MEMORANDUM

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SUBJECT: Case Closure Evaluation of Sites with Free Product, Document Number LPR-SRR-03-2012

TO: Elizabeth Lamp, Regional Directors

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Summary:

The Department of Environmental Quality (DEQ) Storage Tank Program oversees the characterization and cleanup of petroleum releases to mitigate risks to human health and the environment. Case Managers frequently make assessment and remediation decisions for release sites where free product is present. This guidance document is an expansion of Section 5.5 of the Storage Tank Program Technical Manual and was developed to assist Storage Tank Program Case Managers in evaluating the feasibility and practicability of free product removal and to recognize when a case can be closed with no increased risk to human health and the environment.

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An electronic copy of this guidance in PDF format is available for staff internally on DEQNET, and for the public on DEQ's website at: http://www.deq.virginia.gov.

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STORAGE TANK PROGRAM

Case Closure Evaluation of Sites with Free Product

DEQ Guidance Document #LPR-SRR-03-2012

(December 28, 2012)

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I. Introduction

Case Managers for the Virginia Department of Environmental Quality (DEQ) Storage Tank Program frequently make assessment and remediation decisions for release sites where free product is present. Section 9VAC 25-580-270 of the Virginia Underground Storage Tanks regulation states that "...owners and operators must remove free product to the maximum extent practicable as determined by the board...." Section 5.5 Free Product Removal of the DEQ Storage Tank Program Technical Manual recommends that regional staff consider the goal of preventing the spread of contaminants into previously uncontaminated areas when deciding if free product removal may be terminated. This section of the manual also recommends that free product be recovered to the maximum extent practicable (MEP) and that the final product thickness be 0.01 feet or less unless continued recovery efforts are not warranted based upon lack of receptors or product mobility.

Recent advances in the understanding of free product behavior have illustrated that in some cases, continued attempts to reduce free product to an arbitrarily measured thickness (e.g. 0.01 ft. or less) in a monitoring well is neither practicable nor even necessary. Even in cases where the presence of product is the only reason for remediation, continued recovery of product beyond a "practicable" achievable thickness may provide little or no positive environmental protection.

The following document, an expansion of Section 5.5 of the Technical Manual, was developed to assist Storage Tank Program Case Managers in evaluating the feasibility and practicability of free product removal and to recognize when a case can be closed with no increased risk to human health and the environment. This guidance will require that the technical data demonstrate that the free product is stable and not migrating and that the associated dissolved phase will not create a risk. This document provides general guidance and a list of resources (Section VII) that DEQ Storage Tank Program Case Managers can use to make these decisions. The resources referenced within this document serve as the basis for, and are intended to be used in conjunction with, this guidance.

This document will use the term LNAPL (light non-aqueous phase liquid) interchangeably with the term "free product."

II. LNAPL

LNAPL typically has been viewed as free-phase petroleum that can be measured in a well or on a water surface. Storage Tank Program Case Managers have typically used 0.01 foot or less of LNAPL in a well as the free product remedial endpoint. However, even when measureable free product is not detected within a well, free product can remain trapped in nearby soils. Depending on site conditions and how conditions can change, this residual LNAPL may remain trapped or become mobile. Therefore, it is important to keep the following in mind:

- The absence of measurable LNAPL in a well does not definitively establish the absence of mobile LNAPL at a site.
- The presence of measurable LNAPL in a well does not definitively establish the size, volume, thickness, or recoverability of LNAPL at the site or in the vicinity of the well.
- The measured LNAPL thickness in a well may not be indicative of the actual LNAPL thickness within the formation.

- The presence of recoverable LNAPL in a well may only indicate that mobile LNAPL exists in the immediate vicinity of that well.
- The observation that LNAPL is no longer accumulating at a significant or appreciable rate in a well may only indicate that the LNAPL in the vicinity of the well is no longer mobile under the present conditions.
- The mass of residual LNAPL remaining in the soil matrix after recovery to the MEP may be orders of magnitude larger than the amount of mobile LNAPL that was recovered at the site.
- LNAPL may spread in many directions not necessarily coincident with groundwater gradients.
- LNAPL migration rates may not be the same as groundwater flow rates.
- Some mobile LNAPL is persistent and can be bailed, but quantities removed may be relatively small. Product bailing alone rarely achieves significant LNAPL recovery.

