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Standard Guide for Non-Aqueous Phase Liquid (NAPL) Mobility and Migration in Sediment—Conceptual Models for NAPL Emplacement and Influence on NAPL Movement¹

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1. Scope

1.1 This guide is designed for application at a wide range of sediment sites where non-aqueous phase liquid (NAPL) is present or suspected to be present. This guide describes emplacement mechanisms that can result in NAPL presence within sediment and how the characteristics of the sediment, aquatic environment, and NAPL will influence NAPL movement (that is, NAPL mobility, NAPL migration, or both) within sediment. This guide provides example conceptual models for NAPL emplacement in sediment to establish a common evaluation framework that can be used to assess conditions influencing NAPL movement by advection in sediment. This evaluation framework for advective NAPL movement categorizes the NAPL as being either mobile or immobile at the pore scale, or migrating or stable at the NAPL body scale.

1.1.1 Evaluation of the potential for NAPL to move in sediment is important for several reasons, including (but not limited to) the evaluation of risk to potential receptors, determining the need for potential remedial action, and developing potential remedial strategies. For example, if the NAPL is migrating, sensitive receptors could be impacted and this will influence the choice and timing of any remedy selected for an area of the sediment site. If the NAPL is immobile at the pore scale or is stable at the NAPL body scale, then remedial actions (other than to address dissolved-phase contaminants solubilized from the NAPL) may not be warranted to address this immobile or stable NAPL.

1.2 The conceptual models for NAPL emplacement in sediment presented in this guide are a component of the overall Conceptual Site Model (CSM) of the sediment site. A robust CSM is typically needed to optimize potential future work efforts at a sediment site, which may include various risk management and remedial strategies for the site, as well as subsequent monitoring after remedy implementation.

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.

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1.3 This guide discusses three broad categories of NAPL emplacement mechanisms.

1.3.1 The first category is the migration of NAPL by advection (flow through the soil pore network) from an upland site into the pore network of sediment beneath an adjacent water body. This NAPL emplacement most commonly occurs within coarser-grained strata within the sediment column.

1.3.2 The second category is the direct discharge of light non-aqueous phase liquid (LNAPL) into a water body, where it is broken down by mechanical energy to form LNAPL droplets. Oil-particle aggregates (OPAs) are formed in the water column when suspended particulates in the surface water adhere to (or penetrate into) the LNAPL droplets originating from direct discharge to the water body. Once enough particulates have adhered to (or penetrated into) an LNAPL droplet and the OPA becomes denser than the surrounding surface water, it settles through the water column onto a competent sediment surface; here, it forms an in situ deposited NAPL (IDN) and it may be buried by future sedimentation. Because the LNAPL is emplaced by the deposition of the OPAs and LNAPL releases can occur at any time, the LNAPL can be emplaced throughout the sediment column, in both finer- and coarser-grained strata.

1.3.3 The third category is dense non-aqueous phase liquid (DNAPL) flow. This is direct discharge of DNAPL into a water body, followed by settling through the water column and deposition directly onto a relatively competent sediment surface, where it may be buried by future sedimentation. The DNAPL typically experiences gravity flow atop the sediment surface, until it collects in a local sedimentary depression. Unlike the other two emplacement categories, it is the DNAPL that is the matrix and it contains entrained sediment particulates. As DNAPL releases can occur at any time, the DNAPL can be emplaced throughout the sediment column, in both finer- and coarser-grained strata.

1.4 This guide concerns the advective movement of NAPL in sediment. Ebullition-facilitated transport of NAPL from the sediment into the water column by gas bubbles is not within the scope of this guide. The measurement and evaluation of ebullition and associated NAPL/contaminant transport are discussed in Guides E3300 and E3447. Processes associated

with NAPL movement due to erosion (for example, caused by propeller wash) are also beyond the scope of this guide.

