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Risk-Based NAPL Management

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Remediation

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Risk-Based NAPL Management

Prepared by
Remediation Division

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Contents

Appendixes

Tables

Figures

Risk-Based NAPL Management

Objectives: To explain the risk-based management approach for non-aqueous phase liquid under the Texas Risk Reduction Program (TRRP) rule and presents a five-step process to address the rule requirements.

Audience: TCEQ Project Managers, Regulated Community and Environmental Professionals

References: TRRP regulatory citations are provided in Table 2 of this document.

TRRP rule and preamble are online at <www.tceq.texas.gov/remediation/trrp/trrp.html>.

The TRRP rule, together with conforming changes to related rules, is contained in 30 Texas Administrative Code (TAC) Chapter 350, published in the September 17, 1999 Texas Register (24 TexReg 7413-7944). Amendments to the TRRP rule were adopted March 16, 2007 (32 TexReg 1526-1579). Download Tier 1 Protective Concentration Level (PCL) tables, toxicity factors, and other TRRP information at: <www.tceq.texas.gov/remediation/trrp/trrp.html>.

TRRP guidance documents undergo periodic revision and are subject to change. Information on document update schedule and links to current versions at: <www.tceq.texas.gov/remediation/trrp/guidance.html>.

Referenced TRRP guidance documents may be in development; check status at: <www.tceq.texas.gov/remediation/trrp/guidance.html>.

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i. Introduction

This publication is a guide to the risk-based management of non-aqueous phase liquid (NAPL) identified or otherwise inferred to be present at an affected property. This section describes the risk-based NAPL management paradigm and its regulatory basis, definitions, key concepts, and provides an overview of the stepped risk-based NAPL management process. Subsequent sections of detail the five steps of the NAPL management process and guidance for their application.

NAPL occurrences within a *Facility Operations Area* (FOA) should be addressed consistent with the requirements in Section 350.135(a)(9) of the Texas Risk Reduction Rules (TRRP). Guidance for addressing NAPLs in a FOA may be found in TCEQ Guidance Document RG-366/TRRP-34 *Facility Operations Area*.

This guidance does not establish a separate process for NAPL sites when determining whether a landowner's concurrence will be required or whether financial compensation must be made. All of the TRRP provisions established in Section 350.111 to protect landowner private property rights apply fully to NAPL sites.

i.1 Risk-Based NAPL Management Paradigm

NAPL is an organic or inorganic liquid that is not miscible in water. When NAPL is released to the environment it can be a direct source of long-term release of chemicals of concern (COCs) to environmental media or for direct exposure. As such, NAPL is potentially capable of affecting all environmental media, migrating to the various exposure pathways and impacting environmental and ecological receptors. Therefore, *affected property assessments must include the investigation of NAPL when its potential presence is indicated*.

Table 1 summarizes the TRRP NAPL regulatory concerns. This guidance describes how a potential threat to exposure pathways and associated risks posed by NAPL releases can be properly managed in a feasible and appropriate manner. It is recommended that the reader become familiar with the terms defined in Section i.5 of this document.

Table 1. TRRP NAPL Concerns

TRRP Regulatory Concerns for NAPL	Source of explosive vapor accumulations in surface or subsurface structures
	NAPL migration and further impacts
	Source of a nuisance condition or aesthetic impairment
	Direct toxic threat to human or ecological receptors
	Source for cross-media transfer of COCs to air, groundwater, soils, surface water and/or sediments

This guidance addresses the human health and environmental risks associated with the TRRP NAPL concerns (Table 1) by integrating risk-based decision-making into the NAPL management process. Specifically defined NAPL response endpoints offer risk-based protectiveness and readily achievable "extent practicable" NAPL recovery goals. Additionally, this guide clarifies when NAPL recovery is required and when a control-based alternative may be available.

For situations in which NAPL occurrences have not been sufficiently assessed, the application of this risk-based strategy is not available.

It is recommended that the guidance be followed as presented to foster a consistent and intended shift to risk-based NAPL management. Be aware that *this guidance is focused only on NAPL management and that additional response actions may be required within the NAPL zone to fully comply with the TRRP rule requirements*. See Section i.3 for more information on this subject.

i.2 Regulatory Basis

Table 2 summarizes the rule provisions for each NAPL regulatory concern (see Table 1) in the context of specific situations and Remedy Standard A and B. Each of these provisions is discussed in detail in this document.