Free product exists in residual and non-residual (mobile) phases, and staff, RPs, and consultants need to remember that some LNAPL often will remain even after recovery activities. Case Managers should continue to require recovery of free product to the MEP. However, at some point, the site data may indicate that free product has been recovered to the MEP and the remaining free product does not present a risk to human health and the environment. Although the remaining free product may take years to degrade, the low recoverability combined with the low risk posed by the LNAPL source make recovery of remaining free product unnecessary. In such instances, evaluating the site for terminating free product recovery or for case closure is warranted. In order to make an informed decision, the data, called "Lines of Evidence" by the Interstate Technology & Regulatory Council (ITRC 2009b), must demonstrate that the decision to close a case is based on reasonable criteria.

III. Site Characterization and LNAPL Conceptual Site Model

A site characterization is an important step in identifying the presence of LNAPL. Delineation of LNAPL at facilities (typically commercial) with regulated tanks and at other locations with gasoline tanks (typically farm tanks) usually requires more thorough characterization than residential and non-commercial (unregulated) non-gasoline releases. The characterization extent of the latter will be site specific as determined by the staff. Simple visual observations during site work and interpretation of analytical results can help identify the presence of free product. Additional types of information collected in the field may include soil type, porosity (primary and secondary), water table fluctuations (indicated by the possible smear zone size), and viscosity of the LNAPL. Some sites may require more extensive site characterization in order for staff to make informed decisions concerning whether a site may be a candidate for case closure. The characterization of a site with LNAPL includes the development of an appropriate LNAPL Conceptual Site Model (LCSM; ITRC 2009a, ITRC 2009b, and ASTM 2007, Section VII). The LCSM may require revisions as site conditions change due to remediation and other site factors.

Information needed to characterize LNAPL at a site and develop a thorough LCSM typically includes, but is not limited to:

- **Delineation**: LNAPL does not necessarily form a "pancake" on the groundwater surface, but shares the pore space in the vadose zone, the capillary fringe, and/or beneath the water table within the smear zone. Different approaches or technologies can be used to identify LNAPL trapped in soils (e.g. Laser-Induced Florescence (LIF) in conjunction with core photography).

- **Sources and Pathway**: Geologic or manmade features such as fractures in bedrock or clay, and fill material adjacent to underground utilities may also contain LNAPL and may serve as pathways for vapor and dissolved phases. The movement and storage of LNAPL in these features needs to be considered as part of the characterization and their presence may significantly increase risk by accelerating potential migration to receptors.

- **Volume**: Where possible, the volume (or plausible volume range) of LNAPL within the subsurface should be established to allow the development and selection of an appropriate recovery strategy as well as a basis for the risk evaluation. Historic records for the site should be reviewed to determine whether past releases may have contributed to the volume of LNAPL.

- **Age and Chemical/Physical Character**: LNAPL and groundwater can be analyzed to identify or verify the type of product as well as assess if the product poses a risk to receptors. As LNAPL weathers, the physical and chemical properties of the LNAPL can change. Weathered LNAPL can be more viscous and therefore less mobile and less recoverable than unweathered LNAPL. LNAPL properties can also assist in determining a probable date or time frame for the product release. Knowing the amount of time the product has been present compared to the known impacts (or lack thereof) can provide valuable insight on whether case closure is advisable.

- **LNAPL Mobility**: LNAPL in porous media must exist at saturations greater than residual saturation to be mobile. It is the mobile portion of the LNAPL body that is typically recovered by LNAPL extraction and recovery technologies. However, the presence of mobile LNAPL in a well does not necessarily indicate that the LNAPL body is migrating. The potential for mobile LNAPL to migrate may depend on changing hydraulic or LNAPL gradients as well as precipitation and groundwater recharge. Gauging or recovery data from drought and heavy precipitation events may provide mobility data.

