Designation: E2531 – 06 (Reapproved 2020)

Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface[1]

This standard is issued under the fixed designation E2531; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This guide provides a framework for developing a light nonaqueous phase liquid (LNAPL) conceptual site model (LCSM) and for using that LCSM in a corrective action decision framework. LNAPLs are most commonly petroleum or petroleum products liquids. Historically, subsurface LNAPL distribution has been conceptualized based on the thickness observed in monitoring wells. However, these conceptualizations often result in an insufficient risk analysis and frequently lead to poor remedial strategies. By using this guide, the user will be able to perform a more appropriate assessment and develop an LCSM from which better remedial decisions can be made.

The design of this guide is a "tiered" approach, similar to the risk-based corrective action (RBCA) process (Guides E1739 and E2081), where an increase in tiers results from an increase in the site complexity and site-specific information required for the decision-making process. The RBCA guides apply to LNAPL and to dissolved and vapor phases. This guide supplements the RBCA guides by providing more information about identifying LNAPL, linking the LCSM to the RBCA process, and describing how the presence of LNAPL impacts corrective action at sites.

In addition to developing the LCSM, the components of this guide will support the user in identifying site objectives, determining risk-based drivers and non-risk factors, defining remediation metrics, evaluating remedial strategies, and preparing a site for closure. If the processes in this guide are adequately followed for sites with LNAPL, it is expected that more efficient, consistent, economical, and environmentally protective decisions will be made.

1. Scope

1.1 This guide applies to sites with LNAPL present as residual, free, or mobile phases, and anywhere that LNAPL is a source for impacts in soil, ground water, and soil vapor. Use of this guide may show LNAPL to be present where it was previously unrecognized. Information about LNAPL phases and methods for evaluating its potential presence are included in 4.3, guide terminology is in Section 3, and technical glossaries are in Appendix X7 and Appendix X8. Fig. 1 is a flowchart that summarizes the procedures of this guide.

1.2 This guide is intended to supplement the conceptual site model developed in the RBCA process (Guides E1739 and E2081) and in the conceptual site model standard (Guide E1689) by considering LNAPL conditions in sufficient detail to evaluate risks and remedial action options.

1.3 Federal, state, and local regulatory policies and statutes should be followed and form the basis of determining the remedial objectives, whether risk-based or otherwise. Fig. 1 illustrates the interaction between this guide and other related guidance and references.

1.4 Petroleum and other chemical LNAPLs are the primary focus of this guide. Certain technical aspects apply to dense NAPL (DNAPL), but this guide does not address the additional complexities of DNAPLs.

1.5 The composite chemical and physical properties of an LNAPL are a function of the individual chemicals that make-up an LNAPL. The properties of the LNAPL and the subsurface conditions in which it may be present vary widely from site to site. The complexity and level of detail needed in the LCSM varies depending on the exposure pathways and risks and the scope and extent of the remedial actions that are needed. The LCSM follows a tiered development of sufficient

[1] This guide is under the jurisdiction of ASTM Committee E50 on Environmental Assessment, Risk Management and Corrective Action and is the direct responsibility of Subcommittee E50.04 on Corrective Action.

Current edition approved Nov. 1, 2020. Published November 2020. Originally approved in 2006. Last previous edition approved in 2014 as E2531–06(2014). DOI: 10.1520/E2531-06R20.

detail for risk assessment and remedial action decisions to be made. Additional data collection or technical analysis is typically needed when fundamental questions about the LNAPL cannot be answered with existing information.

1.6 This guide does not develop new risk assessment protocols. It is intended to be used in conjunction with existing risk-based corrective action guidance (for example, Guides E1739 and E2081) and regulatory agency requirements (for example, USEPA 1989, 1991, 1992, 1996, 1997).

1.7 This guide assists the user in developing an LCSM upon which a decision framework is applied to assist the user in selecting remedial action options.

1.8 The goal of this guide is to provide sound technical underpinning to LNAPL corrective action using appropriately scaled, site-specific knowledge of the physical and chemical processes controlling LNAPL and the associated plumes in ground water and soil vapor.

1.9 This guide provides flexibility and assists the user in developing general LNAPL site objectives based on the LCSM. This guide recognizes LNAPL site objectives are determined by regulatory, business, regional, social, and other site-specific factors. Within the context of the Guide E2081 RBCA process, these factors are called the technical policy decisions.

1.10 Remediation metrics are defined based on the site objectives and are measurable attributes of a remedial action. Remediation metrics may include environmental benefits, such as flux control, risk reduction, or chemical longevity reduction. Remediation metrics may also include costs, such as installation costs, energy use, business impairments, waste generation, water disposal, and others. Remediation metrics are used in the decision analysis for remedial options and in tracking the performance of implemented remedial action alternatives.

1.11 This guide does not provide procedures for selecting one type of remedial technology over another. Rather, it recommends that technology selection decisions be based on the LCSM, sound professional judgment, and the LNAPL site objectives. These facets are complex and interdisciplinary. Appropriate user knowledge, skills, and judgment are required.

1.12 This guide is not a detailed procedure for engineering analysis and design of remedial action systems. It is intended to be used by qualified professionals to develop a remediation strategy that is based on the scientific and technical information contained in the LCSM. The remediation strategy should be consistent with the site objectives. Supporting engineering analysis and design should be conducted in accordance with relevant professional engineering standards, codes, and requirements.

1.13 ASTM standards are not federal or state regulations; they are voluntary consensus standards.

1.14 The following principles should be followed when using this guide:

1.14.1 Data and information collected should be relevant to and of sufficient quantity and quality to develop a technically-sound LCSM.

1.14.2 Remedial actions taken should be protective of human health and the environment now and in the future.

1.14.3 Remedial actions should have a reasonable probability of meeting the LNAPL site objectives.

1.14.4 Remedial actions implemented should not result in greater site risk than existed before taking actions.

1.14.5 Applicable federal, state, and local regulations should be followed (for example, waste management requirements, ground water designations, worker protection).

1.15 This guide is organized as follows:

1.15.1 Section 2 lists associated and pertinent ASTM documents.

1.15.2 Section 3 defines terminology used in this guide.

1.15.3 Section 4 includes a summary of this guide.

1.15.4 Section 5 provides the significance and use of this guide.

1.15.5 Section 6 presents the components of the LCSM.

1.15.6 Section 7 offers step-by-step procedures.

1.15.7 Nonmandatory appendices are supplied for the following additional information:

1.15.7.1 Appendix X1 provides additional LNAPL reading.

1.15.7.2 Appendix X2 provides an overview of multiphase modeling.

1.15.7.3 Appendix X3 provides example screening level calculations pertaining to the LCSM.

1.15.7.4 Appendix X4 provides information about data collection techniques.

1.15.7.5 Appendix X5 provides example remediation metrics.

1.15.7.6 Appendix X6 provides two simplified examples of the use of the LNAPL guide.

1.15.7.7 Appendix X7 and Appendix X8 are glossaries of technical terminology relevant for LNAPL decision-making.

1.15.8 A reference list is included at the end of the document.

1.16 The appendices are provided for additional information and are not included as mandatory sections of this guide.

1.17 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.18 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

1.19 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D6235 Practice for Expedited Site Characterization of Vadose Zone and Groundwater Contamination at Hazardous Waste Contaminated Sites

D5717 Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured-Rock Aquifers (Withdrawn 2005)[3]

E1689 Guide for Developing Conceptual Site Models for Contaminated Sites

E1739 Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites

E1903 Practice for Environmental Site Assessments: Phase II Environmental Site Assessment Process

E1912 Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases (Withdrawn 2013)[3]

E1943 Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites

E2081 Guide for Risk-Based Corrective Action

E2091 Guide for Use of Activity and Use Limitations, Including Institutional and Engineering Controls

E2205 Guide for Risk-Based Corrective Action for Protection of Ecological Resources

E2348 Guide for Framework for a Consensus-based Environmental Decision-making Process

2.2 *EPA Standard:*[4]

EPA Method 8021B Aromatic and Halogenated Volatiles by Gas Chromatography Using Photoionization and/or Electrolytic Conductivity Detectors

3. Terminology

3.1 *Definitions*—Definitions of terms specific to this standard are included in this section, with additional technical terminology provided for reference in Appendix X7 and Appendix X8.

3.1.1 *active remediation, n*—actions taken to reduce or control LNAPL source flux or the concentrations of chemicals of concern in dissolved- or vapor-phase plumes. Active remediation could be implemented when the no-further-action and passive remediation courses of action are not appropriate.