Table 2. NAPL Management Provisions in TRRP

NAPL Management Provision[1]	Remedy Standard A[2]	Remedy Standard B[8]
Abate explosive conditions	§350.31(c)	§350.31(c)
Prevent or stabilize migrating NAPL zone	§350.37(d), §350.74(i)(2)(A) §350.75(i)(10)	§350.33(f)(4)(F)(iii)(II) §350.37(d) §350.74(i)(2)(A) §350.75(i)(10)
Abate aesthetic impacts or nuisance conditions[3]	§350.74(f)(3) §350.74 (i)	§350.74(f)(3) §350.74 (i)
Abate toxic threat to human and ecological receptors		
Recover or prevent exposure to NAPL in soil via control	§350.31(b) §350.32(a)-(b)	§350.33(b)
Recover NAPL in contact with Class 1 groundwater [3, 4, 5, 6]	§350.31(b) §350.32(a)-(b) §350.74(f)(3)	§350.33(b) §350.33(f)(2) §350.33 (f)(3) §350.33(f)(4)(E) §350.74(f)(3)
Recover or prevent exposure to NAPL in contact with Class 2 or Class 3 groundwater via control [4, 5, 7]	§350.31(b) §350.32(a)-(b) §350.74(f)(3)	§350.33(b) §350.33(f)(2) §350.33(f)(4)(E) §350.74(f)(3)
Recover NAPL in contact with surface water and sediment [3]	§350.74(h)(7)(A) §350.74(h)(7)(B) §350.74(i)	§350.74(h)(7)(A) §350.74(h)(7)(B) §350.74(i)

PMZ = plume management zone **TI = technical impracticability** **WCU = waste control unit**

Footnotes:

1 In some instances, rule provisions cited in this table do not mention NAPL directly. In those instances, the provision is general and as such encompasses NAPL since NAPL is comprised of one or more COCs and represents a potential COC source area.

2 Under Remedy Standard A, NAPL recovery is the only allowable NAPL management objective. Control-based remedies for NAPL may be applied only under Remedy Standard B.

3 Full recovery of NAPL is required if the NAPL is in contact with Class 1 groundwater or surface water, or sediment.

4 This includes cross-media exposure (e.g., toxic vapors from groundwater NAPL-to-air, dissolution of COC from NAPL to groundwater).

5 Possible WCU exclusion for recovery [§350.33(f)(2)].

6 If achieving the NAPL recovery endpoint is demonstrated to be technically impracticable, then submit a TI demonstration with PMZ proposal in response action plan (RAP) for control of remaining NAPL [§350.33(f)(3)].

7 A PMZ may be proposed for Class 2 and Class 3 groundwater to enhance NAPL management flexibility.

8 The person must obtain written consent from the landowner before placing any institutional control within the real property records [§350.111].

TRRP establishes Remedy Standards A and B as a general description of the type of response action taken to address an affected property, including the NAPL zone. Under Remedy Standard A, NAPL *recovery* (NAPL removal and/or decontamination) is the only means to address NAPL concerns. Physical control-based response actions are not allowed under Remedy Standard A. Under Remedy Standard B, NAPL may be either *recovered* and/or *controlled*. However, as explained in this guidance, the control option is not available for certain NAPL responses and recovery is required in those instances. Conversely, when either remedy standard is available and feasible, Remedy Standard A may be considered for implementation to avoid certain aspects of a Remedy Standard B response, such as institutional controls, post-response action care and financial assurance. See TCEQ guidance document *Application of Remedy Standards A and B* (RG-366/TRRP-28) for general information on Remedy Standards A and B.

i.3 Integrated Evaluation of NAPL Zones and PCLE Zones

This guide addresses concerns associated with zones of environmental media that contain NAPL. However, NAPL zone concerns are almost always accompanied by protective concentration level exceedance (PCLE) zone concerns. It is essential to remember that *the management objectives and response actions of both the NAPL zone and PCLE zone are coupled and must be evaluated and addressed concurrent with each other*. This integrated coupling is conceptualized in Figure 1.