- **LNAPL Recoverability/Transmissivity**: LNAPL Transmissivity (LNAPL T_n) is a useful metric for determining the recoverability of mobile free product. Since LNAPL T_n accounts for multiple LNAPL properties such as density, viscosity, and LNAPL saturation, LNAPL T_n can be more useful than just the measured thickness for determining free product recoverability (ASTM E2586, Section VII). However, LNAPL T_n can vary over time due to subsurface conditions such as groundwater fluctuations, corrective action implementation (reduced LNAPL saturation), or weathering of LNAPL.

  LNAPL T_n tests should be performed at sites where free product is present to aid in determining the recoverability of the free product. LNAPL T_n tests can also be completed over time to document the progress of free product recovery efforts. The ASTM Standard E2586 discusses several LNAPL T_n test methods and how to select the most appropriate method for site conditions. More information about LNAPL transmissivity may be found in Appendix A and in the documents referenced in Section VII, particularly ASTM Standard E2856.

Open pollution complaint cases with free product which pre-date the guidance, especially older cases, may require a new assessment and a new characterization in order to develop a current LCSM for the site. Results from a new or updated assessment and corresponding LCSM may provide additional information about LNAPL recovery potential for the site. While new or alternative characterization technologies may appear costly or overly complex, the use of these technologies may assist RPs, consultants, and Storage Tank Program staff to develop the most cost-effective decision regarding LNAPL recovery or case closure.

V. Corrective Action Plans and Lines of Evidence for LNAPL Site Closure

To determine if LNAPL recovery is no longer necessary or if a case with LNAPL can be recommended for case closure, several "lines of evidence" should show that free product has been recovered to the MEP and that the remaining LNAPL poses no risk. The evidence should also show that Natural Source Zone Depletion (NSZD; ITRC, 2009a) or natural attenuation processes are operating to remove the remaining source zone. These lines of evidence should be documented in the Site Characterization Report (SCR) or the Corrective Action Plan (CAP).

Lines of evidence, presented in a site and risk assessment detailing current conditions, may include:

- An estimate, or supportable estimated range, of the total volume of LNAPL present in the subsurface.
- A discussion, including supporting data, regarding the importance of site-specific geology/hydrostratigraphy with an emphasis on the possible existence of macropores, fractures, or conduits in karst.
- A discussion with supporting data that establishes whether free product at the site is a function of groundwater level or confined conditions. Since LNAPL thicknesses are often exaggerated under confined conditions, the SCR must provide adequate characterization of hydrostratigraphy to determine if confining layers are present.
- A demonstration that constituents in the vapor phase do not present a risk to potential receptors.
- Documentation that demonstrates the areal extent of the free phase plume at the site is stable or decreasing.
- Documentation that demonstrates the areal extent of the dissolved phase plume at the site is stable or decreasing.
- Documentation that shows concentrations of chemicals of concern are below site-specific cleanup/target levels.
- An evaluation that shows the effective solubility of remaining LNAPL and dissolved-phase concentrations are below site-specific target levels.
- LNAPL T_n data that documents LNAPL recoverability over a range of aquifer conditions.
- An evaluation of multiple treatment trains.
- A qualitative assessment of NSZD.

The site and risk assessments with supporting data should contain current site and area maps that show all current receptors, such as utilities, basements, drinking water wells, and surface water bodies.

A CAP should be submitted for all sites where free product recovery continues after the site has been characterized. This includes sites with passive or manual product bailing. A CAP should also be submitted if a site is under monitored natural attenuation (MNA). The CAP should specify remediation goals and endpoints. As with all corrective actions, the most cost-effective solutions/technologies should be pursued first. If the CAP recommends closure of a case where LNAPL is present, the CAP should clearly list the lines of evidence that support the recommendation for closing the case.

