

SECTION V. RELATIONSHIP TO OTHER ENVIRONMENTAL STATUTES

Remediation under Act 2 sometimes involves relationships ~~to-with~~ other environmental statutes (e.g., closure of waste management facilities, groundwater pump and treat systems which discharge to a surface water and require an NPDES permit). Although other Department programs (e.g., Water Quality Management) will be involved in requests and approvals, the regional Environmental Cleanup Program Manager will coordinate these activities. ~~All paperwork~~ Therefore, all correspondence necessary for the Act 2 cleanup should be ~~submitted~~ sent to the attention of the regional Environmental Cleanup Program Manager.

A. Solid Waste Facilities

This section provides a general overview of the interface between Act 2 and Act 97 (the Solid Waste Management Act of 1980). ~~The sections that follow are This discussion is~~ meant to provide a broad overview ~~and a general direction~~ of the interrelationship between these statutes and programs, ~~and is are~~ not meant to be used as a substitute for specific regulations that apply to solid waste processing or disposal facilities. Solid waste management facilities, including those facilities that process and dispose of municipal, residual, or hazardous wastes, are primarily regulated under Act 97. The permitting, bonding and compliance requirements of Act 97 are implemented through policies and regulations adopted as follows: Chapters 260(a) through 270(a) for hazardous waste, Chapters 271 through 285 for municipal waste, and Chapters 287 through 299 for residual waste.

The Management of Fill Policy (August 7, 2010 - Document Number 258-2182-773) provides the Department's procedures for determining whether material qualifies as clean fill or regulated fill under Act 97, and provides guidance as to whether a permit is required when using fill.

1. Movement of Excavated Contaminated Media and Other Solids

Under Section 287.101(e), the Department will not require a permit for the ~~onsite~~ movement of residual waste ~~encountered when performing a remediation~~ within an Act 2 site for use during remediation in the remedy (e.g., grading of the site, placement back into exploratory holes), ~~so long as the site attains the site-specific standard of Act 2. A permit is not required when moving regulated fill from one Act 2 site to a receiving site that is being remediated to attain an Act 2 standard. Movement of regulated fill between Act 2 sites must be documented in both the sending and the receiving sites' cleanup plans and final reports. Regulated substances contained in the regulated fill must be incorporated into the notice of intent to remediate.~~ Excavated hazardous waste should be removed for proper disposal under the hazardous waste generator requirements of Chapter 262(a). Movement of any contaminated media or solids offsite, other than to another Act 2 site, is the generation of waste under Section 250.3. Under these circumstances,

the remediator is subject to the generator requirements of the Solid Waste Management Act.

2. Disposal Prior to September 7, 1980

Solid waste management facilities that were permitted under the Pennsylvania Solid Waste Management Act of 1968 (Act 241), or had an approved closure plan or consent order and agreement, that ceased disposal activities prior to September 7, 1980, are subject to the terms and conditions of their original permit relating to closure or ~~of to~~ the approved closure plan or consent order and agreement. The permittee may request approval from the Department for a modification of the permit or closure plan to be consistent with Act 2 standards for remediation of any release of a regulated substance to soil or groundwater.

Solid waste management areas or facilities that were not permitted or did not have an approved closure plan that ceased disposal prior to September 7, 1980, may be remediated under the provisions of Act 2 by either removing the non-media solids and using any combination of Act 2 standards, or closing in place. Closing in place may be accomplished by covering the non-media solids with a suitable cover and using pathway elimination under the site-specific standard for the non-media solids, and any combination of Act 2 standards for soils and groundwater outside the perimeter of the cover under Section 250.9(a). Liability protection afforded under Section 501 of Act 2 would be provided upon approval of the final report by the Department. The covering, grading, revegetation, and related closure activities for waste left in place are to be consistent with best management practices to prevent pollution, odors, and other public nuisances.

3. Disposal after September 7, 1980, for Residual Waste and Construction /Demolition Waste, and between September 7, 1980 and October 9, 1993 for Municipal Waste.

Municipal and residual waste disposal activities that occurred after September 7, 1980 are subject to Act 97, the terms and conditions of permits issued pursuant to Act 97 and to the municipal and residual waste regulations including an approved closure plan. Permitted facilities that are closed (prior to October 9, 1993 for municipal waste facilities) may use any one or a combination of the remediation standards for releases into soils or groundwater under Sections 271.113(g), 271.342(b)(4) or 287.342(c). In addition, the permitted facility may elect to proceed under Act 2, and upon approval of the final report obtain the liability protection afforded by Section 501 of Act 2 for the release. The cause of the release or spill must be addressed in accordance with the terms and conditions of the closure plan or permit. Any relief of liability afforded under ~~a~~Act 2 relates only to the regulated substances identified and in no way is to supercede the terms and conditions of the closure plan or permit.

An unauthorized municipal waste landfill that ceased disposal prior to October 9, 1993 or an authorized construction/demolition waste landfill, residual waste landfill or an unauthorized disposal impoundment that ceased after

September 7, 1980, where the Department has not required removal of the solid waste on the ground and use of Act 2 ~~to~~ for the remaining contaminated media, must be remediated in accordance with the following¹:

- removal of the non-media solids and use of any one or a combination of Act 2 standards for the remaining contaminated media, or
- closing in place by applying the applicable closure standards of the regulated facility encountered specified in Chapters 271, 273, 287, 288 and 289 as required by Section 250.9(b) of the Act 2 regulations (unless applicable operational standards are specifically waived by the Department under the requirements of such waivers set forth at Sections 271.113(d), 287.117(b) and Section 902(b) of Act 2), pathway elimination under the site-specific standard for the non-media solids on the ground, and any one or a combination of Act 2 standards for soils and groundwater outside the perimeter of the closure area.

In addition, the unauthorized facility can elect to proceed under Act 2 and, upon approval of the ~~final~~ final report, obtain the liability protection afforded by Section 501 of Act 2 for the release.