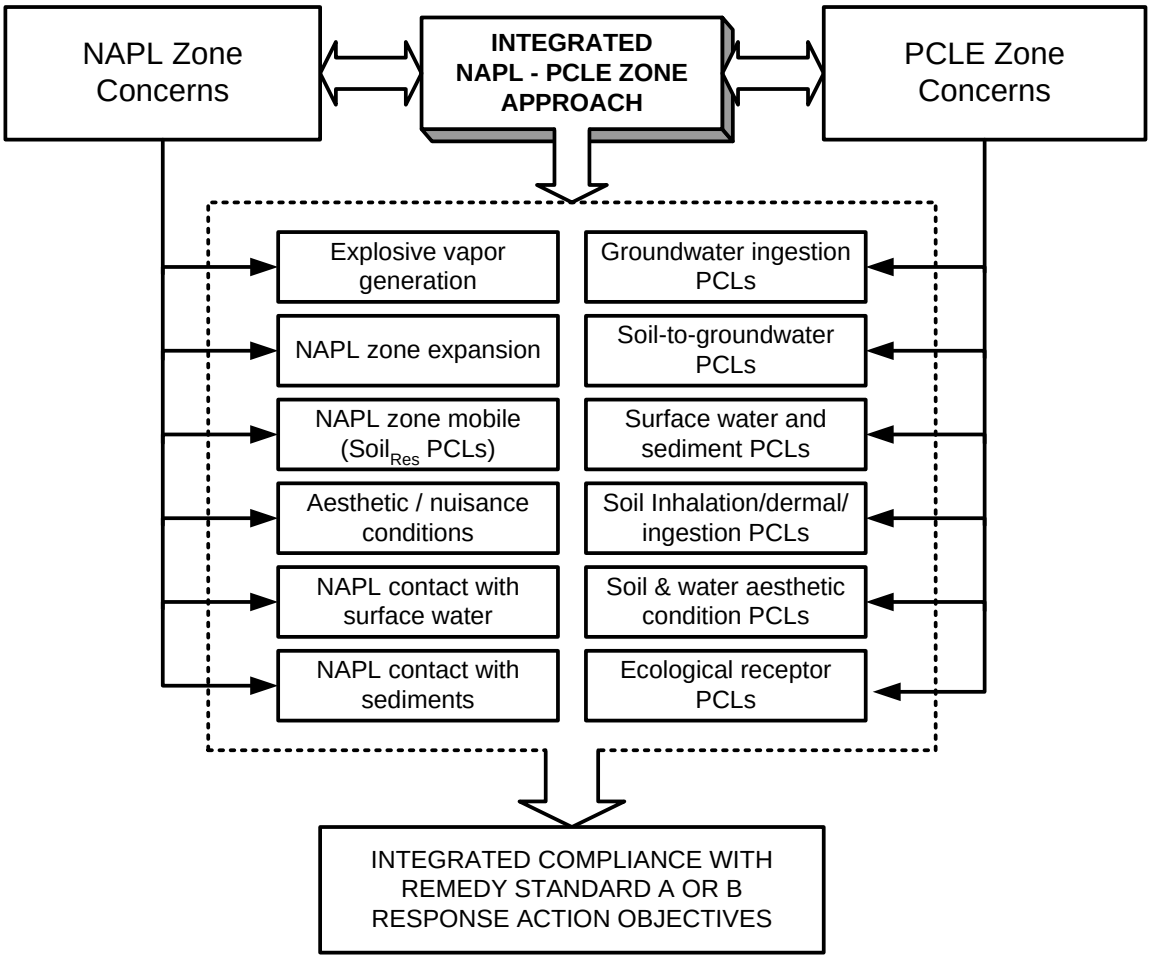

Figure 1. Conceptual Integration of NAPL-Based and PCL-Based Response Actions for Compliance with Remedy Standard A or B.

See additional discussion on this topic in Section 4 (*STEP 4: Develop NAPL Management Strategy*) of this guide. Also, see TCEQ guidance documents *Critical PCLs* (RG-366/TRRP-25) and *Affected Property Assessment Requirements* (RG-366/TRRP-12) for more information on PCLs and defining PCLE zones.

i.4 NAPL Release Abatement and Hazard Mitigation

When an ongoing NAPL release is discovered, take immediate actions to stop further release of the NAPL from the primary source (e.g., tank, pipeline, etc.) and mitigate any hazards created by the NAPL, such as fire hazards and other safety concerns. Interim emergency and hazard mitigation actions to stop the NAPL release and to stabilize or control the situation need not be proposed in a Response Action Plan (RAP) [§350.1]. NAPL interim actions are not discussed further in this guidance. It is presumed that these interim actions have been implemented prior to the application of TRRP and that the ongoing release is eliminated and any hazards are mitigated. At that point, this guide can be properly applied.

i.5 Definitions

Alternative NAPL recovery technology: NAPL removal, mobilization or *in situ* destruction via biological, chemical, electromagnetic, or thermal processes. Also includes physical alteration of soil structure (e.g., soil fracturing). See Appendix B for examples of alternative NAPL recovery technologies.

Conventional NAPL recovery technology: NAPL recovery using only hydraulic and/or pneumatic physical processes for direct liquid or vapor phase removal and excavation. See Appendix B for examples of conventional NAPL recovery technologies.

Dense non-aqueous phase liquid (DNAPL): NAPL that has a specific gravity greater than 1.0 (e.g., chlorinated solvents, creosote, or polychlorinated biphenyls).

Light non-aqueous phase liquid (LNAPL): A NAPL with a specific gravity less than 1.0 (e.g., gasoline, benzene, etc.).

Migrating NAPL zone: A NAPL zone that is expanding laterally or vertically, or otherwise results in an increased volume of the NAPL zone; usually indicated by time-series data.