V. Closure of Sites with LNAPL

Prior to considering a site with LNAPL for case closure, the case information should demonstrate that various technologies (*i.e.*, a treatment train) have been used and/or evaluated, and LNAPL has been

recovered to the maximum extent practicable. The data should support the claim that the technologies are no longer effective and that additional recovery is not practicable. For purposes of this guidance, recovery to MEP is considered complete if any of the following three options has been demonstrated:

1. LNAPL remains onsite at a thickness greater than 0.01 ft., but the following have been achieved:
    a. Remaining LNAPL and dissolved-phase constituents are not a risk to human health or the environment, and
    b. NSZD of the LNAPL body and natural attenuation of the dissolved-phase plume are documented as occurring at the site and are expected to further mitigate risk from the release, and
    c. The areal extent of the free phase plume at the site is shown to be stable or decreasing, and
    d. For sites with active LNAPL recovery, evaluation of corrective actions performed at the site shows asymptotic recovery trends through seasonal water table variations, and
    e. Remaining product is not recoverable, or has low mobility/recoverability (as evidenced by LNAPL T_n tests)

OR

2. LNAPL remains onsite at a thickness greater than 0.01 ft., and the following conditions exist:
    a. Remaining LNAPL and dissolved-phase constituents are not a risk to human health or the environment, and
    b. The areal extent of the free phase plume at the site is shown to be stable or decreasing, and
    c. NSZD of the LNAPL body and natural attenuation of the dissolved-phase plume are documented as occurring at the site and are expected to further mitigate risk from the release, and
    d. Access to the LNAPL body is an issue, i.e. remaining product lies under a structure or roadway and cannot be reached, and/or geology or hydrostratigraphy prevents or greatly restricts product removal, e.g. product trapped in fractured bedrock.

OR

3. LNAPL has been recovered (and maintained for a timeframe specified in the approved CAP) to a thickness of 0.01 ft or less.

A summary report containing the supporting documentation discussed above should be submitted. The compilation of site history data and newer assessment information should provide substantial reasons for site closure.

Note: A closed case may be re-opened if significant previously unidentified environmental problems related to the original release (for example, additional free product, extensive saturated soils, or an impacted receptor) are discovered.

VI. Summary

Situations do exist in which LNAPL can justifiably remain at a site after case closure. However, Storage Tank Program Case Managers should have a full understanding of the site-specific geological, hydrogeological, and receptor risk factors before closing a case with measurable LNAPL. A comprehensive site characterization and a LCSM should be developed. For existing free product cases, updated and possibly expanded site, risk, and remediation assessments may be required. New types of approaches and the gathering of additional lines of evidences may be required to ensure that area dynamics have not changed since the original site characterization or corrective action report. The evidence should support a proposal for discontinuance of LNAPL recovery and for possible case closure. Revision of remediation endpoints may also need to undergo Public Notice.

VII. Resources

Alaska, 2006. Maximum Allowable Concentration, Residual Saturation, and Free Product Mobility – Technical Background Document and Recommendations. Prepared for Alaska Statement of Cooperation Working Group, September 2006. Prepared by Geosphere, Inc., CH2MHILL. http://www.dec.alaska.gov/SPAR/csp/docs/soc/4_max_allow_conc.pdf

API, 2000. Non-Aqueous Phase Liquid (NAPL) Mobility Limits in Soil. Bulletin 9, June 2000. American Petroleum Institute (API). http://www.api.org/environment-health-and-safety/clean-water/ground-water/bulletins.aspx

API, 2002. Evaluating Hydrocarbon Removal from Source Zones and its Effect on Dissolved Plume Longevity and Concentration. Publication 4715. American Petroleum Institute (API). http://www.api.org/ehs/groundwater/4715.cfm#download

API, 2006. API Interactive LNAPL Guide Version 2.0.4. American Petroleum Institute (API). http://www.api.org/ehs/groundwater/lnapl/lnapl-guide.cfm

ASTM, 2007. Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface. Publication E2531-06e1. American Society for Testing and Materials, West Conshohocken, PA. www.astm.org

ASTM, 2011. Standard Guide for Estimation of LNAPL Transmissivity. Publication E2856-11E01. American Standard Testing Material International, West Conshohocken, PA. www.astm.org

ITRC (Interstate Technology & Regulatory Council), 2009a. Evaluating Natural Source Zone Depletion at Sites with LNAPL. LNAPL-1. Washington, D.C. : Interstate Technology and Regulatory Council. www.itrcweb.org, www.itrcweb.org/guidancedocument.asp?TID=59.