3.1.2 *attenuation, n*—the reduction in concentrations of chemicals of concern in the environment with distance and time due to processes such as diffusion, dispersion, sorption, chemical degradation, and biodegradation.

3.1.3 *chemicals of concern, n*—specific chemicals that are identified for evaluation in the corrective action process that may be associated with a given LNAPL release and are a concern because of potential risk or aesthetic issues.

3.1.3.1 *Discussion*—Identification can be based on their historical and current use at a site, detected concentrations in environmental media and their mobility, toxicity, and persistence in the environment. Because chemicals of concern may be identified at many points in the corrective action process, including before any determination that they pose an unacceptable risk to human health or the environment, the term should not automatically be construed to be associated with increased or unacceptable risk.

3.1.4 *conceptual model, n*—integration of site information and interpretations generally including facets pertaining to the physical, chemical, transport, and receptor characteristics present at a specific site.

3.1.4.1 *Discussion*—A conceptual model is used to describe comprehensively the sources and chemicals of concern in environmental media and the associated risks for particular locations, both now and in the future, as appropriate, at a site.

3.1.5 *corrective action, n*—sequence of actions taken to address LNAPL releases, protect receptors, and meet other environmental goals.

3.1.5.1 *Discussion*—Corrective actions may include site assessment and investigation, risk assessment, response actions, interim remedial action, remedial action, operation and maintenance of equipment, monitoring of progress, making no-further-action determinations, and termination of the remedial action.

3.1.6 *dense nonaqueous phase liquids (DNAPL), n*—nonaqueous phase liquid with a specific gravity greater than one (for example, a chlorinated solvent, creosote, polychlorinated biphenyls).

3.1.7 *engineering controls, n*—physical modifications to a site or facility (for example, slurry walls, capping, and point-of-use water treatment) to reduce or eliminate the potential for exposure to LNAPL or chemicals of concern in environmental media.

3.1.8 *entrapped LNAPL, n*—residual LNAPL in the form of discontinuous blobs in the void space of a porous medium in a submerged portion of a smear zone resulting from the upward movement of the water table into an LNAPL body.

3.1.8.1 *Discussion*—At a residual condition, however, a transient fall of the water table can result in local area redistribution of LNAPL that is no longer in a residual condition.

3.1.9 *exposure pathway, n*—course a chemical of concern takes from the source area to a receptor or relevant ecological receptor and habitat.

3.1.9.1 *Discussion*—An exposure pathway describes the mechanism by which an individual or population is exposed to a chemical of concern originating from a site. Each exposure pathway includes a source or release from a source (for example, LNAPL released from a tank or pipeline), a point of

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from United States Environmental Protection Association (EPA), Ariel Rios Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov.

exposure, an exposure route, and the potential receptors or relevant ecological receptors and habitats. If the exposure point is not at the source, a transport or exposure medium (for example, air), or both, are also included.

3.1.10 *facility, n*—property containing the source of the LNAPL or chemical of concern where a release has occurred.

3.1.10.1 *Discussion*—A facility may include multiple sources and, therefore, multiple sites.

3.1.11 *flux, n*—mass crossing a unit area per unit time in any phase (for example, LNAPL, dissolved-phase, vapor-phase).

3.1.11.1 *Discussion*—Mass flux controls the concentrations potentially reaching receptors and accounts for the depletion of LNAPL bodies through time. See Fig. 5 and Appendix X2 for more information.

3.1.12 *free LNAPL, n*—LNAPL that is hydraulically connected in the pore space and has the potential to be mobile in the environment.

3.1.12.1 *Discussion*—Often exhibited by LNAPL accumulations in wells. Free LNAPL exceeds the residual saturation. Not all free LNAPL is mobile LNAPL.

3.1.13 *institutional controls, n*—legal or administrative restriction on the use of, or access to, a property so as to eliminate or minimize potential exposure to a chemical of concern (for example, restrictive covenants, restrictive zoning).

3.1.14 *interim remedial action, n*—remedial action taken in the near-term before designing a final remedy to reduce migration of chemicals of concern in the vapor phase, dissolved phase, or LNAPL, or to reduce the concentrations of chemicals of concern or the mass of LNAPL at a source area.

3.1.15 *LNAPL, n*—a light nonaqueous phase liquid having a specific gravity less than one and composed of one or more organic compounds that are immiscible or sparingly soluble in water and the term encompasses all potential occurrences of LNAPL (for example, free, residual, mobile, entrapped). (See Fig. 2.)

3.1.16 *LNAPL body, n*—three-dimensional form and distribution of LNAPL in the subsurface existing in all phases (for example, free, residual, mobile, entrapped).

3.1.17 *LNAPL body footprint, n*—two-dimensional form and distribution of LNAPL in the subsurface existing in all phases (for example, free, residual, mobile, entrapped).

3.1.18 *LNAPL body state, n*—status and conditions of the LNAPL body now and in the future, including whether it is geographically stable, mobile, or recoverable.

3.1.18.1 *Discussion*—The estimates of vapor phase and dissolved phase flux from the LNAPL body are also included in the description of the LNAPL body state. It is a dynamic description of the LNAPL body used in risk assessment and remedial action evaluations.

3.1.19 *LNAPL conceptual site model (LCSM), n*— 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.

3.1.19.1 *Discussion*—The LCSM should be a dynamic, living conceptual model (see 3.1.4) that changes through time as new knowledge is gained or as a result of natural or engineered processes altering LNAPL body and ground water and vapor plume conditions. The LCSM can be presented as text or figures, or both.

3.1.20 *LNAPL properties, n*—physical and chemical properties of a specific LNAPL.

3.1.20.1 *Discussion*—Since many petroleum products are composed of multiple chemicals, and because of environmental interactions, both physical and chemical properties can be quite variable between LNAPLs and over time for an LNAPL body at a site, as are the associated potential environmental risks and amenability to different remedial actions.

3.1.21 *LNAPL site objectives, n*—specific set of well-defined, desired outcomes that serve as a basis for remedial action.

3.1.21.1 *Discussion*—For instance, performing an appropriate remedial action should protect human health and relevant ecological receptors and habitats. The corrective action goals defined under a RBCA process are a subset of the LNAPL site objectives. Remediation metrics (specific measurements of the results of the remedial action) are developed to be consistent with the site objectives. Section 7.5 discusses the LNAPL site objectives in more detail.

3.1.22 *LNAPL type-area, n*—type-area is a description, which may include text, or figures or both, of the geologic, chemical, and LNAPL conditions for a sub-area of a site that represents, or may conservatively represent, the remainder of the site.

3.1.22.1 *Discussion*—Multiple type-areas may be defined for large sites or sites with multiple sources. The intent of using a type-area is to constrain key questions in adequate detail for the type-area, and then apply those findings elsewhere at the site, as appropriate.

3.1.23 *mobile LNAPL, n*—free LNAPL that is moving laterally or vertically in the environment under prevailing hydraulic conditions.