Mobile NAPL: NAPL present at or above the residual saturation PCL ($Soil_{res}$) within the vadose zone that is theoretically capable of migrating, or is otherwise observed to migrate—such as NAPL flow into a well, boring or trench that penetrates a NAPL zone.

NAPL control response: A NAPL management objective for which the control option is available. This response action is coupled with, or relies exclusively on, an institutional control to manage NAPL concerns (Table 1).

NAPL management: The application of a NAPL recovery and/or NAPL control response action to a NAPL zone.

NAPL recovery response: A NAPL management strategy comprising the complete or partial removal of the NAPL zone using either a conventional and/or an alternative recovery technology. NAPL "recovery" is synonymous with the "remove and/or decontaminate" performance standards of Remedy Standards A and B.

NAPL zone: The three-dimensional multimedia extent of NAPL in the environment.

Non-aqueous phase liquid (NAPL): An organic or inorganic liquid that is not miscible with water. A NAPL may be a *pure phase* NAPL (comprised of a single chemical component, e.g., benzene) or a *mixed phase* NAPL (comprised of multiple components, e.g., gasoline).

Readily recoverable NAPL: A NAPL endpoint applicable to NAPL in contact with Class 2 / Class 3 groundwater within a PMZ. Its applicability is based on the feasibility of recovery by conventional technologies.

Residual NAPL: NAPL occurring at or below its residual saturation concentration in an environmental medium. It is observed to be hydraulically discontinuous and immobilized under field gravity conditions in soil pore spaces or fractures by a balance of capillary forces.

Residual saturation: NAPL saturation (the fraction of total pore space containing NAPL) above which NAPL becomes theoretically mobile (see TCEQ draft guidance document *NAPL Assessment Requirements*.)

Secured/restricted facility: A facility at which unauthorized entry is actively prohibited and operational controls (e.g., work permits and chemical exposure and handling safety procedures) are in effect that prevent unauthorized workers and visitors from conducting site work, such as the installation or maintenance of subsurface utilities or similar activities.

Technical impracticability (TI) demonstration: A formal analysis of the performance of an existing appropriately designed NAPL recovery system, or recovery pilot test, upon which it can be concluded that a mandatory NAPL recovery endpoint cannot be met.

i.6 NAPL Management Process Overview

The NAPL management process comprises a stepped process with requirements for managing occurrences of NAPL. The steps in the NAPL management process are listed in Table 3.

Table 3. NAPL Management Process STEPs

	STEP	Discussion	Flowcharts
STEP 1	Conduct NAPL Assessment	Section 1 and draft NAPL Assessment Requirements document	Figure 3
STEP 2	Identify NAPL Response Triggers	Section 2	Figure 4
STEP 3	Determine NAPL Response Objectives and Endpoints	Section 3	Figure 5
STEP 4	Develop NAPL Management Strategy	Section 4	Figure 8
STEP 5	Implement NAPL Management Strategy and Evaluate NAPL Response Effectiveness	Section 5 (and draft TRRP-31A)	-

Follow NAPL management process STEPs sequentially, as depicted in the logic-decision flowchart in Figure 2. Figure 2 also relates each STEP in the NAPL management process to its respective TRRP

response action phase and documentation. A summary of each NAPL management STEP is given below and a complete description of each STEP is provided in subsequent sections.