ITRC (Interstate Technology & Regulatory Council), 2009b. Evaluating LNAPL Remedial Technologies for Achieving Project Goals. LNAPL-2. Washington, D.C.: Interstate Technology and Regulatory Council. www.itrcweb.org, www.itrcweb.org/guidancedocument.asp?TID=59

New Jersey, 2012. Light Non-aqueous Phase Liquid (LNAPL) Initial Recovery and Interim Remedial Measures Technical Guidance. New Jersey Department of Environmental Protection Site Remediation Program. http://www.state.nj.us/dep/srp/guidance/index.html

Remediation Technologies Development Forum (RTDF), Non-Aqueous Phase Liquid (NAPL) Cleanup Alliance. www.rtdf.org/public/napl/

Appendix A

LNAPL Transmissivity

DEQ Case Managers, RPs, consultants, and other stakeholders are encouraged to become familiar with best practices for LNAPL T_n tests which are covered in detail in the ASTM Standard E2856 (listed in the Section VII, Resources).

LNAPL T_n tests should be utilized to evaluate the recoverability of the LNAPL. LNAPL T_n tests should also be completed over time to document the progress of LNAPL recovery efforts at remediation sites. The ASTM Standard E2586 discusses several LNAPL T_n test methods and how to select the most appropriate test method for site conditions. Various test methods include LNAPL baildown/slug tests, LNAPL manual skimming tests, tracer tests and recovery system tests. Each test method offers different benefits/constraints (cost, time, site-specific conditions). Care should be used when selecting a LNAPL T_n test method. Certain test methods are not applicable to every site. Prior to attempting LNAPL T_n testing, a thorough LCSM is required. More information about LCSMs may be found in the ITRC publications referenced in Section VII of this document.

When conducting (or reviewing) LNAPL T_n tests, the following should be considered (for additional considerations, see ASTM E2586):

1. Equilibrium conditions are required for LNAPL T_n testing.
2. Certain LNAPL T_n test methods require a minimum LNAPL thickness in monitoring wells. For example, LNAPL baildown/slug tests are not recommended for wells with LNAPL thicknesses of less than 0.5 feet (ASTM E2586).
3. Tidal influences, vertical gradients, groundwater/surface water interaction, etc. can cause error in interpreting LNAPL T_n test data.
4. LNAPL T_n can be underestimated in certain hydrogeologic settings (perched water tables, confined aquifers) due to overestimation of LNAPL drawdown; therefore, care must be exercised when calculating drawdown for LNAPL T_n tests.
5. LNAPL T_n can vary across a site due to soil heterogeneities, petroleum chemistry, LNAPL properties, etc.; therefore, it is good practice to complete LNAPL T_n tests in multiple wells to gain an adequate understanding of LNAPL recoverability at the site.
6. LNAPL T_n tests should be conducted over a period of time to determine the effect of seasonal water table fluctuations.

Though LNAPL T_n is related to product recoverability, it may not be prudent to use LNAPL T_n data collected at the beginning of site investigation to justify a remediation course of "no LNAPL recovery". LNAPL T_n is a relatively new metric for tracking LNAPL recoverability, and there are little data to support a blanket "unrecoverable" LNAPL T_n value that can be applied to every site. LNAPL T_n values that might be considered "unrecoverable" will likely be site specific, and vary with hydrogeologic settings and remediation technologies. Over the course of LNAPL recovery efforts, it is expected that LNAPL T_n should decrease as remediation of the LNAPL progresses towards recovery to the MEP. LNAPL T_n data can be used (in addition to asymptotic LNAPL recovery system data) to determine whether or not recovery to the MEP has been achieved and case closure might be pursued.