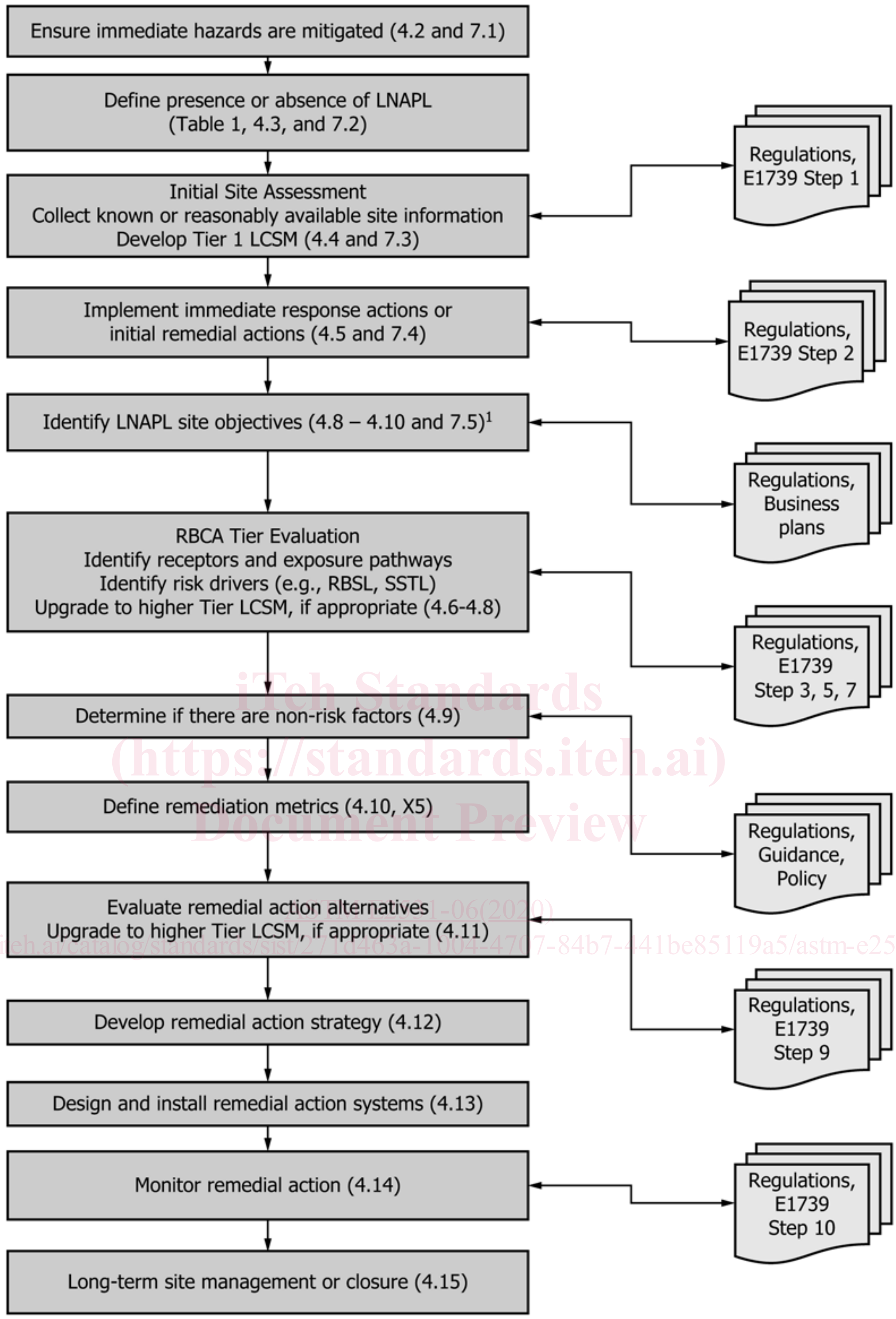
3.1.23.1 *Discussion*—The result of the LNAPL movement is a net mass flux from one point to another. Not all free LNAPL is mobile, but all mobile LNAPL is free LNAPL.

3.1.24 *multi-component, n*—refers to petroleum products or other mixtures composed of many different individual chemicals at varying molar fractions, such as in most petroleum-based fuels, solvents, petrochemicals, and other products.

3.1.25 *natural attenuation, n*—reduction in the mass or concentration of chemicals of concern in environmental media as a result of naturally occurring physical, chemical, and biological processes (for example, diffusion, dispersion, adsorption, chemical degradation, and biodegradation).

3.1.26 *non-risk factors, n*—these are a subset of the desired outcomes that determine the site objectives and they are not strictly based on risks to human health or the environment, although they may have an impact on the risk at a site.

3.1.26.1 *Discussion*—They are often determined by regulations or statutes that are applicable to a site. Examples of non-risk factors include elimination of nuisance conditions and reduction of LNAPL in wells. The non-risk factors should be secondary to risk-based drivers at a site. Section 7.7 provides additional discussion of the non-risk factors.



Ensure immediate hazards are mitigated (4.2 and 7.1)
Define presence or absence of LNAPL (Table 1, 4.3, and 7.2)
Initial Site Assessment
Collect known or reasonably available site information
Develop Tier 1 LCSM (4.4 and 7.3)
Implement immediate response actions or initial remedial actions (4.5 and 7.4)
Identify LNAPL site objectives (4.8 – 4.10 and 7.5)1
RBCA Tier Evaluation
Identify receptors and exposure pathways
Identify risk drivers (e.g., RBSL, SSTL)
Upgrade to higher Tier LCSM, if appropriate (4.6-4.8)
Determine if there are non-risk factors (4.9)
Define remediation metrics (4.10, X5)
Evaluate remedial action alternatives
Upgrade to higher Tier LCSM, if appropriate (4.11)
Develop remedial action strategy (4.12)
Design and install remedial action systems (4.13)
Monitor remedial action (4.14)
Long-term site management or closure (4.15)
Regulations, E1739 Step 1
Regulations, E1739 Step 2
Regulations, Business plans
Regulations, E1739 Step 3, 5, 7
Regulations, Guidance, Policy
Regulations, E1739 Step 9
Regulations, E1739 Step 10

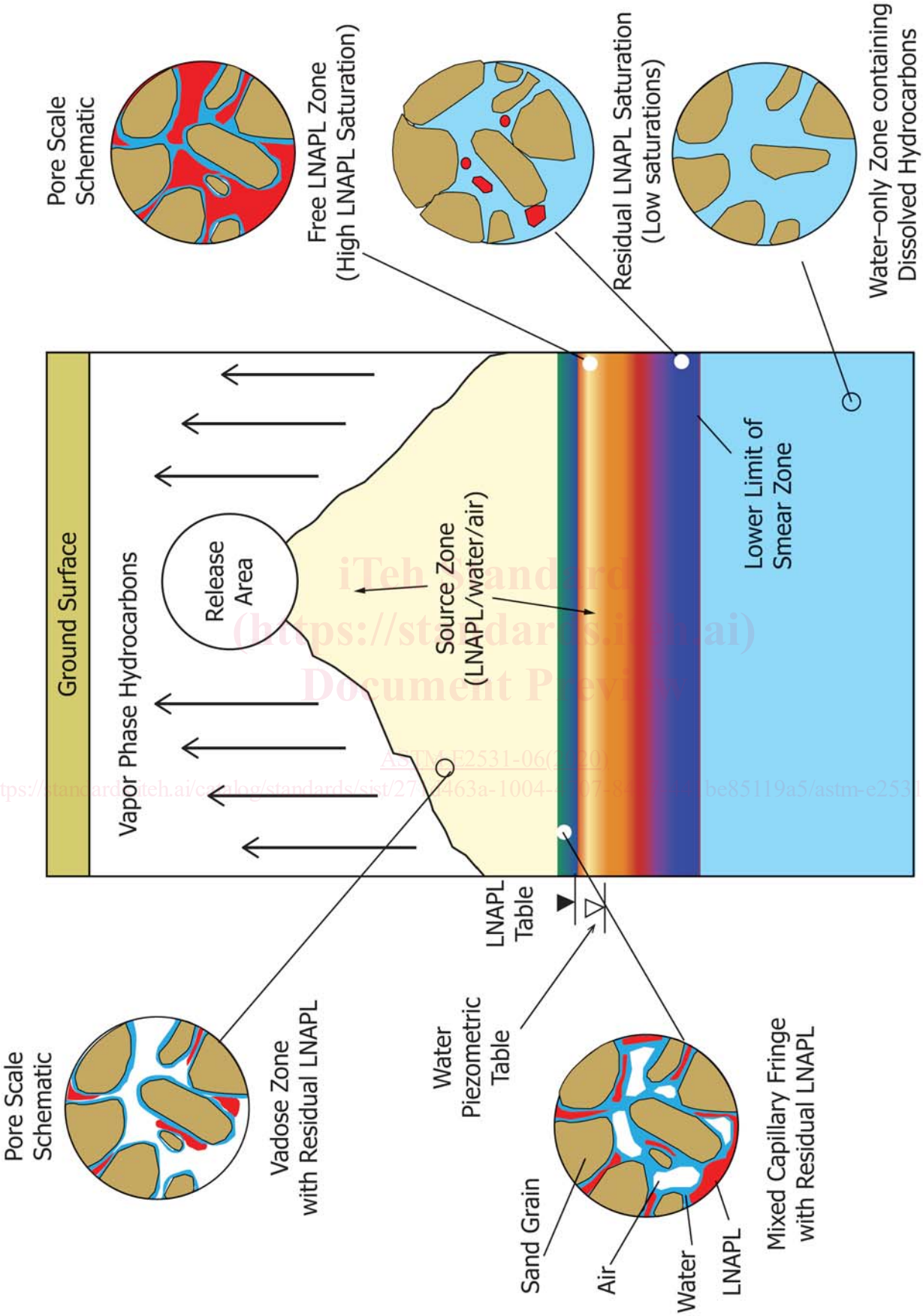
(After Guide E1739 and USEPA 2005 (Ref **1**))

NOTE 1—The user is directed to Fig. 6 for details of the decision process beginning with identifying LNAPL site objectives.

FIG. 1 Summary of the LCSM Guide

3.1.27 *petroleum, n*—including crude oil or any fraction thereof that is liquid at standard conditions of temperature and pressure.