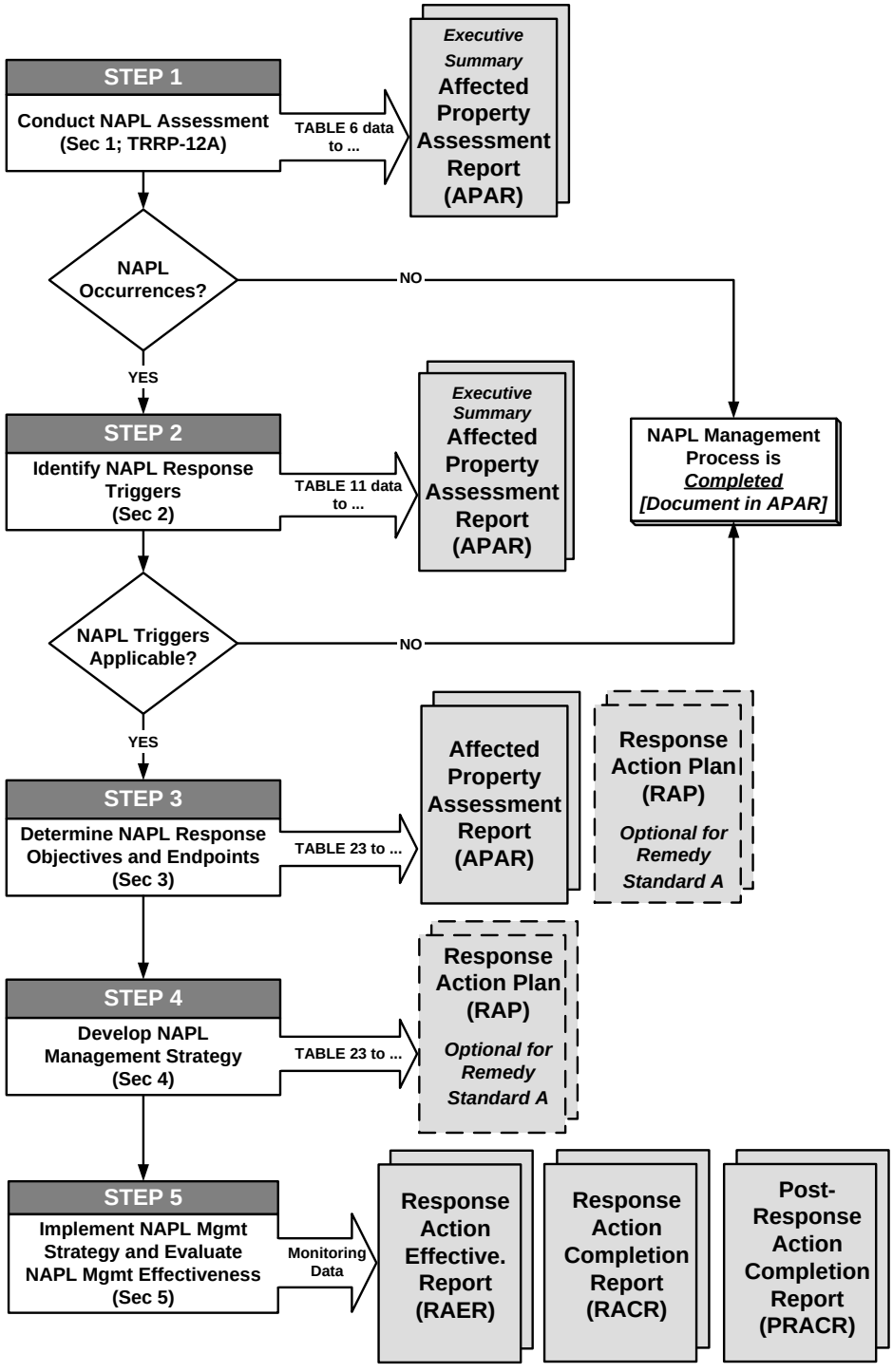

Figure 2. NAPL Management Steps and Associated Documentation.

STEP 1: Conduct NAPL Assessment

STEP 1 (Section 1) determines the nature and extent of all NAPL occurrences within all applicable environmental media at a site. NAPL assessments are performed concurrent with other affected property assessment activities. STEP 1 is completed when all applicable NAPL occurrences have been fully delineated. See TCEQ draft guidance document *NAPL Assessment Requirements* for NAPL assessment details. *Failure to perform a complete NAPL assessment will preclude persons from availing themselves of the subsequent risk-based NAPL management process steps*.

STEP 2: Identify NAPL Response Triggers

STEP 2 (Section 2) determines which NAPL response triggers are applicable at the affected property. NAPL triggers are specific NAPL occurrences and conditions that prompt a response action. Based on the results of the STEP 1 NAPL assessment, *every* applicable trigger is identified (there may be more than one applicable NAPL trigger). STEP 2 is completed when all applicable NAPL triggers have been identified and reported in the APAR. If no triggers are applicable (rare, but possible), the NAPL management process is completed.

STEP 3: Determine NAPL Response Objectives and Endpoints

STEP 3 (Section 3) determines the NAPL response objectives and endpoints for *each* applicable trigger identified in STEP 2. A NAPL endpoint is a NAPL recovery and/or control response action goal established for specific NAPL triggers and site conditions. Each NAPL endpoint is the performance basis by which to measure whether a NAPL trigger has been sufficiently addressed. STEP 3 is completed when all appropriate endpoints have been selected for each applicable trigger and the results are reported in the Affected Property Assessment Report (APAR).

STEP 4: Develop NAPL Management Strategy

STEP 4 (Section 4) develops a NAPL management strategy designed to achieve the goal of *each* endpoint established in STEP 3. Typically, most endpoints can be addressed if the NAPL strategy is designed for the most stringent endpoint(s). For example, if three triggers apply to the occurrence of NAPL in contact with groundwater, three endpoints are applicable to that groundwater NAPL occurrence. By developing a strategy designed to address the most stringent endpoint, the remaining two less-stringent endpoint goals also should be satisfied. The NAPL strategy also includes the performance criteria by which response action effectiveness is measured.

