maintenance);
- credible evidence exists that a release of an LNAPL occurred or likely occurred at the site; or
- available groundwater, soil gas, or indoor air data at the site exceed MCP reporting thresholds for petroleum constituents.

These proactive investigatory steps may include soil borings, test pits, groundwater monitoring wells, and/or soil cores/samples. The level of effort in this regard should reflect the nature and quantities of petroleum products of interest, site complexity, and presence of sensitive receptors, consistent with the Conceptual Site Model.

If it is determined that LNAPL is not present at a site, other MCP concerns and requirements must be addressed as applicable.

12.4 Simplified Approach: Determining Whether Mobile LNAPL is Present

At sites where LNAPL is present or likely present, investigatory actions must taken to ascertain its potential mobility. For the purposes of this approach, an LNAPL is or is likely to be mobile if:

Comment [WS22]: Must be taken

- A spill of a total of 10 or more gallons of oil/waste occurred or likely occurred at the site in the previous 10 years which was not promptly and adequately remediated via removal of the LNAPL, applied sorbents, and/or impacted soils;
- Total hydrocarbons in soil exceed 10,000 mg/kg (via a TPH test method or via the summation of fractions and Target Analytes from a VPH or EPH test method); or
- Equal to or greater than 1/8 inch of LNAPL is identified any groundwater monitoring well or in any excavation at the site.

Comment [WS23]: Identified in any

A finding that mobile LNAPL is present or likely present at a site necessitates an evaluation of its mobility per Section 12.5 and recoverability per Section 12.6

12.5 Simplified Approach: Determining Whether Mobile LNAPL at a Site is Non-Stable

At sites where mobile LNAPL is present or likely present, initial investigatory actions must be promptly taken to determine whether it is Non-Stable.

These initial efforts shall focus on proactive and systematic observations in proximate (< 50 – 100 feet) buildings, utilities, and surface water bodies. At sites at which a significant (>100 gallons) release of LNAPL had occurred within the previous 2 years, subsurface explorations must be undertaken to determine if the LNAPL plume is expanding. These explorations must include, as appropriate, the advancement of soil borings, installation of groundwater monitoring wells, and/or excavation of test pits.

As a result of these efforts, or any other available observational/site assessment data, an LNAPL present in the subsurface shall be deemed Non-Stable if:

- It is discharging or periodically discharging to a Surface Water;
- It is discharging or periodically discharging into a building, including drainage sumps within such building;
- It is discharging or periodically discharging into a utility structure, including manholes, vaults, and piping/conduits;
- It is observed to be present within a preferred flow path, including in the pervious backfill of utility conduits or in bedrock fracture; and/or
- Its footprint is expanding as described below.

For the purposes of this approach, “periodically” means any discharge that occurs one or more times within a 12 month period.

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Even when LNAPL is not actively discharging to surface waters or other receptor of concern, it may still meet the MCP definition of Non-Stable if it is moving as a separate phase through subsurface porous media (i.e., the LNAPL footprint is expanding, and Macro-Scale stability has not been achieved). This is most likely to occur when the amount of oil/waste oil within a subsurface LNAPL plume is sufficient to overcome pore entry pressures within adjacent impacted media. While not a perfect instrument, the measured thicknesses of LNAPL in a monitoring well network is generally the most readily available surrogate to judge whether this condition may exist, and researcher have developed well thickness criteria as a means to evaluate this concern.

Comment [WS24]: Not an MCP term or end point

Comment [WS25]: researchers

Accordingly, for the purposes of this approach, a condition of Non-Stable LNAPL may exist at a site if, during the course of investigating an LNAPL spill or obtaining data for other site assessment purposes, LNAPL is observed/measured in any boring, excavation, or groundwater monitoring well at any time at a thickness equal to or greater than the Stability Action Levels contained in **Table 2**.

Table 2: Stability Action Levels (Golder Associates, 2008)

Soil Type*	Characteristic Fraction	Percent Fines (silt and clay)	LNAPL Thickness (inches)
Coarse sand or gravel	> 20% Coarse sand	< 3	**1.2 inch**
Coarse sand or gravel	> 20% Coarse sand	3-10	**2 inches**
Medium sand	Medium sand	< 10	**4 inches**
Fine sand	Fine sand	< 10	**8 inches**
Silty sand	Sand	> 10	**12 inches**

*If soil at a site does not match any of the listed types, judgment shall be used to select an available category and metric that is a reasonably conservative approximation.