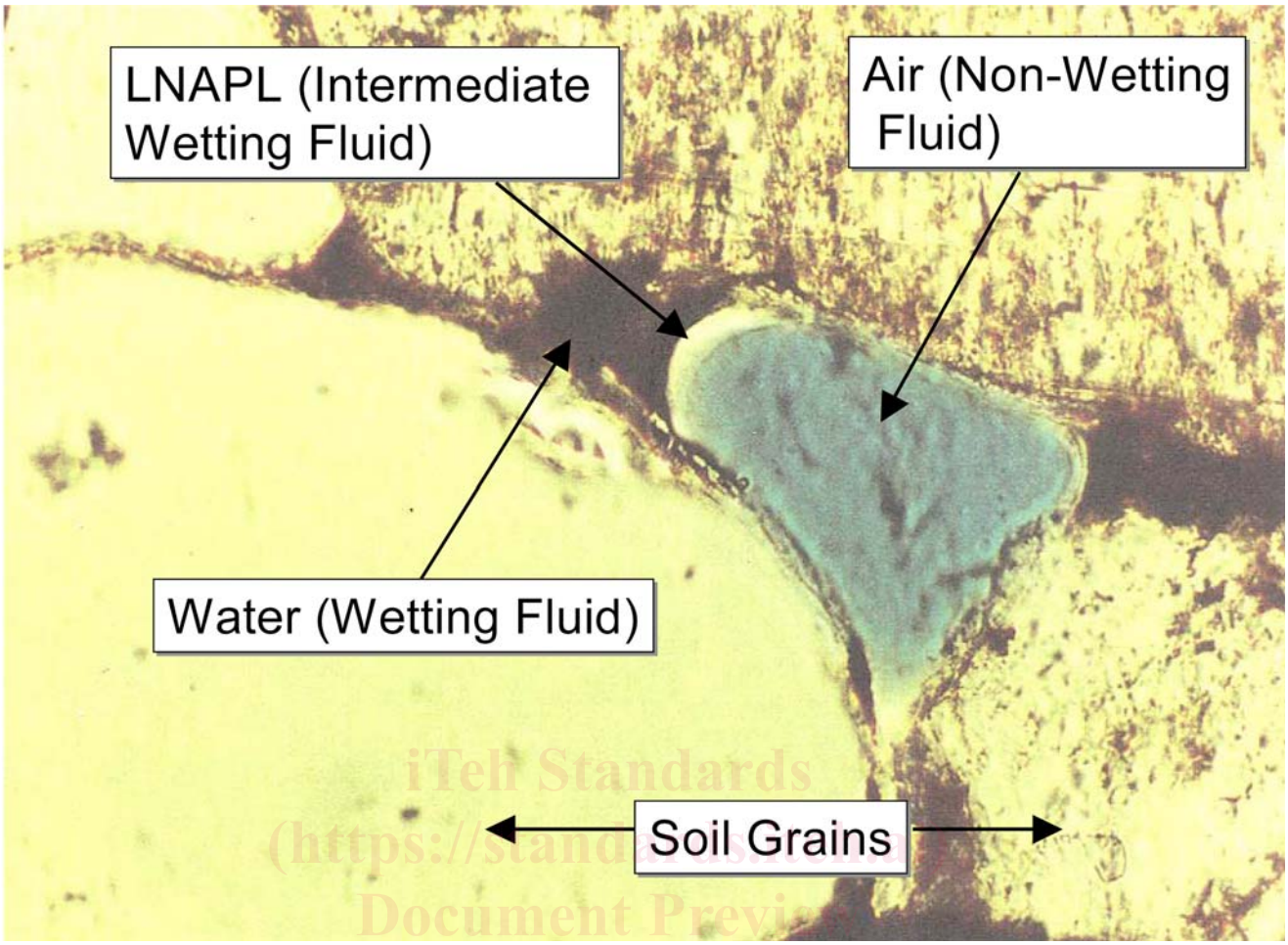
3.1.27.1 *Discussion*—The term includes petroleum-based substances comprised of a complex blend of hydrocarbons derived from crude oil through processes of separation,



LNAPL = light nonaqueous phase liquid
COC = chemicals of concern
(From Huntley and Beckett 2002 (Ref 2))

NOTE 1—During the early stages of an LNAPL release, LNAPL can be mobile (free) in all zones.
NOTE 2—The schematic is intended to convey generalized zones, not the dynamics of an active LNAPL release.

FIG. 2 Illustration of LNAPL Zones



LNAPL = light nonaqueous-phase liquid
(credit: John L. Wilson, 1990)

NOTE 1—Wettability aspects are discussed in Appendix X2.

FIG. 3 Illustration of Residual LNAPL (Immobile) as Identified in a Photomicrograph

conversion, upgrading, and finishing (for example, motor fuels, jet oils, lubricants, petroleum solvents, and used oils).

3.1.28 *plume stability, n*—lack of significant geographic movement in the dissolved phase or vapor phase.

3.1.28.1 *Discussion*—The significance of the movement would typically be measured at a scale pertinent to LNAPL site objectives. For example, if a receptor is nearby, then stability would be demonstrated at a finer-scale than if a receptor is at a more distant location in order to meet the LNAPL site objectives. Different phases can have different stability conditions. For example, the LNAPL body may be geographically stable, but dissolved-phase flux emanating from that body may not be stable.

3.1.29 *point of compliance, n*—location selected between the source area and the potential point of exposure, or other relevant location, where remediation metrics are demonstrated to be met (for example, concentrations of chemical of concern at or below the determined site-specific target levels).

3.1.29.1 *Discussion*—Depending on site conditions, multiple points of compliance may be selected for one source area and point of exposure.

3.1.30 *point of exposure, n*—point at which an individual or population may come in contact with a chemical of concern originating from a site.

3.1.31 *reasonably anticipated future use, n*— future use of a site or facility that can be predicted with a high degree of certainty given current use, local government planning, and zoning.

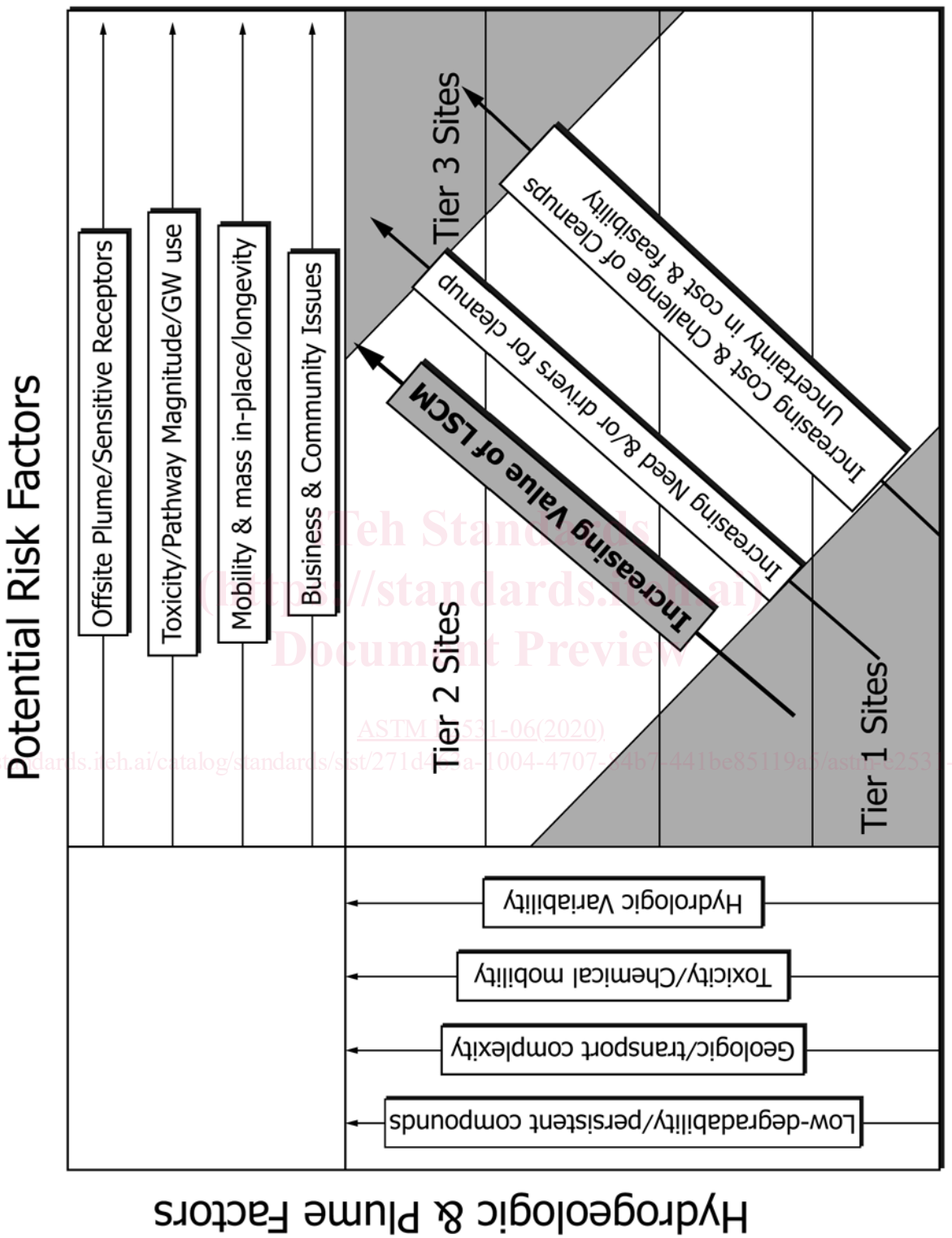
3.1.32 *receptors, n*—persons that are or may be affected by a release (see relevant ecological receptors and habitats for non-human receptor definition).