1.5 Petroleum hydrocarbon, coal tar, and other tar NAPLs (including fuels, oils, and creosote) are the primary focus of this guide. These forms of contamination are commonly related to historical operations at petroleum refineries, petroleum distribution terminals, manufactured gas plants (MGPs), and various large industrial sites.

1.5.1 Although certain technical aspects of this guide apply to other NAPLs (for example, DNAPLs such as chlorinated hydrocarbon solvents), this guide does not completely address the additional complexities of those DNAPLs.

1.6 *Related ASTM Standards*—This guide is related to several other guides that cover various aspects of NAPL mobility and migration in sediment. Guide [E3268](#) provides guidance on the collection and handling of sediment samples that are representative of in situ conditions for laboratory geotechnical and NAPL mobility testing. Guide [E3281](#) discusses the use of field screening methodologies to select sediment samples to be submitted for laboratory NAPL mobility testing. Guide [E3282](#) discusses metrics (for various lines-of-evidence (LOE)) to evaluate whether NAPL is mobile or immobile at the pore scale and, if the NAPL is mobile, describes other metrics (using additional LOE) to evaluate whether NAPL is migrating or stable at the NAPL body scale. Guide [E3282](#) also presents example decision analysis frameworks for ascertaining whether NAPL is mobile at the pore scale or migrating at the NAPL body scale (or both). Guide [E3300](#) discusses ebullition fundamentals and how to obtain ebullition-facilitated transport (EFT) rates for NAPL and associated contaminants (which can be used to estimate NAPL/contaminant loadings to the water body). Guide [E3447](#) discusses the use of flux chambers to obtain the data used to calculate EFT rates.

1.7 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

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

1.9 *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

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

[E1689](#) Guide for Developing Conceptual Site Models for Contaminated Sites

[E1739](#) Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (Withdrawn 2024)³

[E2081](#) Guide for Risk-Based Corrective Action

[E2531](#) Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface

[E2993](#) Guide for Evaluating Potential Hazard in Buildings as a Result of Methane in the Vadose Zone

[E3163](#) Guide for Contaminated Sediment Site Risk-Based Corrective Action—Selection and Application of Analytical Methods and Test Procedures

[E3240](#) Guide for Risk-Based Corrective Action for Contaminated Sediment Sites

[E3268](#) Guide for NAPL Mobility and Migration in Sediment—Sample Collection, Field Screening, and Sample Handling

[E3281](#) Guide for NAPL Mobility and Migration in Sediments – Screening Process to Categorize Samples for Laboratory NAPL Mobility Testing

[E3282](#) Guide for NAPL Mobility and Migration in Sediments – Evaluation Metrics

[E3300](#) Guide for NAPL Mobility and Migration in Sediment—Evaluating Ebullition and Associated NAPL/Contaminant Transport

[E3382](#) Guide for Developing Representative Background Concentrations at Sediment Sites—Framework Overview, Including Conceptual Site Model Considerations

[E3447](#) Guide for NAPL Mobility and Migration in Sediments—Use of Ebullition Flux Chambers

3. Terminology

3.1 Definitions:

3.1.1 *conceptual site model (CSM), n*—the integrated representation of the physical and environmental context, the complete and potentially complete exposure pathways, and the potential fate and transport of potential contaminants of concern at a site. **E3382**

3.1.1.1 *Discussion*—The CSM should include the current understanding of the sediment site and an understanding of the potential future conditions and uses for the site. It provides a method to conduct the exposure pathway evaluation; inventory the exposure pathways evaluated; and determine the status of the exposure pathways as incomplete, potentially complete, or complete.

3.1.2 *contaminant, n*—substance not normally found in an environment at the observed concentration. **E2993**

3.1.3 *ebullition, n*—a process of gas (primarily methane) generation in sediments where the quantity of gas generated is sufficient for gas bubbles to nucleate, grow, fracture the sediment, and then escape into the overlying water body. **E3300**

3.1.3.1 *Discussion*—Depending on the composition of a particular sediment, the gas bubbles generated and released by

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