If an appropriate Stability Action Level in Table 2 is exceeded, two years of quarterly monitoring is required to determine whether a condition of Non-Stable LNAPL is present. This monitoring effort shall include the installation of additional monitoring wells if:

Comment [WS26]: you are going to wait another two years before you decide if response actions are needed? They most likely won't be needed after two additional years of the LNAPL being in the environment…….

- a thickness value is exceeded by more than a factor of 2 in any well/excavation within 50 feet of a potential subsurface LNAPL receptor if no additional wells are already present in this zone, with potential subsurface LNAPL receptors defined as Surface Waters and building/building sumps and utility structures located within the groundwater fluctuation (LNAPL smear) zone; or
- one or more key monitoring wells in the area of interest are not screened over the water table fluctuation (smear) zone.

LNAPL above the notification threshold at 310 CMR 40.0311(5) shall be reported to MassDEP within 2 hours and above the notification thresholds at 310 CMR 40.0313(1) or (4)(f)3. within 72 hours. All such notifications require the implementation of Immediate Response Actions to assess the condition and, as appropriate, to implement immediate measures to contain the LNAPL and prevent or mitigate exposures. See the Summary of LNAPL-related notification requirements in **Section 3**.0.

Quarterly monitoring of wells shall consist of gauging wells for the present and thickness of LNAPL. Only wells that straddle the groundwater fluctuation (smear) zone have relevance in this evaluation effort. Following each gauging round, at least one well volume of LNAPL must be evacuated from each well, in an attempt to maintain reasonable communication with the surrounding formation.

In addition to gauging monitoring wells, assessment efforts shall also include the inspection of potential subsurface receptors within 50 feet of the presumed edge of the LNAPL plume.

Following this two-year monitoring program, it can be concluded that there is no current indication of Non-Stable LNAPL if:

- Subsurface LNAPL did not discharge to surface waters, buildings, building sumps, or subsurface utility conduits and/or structures; and
- Observed LNAPL thickness levels did not consistently or significantly increase in downgradient monitoring/sentinel wells.

Comment [WS27]: You say that well thickness are not reliable in Section 7.1 and then go on and use the thickness data at very low thickness to support a conclusion that Non-stable NAPL does not exist?

Comment [WS28]: Clarify by using terms Non-stable NAPL or Micro-scale NAPL?

12.6 Simplified Approach: Determining the Feasibility of Removing or Containing Mobile LNAPL

A feasibility evaluation must be conducted in accordance with the provisions of 310 CMR 40.860, as further discussed in Section 9.0.

In applying this simplified approach at sites where the feasibly evaluation is appropriately limited to conventional hydraulic/vacuum LNAPL recovery technologies, the graph contained in **Figure 8** may be used to conclude that such LNAPL recovery efforts are infeasible.

In applying the criteria in **Figure 8**:

- The Hydraulic Conductivity value selected for the site shall be based upon the most pervious/ transmissive soils present within the LNAPL plume. Conservative (i.e., more permeable) values shall be assumed at sites where this determination is based upon soil type, not site-specific testing data.
- The Dynamic Viscosity value (C_p) value may be selected on the basis of the type of oil/waste oil present, with conservative (lower) values assumed when a mixture of products is present or when the identity of the LNAPL is not conclusively established.
- The maximum observed thickness of LNAPL in any monitoring wells over a 1-2 year gauging cycle shall be determined and be used as the basis for determining the thickness level in the graph.
- Values between the indicated inches may be extrapolated, within the range of 0.125 to 5.0 inches.
- A condition of infeasibility may be assumed in cases where the intersection of the Hydraulic Conductivity (cm/sec) and Dynamic Viscosity (cP) values is above the indicated or extrapolated thickness line.