3.1.33 *recover ability, n*—general term for the degree to which LNAPL can be removed from the subsurface, often defined as the fraction of the total in situ LNAPL mass or of the free or residual volumes.

3.1.33.1 *Discussion*—The recoverability is a function of the in situ LNAPL conditions, the hydrogeologic setting, the type of technology to be used, and the manner in which it is applied.

3.1.34 *release area, n*—area in and around the location where LNAPL was first released to the subsurface.

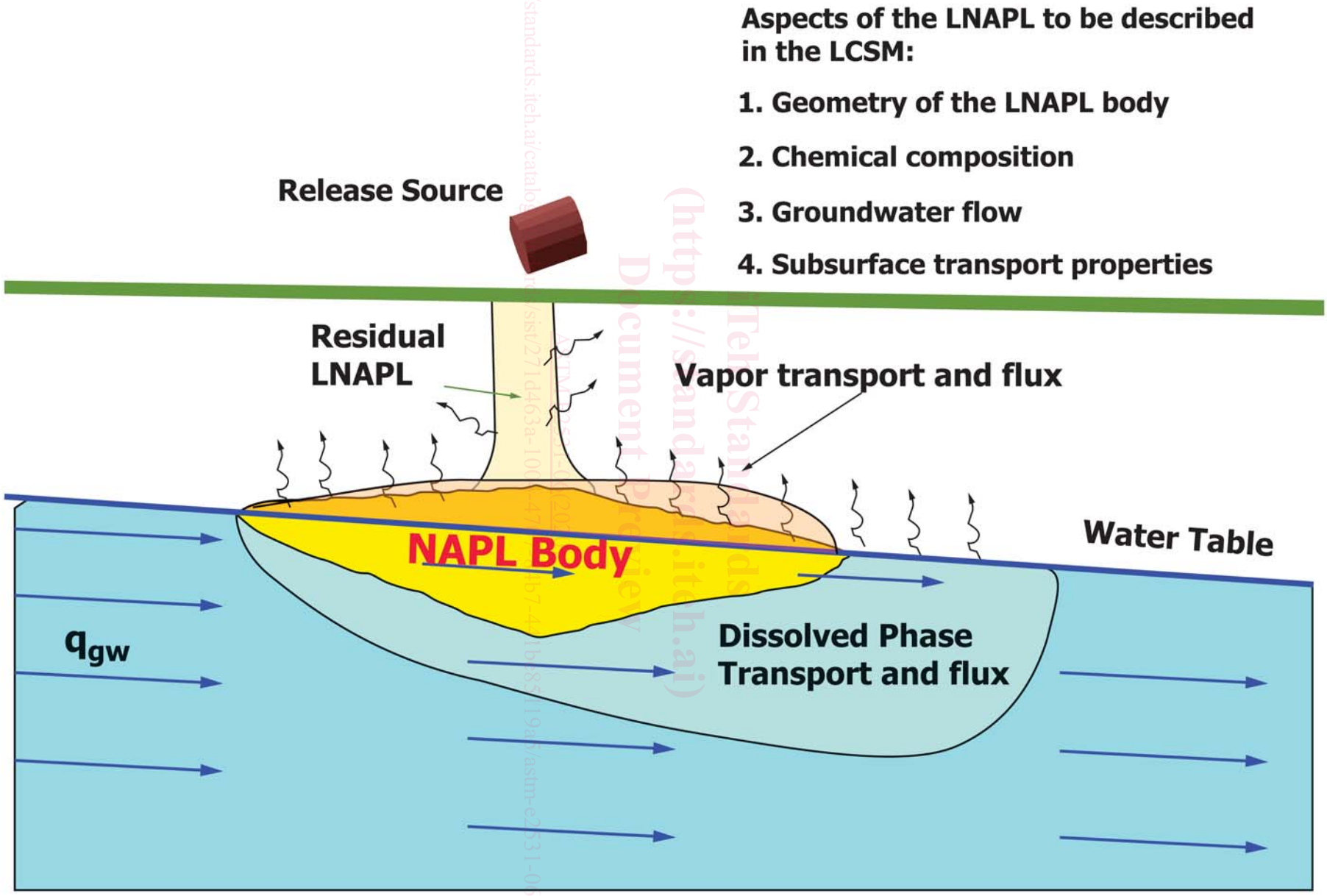
3.1.34.1 *Discussion*—The source zone is the subsequent



NOTE 1—This is an example list that is not exhaustive, the boundary between tiers is subjective and based on user judgment.

NOTE 2—(Concept after Sale 2002. (Ref 3))

FIG. 4 Example Factors Affecting LCSM Complexity (see also Table 2)



(After Huntley and Beckett 2002 (Ref 2))

FIG. 5 Fluxes in Groundwater and Vapor Emanate from the LNAPL

subsurface distribution of LNAPL that forms the source term for dissolved- and vapor-phase plumes, as applicable.

3.1.35 *relevant ecological receptors and habitats, n*—ecological resources that are valued at the site.

3.1.35.1 *Discussion*—Identification of relevant ecological receptors and habitats is dependent on site-specific factors and technical policy decisions. Examples may include species or communities afforded special protection by law or regulation; recreationally, commercially, or culturally important resources; regionally or nationally rare communities; communities with high aesthetic quality; and habitats, species, or communities that are important in maintaining the integrity and bio-diversity of the environment. See Guide E2205 for additional discussion.

3.1.36 *remedial action/remediation, n*—activities conducted to protect human health, safety, and the environment.

3.1.36.1 *Discussion*—Included in remedial actions are monitoring programs, activity and use limitations, engineering controls and active clean up systems. Associated with each of the remedial actions are the applicable implementing, operating and monitoring tasks. Remedial actions include activities that are conducted to recover LNAPL, reduce fluxes of chemicals of concern from the LNAPL, reduce sources of exposure, sever exposure pathways, or make other changes to meet LNAPL site objectives.

3.1.37 *remediation metric, n*—specific measurement associated with progress or performance of a remedial action.

3.1.37.1 *Discussion*—Remediation metrics can be cost metrics or benefit metrics. For example, if chemical flux reduction to a receptor were an LNAPL site objective, measurements of flux before, during, and after remediation would be a metric of that remedial action. Other remediation metrics might be a measurement to determine the minimum mobility potential for observable LNAPL, a maximum allowable concentration of an LNAPL chemical of concern at a point of compliance, or a percentile of the potentially recoverable LNAPL.

3.1.38 *residual LNAPL, n*—LNAPL that is hydraulically discontinuous and immobile under prevailing conditions.

3.1.38.1 *Discussion*—Residual LNAPL that cannot move through hydraulic mechanisms (unless prevailing conditions change), but is a source for chemicals of concern dissolved in ground water or in the vapor-phase in soil gas. The residual LNAPL saturation is a function of the initial (or maximum) LNAPL saturation and the porous medium. (See Fig. 3.)

3.1.39 *risk assessment, n*—analysis of the potential for adverse human health effects or adverse effects to ecological receptors and habitats caused by the LNAPL or chemicals of concern from a site to determine the need for remedial action or the development of LNAPL site objectives (for example, corrective action goals under a RBCA process) in which remedial action is required.

3.1.40 *risk-based drivers, n*—these are remedial requirements that are based solely on the potential risk to human health or ecological receptors and habitats, as compared to remedial requirements based on other factors (for instance, nondegradation of ground water).