Integrate NAPL strategy with response actions planned for other site response actions. Do not separate NAPL response objectives from the other protective contaminant level exceedance (PCLE) zone objectives. STEP 4 is completed when a NAPL management strategy for all applicable NAPL triggers, objectives, and endpoints is reported to the TCEQ in a Self-Implementation Notice (SIN) or a proposed RAP is approved.

STEP 5: Implement NAPL Management Strategy and Evaluate NAPL Response Effectiveness

STEP 5 (Section 5) comprises the execution of the NAPL strategy and its subsequent effectiveness evaluation. The NAPL management effectiveness criteria defined in STEP 4 are compared to the data submitted with each subsequent *Response Action Effectiveness Report* (RAER)—or a similar periodic monitoring report—used to regularly report on the progress of the NAPL management strategy in achieving the endpoints. STEP 5 is completed when all applicable endpoints are achieved per the established effectiveness criteria. See TCEQ guidance document *NAPL Response Action Effectiveness* (draft RG-366/TRRP-31A) for evaluation information.

Upon completion of STEP 5, post-response action care may be required per §350.33(g),(h) and (i). Additionally, other non-NAPL-related response actions at the site also must be addressed.

1.0 STEP 1: Conduct NAPL Assessment

STEP 1 comprises the assessment of NAPL occurrences at the affected property. The intent of a NAPL assessment is to proactively investigate each assessment zone (i.e., vadose zone, capillary fringe, saturated zone, and surface water/sediment) and to confirm occurrences of NAPL, if present. Figure 3 depicts the logic-decision overview flowchart for STEP 1. Appendix D (gas station) and Appendix E (dry cleaner) provide examples of NAPL assessments.