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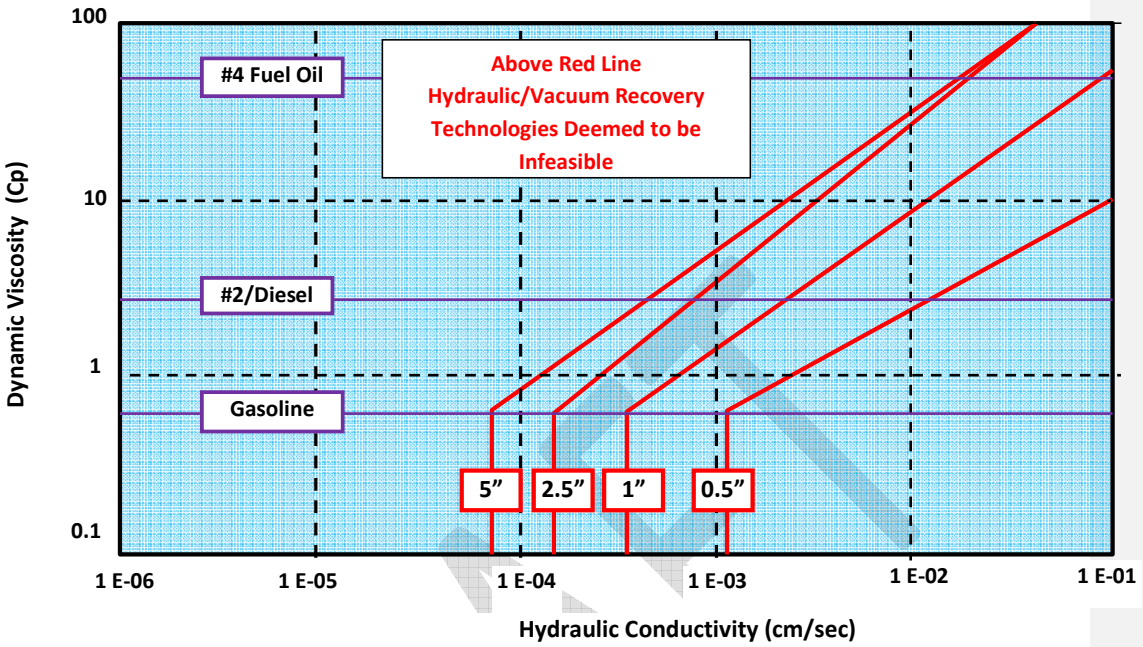

Figure 8: Conditions of Infeasibility of LNAPL Recovery by Conventional Technologies (based on API, 2007)

- Thickness levels less than 1/8 (0.125) inch are deemed to be infeasible to recover for all petroleum products in all media. Under the terms of this simplified approach, it is not possible to conclude that it is infeasible to recover LNAPL at sites where the maximum LNAPL thickness level is greater than 5 inches.

At those sites where remedial actions are not required to address stability, vapor, or other critical LNAPL concerns, a finding that it is not feasible to institute conventional recovery operations may allow the achievement of a Permanent Solution, assuming all other (non-LNAPL) MCP requirements and standards have been satisfied.

12.7 Simplified Approach: Determining when it is No Longer Feasible to Continue Conventional LNAPL Recovery Operations

The continued operation of a properly designed, constructed, and operated conventional LNAPL recovery system can be deemed infeasible if and when:

- The LNAPL Transmissivity value (T_n) in all recovery wells is shown to be less than 0.8 ft^2/day; or
- The total volume of LNAPL recovered at a site is less than 1 gallon in any 3 month period; or

Comment [WS29]: How should this be determined if need at least .5 to 1.0 feet of measured thickness to attempt an in well test?

Comment [WS30]: How about using 25 percent of running average monthly recovery for last six months

- A decline curve analysis of at least 12 months of cumulative LNAPL recovery data demonstrates an asymptotic condition.

At sites where conventional LNAPL recovery operations are being conducted to address stability, vapor, or other critical LNAPL concerns, such a finding would necessitate the need to evaluate and implement alternative/innovative technologies.

At all other sites, such a finding may allow the achievement of a Permanent Solution, assuming all other (non-LNAPL) MCP requirements and standards have been satisfied.

12.8 Simplified Approach: Achieving a Permanent Solution

An LNAPL site can achieve a Permanent Solution if:

- Non-Stable LNAPL is not or longer present, as articulated in Section 12.5;
- LNAPL has been recovered or removed to the extent feasible, as articulated in Section 12.6; and
- all other MCP requirements and standards have been met, including those related to Source Elimination or Control, Migration Control, site characterization and risk assessment.

In accordance with the provisions of 40.1012(2)(d), an Activity and Use Limitation (AUL) is required for sites where a Permanent Solution has been achieved and LNAPL with Micro-Scale Mobility is present. The presence of LNAPL with Micro-scale Mobility shall be assumed if the maximum observed thickness in any groundwater monitoring well was equal to or greater than ½ inch, at any time in the 12 months previous to the filing of the Permanent Solution, including during times of a low or falling water table.

13.0 RECOMMENDED SUPPORTING TECHNICAL REFERENCES

MassDEP's Recommended Supporting Technical References for some of the more comprehensive detailed and technically sound works from other regulatory agencies, organizations and experts are listed below. Familiarity with these references is recommended and may be necessary to properly assess complex LNAPL sites. While MassDEP does not necessarily or explicitly endorse (or even agree with) each and every single conclusion or thesis in these works collectively they clearly represent "accurate and up-to-date methods, standards and practices, equipment and technologies which are appropriate, available and generally accepted by the professional and trade communities conducting response actions in accordance with M.G.L. c. 21E and 310 CMR 40.0000 under similar circumstances" as articulated by the MCP's Response Action Performance Standard 310 CMR 40.0191(2)(b).