3.1.40.1 *Discussion*—Examples of risk-based drivers include reduction of vapor-phase concentrations to protect people in indoor environments and controlling ground water migration to protect drinking water wells. The risk-based drivers should generally be the priority, while recognizing other factors exist as well.

3.1.41 *risk reduction, n*—lowering or elimination of the level of risk posed to human health or relevant ecological receptors and habitats through interim remedial action, remedial action, or institutional or engineering controls.

3.1.42 *site, n*—area defined by the likely physical distribution of LNAPL and chemicals of concern from a source.

3.1.42.1 *Discussion*—A site could be an entire property or facility, a defined area or portion of a facility or property, or multiple facilities or properties. One facility may contain multiple sites. Multiple sites at one facility may be addressed individually or as a group.

3.1.43 *site assessment, n*—characterization of a site through an evaluation of its physical and environmental context (for example, subsurface geology, soil properties and structures, hydrology, and surface characteristics) to determine if a release has occurred, including the levels of the chemicals of concern in environmental media, the likely physical distribution of LNAPL and chemicals of concern, and LNAPL characteristics.

3.1.43.1 *Discussion*—As an example, the site assessment collects data on soil, ground water and surface water quality, land and resource use, potential receptors, and potential relevant ecological receptors and habitats. It also generates information to develop the LCSM and to support corrective action decision-making. The user is referred to Guide E1912 and Practice D6235, and other references in Appendix X1 for more information.

3.1.44 *site-specific, adj*—activities, information, and data unique to a particular site.

3.1.45 *smear zone, n*—zone in and around the historic water table where there is residual and potentially free LNAPL that may be above or below the current water table.

3.1.45.1 *Discussion*—The smear zone results from fluctuations of the water table and redistribution of free LNAPL in that zone at sometime in the past or present.

3.1.46 *source zone, n*—three-dimensional zone in the subsurface associated with the release area where LNAPL acts as source for dissolved-phase and vapor-phase plumes of chemicals of concern.

3.1.47 *stakeholders, n*—individuals, organizations, or other entities that directly affect or are directly affected by a corrective action.

3.1.47.1 *Discussion*—Stakeholders include, but are not limited to, owners, buyers, developers, lenders, insurers, government agencies, and community members and groups.

3.1.48 *user, n*—individual or group using this LNAPL guide including owners, operators, regulators, underground storage tank (UST) fund managers, federal or state government case managers, attorneys, consultants, legislators, and other stakeholders.

4. Summary of Guide

4.1 This LNAPL guide assists in developing an LCSM for making site management decisions. Fig. 1 and the following

TABLE 1 Example LNAPL Indicators

NOTE 1—Items 1 through 3 are direct indicators of LNAPL presence.

NOTE 2—Items 4 through 9 are indirect indicators of potential LNAPL presence.

NOTE 3—The user is encouraged to include additional indicators, as needed.

NOTE 4—Positive responses on indirect indicators increase the likelihood of the presence of LNAPL; additional testing should be conducted to confirm LNAPL presence.

NOTE 5—For any measurement device the reliability of the equipment should be understood (for example, rate of false negatives, rate of false positives) in order to interpret the results.

Measures	Yes/No	Site Information
1. Known LNAPL release		
2. Observed LNAPL (for example, in wells or other discharges)		
3. Visible LNAPL or other direct indicator in samples		
4. Fluorescence response in LNAPL range		
5. Near effective solubility or volatility limits in dissolved or vapor phases.		
6. Dissolved plume persistence and center-of mass stability		
7. TPH concentrations in soil or groundwater indicative of LNAPL presence		
8. Organic vapor analyzer (OVA) and other field observations		
9. Field screening tests positive (for example, paint filter test, dye test, shake test)		

sections summarize the procedure. The figure and text may indicate a linear process; however, as additional data are collected, remedial action is conducted, and knowledge is gained about the LNAPL and the site, the LCSM should be updated and the evaluation processes revisited to incorporate this new information.

4.2 Ensure that immediate or eminent threats and hazards are mitigated. These are conditions such as explosive vapors, flammable materials, or other threatening conditions. State and local regulations and other guidance materials address these facets, as warranted.

4.3 Define the presence or absence of LNAPL based on existing data, if applicable. Table 1 presents some example indicators that individually, or in combination, may suggest the presence of LNAPL at a given site. These are examples only; the list is not comprehensive. The user may develop additional LNAPL screening indicators as technically appropriate. This guide is pertinent to all occurrences of LNAPL, including conditions where it is observable in monitoring wells and where it is not visible, but rather held by capillary forces in the pore space.

4.3.1 LNAPL, where present, is typically the source zone for dissolved- and vapor-phase plumes (that is, assuming that the chemicals of concern that are dissolved in ground water or are volatilized to soil vapor are components of the LNAPL). The LNAPL is often conceptualized as an infinite mass with respect to the dissolved and vapor phases; additional background is included in Appendix X2 and Appendix X4. While the infinite mass concept is useful, it is clear that the LNAPL is in fact a finite mass that will change in character through time as a result of natural processes and remedial actions.

4.3.2 Dissolved- and vapor-phase concentrations of chemicals of concern, which are components of the LNAPL, will remain elevated and be complexly and non-linearly related to the concentration or saturation of LNAPL until the amount of LNAPL remaining is less than the mass capacity in other phases (for example, sorbed, dissolved, vapor). When LNAPL ceases to be present, this guide no longer applies.

4.3.3 A schematic of different LNAPL occurrences considered by this guide is shown in Fig. 2. A photomicrograph showing observed residual, immobile LNAPL in soil is shown in Fig. 3.

4.4 Develop a Tier 1 LCSM based on available information and procedures outlined in this guide. Table 2 is an example evaluation that provides information to identify the potential level of complexity that may be needed for the LCSM. If key elements of the LCSM cannot be developed because of an absence of information, and those elements are necessary to estimate risks to human health or ecological receptors and habitats, then either additional data collection or a remedial action is warranted.

4.5 Determine whether immediate response actions or initial remedial actions are needed based on Guides E1739 and E2081, and federal, state, and local regulations and policies.

4.6 Determine the appropriate activities for stakeholder involvement and public participation for the site, see Guide E2348 and USEPA 2005 (**1**)[5] for additional information.

4.7 Determine if the Tier 1 LCSM is adequate to answer risk questions and remedial action questions. Collect additional information and upgrade to a Tier 2 LCSM, if appropriate, or alternatively, elect to perform a remedial action. For the Tier 2 LCSM, define the LNAPL type-area based on LNAPL occurrence, characteristics of the chemicals of concern, and physical properties of the soil and rock. Guide E1903 contains additional information about environmental site assessments.

4.8 Determine whether risks to human health or ecological receptors or habitats are present using the site-specific LCSM and the RBCA process detailed in Guides E1739 and E2081. Identify the risk-based drivers for the LNAPL site objectives (for example, risk-based screening levels (RBSL), site-specific

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

TABLE 2 Example LNAPL Conceptual Site Model Adequacy Checklist

NOTE 1—The use of the scoring is site- and regulation-specific. As the complexity of the site increases, the benefit of a detailed LSCM increases. This table is designed to help the user identify what level of complexity, or what tier, for the LSCM is likely to be beneficial to the site. See also Fig. 4.

NOTE 2—The factors should be used to develop a weight-of-evidence to suggest the level of complexity for the LSCM. Sites that have a majority of low scores on the factors would likely fall into a Tier 1 LSCM; sites with mostly low and medium scores on the factors would fall into a Tier 2 LSCM; sites with mostly medium and high scores would fall into a Tier 3 LSCM.

NOTE 3—The user is encouraged to include additional, site-specifc factors as needed.

Factors	Score	Data Available	Site Information
Potential Risk Factors			
1. Exposure pathways complete	H/M/L	Y/N	
1a. Risk magnitudes	H/M/L	Y/N	
1b. Toxicity	H/M/L	Y/N	
1c. Sensitive receptors	H/M/L	Y/N	
2. Business issues	H/M/L	Y/N	
3. Community issues	H/M/L	Y/N	
Hydrogeologic and Plume Factors			
4. Chemicals of concern	H/M/L	Y/N	
4a. Degradation	H/M/L	Y/N	
4b. Persistence	H/M/L	Y/N	
5. Plume characteristics	H/M/L	Y/N	
5a. Plume COC/mass distribution	H/M/L	Y/N	
5b. Offsite plume	H/M/L	Y/N	
5c. Uncertainty in LNAPL body	H/M/L	Y/N	
6. Geologic complexity	H/M/L	Y/N	
6a. Conductivity/ grain-size	H/M/L	Y/N	
6b. Degree of heterogeneity	H/M/L	Y/N	
6c. Uncertainty in hydrogeologic conditions	H/M/L	Y/N	
Remediation Factors			
9. Groundwater classification	H/M/L	Y/N	
11. Land use	H/M/L	Y/N	
12. Challenges of remediation	H/M/L	Y/N	
13. Cost of remediation	H/M/L	Y/N	
14. Uncertainty in remediation	H/M/L	Y/N	
Applicable factors			
Total score			

target levels (SSTL), other relevant measurable criteria (ORMC)). See Guide E2081 for further information about risk-based drivers.