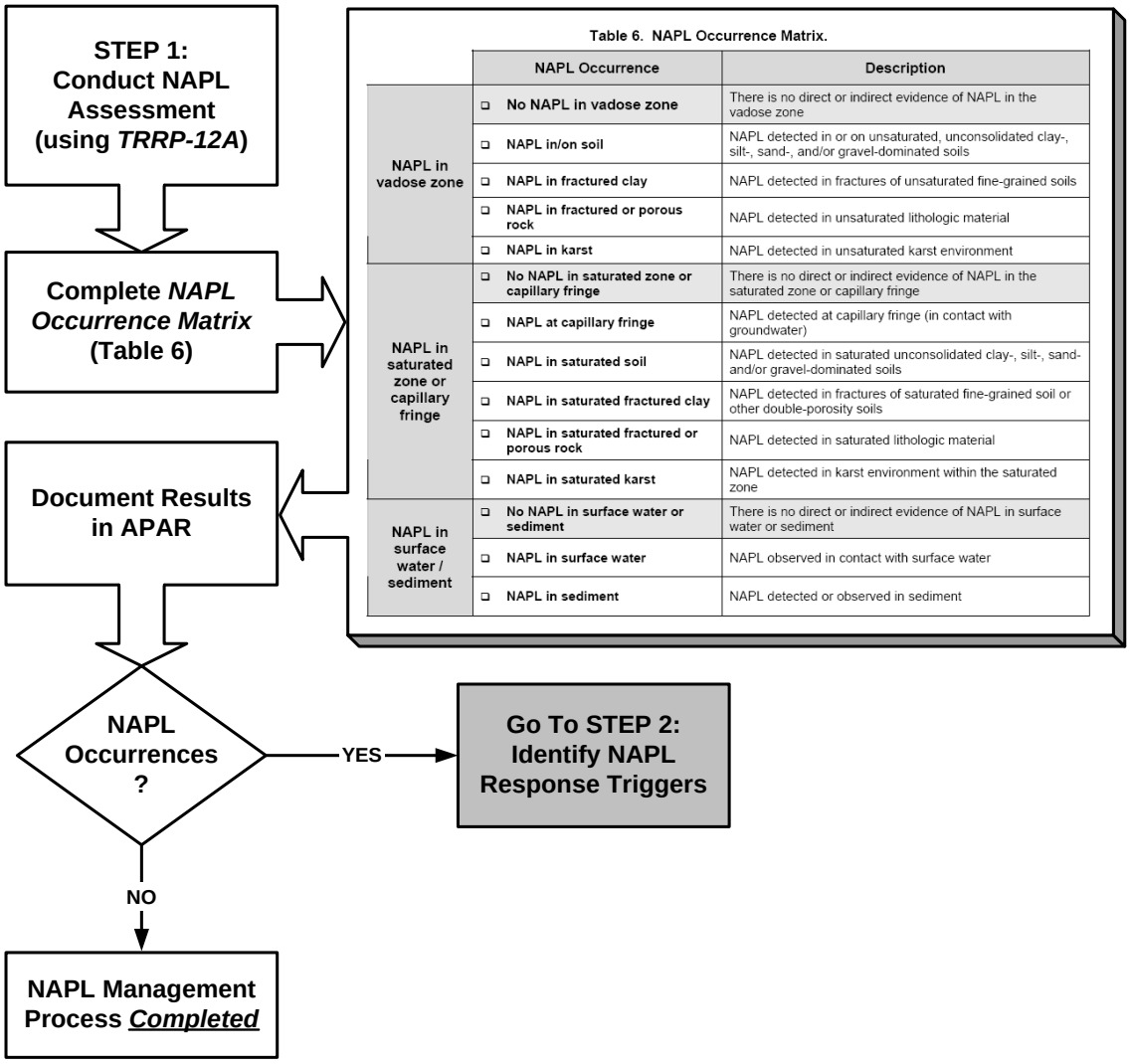

Table 6. NAPL Occurrence Matrix.

	NAPL Occurrence	Description
NAPL in vadose zone	❑ No NAPL in vadose zone	There is no direct or indirect evidence of NAPL in the vadose zone
	❑ NAPL in/on soil	NAPL detected in or on unsaturated, unconsolidated clay-, silt-, sand-, and/or gravel-dominated soils
	❑ NAPL in fractured clay	NAPL detected in fractures of unsaturated fine-grained soils
	❑ NAPL in fractured or porous rock	NAPL detected in unsaturated lithologic material
	❑ NAPL in karst	NAPL detected in unsaturated karst environment
NAPL in saturated zone or capillary fringe	❑ No NAPL in saturated zone or capillary fringe	There is no direct or indirect evidence of NAPL in the saturated zone or capillary fringe
	❑ NAPL at capillary fringe	NAPL detected at capillary fringe (in contact with groundwater)
	❑ NAPL in saturated soil	NAPL detected in saturated unconsolidated clay-, silt-, sand- and/or gravel-dominated soils
	❑ NAPL in saturated fractured clay	NAPL detected in fractures of saturated fine-grained soil or other double-porosity soils
	❑ NAPL in saturated fractured or porous rock	NAPL detected in saturated lithologic material
	❑ NAPL in saturated karst	NAPL detected in karst environment within the saturated zone
NAPL in surface water / sediment	❑ No NAPL in surface water or sediment	There is no direct or indirect evidence of NAPL in surface water or sediment
	❑ NAPL in surface water	NAPL observed in contact with surface water
	❑ NAPL in sediment	NAPL detected or observed in sediment

Figure 3. Overview of STEP 1: Conduct NAPL Assessment.

The TCEQ draft guidance document *NAPL Assessment Requirements* is a companion document to STEP 1 to guide NAPL assessments.

Although the full delineation of the NAPL zone may not be possible in some instances, a NAPL assessment should,

The TCEQ draft Guidance Document *NAPL Assessment Requirements* contains detailed information on NAPL site investigation strategies, field methods, NAPL behavior, and assessment-related calculations.

at a minimum, identify areas of likely NAPL source zones that may warrant a response action (i.e., locations of typical activities prone to NAPL releases). If NAPL occurrences are not present at the affected property, the NAPL management process is terminated.

Apply the risk-based NAPL management paradigm only after completing a comprehensive and purposeful NAPL assessment. Failure to completely assess a NAPL release will preclude the availability of risk-based NAPL response endpoints and eliminate alternatives to NAPL recovery without specific goals. The more completely that NAPL conditions at an affected property are characterized and understood, especially for what may be lower-risk situations, the greater the benefit (regulatory flexibility) that may be afforded by the risk-based NAPL management approach.

During NAPL assessment, the presence of NAPL is confirmed by methods described in TCEQ draft guidance document *NAPL Assessment Requirements*. TRRP defines two NAPL-related threshold concentration values that are applicable to risk-based NAPL management: the *Theoretical Soil Saturation Limit* (C_{sat}) [§350.75(i)(9)], i.e., the COC concentration at which NAPL can form in a soil; and the *Theoretical Residual Soil Saturation Limit PCL* ($Soil_{Res}$) [§350.75(i)(10)], i.e., the soil COC concentration at which NAPL can become mobile. The presence of NAPL should be confirmed when soil COC concentrations exceed C_{sat}.

1.1 NAPL Assessment Objectives

Investigate the presence of NAPL *concurrent* with other affected property assessment activities. The objectives of NAPL assessments are to:

- detect, identify, and define extent of NAPL occurrences in the vadose zone, capillary fringe, saturated zone, and surface water/sediments;
- characterize NAPL occurrences sufficient to identify all triggers evaluated in STEP 2.

1.1.1 Detection and Characterization of NAPL Zone

Fulfill NAPL assessment objectives using an investigation strategy specifically designed to find NAPL. Perform a NAPL-specific assessment when, based on the current and historical operations (e.g., storage of petroleum products, chlorinated solvents, etc.), it is known or suspected that a NAPL-forming compound has been released. Design an integrated affected property assessment to include determination of NAPL presence, location of all NAPL occurrences, and identification of all applicable NAPL triggers.