MassDEP LNAPL Workgroup
http://www.state.ma.us/dep

Licensed Site Professionals Association (LSPA)
LNAPL and The Massachusetts Contingency Plan Part II; Prepared by: LSPA Technical Practices Committee; July, 2008.
http://www.LSPA.org

MassDEP:
Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the VPH/EPH Approach; Policy #WSC-02-411; October 31, 2002.

Interstate Technology & Regulatory Council (ITRC)

Archived On-Line Classes: http://cluin.org/live/archive/default.cfm?display=all&group=itrc#

LNAPL Training Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface - State of Science vs. State of Practice
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?
http://www.itrcweb.org/Training#LNAPLPart2

LNAPL Training Part 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
http://www.itrcweb.org/Training#LNAPLpart3

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. (API changing web site, use their search box with "Bulletin 9")
http://www.api.org/ehs/groundwater/upload/09_bull.pdf
http://www.clu-in.org/conf/itrc/iuLNAPL/030513_residual.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

American Society for Testing and Materials (ASTM International)

ASTM E2856-13 *Standard Guide for Estimation of LNAPL Transmissivity*
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

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.
http://www.clu-in.org/conf/itrc/iuLNAPL/030513_residual.pdf

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

Johnston, C., Adamski, M., 2005, Relationship Between Initial and Residual LNAPL Saturation for Different Soil Types, 2005 Petroleum Hydrocarbons and Organics Chemicals in Ground Water Conference, Costa Mesa, CA, August 18-19, 2005, Proceedings.
http://www.ngwa.org/_bdc/http___www_ngwa_org/GWOL%20Data_1.aspx?RecordID=653494

Applied NAPL Science Review **"***Applied NAPL Science Review* (ANSR) is a scientific ejournal that provides insight into the science behind the characterization and remediation of non-aqueous phase liquids (NAPLs) using plain English"; Hawthorne, Adamski, Charbeneau, Garg, Johnson, Kirkman, Malander.
http://www.h2altd.com/ansr

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

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APPENDIX I
LNAPL SCREENING CHECKLIST & LINES OF EVIDENCE MATRIX

LNAPL SCREENING CHECKLIST

Date/age of release:
LNAPL type:
LNAPL volume:
Soil Type:
Max Soil TPH range

Do monitoring wells adequately cover the LNAPL footprint?
Spatially:_____ wells/SF
Temporally: _____ sampling events over _____ years
Represent both High and Low water Table elevations
Well completion/screen through entire smear zone into GW table?

Existing soil TPH Data:
Spatially: _____ locations over _____ SF
Vertically: sample depth intervals_____
Samples in Vadose Zone? Smear Zone? GW table?

Have CSM requirements (including LNAPL CSM) been met?

Is the LNAPL plume stable?
Based on what Line(s) of Evidence?

Has LNAPL been "removed if and to the extent feasible?"
Based on what Line(s) of Evidence?

Does LNAPL with Micro-scale mobility remain?
Based on what Line(s) of Evidence?

Is an AUL Required? (1/2 inch criterion exceeded)

Have all other MCP Source Control and risk-based closure requirements been met (including soil, groundwater and vapor phases)?

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LINES OF EVIDENCE	**MCP PERMANENT and TEMPORARY SOLUTION REQUIREMENTS**			
	LNAPL presence & characterization using LCSM	Non-Stable LNAPL (or macro-scale mobility)	LNAPL Removal "if and to the extent feasible"	LNAPL Micro-scale Mobility and AULs
Site/release history, LNAPL type, soil type, TPH data	**X**	**X**		**X**
Product Thickness Measurements (spatial and temporal)	**X**	**XX**		**XX**
Pore Entry Pressure Correlations		**X**		
Recovery "Decline Curve"			**X**	
Transmissivity (ASTM)	**X**		**XX**	
Comparison of TPH to Residual Saturations	**X**	**X**	**X**	
Supporting References	**X**	**X**	**X**	**X**

LINES OF EVIDENCE MATRIX

X indicates the Line of Evidence is relevant in the evaluation of the MCP Performance Standard

XX indicates the Line of Evidence is relevant and favorably weighted in the evaluation of the MCP Performance Standard

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