4.9 Determine if there are non-risk factors, in addition to the risk-based drivers, for the LNAPL site objectives and remedial action.

4.10 Enumerate the LNAPL site objectives for the risk-based drivers and non-risk factors in adequate detail such that a remediation strategy may be developed based on the LCSM. Define the remediation metrics and determine which remedial action alternatives may be suitable to achieve the LNAPL site objectives. The LNAPL site objectives and remediation metrics should be consistent with the overall site context and other management or remedial goals that may exist for conditions other than the LNAPL and associated plumes.

4.11 Develop a higher tier LCSM or revise LNAPL site objectives if none of the remedial action options appears to address the LNAPL site objectives, or if there is unacceptable uncertainty in the LNAPL remedial action evaluation.

4.12 Develop a remediation strategy using a remedial action option, or set of options. The remediation strategy should be holistic in that it addresses the risks and considers chemicals of concern in the soluble phase, the vapor phase, and the LNAPL. The remediation strategy is based on the evaluation of the benefits and costs of the considered LNAPL remedial action options and the overall site context of site objectives and remediation metrics.

4.13 Use appropriate technical resources to properly design and install the remedial action elements within the remediation strategy. These remedial engineering aspects are not covered in this guide.

4.14 Monitor the remedial action systems; verify the remediation metrics are met.

4.15 Complete the remedial action or implement long-term monitoring and site management, depending on site context and the remedial action evaluations described in this guide.

5. Significance and Use

5.1 This guide will help users answer simple and fundamental questions about the LNAPL occurrence and behavior in the subsurface. It will help users to identify specific risk-based drivers and non-risk factors for action at a site and prioritize resources consistent with these drivers and factors.

5.2 The site management decision process described in this guide includes several features that are only examples of standardized approaches to addressing the objectives of the particular activity. For example, Table 1 provides example indicators of the presence of LNAPL. Table 1 should be

customized by the user with a modified list of LNAPL indicators as technically appropriate for the site or group of sites being addressed.

5.3 This guide advocates use of simple analyses and available data for the LCSM in Tier 1 to make use of existing data and to interpret existing data potentially in new ways. The Tier 1 LCSM is designed to identify where additional data may be needed and where decisions can be made using existing data and bounding estimates.

5.4 This guide expands the LCSM in Tier 2 and Tier 3 to a detailed, dynamic description that considers three-dimensional plume geometry, chemistry, and fluxes associated with the LNAPL that are both chemical- and location-specific.

5.5 This guide fosters effective use of existing site data, while recognizing that information may be only indirectly related to the LNAPL body conditions. This guide also provides a framework for collecting additional data and defining the value of improving the LCSM for remedial decisions.

5.6 By defining the key components of the LCSM, this guide helps identify the framework for understanding LNAPL occurrence and behavior at a site. This guide recommends that specific LNAPL site objectives be identified by the user and stakeholders and remediation metrics be based on the LNAPL site objectives. The LNAPL site objectives should be based on a variety of issues, including:

5.6.1 Potential human health risks and risks to relevant ecological receptors and habitats;

5.6.2 Specific regulatory requirements; and

5.6.3 Aesthetic or other management objectives.

5.7 This guide provides a framework by which users specify benefit remediation metrics that are consistent and achievable given the conditions of the LCSM.

5.8 Guidance is focused on the information needed to make sound decisions rather than specific methods or evaluations that might be used in deriving that information. This guide is weighted toward field data rather than modeling, though modeling is clearly recognized as a useful tool in generating scenarios and bracketing conditions of the LNAPL body conditions. Limited examples of site specific data used to develop the LCSM are provided in Appendix X6.

5.9 By defining specific, measurable attributes of remedial actions acting upon an LCSM, users can determine which actions may be feasible and which likely are not, using an evaluation of a consistent set of factors and expectations.

5.10 A sound LCSM will lead to better decisions about remedial actions. The site management decision process premised on the LCSM is intended to result in more efficient and consistent decision-making about LNAPL risk evaluations and remedial actions.

5.11 The complexity of multiphase LNAPL issues and the wide variety of analysis and interpretation methods that are available has lead to uncertainty in decision-making regarding sites with LNAPL and has sometimes resulted in misleading expectations about remedial outcomes.

5.12 Current risk assessment methods often assume the LNAPL is an infinite source of chemicals of concern. The remediation decision-making may be better defined by considering the LNAPL as the source material for chemicals of concern by explicitly characterizing the chemical composition and physical characteristics of the LNAPL body.

5.13 When LNAPL presents the main source of risk, the LNAPL should be the primary target of remedial actions and those remedial actions should be determined by following the decision evaluations described in this guide.

5.14 LNAPL regulatory policies that define remediation metrics by small LNAPL thicknesses in wells are, on a site-specific basis, often inconsistent with risk-based screening levels (RBSLs) and with current technical knowledge regarding LNAPL mobility and recoverability. LNAPL remediation metrics should be connected to the current or potential future exposures and risks, as well as to other non-risk drivers present for a particular site.

5.15 The user of this guide is encouraged to identify the appropriate process for public involvement and stakeholder participation in the development of the LCSM and the site management decision process.

5.16 By providing a flexible framework, this guidance will continue to be applicable in principle while the many unknowns and uncertainties in LNAPL movement and the associated risks in all plume phases (for example, sorbed, dissolved, vapor) are studied through future research efforts. Like the LCSM itself, this is a “living” document that must embrace advances in knowledge and in technology.

6. Components of the LNAPL Conceptual Site Model

6.1 The LCSM describes the physical properties, chemical composition, and setting of the LNAPL body from which assessments of flux, risk, and potential remedial action can be generated. The LCSM is a dynamic, living model that will change through time as new knowledge is gained or as a result of natural or engineered processes altering conditions. The goal of the LCSM is to describe the nature, geometry, and setting of the LNAPL body and associated dissolved-phase and vapor-phase plumes in sufficient detail so that questions regarding current and potential future risks, longevity, and amenability to remedial action can be adequately addressed.

6.2 The LCSM is developed in a tiered fashion. The level of complexity and refinement of the LCSM, including the complexity of the various specific aspects of the LCSM, are determined based on the questions to be answered at each tier of the assessment (as in the RBCA tiers). The Tier 1 LCSM is developed based on existing site knowledge and using generic assumptions about LNAPL behavior. The Tier 2 LCSM includes some simple site-specific analyses. The Tier 3 LCSM may include more complex evaluations and modeling for any aspect of the LCSM.

6.3 In general the LCSM includes:

6.3.1 LNAPL physical characteristics and chemical composition;

6.3.2 Information about the horizontal and vertical location of the LNAPL body;

6.3.3 Hydrogeologic conditions, history, and properties, and the distribution of those properties;

6.3.4 Information to determine if the LNAPL is mobile at the scale of the LNAPL body footprint (for example, comparisons of the LNAPL body geometry over time);

6.3.5 Information about exposure pathways and potential receptors and relevant ecological receptors and habitats under current and future use scenarios; and

6.3.6 Specific components of the LCSM are discussed further in 6.6.

6.4 The complexity and level of detail in the LCSM follows a tiered approach. Table 2 provides an example LCSM checklist that can be used to assess the needed complexity of the LCSM. The user can customize Table 2 to include more factors or information that may be relevant to a specific site or class of sites. The example table can be used to develop a weight-of-evidence determination for the level of complexity needed in the LCSM. Factors that can affect the relative complexity of the LCSM are shown in Fig. 4.

6.4.1 *Tier 1 LCSM*—These are sites where new or existing standard site assessment data are sufficient to describe risk conditions and potential remedial action alternatives. The complexity and level of detail required in the LCSM is likely to be low. These sites may have the lowest scores (for example, a majority of low scores) on the Table 2 example LCSM checklist. To develop a Tier 1 LCSM:

6.4.1.1 Use existing information, as available for sites that have had historic site assessment activities, including but not limited to soil and ground water sampling, fluid level gauging, boring logs, hydrogeologic testing, release and operations history, and other related information.

