Table A-17.C. Technical implementation considerations for natural source zone depletion

Data requirements	NSZD design parameters to implement NSZD	LCSM (saturated zone and unsaturated zone)	Detailed LCSM, appropriate for verification of LNAPL depletion mechanisms and monitoring network.
		LNAPL physical and chemical characteristics	Measure fluid density and representative hydrocarbon for stoichiometric conversions. Estimate mass fraction of COCs in the LNAPL and effective solubility of submerged LNAPL in saturated zone.
	Selection of NSZD monitoring method(s) Various methods are available to measure NSZD rates. Review these site conditions and select the most appropriate method(s) to meet the established data objectives of the NSZD evaluation.	Soil type and moisture content	Movement of gases from NSZD is affected by soil gas permeability and water content. This information can typically be obtained from borehole logs prepared by experienced geologists.
		Depth to top of hydrocarbon impacts	Delineate the depth of LNAPL impacts to base depth interval where biogenic gases could be expected to occur.
		Diversity of ground cover (e.g., pervious, vegetated)	Type of ground cover will drive selection of the measurement method -- e.g., sites with pavement or capped surfaces can be challenging for CO_2 flux methods.
		Shallow soil gas oxygen/ methane concentrations	Measure oxygen and methane concentration in shallow soil gas; it provides insight into magnitude of soil gas exchange and magnitude of subsurface oxidation
		Monitoring locations, timing, and frequency	The number of NSZD monitoring locations, best timing for measurement, and frequency will depend upon the established data objectives and climatic/hydrogeologic conditions.
		Background correction approach	Several methods are available to eliminate the contribution from non-NSZD processes on field measurements. Background correction methods vary based on the NSZD assessment method; confirm that the background correction involved in a proposed NSZD method is feasible for the site.
	Site-Specific Data for NSZD Qualitative Assessment (some or all of these data can be used)	Field Screening of Soil Gas	Field-screening of soil gas composition from existing monitoring wells screened across the water table to identify areas of elevated methane or carbon dioxide and depleted oxygen
		Groundwater sampling	Groundwater sampling to identify areas of increased dissolved-phase hydrocarbons, dissolved iron, manganese, methane, and carbon dioxide, and decreased dissolved oxygen, sulfate, and/or nitrate
		Short-term temperature screening	Temperature profiles showing heat signatures consistent with methane oxidation in the vadose zone
	Site-specific data for NSZD evaluation via Gradient Method	Vertical profile of soil gas composition (including O_2, CO_2, CH_4)	Measure soil gas concentration profiles in the field using multi-depth soil gas probes
		Effective vapor phase diffusion coefficient	Measure in the field or estimate from soil moisture and total porosity
	Site-specific data for NSZD evaluation via Passive CO_2 Flux and Dynamic Closed Chamber Methods	CO2 Flux	Measure CO^2 flux with appropriate method.
		Background correction	Utilize cabon-14 isotope or background CO_2 flux from outside LNAPL body/active NSZD zone

	Site-specific data for NSZD evaluation via Biogenic Heat Method	Subsurface temperature	Measure range of subsurface temperatures to identify biogenic heat signatures
		Thermal Conductivity	Measure or estimate thermal conductivity to quantify NSZD rate
		Background correction	Use location outside LNAPL body/active NSZD zone or model a theoretical background profile.
	Site-specific data for NSZD evaluation via Aqueous Phase Mass Budget	Groundwater hydraulics of saturated zone	Hydraulic conductivity, groundwater-specific discharge.
		Dissolved LNAPL concentrations	Dissolved LNAPL constituent fraction concentrations upgradient and downgradient of submerged LNAPL source zone.
		Dissolved electron acceptor/ biotransformation products	Dissolved cation, anion, and gases groundwater geochemical constituents used to quantify mass loss via aqueous phase-related biodegradation processes.
	Bench-scale tests for LNAPL longevity	An example of a potential bench test for LNAPL longevity was described in ITRC, 2009. However, bench tests are not typically performed.	
	Example performance metrics	Stable or decreasing extent of in-well LNAPL presence	Monitor changes of the extent of monitoring wells containing in-well LNAPL across the LNAPL footprint.
		Aqueous-phase dissolution/ biodegradation mass loss rate	Current source zone mass loss rate associated with LNAPL dissolution and subsequent biodegradation as manifested in changes to dissolved chemicals (e.g., contaminants of concern, electron acceptors, and/or biodegradation by-products) in groundwater.
		Vapor-phase volatilization/offgasing/biodegradation mass loss rate	Current LNAPL source zone mass loss rate as manifested in changes to gases (VOCs, CH_4, CO_2, and O_2) in the vadose zone.
		Decreasing mass fractions of COCs in the LNAPL	Statistical analysis of time series changes in COC content of the LNAPL chemical composition.
Modeling tools/ applicable models		Empirical relationships	Empirically-derived models or mathematical relationships can be useful to estimate inputs that may be difficult to practically measure at a site. For example, Millington and Quirk (1961) provide a method to estimate effective diffusion coefficients for soil, and van Wijk and de Vries (1963) provide a way to estimate background subsurface temperature.
Further information		See the NSZD appendix of this document.	
		American Petroleum Institute (API), 2017. Quantification of Vapor Phase-related Natural Source Zone Depletion Processes, 1st Edition. API Publication 4784. https://publications.api.org/	