At properties where solid or liquid municipal or residual wastes such as metal, brick, block or debris were disposed, without permit, and became mixed with soil, thereby becoming a part of the environmental media, the Act 2 program would govern remediation. The remediator would choose the best applicable management practices to include covering, grading, revegetation, and related activities to prevent pollution, odors and other nuisances that would apply to the remediation of mixed media. Liability relief afforded by Act 2 would only apply to the area characterized and to the contaminants identified in the Act 2 final report. If the soil/waste mixture is moved offsite, the material must be managed as waste pursuant to Section 250.3 of the Act 2 regulations and the municipal or residual waste regulations in accordance with 25 Pa. Code 287.2 or 271.2, definition of waste in the residual waste regulations.

4. Disposal of Hazardous Waste after September 7, 1980 or Municipal Waste after October 9, 1993 Subject to Federal Closure Requirements

To ensure primacy and program authorizations under RCRA at properties where disposal of hazardous waste occurred after September 7, 1980 or municipal waste disposal occurred after October 9, 1993, regardless of whether a permit or approval was obtained, the remediation and closure of such federally regulated waste management units are governed by the appropriate Act 97 regulations. Waivers of operational standards under Section 902(b) of Act 2 are generally not

¹ In each of these situations it is assumed that the Department would exercise its enforcement discretion. If the Department determines that the responsible party/property owner conducted the intentional culpable long-term practice of placing waste into the environment Act 97 would apply.

applicable unless approved by EPA. The Department will consult with EPA to ensure that federal closure requirements are properly applied.

Hazardous Waste sites that have RCRA Subtitle C corrective action obligations may satisfy federal requirements by also participating in the voluntary cleanup process provided by Act 2. For RCRA facilities with “low” or “medium” priority corrective action obligations, Act 2 standards may be applied as described below to satisfy both state and federal requirements concurrently. For “high” priority RCRA corrective action facilities, application of Act 2 standards as described below may also be used, but with greater interaction with EPA.

a) Hazardous waste

If hazardous waste was disposed before September 7, 1980 and continued after September 7, 1980 but before September 26, 1982 [see 40 CFR 270.1(c) incorporated by reference in Section 270a.1] without interim status and the Department has not required removal of the hazardous waste and use of Act 2 to remaining contaminated media, the remediator must close the “existing” facility under closure standards provided in Chapter 265a of the hazardous waste regulations for the facility unit encountered, and, upon approval of the final report by the Department, obtain the liability protection afforded by Section 501(a) of Act 2.

As examples, typical units encountered are surface impoundments and waste piles. Closure requirements set forth in 40 CFR 265.228 (surface impoundment closure) and 40 CFR 265.258 (waste pile closure), incorporated by reference in Chapter 265a, require removal of the solids and contaminated subsoils. To attain clean closure, the remediator should remove solids and contaminated soils that are above the level of the listing; *i.e.*, characteristically hazardous solids and soils, and solids and soils contaminated by ~~KPUF~~ waste disposal above the residential Statewide health standard for used aquifers. Any soil or groundwater contamination remaining after clean closure must be remediated using any one or a combination of Act 2 standards. If clean closure is not attained, the remediator must close the hazardous waste regulated unit in place using the closure standards for landfills set forth in 40 CFR 265.310 and use the site-specific standard for the in-place closed area. Any release into groundwater or soil outside the approved in-place closure area is subject to any one or a combination of Act 2 standards (except the Statewide health nonuse aquifer standard, which has not been approved by EPA but which may be derived through use of the site-specific standard).

Hazardous waste facilities created after September 7, 1980 and hazardous waste facilities existing on September 7, 1980 which continued to receive waste after September 26, 1982 are subject to the closure, post-closure and corrective action requirements of 40 CFR Part 264, as incorporated by reference in Chapter 264a. As examples, a surface impoundment in this category is subject to the closure requirements of 40 CFR 264.228 and a waste pile in this category is subject to the closure requirements of 40 CFR 264.258. If clean closure is not attained, the

remediator must close the regulated hazardous waste unit in place, using the closure standards for landfills set forth in 40 CFR 264.310 and use the site-specific pathway elimination standard for the in-place closed area. Any release into groundwater or soils outside the approved in-place closure area is subject to one or a combination of Act 2 standards (except the Statewide health nonuse aquifer standard as explained above) at a point of compliance for groundwater set forth in 40 CFR 264.95.

b) Municipal waste

If a permitted municipal waste landfill received waste between October 9, 1993 and December 23, 2000, a release from the landfill of a regulated substance must be remediated in accordance with a closure plan approved prior to December 23, 2000 or remediation standards in the municipal waste regulations that are similar to the federal requirements under Subtitle D of RCRA.

A release of a regulated substance from a municipal waste landfill permitted on or after December 23, 2000 must be remediated in accordance with the remediation standards in the municipal waste regulations that are similar to the Subtitle D requirements in Section 271.342(b)(2).

At properties where the unauthorized disposal of municipal waste occurred after October 9, 1993, remediation shall consist of removal of the non-media solids and the use of any one or a combination of Act 2 standards for the remaining contaminated media.

Where the Department determines that the removal of the waste, which was not authorized disposal, is impracticable or will cause unacceptable impacts to public health or the environment, the remediation shall consist of closing the facility in place by applying the applicable closure standards of the regulated facility encountered specified in Chapters 271 and 273, as required by Section 250.9(b) of the Act 2 regulations and by using pathway elimination under the site-specific standard for the non-media solids on the ground, and any one or a combination of Act 2 standards for soils and groundwater outside the perimeter of the closure area that is consistent with the applicable requirements for groundwater remediation standards and point of compliance set forth in Section 271.342(b).

B. Clean Streams Law Interface

1. Point Source Discharges

Surface water discharges associated with contaminated sites are classified as point and nonpoint sources. A point source is a distinct discharge of sewage or industrial waste into a surface water such as a leachate discharge from a disposal unit. Such point source discharges are required to be permitted as National Pollutant Discharge Elimination System (NPDES) point source discharges. In other situations, runoff from a contaminated site discharges through a storm sewer. Such a discharge would also be classified as a point source of wastewater subject to NPDES requirements.