6.4.1.2 For sites with no existing information, collect sufficient data to construct a Tier 1 LCSM. Use Table 2 to assist in considering whether a more advanced LCSM is needed for the specific site conditions to ensure data collection efforts, as needed, are executed at the appropriate level of detail and density. This is applicable at any stage of this process where additional data are determined to be necessary.

6.4.2 *Tier 2 LCSM*—These are sites where the Tier 1 LCSM is inadequate to address the risk and remedial action questions that need to be answered. In these cases, the level of detail required in the LCSM is greater. Sites in this category may also require more advanced evaluations of costs and benefits for remedial action alternatives for the selection of applicable remedial action alternatives. These sites may have mid-level scores (for example, a majority of low and medium scores) on the Table 2 example LCSM checklist.

6.4.3 *Tier 3 LCSM*—By definition, if a Tier 2 LCSM has been developed and site assessment, risk assessment, or remedial action questions cannot be answered with existing information, or where it is important to reduce uncertainties, then additional data collection is needed and a more detailed Tier 3 LCSM is developed. These sites may have the highest scores (for example, mostly medium and high scores) on the Table 2 example LCSM checklist.

6.4.4 At any juncture, a remedial action can be implemented in lieu of additional data collection or analysis resulting in higher LCSM tiers. This option would be based on the user's judgment in context with the remedial decision process. If a remedial action is more direct, cost-effective, or otherwise warranted, the user could opt for that action and would not need to develop higher LCSM tiers. However, insufficient understanding of the site can lead to inaccurate remedial decision-making, so it is still recommended that the LCSM be developed at a level of detail that is adequate for the remedial objectives and decisions.

6.5 The LCSM forms the basis for LNAPL corrective action decisions.

6.6 Specific components of the LCSM are presented in this section. The descriptions for each component span the range from Tier 1 through Tier 3 LCSM. Fig. 5 is a schematic of the components that should be addressed in the LCSM. One or more of the components may be unknown or have limited information. If a potential lack of information directly affects a risk assessment or remedial action decision, then additional data or information should be collected. Conversely, if that lack of information has no impact on the risk assessment or remedial action decision, then there would be little or no value to additional data collection.

6.6.1 *Release Source and Timing*—What happened or may have happened during the LNAPL release (for example, location, rate, timing) provides information that may be useful in developing an understanding of the LNAPL body. Its age, conditions of the release and timing assist interpretations about the LNAPL geometry, stability, chemical composition, flux, and other related issues.

6.6.2 *Geometry of the LNAPL Body*—To make flux and risk estimates and to evaluate the potential success of a remedial action for an LNAPL body, the geometry of the LNAPL body must be known in sufficient detail to address these questions.

6.6.2.1 To understand the geometry of the LNAPL body, define the top, bottom, and lateral dimensions of the LNAPL body through direct or indirect observations.

(1) Direct observations could include detectable LNAPL, sheens, emulsification, or oil droplets, or visual signs of LNAPL.

(2) Indirect observations could include ground water or soil vapor concentrations at or near effective solubility or volatility limits, fluorescence in the appropriate ranges, volatility readings, dye testing, or passive sampling of ground water for chemicals of concern at different elevations in wells. The reliability of the indirect measurements (for example, rate of false positives and false negatives) should be considered when interpreting the results from these methods. Often confirmation of indirect results is needed through direct measurement methods. Advances in technology may expand the potential list of available measurement tools and their application in the future.

6.6.3 *LNAPL Chemical Composition and Physical Characteristics*—The chemical composition of the LNAPL and site physical characteristics define the risk and play a key role in estimating mobility and amenability to specific types of remedial action. These characteristics include:

6.6.3.1 Chemicals of concern for risk evaluations;

(1) To understand the LNAPL chemical composition and physical characteristics, define the chemical makeup of the LNAPL body through direct or indirect analytical measurements taken within the LNAPL body.

(a) Direct measurements include laboratory analyses of soils or LNAPL; LNAPL may be extracted from soil cores and need not come only from liquid-phase sampling.

(b) Indirect measurements may include inferences drawn from the chemical composition of the dissolved or vapor phase plumes in contact with the LNAPL source, or from other indirect methods such as geophysical characterization or knowledge about the original released materials.

6.6.3.2 General chemistry for total lifespan and remedial action questions; and

6.6.3.3 Physical properties of the LNAPL (for example, viscosity, interfacial tension density) for mobility, recoverability, and remedial action evaluations.

6.6.4 *Ground Water and Hydrogeologic Conditions*—The ground water and hydrogeologic setting of the site play a key role in identifying the important exposure pathways, estimating mobility and amenability to specific types of remedial action. The ground water and hydrogeologic conditions to consider include:

6.6.4.1 Properties and distribution of soil and rock materials;

(1) To understand the soil and rock conditions, define the physical properties of the soil and rock materials that affect chemical flux, transport, and remedial action (for example, hydraulic conductivity, dispersivity, porosity, density, capillarity, tortuosity, organic content). Additional information is available in Terminology D653.

6.6.4.2 Ground water and hydrologic conditions (for example, gradient, piezometric variability, climatic conditions).

(1) To understand the ground water conditions, define the aquifer and vadose zone features pertinent to flux and potential receptors. These may include factors like effective diffusion coefficients, sorption, degradation half-lives, and others that affect the fate and transport of chemicals to those potential receptors.

6.6.5 *Receptors and Location Characteristics*—The receptor characteristics and their locations relative to the LNAPL body are important to defining the exposure pathways. The information needed includes:

6.6.5.1 Human receptors, relevant ecological receptors and habitats, and resource receptors, see Guides E1739, E2081, and E2205 and USEPA 1989 (**4**) for additional information;

6.6.5.2 Conditions now and likely in the future, including changing land use; and

6.6.5.3 Definition of remedial action timeframe and future uncertainties.

6.6.6 *Estimated Chemical Fluxes or Concentrations in All Phases at Points of Compliance*—An understanding of the concentrations or fluxes in the vapor phase and the dissolved phase at each of the points of compliance is important in determining the actions that are needed for the site.

6.6.7 *Definition of the Mobility or Stability Conditions of the LNAPL Body, Ground Water, and Vapor Plumes*—The condition of the LNAPL body (for example, is the LNAPL body stable, contracting, or expanding?) is important for understanding the risks and the potential remedial action needed for the site.

7. Procedure

7.1 LNAPL, depending on its physical properties and chemical composition, can present immediate concerns for flammability, vapor intrusion, explosivity, and other imminent dangers. Those concerns are dealt with directly by the responsible parties based on regulatory requirements or guidance documents, and while included for context, they are not the focus of this guide.

7.2 Define the presence or absence of LNAPL, and its occurrence (for example, free LNAPL, residual LNAPL; Figs. 2 and 3). If there is no LNAPL present, this guide does not apply. LNAPL presence may be determined from direct or indirect information such as measurement of free LNAPL in wells, LNAPL body or ground water plume persistence, center-of-mass stability, or other relevant features. Table 1 presents some example indicators that individually, or in combination, may suggest the presence of LNAPL at a given site. These are examples; the list is not comprehensive. The user may develop different or additional LNAPL screening indicators as technically appropriate.

7.3 Develop the LCSM. The specific tier of the LCSM is determined based on the information presented in 6.4 and 6.6 and the following sections.

7.3.1 Develop a Tier 1 LCSM that includes the information listed in 6.4.1 using known or reasonably available site data and information. When one of the RBCA standard guides is used at a site, the Tier 1 LCSM would be developed in parallel with the RBCA Tier 1.

7.3.2 Develop a Tier 2 LCSM, addressing the information in 6.4.2 where critical elements are unavailable and cannot be adequately interpreted from the existing or easily obtainable data (for a Tier 1 LCSM). In particular, if the Tier 1 LCSM is inadequate to evaluate risk and remedial action options, a Tier 2 LCSM should be developed. When one of the RBCA standard guides is used at a site, the Tier 2 LCSM would be developed in parallel with the RBCA Tier 2.

7.3.3 Develop a Tier 3 LCSM, addressing the information in 6.4.3 where critical elements are unavailable and cannot be adequately interpreted from the simple site-specific analyses conducted for the Tier 2 LCSM. In particular, if the Tier 2 LCSM is inadequate to evaluate risk and remedial action options, a Tier 3 LCSM should be developed. When one of the RBCA standard guides is used at a site, the Tier 3 LCSM would be developed in parallel with the RBCA Tier 3.

7.3.4 When additional data are collected at a site, including data collected during remedial action implementation and operation, the LCSM should be updated to account for the additional data and observations, regardless of the specific tier where the LCSM development was completed.