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Standard Guide for NAPL Mobility and Migration in Sediments – Evaluation Metrics¹

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1. Scope

1.1 This guide discusses methodologies that can be applied to evaluate the potential for the movement (that is, pore-scale mobility or NAPL body-scale migration) of non-aqueous phase liquid (NAPL) in sediments. NAPL movement assessment in sediments is significantly different than in upland soils. As such, the frameworks for evaluating NAPL movement in upland soils have limited applicability for sediments. In particular, because upland NAPL conceptual site models may not be applicable to many sediment sites, this guide provides a framework to evaluate whether NAPL is mobile (at the pore scale) or migrating (at the NAPL body scale) in sediments.

1.2 Assessment of the potential for NAPL to move in sediment is important for several reasons, including (but not limited to) evaluation of risk to potential receptors, the need for potential remedial action, and potential remedial strategies. For example, if the NAPL is migrating, sensitive receptors may 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 not mobile or migrating, then remedial actions may not be warranted.

1.3 This guide is applicable at sediment sites where NAPL has been identified in the sediment by various screening methods and the need for a NAPL movement evaluation is warranted (Guide E3248).

1.4 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 refineries, petroleum distribution terminals, manufactured gas plants (MGPs), and various large industrial sites.

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

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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1.6 The goal of this guide is to provide a sound technical basis to determine if NAPL at the site is mobile or immobile at the pore scale, and if mobile, whether it is stable or migrating at the NAPL body scale. The potential for NAPL movement in the sediment is a key component in the development of the conceptual site model (CSM) and in deciding what remedial options should potentially be chosen for the site to reduce potential risks to human health and ecological receptors.

1.7 This guide can be used to help develop, or refine, a CSM for the sediment site. A robust CSM is typically needed to optimize potential future work efforts at the site, which may include various risk management and remedial strategies for the site, as well as subsequent monitoring after any remedy implementation.

1.8 This guide considers the mobility of NAPL in sediments that originated from three broad categories of potential NAPL emplacement mechanisms (Guide E3248).

1.8.1 Migration of NAPL by advection (flow through the soil pore network) from an upland site into the pore network of sediments beneath an adjacent water body is one category of NAPL emplacement mechanism. This most commonly occurs within coarse-grained strata in the sediment.

1.8.2 Direct discharge of light NAPL (LNAPL) into a waterway, where it is broken down by mechanical energy to form LNAPL beads, is another category of NAPL emplacement mechanism. Oil-particle aggregates (OPAs) are formed when suspended particulates in surface water adhere to LNAPL beads. Once enough particulates have adhered to an LNAPL bead and the OPA becomes dense enough, it settles through the water column onto a competent sediment surface, where it forms an in situ deposited NAPL (IDN) and may be buried by future sedimentation.

1.8.3 The third category of NAPL emplacement mechanism is DNAPL flow (that is, direct discharge of DNAPL into a waterway), followed by settling through the water column and deposition directly onto a competent sediment surface, where it may be buried by future sedimentation.

1.9 Ebullition-facilitated transport of NAPL from the sediment to the water column by gas bubbles is *not* within the scope of this guide. The evaluation of ebullition and associated NAPL/contaminant transport is covered in Guide E3300.

Transport of NAPL due to erosional forces (for example, propeller wash) *is not* within the scope of this guide.

1.10 This guide (see Section 5) presents an overall framework to evaluate if NAPL at the site is mobile or immobile at the pore scale, and migrating or stable at the NAPL body scale. It provides guidance on approaches and methodologies that address questions regarding NAPL movement evaluation.

1.11 This guide (see Section 6) discusses the use of data from various laboratory tests (Appendix X1), calculation methodologies, and other methodologies to technically evaluate if NAPL in sediment at various locations in the site is mobile or immobile at the pore scale, and stable or migrating at the NAPL body scale. This evaluation can be performed using tiered and weight of evidence (WOE) frameworks. For example, it may be possible that NAPL is mobile or migrating in one part of the site, but is immobile in other parts of the site. There are currently no industry standard tiered and WOE frameworks to evaluate if NAPL in sediment is mobile or migrating, but illustrative examples of such frameworks are presented in Appendix X2. Case studies demonstrating the application of the example tiered and WOE frameworks exhibited in Appendix X2 are presented in Appendix X3.

1.12 This guide (see Section 7) discusses applicable laboratory centrifuge testing methodologies that are used to evaluate NAPL mobility or immobility at the pore scale under the applicable test conditions (also see Appendix X4). Appendix X5 discusses the laboratory preparation of sediment samples used in centrifuge testing.

1.13 This guide (see Section 8) discusses applicable laboratory water drive testing methodologies that are used to evaluate NAPL mobility or immobility at the pore scale under the applicable test conditions. This section discusses both rigid wall and flexible wall permeameter testing (also see Appendix X6). Appendix X5 discusses the laboratory preparation of sediment samples used in water drive testing.

1.14 This guide (see Section 9) discusses calculation methodologies that provide insight into pore-scale NAPL mobility and NAPL body-scale migration at the site. To perform some of these calculations, NAPL property data such as density, viscosity, and NAPL–water interfacial tension are needed (see Appendix X1). The calculation methodologies include NAPL density versus hydraulic gradient calculations; pore entry pressure calculations; critical NAPL layer thickness calculations; and NAPL pore velocity calculations (also see Appendix X7 and Appendix X8).

1.15 This guide (see Section 10) presents other field observation approaches that are useful in evaluating pore-scale NAPL mobility and NAPL body-scale migration. These methodologies include vertical profiles of NAPL saturation (including isopach mapping of the thickness of unimpacted sediment above the NAPL zone); and installation of monitoring wells in sediment.

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

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 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

- D425 Test Method for Centrifuge Moisture Equivalent of Soils
- D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
- D971 Test Method for Interfacial Tension of Insulating Liquids Against Water by the Ring Method
- D1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer
- D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
- D5856 Test Method for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter
- D6836 Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, or Centrifuge
- D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
- D7263 Test Methods for Laboratory Determination of Density and Unit Weight of Soil Specimens
- D7928 Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis
- E2531 Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface
- E2856 Guide for Estimation of LNAPL Transmissivity
- E3164 Guide for Sediment Corrective Action – Monitoring
- E3248 Guide for NAPL Mobility and Migration in Sediment – Conceptual Models for Emplacement and Advection
- E3281 Guide for NAPL Mobility and Migration in Sediments – Screening Process to Categorize Samples for

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.