2. Nonpoint Source Discharges

Act 2 requires that any site selecting the statewide health or site-specific standard must also demonstrate compliance with surface water quality criteria when a nonpoint source discharge such as contaminated groundwater discharges into surface water.

The Department has developed a contaminant dependent hierarchical process described in Section IV.A.3 Section III.A.3 of this manual for demonstrating attainment of surface water quality criteria.

The waiver provision of Chapter 250.406 (Relationship to surface water quality requirements) was included as part of the initial Chapter 250 Land Recycling Program regulations, as promulgated by the Environmental Quality Board on August 16, 1997. The preamble of the rulemaking explains: "This section was added on final rulemaking to clarify the relationship between the surface water quality standards and Act 2." The preamble further clarifies the intent of the waiver provision in the section stating: "Section 902(b) of Act 2 authorizes the Department to waive applicable requirements where responsible persons can demonstrate, among other things, that the proposed remedial action will attain a standard of performance that is equivalent to that required under the otherwise applicable requirement through use of an alternative method or approach."

The substance of this waiver provision is provided in Chapter 250.406(c). The waiver provision of Chapter 250.406 allows the remediator to apply to the Department for a waiver of the otherwise applicable requirements of Chapter 93 relating to human health criteria based on the use of alternative site-specific exposure factors associated with the surface water pathway.

In order for a remediator to "demonstrate to the Department that the proposed remedial alternative will result in attainment of a concentration that does not exceed human health criteria" for a waiver of provisions in Chapter 93, they would need to use alternative site-specific exposure factors that would demonstrate that human health exposures to the surface water pathway are controlled. The remediator could make this demonstration using a qualitative evaluation of alternative site-specific exposure factors. The remediator would not necessarily need to use a quantitative risk assessment process.

In cases where the remediator can demonstrate to the Department that future human health exposures to the surface water pathway are controlled the Department may issue the waiver.

3. Erosion and Sedimentation Control

In addition to evaluating the impact of discharges into surface water, the remediator must carefully evaluate remedial activities to minimize erosion and sedimentation in conformance with the requirements of Chapter 102 of the PA Code (Erosion and Sediment Control). In-place closures of unregulated and unauthorized disposal units will satisfy these requirements through the development, implementation, and maintenance of erosion and sediment control best management practices (BMP).

Remedial actions implemented during Act 2 cleanups that include any earth disturbance activities should be undertaken using the following procedures:

a) For earth disturbances less than 5,000 square feet (ft²)

If the proposed earth disturbance at an Act 2 cleanup site involves an area of less than 5,000 ft² and the potential discharge is to waters other than special protection, the remediator should implement and maintain applicable erosion and sedimentation (E&S) BMPs as outlined in the Best Management Practices program guidance manual on the DEP website (*Pennsylvania Stormwater BMP Manual*, December, 2006). Chapter 7 of DEP's BMP manual is devoted to Special Management Areas, including Brownfields sites.

If the earth disturbance involves an area of less than 5,000 ft² and the potential discharge is to waters that are special protection, then the requirements in the following section apply.

b) For earth disturbances 5,000 ft² to 1 acre (and discharge to special protection waters for any size of earth disturbance less than 1 acre)

If the proposed earth disturbance at an Act 2 cleanup site involves an area 5,000 ft² or greater, the remediator should prepare an E&S plan. All earth disturbance activities should be conducted in accordance with the E&S plan. The remediator should have a copy of the E&S plan, and all subsequent inspection reports and monitoring records on site during all stages of the earth disturbance activity. The remediator should contact the County Conservation District for any technical assistance prior to preparing the E&S plan. In some cases the County Conservation District may wish to review the plan voluntarily, or they may require the review on behalf of the local municipality. In addition, the County Conservation District may inspect the site as a follow-up to the plan review, as part of routine inspections, or in response to a complaint.

c) For earth disturbances 1 acre or greater

If the proposed earth disturbance at an Act 2 cleanup site involves an area of 1 acre or more, the planned action may require a general or individual NPDES permit for stormwater discharges associated with construction activities. In

these cases, the remediator should contact the DEP regional Waterways and Wetlands Program staff or assistant regional director to schedule a pre-application meeting. At the pre-application meeting DEP and county conservation district staff will provide the remediator with the relevant information regarding the permit procedures and requirements. It is important to note that in addition to the development of an E&S Plan, the remediator will be required to develop a post construction stormwater management plan for any new structures (e.g. buildings, parking lots, etc.). The remediator is not authorized to initiate any Act 2 earth disturbance activities until DEP issues the permit to the remediator.

As previously detailed, a portion of Chapter 7 of the DEP's BMP manual is devoted to BMPs at Brownfield sites. The remediator should consult with the manual and EC&B regional office staff in the coordination of any required E&S plan development and all permit applications.

Additional guidance may be found in DEP's *Erosion and Sediment Pollution Control Program Manual*, March 2012. The manual may be found on the DEP website.

d) Post construction stormwater management (PCSM)

A remediator proposing a new earth disturbance activity that requires permit coverage under Chapter 102 or other Department permit that requires compliance with Erosion & Sediment Control shall be responsible to ensure that a written PCSM Plan is developed, implemented, operated and maintained in accordance with the requirements of Chapter 102.8.

The remediator should keep in mind that a completed Act 2 cleanup site may contain existing site conditions which have public health or environmental limitations. Because of such limitations, the remediator may be able to demonstrate to the Department that it would not be practicable to complete all aspects of the E&S PCSM BMPs as outlined and required within Chapter 102.

C. Clean Air Act and Air Pollution Control Act Interface

One area of interface is the case of applying remediation technologies (*e.g.*, air strippers or incineration units) which result in air emissions. In such a situation, a remediator may be required to obtain a general air quality plan approval and operating permit under Chapter 127, Subchapter H.

Installation of radon-type vapor mitigation systems as part of an Act 2 remediation does not require a permit if the emission will be of minor significance. These systems do not require testing after installation for purposes of determining compliance with air emissions criteria. However, the installed radon-type vapor mitigation systems will need to be tested to demonstrate that sub-slab depressurization is occurring (i.e. the pressure gradient indicates that advective air flow is out of the structure, rather than into the structure). Section IV of this manual (Vapor Intrusion) discusses this process in greater detail.

In cases of interface other than remediation technology emissions, care should be taken to conduct the remediation such that odor nuisances will be addressed.

Asbestos is regulated as a hazardous air pollutant under Section 112 of the Clean Air Act. Guidance for the management of asbestos is available from EPA's web page at www.epa.gov/cbtpages/airairpoasbestos.html.

D. Regulated Storage Tank Release Sites

1. Introduction

Storage tank cleanups conducted pursuant to the Storage Tank and Spill Prevention Act (Act 32 of 1989, as amended) ~~which are required to~~ meet one or more of the standards established under Act 2 ~~are Act 2 cleanups~~. Section 904(c) of Act 2 ~~preserved~~ preserves the corrective action process for the remediation of releases from storage tanks regulated by Act 32. Regulated storage tanks include a wide range of underground and aboveground tanks containing petroleum products and hazardous substances. ~~Notable exceptions to the regulated tank community are tanks containing heating oil for consumptive use on the premises where stored, and hazardous waste tanks.~~

The corrective action process applies to releases from regulated tanks for which remediation (anything beyond notification) was initiated on or after August 5, 1989, the effective date of Act 32. Persons Remediators who take corrective action under Act 32, and ~~can~~ demonstrate attainment of one or more of the standards under Act 2, will be afforded liability protection. ~~The three cleanup standards available are background, Statewide health and site specific.~~ Where Act 32 applies, ~~persons remediators cleaning up these releases~~ are not subject to the notice, fee and approval provisions contained in Act 2. ~~However, as discussed in Section IV.E.2, Department, but are subject to~~ review times and deemed approval provisions of Chapter 245. ~~have been established for reports and plans submitted under the corrective action process.~~

~~Those persons~~ A remediator who initiated cleanup prior to ~~their a~~ tanks becoming deregulated by Act 16 of 1995 (which amended Act 32) should continue to implement the corrective action process, along with use of the Act 2 remediation standards, to receive liability protection. ~~This would include releases from commercial heating oil tanks provided the remediation was initiated before August 25, 1995. On this date, commercial heating oil tanks became deregulated.~~

Where a tank is not governed by Act 32 (non-regulated tanks), adherence to the Act 2 administrative process and cleanup standards will be required in order to receive liability protection. ~~This would apply applies to releases from storage tanks for which remediation was initiated prior to August 5, 1989, and releases from unregulated storage tanks, including tanks formerly regulated as commercial heating oil tanks. Persons cleaning up releases from deregulated commercial heating oil tanks where the remediation was initiated on or after August 25, 1995, would have to must adhere to the Act 2 process to receive liability protection.~~

~~Where~~ When a person is responding to releases of petroleum products occur from at sites with both tanks governed by regulated and non-regulated storage tanks as well as releases from other tanks (which are then governed by Act 2), the ~~person remediator doing the remediation~~ may elect to address the tanks releases together, or to address them separately on a dual track of the Act 2 and Act 32

processes. If the ~~remediator~~~~person~~ elects to address the ~~tanks~~~~releases~~ together, ~~he or she may submit~~ combined reports and notices that satisfy the requirements of each statute, as they apply to the particular tanks, ~~may be submitted.~~ Department Reviews will also be conducted to satisfy the requirements of both statutes

For example, a ~~person~~ remediator may submit a combined site characterization/remedial investigation report that contains the information required under the corrective action process and under ~~the~~ Act 2 ~~process~~, and it will serve a dual function under both Act 32 and Act 2. It should be submitted on a time frame that meets both statutes; thus, if there is no specific time required to submit the remedial investigation report under Act 2, but a site characterization report under Act 32 is required within 180 days of reporting the release, the site characterization/remedial investigation report should be submitted within 180 days. Compliance with Act 2 notice and public participation requirements ~~will be~~ necessary ~~for to receive~~ liability protection for non-regulated tanks governed by Act 2.

2. Short List of Petroleum Products

The Department has developed an abbreviated list (“short list”) of regulated substances for specific petroleum products. The short list for releases of petroleum products is discussed in detail in Section III, Technical and Procedural Guidance.

3. Management of Separate Phase Liquid under Act 2 and Act 32

When a pure liquid (such as gasoline or chlorinated solvent), also referred to as free product, is released to the environment, accumulations of the free product as a separate phase (separate phase liquids or SPL) may occur within soil or bedrock. Depending on the density of the liquid relative to water, the SPL may migrate under gravity through the subsurface and either remain on or just below the water table or sink through the water column and accumulate on impermeable surfaces lower in the aquifer. Substances that are less dense than water, like most petroleum products, are called Light Non-Aqueous Phase Liquids (LNAPL). Substances that are denser than water, such as chlorinated substances, are called Dense Non-Aqueous Phase Liquids (DNAPL).

The presence of SPL may be found in various media and locations including the soil, vadose zone, aquifer, surface water, or sediments. SPL may also be present in differing phases. Residual SPL are separate phase liquids in the subsurface that are hydraulically disconnected in the pore spaces in a porous media or fractures in bedrock/clay. The SPL may be present at concentrations below saturation, may not extend great lateral distances from the source of the release, and they tend to be relatively immobile. Mobile SPL are separate phase liquids that are hydraulically connected in the pore space or fractures and have the

potential to move under the prevailing hydraulic conditions. Mobile SPL that is stable has the potential migrate if the prevailing hydraulic conditions are altered.

If not removed, the presence of SPL may be a long term management concern at sites undergoing remediation. SPL might constitute a continuing source of contamination and could greatly increase the time and cost for post closure care monitoring. The presence of SPL introduces complex fate and transport issues and uncertainties regarding the future migration of contamination and its impact. Remediation should be based on a thorough site conceptual model.

SPL at contaminated sites should be addressed in the following manner:

a) Management of SPL under Act 32 and Chapter 245

Under Act 32 and Chapter 245, Subchapter D, the corrective action obligation for releases from regulated aboveground and underground tanks must include the removal of SPL from the environment to prevent migration into uncontaminated areas (25 Pa. Code Chapter 245.306(b)(1)). This obligation begins immediately upon release as required under interim remedial action requirements discussed below and continues until the SPL body is no longer capable of migrating into uncontaminated areas.

USEPA regulation 40 CFR§ 280.64 requires owners and operators to remove “free product” to the maximum extent practicable (MEP) as determined by the implementing agency. As the implementing agency, the Department defines MEP as the extent of removal necessary to prevent migration of SPL to uncontaminated areas and prevent or abate immediate threats to human health or the environment. MEP is discussed further in Section III of this guidance.

Section 245.306(a)(3)(ii) requires that SPL recovery resulting from a release from a regulated storage tank be initiated IMMEDIATELY upon its discovery to prevent or address an immediate threat to human health and the environment. This may include the abatement or prevention of vapors from entering structures and creating unacceptable health, fire or explosion risks.

Section 245.306(b)(1) requires that SPL removal be conducted in a manner that prevents the spread of contamination into uncontaminated areas. Interim remedial actions that prevent the further migration of SPL into uncontaminated areas include, but are not limited to, the following:

- Excavation of contaminated soils for treatment or disposal. Excavation that intends to remove SPL with highly contaminated soil should include any saturated contaminated soils and unconsolidated material at and just below the water table, to the extent feasible, because a significant volume of an LNAPL release is contained within and below the vadose zone. Removal of this mass reduces both contaminant flux into groundwater and plume migration.

- Rapid containment, absorption, and removal of surface releases.
- Installation of subsurface extraction or deployment of in-situ destruction technologies to remove SPL that causes vapor migration or fire and explosion hazards.

If a sufficient volume of SPL is released into the subsurface, then multiple phases (e.g. soil, water, vapor) are generally present. As each of these phases behaves differently, the ultimate remediation to a cleanup standard may require a combination of corrective action technologies. Initial recovery of SPL is an especially important aspect of site remediation because improper recovery techniques may cause reduced effectiveness and transfer significant portions of the contaminant mass into other phases.

b) Management of SPL under Act 2 and Chapter 250

While Act 2 and Chapter 250 do not specifically mandate SPL recovery within the property, the Department encourages removal of SPL within the property to the MEP, as described above, as an immediate or interim response. The extent of SPL removal will be determined by the standard(s) selected by the remediator after immediate threats to human health and safety and the environment have been mitigated. The Department recognizes that the amount of SPL that can be removed will depend on the hydrogeologic framework of the site, the type of product, the remediation technology employed. In cases relying on natural attenuation, removal of SPL may simplify and shorten the timeframe for fate and transport analyses, attainment of a standard and post remediation care monitoring.

c) Relationship of SPL to Compliance with Act 2 Standards

i) Background standard

The background standard is available at sites where SPL is migrating onto the property from an off-site source. Remediators will be required to demonstrate through the use of monitoring and fate and transport analysis that they have removed an amount of SPL equivalent to the mass contributed by the release from their site.

ii) Statewide health standard

For an Act 2 remediation using the Statewide health standard, the Department urges removal of SPL throughout the plume to the MEP, as described above.

(a) Groundwater

Attainment of the Statewide health standard is not possible when SPL, as LNAPL or DNAPL, is present in point of compliance wells. Each constituent's aqueous solubility cap is used as the maximum possible value for a groundwater MSC. The presence of SPL means that the solubility caps, and therefore the groundwater MSCs, have been exceeded at the point of compliance. When the MSCs are exceeded at the point of compliance, a remediator cannot demonstrate attainment of the Statewide health standard.

(b) Soil-

In addition, within the property, the lesser of the direct contact number to a depth of fifteen feet for chemicals of concern and the soil-to-groundwater pathway number throughout the entire soil column should be attained in soil that is saturated with the SPL. This soil requirement applies to all sites including both those where the SPL has been removed and those where some amount remains.

At sites where applicable soil standards have been attained, and the remediator has determined that unrecoverable SPL remains, the remediator will need to establish through monitoring and fate and transport modeling that any remaining SPL will not migrate to compliance points before a release of liability under the Statewide health standard will be conveyed.

iii) Site-specific standard

Under Act 2, attainment of the site-specific standard when SPL is present at the POC may be permissible as long as there is no discharge to surface water, no unacceptable risk-based exposure, and sufficient evidence to demonstrate that SPL is unlikely to migrate off-site. If the contamination is from a regulated tank site, compliance with 25 Pa. Code §245.306 to demonstrate the SPL has been removed to the MEP. Activity and use limitations that are part of the post remediation care plan should be included in the environmental covenant.

d) Management of Light Non-Aqueous Phase Liquids (LNAPL) under Act 32

LNAPL typically has been viewed as separate phase liquid that is less dense than water and can be measured in a well or on a water surface. When measureable LNAPL is not detected within a well, LNAPL 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 or volume 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 and/or rock 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 (including but not limited to structural influences, preferential pathways, permeability contrasts, and pumping well influences).
- LNAPL migration rates may not be the same as the 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.

LNAPL exists in residual and non-residual (mobile) phase, so some LNAPL may remain at the site after reaching removal to the MEP. Although the remaining LNAPL may take years to degrade, the low recoverability combined with the low risk posed by the LNAPL source may make recovery of remaining LNAPL infeasible or unnecessary. In such instances, evaluating the site for terminating LNAPL recovery is warranted. Information necessary to determine when LNAPL removal meets the MEP is identified below.

1) Site Characterization and LNAPL Conceptual Site Model

25 Pa. Code § 245.309 requires completion of a site characterization. A complete and concise site characterization is an important step in identifying the presence, properties, distribution and migration of LNAPL. Simple visual observations during site work and interpretation of analytical results can help identify the presence of LNAPL. The characterization of a site with LNAPL includes the development of an appropriate LNAPL Conceptual Site Model (LCSM). The level of detail

required for a given LCSM is site-specific and based on the complexity of environmental conditions at each site. As the corrective action progresses, the LCSM should be regularly re-evaluated in the light of additional site/LNAPL data, pilot test data, remedial technology performance metrics, and monitoring data. A complete and up-to-date LCSM allows the best possible decisions about application and operation of remedial technologies to be made and when removal actions are no longer necessary. Documents that should be used to guide the development of a LCSM are included in the list of references, below. The LCSM may require revisions as site conditions change due to remediation and other site factors. Figure V-1 is a worksheet that can be used when preparing a LCSM.

Older LNAPL cases which pre-date the guidance may require additional assessment in order to update the LCSM for the site purposes of making MEP decisions. Results from an updated LCSM may provide additional information about LNAPL recovery potential for the site. While technologies may appear costly or overly complex, the use of these technologies may assist RPs, consultants, and staff to develop the most cost-effective decision regarding LNAPL recovery or case closure. 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 industry standard practices can be used to identify LNAPL trapped in soils or bedrock (ranging from shake test to 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 identify past releases that 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 Migration:** LNAPL moving into previously uncontaminated areas. It is a condition requiring immediate recovery under the regulations. The potential for mobile LNAPL to migrate may depend on geologic conditions, changing hydraulic or LNAPL gradients as well as precipitation and groundwater recharge. The presence of other contaminants may impact migration of LNAPL.
- **LNAPL Mobility:** LNAPL in porous media 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. Gauging or recovery data from drought and heavy precipitation events may provide mobility data.
- **LNAPL Recoverability/Transmissivity:** LNAPL Transmissivity (LNAPL Tn) is a useful metric for determining the recoverability of mobile LNAPL. Since LNAPL Tn accounts for multiple LNAPL properties such as density, viscosity, and LNAPL saturation, LNAPL Tn can be more useful than just the measured thickness for determining LNAPL recoverability (ASTM E2856). However, LNAPL Tn can vary over time due to subsurface conditions such as groundwater fluctuations, corrective action implementation (reduced LNAPL saturation), or weathering of LNAPL.

LNAPL Tn tests should be performed at sites where LNAPL is present to aid in determining the recoverability of the LNAPL. LNAPL Tn tests can also be completed over time to document the progress of LNAPL recovery efforts. The ASTM Standard E2856 discusses several LNAPL Tn test methods and how to select the most appropriate method for site conditions. More information about LNAPL transmissivity may be found in the references to this section particularly ASTM Standard E2856.

Characterization of LNAPL is found through direct and indirect indicators. Both types of indicators determine where and how much LNAPL is on the property and are especially important if the release history is unknown. The level of detail needed when using these methods is commensurate with the complexity of the site.

Some direct methods of detecting the presence of LNAPL include:

- Direct push technologies that can measure for the presence of LNAPL such as Laser Induced Fluorescence (LIF), Rapid Optical Screening Tool LIF, Membrane Interface Probes and cone penetrometers;

- LNAPL presence in wells, borings or test pits;
- Field screening tests such as staining, odors, Organic Vapor Analyzers, Photo Ionization Detectors, Flame Ionization Detectors, shake test using oleophyllic dyes, paint filter test (EPA method 9095B) and paper towel tests;
- Ultra violet light boxes and soil cores;
- Soil and rock core lab analysis;
- Core photography under UV light, pore fluid saturations, soil properties, fluid properties, and LNAPL fingerprinting.

LIF is used to collect real-time, in-situ field screening of residual and non-aqueous phase hydrocarbons in undisturbed vadose, capillary fringe and saturated subsurface soils and groundwater. Detailed information regarding this technology can be found at EPA's Contaminated Site Clean-Up Information website.

LNAPL presence in wells, borings or test pits indicates that LNAPL is in the surrounding formation. In unconfined conditions, the LNAPL could rise and fall with the fluctuation of the water table. However, it is not a reliable indicator of vertical and lateral extent in the formation or for determining the volume of the release. The absence of LNAPL in a well does not necessarily mean the source is eliminated; it may be trapped deeper in the formation by a high water table.

Some indirect indicators of LNAPL presence in the formation include:

- A persistent dissolved phase plume;
- Dissolved phase groundwater concentrations that are close to the effective solubility of the LNAPL that was released;
- Total Petroleum Hydrocarbons (TPH) concentrations (EPA method 418.1) that are greater than the Carbon Saturation (C_{sat}) in a given soil type.

2) Is the LNAPL Body Migrating?

Removal of LNAPL must be conducted to prevent the spread of contamination into previously uncontaminated zones. Following a release, LNAPL moves at higher rates than groundwater due to a large LNAPL hydraulic head. The LNAPL can be "upgradient" due to the mounding effect. Once the release is abated, the LNAPL body will eventually stop migrating.

In order to demonstrate that an LNAPL body is not migrating, the Department requires an evaluation of migration potential. The following can be used to make this determination. A more detailed description of each follows the list. This list is not all inclusive. Some methods that may be used to demonstrate that LNAPL is not migrating include:

- Monitoring results
- LNAPL velocity
- Recovery rate
- Age of the release
- Tracer test

Monitoring results are most important in evaluating migration potential. Assuming that there is an adequate monitoring network and sufficient temporal data, there are several factors that are evidence for a stable footprint, which are a stable or decreasing thickness of LNAPL in monitoring wells, sentinel wells outside of the LNAPL zone that remain free of SPL and a shrinking or stable dissolved phase plume.

Calculating the potential LNAPL velocity using Darcy's Law is also important in the evaluation. The key parameter is LNAPL conductivity which may be estimated from bail down tests, or from the measured LNAPL thickness, soil capillary parameters and a model that assumes static equilibrium. The American Petroleum Institute (API) Interactive LNAPL Guide is one tool that may be used to estimate the LNAPL velocity using this model. It is important to recognize that use of Darcy's Law would be precluded for some site conditions, such as a fractured bedrock site.

The recovery rate that is observed as LNAPL is removed from a well is important to the evaluation. Although not directly correlated to LNAPL migration, declining recovery rates would generally indicate reduced potential for LNAPL to migrate.

The age of the release, when known, aids in determining migration potential. If a relatively long time has transpired since the release there is reduced potential for migration due to smearing of LNAPL within soil and weathering of LNAPL through dissolution, volatilization, and biodegradation.

Tracer tests using hydrophobic dye can also be used for this evaluation. The dilution rate of the dye gives an indication of the rate of movement of the LNAPL. Monitoring wells need to have at least 0.2 feet of LNAPL for this method to work.

3) Remedial Action Plan

After a complete Site Characterization as outlined in 25 Pa. Code §245.309 has been completed and when LNAPL recovery continues, a Remedial Action Plan (RAP) addressing the technologies and methods to remediate both the LNAPL and the dissolved phase portion of the contamination is required under Section 245.311. The RAP should specify remediation goals and endpoints that can be obtained with the most cost effective

solutions/technologies currently proven to remediate the identified contaminants.

If the RAP recommends the ceasing of or no LNAPL recovery, the RAP should clearly list the lines of evidence that demonstrate the LNAPL is not recoverable, is stable, is not migrating and poses no risk to human health and the environment. Once the dissolved phases in groundwater and in soils have met attainment under the selected remediation standard, a Remedial Action Completion Report (RACR) can be submitted.

4) Demonstrating LNAPL Meets MEP Criteria

To determine when LNAPL recovery is no longer necessary or if a case with LNAPL can be recommended for closure, several lines of evidence should show that LNAPL has been recovered to the MEP and that the remaining LNAPL is not migrating and poses no risk. These lines of evidence should also show that natural attenuation processes are continuing, further demonstrating the LNAPL body is stable and not migrating. Lines of evidence should be documented in the RAP and RACR for Act 32 and in the Cleanup Plan and/or Final Report for Act 2. Lines of evidence may include the following:

- An estimate, or supportable estimated range, of the total volume of LNAPL released and present in the subsurface. Volume estimates help determine dissolved plume longevity and the potential to migrate to new areas.
- A discussion, including supporting data, regarding the importance of site-specific soil structure, geology/hydrostratigraphy with an emphasis on the possible existence of macropores, fractures, or conduits in karst. All potential pathways for migration should be analyzed to ensure LNAPL migration to new areas is not occurring.
- A discussion with supporting data that establishes whether LNAPL at the site is a function of groundwater level or confined conditions. Since LNAPL thicknesses are often exaggerated under confined conditions, the LCSM 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. All potential pathways for vapor migration should be analyzed to ensure migration to new areas is not occurring.
- Documentation that demonstrates the areal extent of the LNAPL plume at the site is stable or decreasing. Monitoring of LNAPL thickness in wells over time is needed to determine stability.
- 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 and dissolved plume is undergoing attenuation.
- An evaluation that shows the effective solubility of remaining LNAPL and dissolved-phase concentrations are below site-specific target levels.
- LNAPL Tn data that documents LNAPL recoverability over a range of aquifer conditions. If LNAPL transmissivity as measured by ASTM E2856 is below 0.1, then hydraulic recovery is not feasible. If values exceed 0.1, demonstrate that LNAPL body is not migrating or that Tn values have been decreasing with recovery efforts and have reached asymptotic conditions.
- A qualitative assessment of natural attenuation.
- Information which demonstrates that a description of the removal methods and technologies which have been used and/or evaluated. Evaluation of the results of product removal including whether data shows asymptotic recovery trends through seasonal water table variations. Data that which demonstrates the technologies and additional recovery are not effective.
- Supporting data which contains current site and area maps that show all current receptors, preferential pathways (such as utilities), basements, drinking water wells, and surface water bodies including high quality and exceptional streams, wetlands, and sensitive ecological areas.
- Documentation that the Natural Source Zone Depletion (NSZD) of the LNAPL body and natural attenuation of the dissolved-phase plume are continuing at the site and are expected to further mitigate risk from the release.

5) Closure of Sites with LNAPL

For purposes of this guidance, recovery to MEP is considered complete if the following have been demonstrated:

LNAPL remains onsite, but the following have been achieved:

Receptor evaluation demonstrates that remaining LNAPL, dissolved phase constituents, and associated vapors are not a risk to human health or the environment, and

- i. Natural Source Zone Depletion 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

- ii. Multiple lines of evidence demonstrate that LNAPL had been recovered to MEP, and
- iii. For sites with active LNAPL recovery, evaluation of corrective actions performed at the site shows asymptotic recovery trends through seasonal water table variations, and
- iv. Remaining LNAPL is not recoverable, or has low mobility/recoverability (as evidenced by LNAPL Tn tests)

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

Situations do exist in which LNAPL can justifiably remain at a site after case closure. However, Project Officers should have a full understanding of the site-specific geological, hydrogeological and receptor risk factors before closing a case with measurable LNAPL.

Figure V-1: LNAPL Conceptual Site Model (LCSM) Worksheet

LCSM-describes the physical properties, chemical composition, occurrence and geologic setting of the LNAPL body from which estimates of flux, risk and potential remedial action can be generated (definition taken from ASTM E2531-06).

<u>Site Characterization</u>	<u>Yes</u>	<u>No</u>	<u>N/A</u>	<u>Comments</u>
<u>1. Do you know the past and present site use?</u>	-	-	-	- - - - -
<u>2. Do you know the geology of the site (i.e. soil and bedrock characteristics)?</u>	-	-	-	- - - - -
<u>3. Do you know the hydrogeology of the site?</u>	-	-	-	- - - - -
<u>3.a. Unconfined aquifer?</u>	-	-	-	- - - - -
<u>3.b. Confined/Semi-confined aquifer?</u>	-	-	-	- - - - -
<u>3.c. Perched aquifer</u>	-	-	-	- - - - -
<u>4. Is the source known?</u>	-	-	-	- - - - -
<u>4.a. If yes, what is the source and quantity released?</u>	-	-	-	- - - - -
<u>5. Has the vertical and horizontal extent of the LNAPL body been delineated?</u>	-	-	-	- - - - -
<u>5.a. If yes, have direct or indirect indicators been used to detect presence of LNAPL trapped in soils and/or bedrock?</u>	-	-	-	- - - - -
<u>6. Has dissolved phase or vapor phase plume data been evaluated?</u>	-	-	-	- - - - -

SECTION III.V - RELATIONSHIP TO OTHER ENVIRONMENTAL STATUTES

DG. Regulated Storage Tank Release SitesReferences

<u>6.a. Do any dissolved concentrations in groundwater approach their effective solubility?</u>	-	-	-	-	-	-	-	-
<u>7. Have the physical (density, viscosity, interfacial tension, vapor pressure) and chemical properties (constituent solubilities and mole fractions) of the LNAPL been determined?</u>	-	-	-	-	-	-	-	-
<u>8. Have potential migration pathways been identified (i.e. fractures in bedrock and clay, karst features, utilities)?</u>	-	-	-	-	-	-	-	-
<u>9. Are there complete or potentially complete exposure pathways present (potable wells, surface water, vapor intrusion, etc.)?</u>	-	-	-	-	-	-	-	-
<u>10. Are there ecological receptors impacted by the LNAPL body?</u>	-	-	-	-	-	-	-	-
<u>11. Has sufficient gauging data been gathered to determine if LNAPL is mobile?</u>	-	-	-	-	-	-	-	-
<u>11.a. Has gauging taken place during drought or after heavy precipitation events?</u>	-	-	-	-	-	-	-	-
<u>12. Has LNAPL transmissivity been determined?</u>	-	-	-	-	-	-	-	-
<u>13. Has a qualitative assessment of NSZD been completed?</u>	-	-	-	-	-	-	-	-
<u>14. Does characterization indicate that the LNAPL is no longer migrating?</u>	-	-	-	-	-	-	-	-

SECTION III.V - RELATIONSHIP TO OTHER ENVIRONMENTAL STATUTES

DG. Regulated Storage Tank Release Sites References

E. HSCA/CERCLA Remediation

1. Hazardous Sites Cleanup Act (HSCA) Sites

HSCA is the state Hazardous Sites Cleanup Act (P.L. No. 108 of 1988; 35 P.S. Sections 6020.101-6020.1305). HSCA is the state cleanup law that provides for the remediation of sites contaminated with hazardous substances. HSCA provides the Department with enforcement authorities to encourage parties who are responsible for the release of hazardous substances to conduct the necessary response actions. HSCA also provides the Department with the funding and the authority to conduct response actions when the responsible parties are unwilling or unable to conduct the appropriate response action. The responsible parties can then be held liable for those response costs.

HSCA sites are a limited set of sites that have been officially designated by the Department as meeting the criteria for response action under HSCA. Some HSCA sites are listed on the ~~state~~ Pennsylvania priority Priority list List (PAPL) for remedial response pursuant to Section 502 of HSCA. These are the HSCA sites where the response is expected to cost more than \$2 million or take more than one year to conduct. Pursuant to Section 904(b) of Act 2, "any remediation on a site included on the state priority list established under ... [HSCA], shall be performed in compliance with the administrative record and other procedural and public review requirements of ... [HSCA]." For these listed sites, a party interested in conducting a remedial response can submit a proposal to the Department and work with the Department to reach a settlement. A proposal to conduct a remedial response should be in the form of a letter to the Environmental Cleanup Program Regional Manager, not an NIR. Responsible parties under HSCA are encouraged to propose an Act 2 remedy they would like to perform on the HSCA site. The proposal will be evaluated and published in accord with HSCA. The Department is responsible for choosing a remedy that satisfies Act 2, and that considers public comments and the Department's analysis of the alternatives, pursuant to Section 506(e) of HSCA. It is possible that the Department will select an Act 2 remedy other than that proposed by a responsible party based upon these considerations. Persons who wish to conduct the remediation may follow the settlement procedures established under HSCA. The settlement process would follow the procedures established under HSCA. This would result in a binding settlement agreement which would be subject to the public notice and comment provisions of HSCA.

Most HSCA sites are not listed on the ~~state~~ priority list PAPL for remedial response. These are sites where a HSCA site study or a HSCA interim response is planned. For these HSCA sites where the Department has not yet taken an interim response action or committed to a remedy for the site, a party interested in conducting a voluntary response can submit a NIR and proceed using the normal Act 2 procedures. The Department would monitor the progress of the voluntary response action. If the Department determined that the pace and the scope of the voluntary response was acceptable then no further action pursuant to HSCA would be required. If the Department determined that the pace or the

scope of the voluntary response was not acceptable then the Department could proceed with further action pursuant to HSCA.

2. CERCLA Sites

CERCLA is the federal Superfund law. Under CERCLA the U.S. Environmental Protection Agency (EPA) can place sites on the National Priority List (NPL) "Superfund List" for remedial response. For sites listed on the NPL, EPA requires that all remedial response actions be conducted pursuant to the procedural requirements of CERCLA. As a state law, Act 2 does not waive or supersede the procedural requirements of the federal law, and therefore the Act 2 liability relief cannot automatically confer release from CERCLA liability. However, the Act 2 remediation standards ~~are~~ may be considered applicable standards for remediations conducted at CERCLA sites. EPA also has authority under CERCLA to conduct removal response actions or take enforcement actions at sites that are not listed on the NPL.

F. One-Cleanup Program (RCRA) Oil and Natural Gas Site Remediation

More information to come later

G. References

ASTM E2531, Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface.

ASTM E2856, Standard Guide for Estimation of LNAPL Transmissivity.

EPA. 1996. How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites: A Guide for State Regulators. EPA 510-R-96-001.

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ITRC (Interstate Technology & Regulatory Council) 2009. Evaluating LNAPL Remedial Technologies for Achieving Project Goals. LNAPL-2. Washington, D.C.: Interstate Technology & Regulatory Council, LNAPLs Team. www.itrcweb.org

API (American Petroleum Institute) Interactive LNAPL Guide.

<http://www.api.org/environment-health-and-safety/clean-water/ground-water/lnapl/api-interactive-lnapl-guide>

EPA. Contaminated Site Clean-Up Information. <http://clu-in.org/characterization/technologies/lif.cfm>

EPA. <http://www.epa.gov>