1.1.2 Documentation of NAPL Occurrences

Since NAPL can be present in the different assessment zones (i.e., vadose zone, capillary fringe and saturated zone, surface water/sediments), conduct the assessment of NAPL occurrences in all applicable assessment zones that are commensurate with the behavior of a NAPL type (e.g., DNAPL vs LNAPL; see TCEQ draft guidance document *NAPL Assessment Requirements*). Some NAPL triggers only occur in certain assessment zones, so the process of investigating the location of all applicable NAPL occurrences should be purposefully designed to account for those specific triggers. Table 4 summarizes the assessment zones and their corresponding NAPL management triggers.

Upon achievement of a complete NAPL assessment, document information on all NAPL occurrences (and assessment) in the APAR as described in Table 5.

Table 6 shows the NAPL Occurrence Matrix, a reproduction of which also is included in the Executive Summary of the APAR. It is completed by selecting each NAPL occurrence encountered or inferred during assessment. If there are no NAPL occurrences, check appropriate boxes for each assessment zone in the matrix and the NAPL management process terminates at STEP 1. Otherwise, proceed to STEP 2.

Table 4. Assessment Zones, NAPL Occurrences and Triggers

Assessment Zone	NAPL Occurrences	Applicable NAPL Management Triggers
Vadose zone	NAPL in: porous media fractured clay fractured rock/karst	❑ NAPL generating vapors ❑ Migrating NAPL zone ❑ Mobile NAPL zone ❑ NAPL aesthetic impact/nuisance
Saturated zone and capillary fringe	NAPL in: porous media fractured clay fractured rock/karst	❑ NAPL generating vapors ❑ Migrating NAPL zone ❑ NAPL aesthetic impact/nuisance ❑ NAPL in contact with groundwater
Surface water / sediment	NAPL in: surface water sediment	❑ NAPL in contact with surface water ❑ NAPL in or on sediments

Table 5. NAPL Occurrence Documentation

	Document	Location
NAPL Occurrence Matrix	**TRRP 32**	Table 6 (this document)
	APAR	Executive Summary
NAPL Soil Assessment	**APAR**	Section 4.2
NAPL Groundwater Assessment	**APAR**	Section 5.2
NAPL Surface Water / Sediment Assessment	**APAR**	Section 6.3 / Section 7.3

Table 6. NAPL Occurrence Matrix

	NAPL Occurrence	Description
NAPL in vadose zone	❑ **No NAPL in vadose zone**	There is no direct or indirect evidence of NAPL in the vadose zone
	❑ **NAPL in/on soil**	NAPL detected in or on unsaturated, unconsolidated clay-, silt-, sand-, and/or gravel-dominated soils
	❑ **NAPL in fractured clay**	NAPL detected in fractures of unsaturated fine-grained soils
	❑ **NAPL in fractured or porous rock**	NAPL detected in unsaturated lithologic material
	❑ **NAPL in karst**	NAPL detected in unsaturated karst environment
NAPL in saturated zone or capillary fringe	❑ **No NAPL in saturated zone or capillary fringe**	There is no direct or indirect evidence of NAPL in the saturated zone or capillary fringe
	❑ **NAPL at capillary fringe**	NAPL detected at capillary fringe (in contact with groundwater)
	❑ **NAPL in saturated soil**	NAPL detected in saturated unconsolidated clay-, silt-, sand- and/or gravel-dominated soils
	❑ **NAPL in saturated fractured clay**	NAPL detected in fractures of saturated fine-grained soil or other double-porosity soils
	❑ **NAPL in saturated fractured or porous rock**	NAPL detected in saturated lithologic material
	❑ **NAPL in saturated karst**	NAPL detected in karst environment within the saturated zone
NAPL in surface water / sediment	❑ **No NAPL in surface water or sediment**	There is no direct or indirect evidence of NAPL in surface water or sediment
	❑ **NAPL in surface water**	NAPL observed in contact with surface water
	❑ **NAPL in sediment**	NAPL detected or observed in sediment

2.0 STEP 2: Identify NAPL Response Triggers

STEP 2 comprises the evaluation and determination of applicable NAPL response triggers based on observed or inferred NAPL occurrences from the NAPL assessment completed in STEP 1 (Sec 1). NAPL triggers are the specific *NAPL occurrences and site conditions* that prompt a specific NAPL response action. This section describes the field occurrence and recognition of the NAPL triggers and the associated site conditions that qualify them. Figure 4 provides the logic-decision flowchart for STEP 2. Exercises in Appendix D (gas station) and Appendix E (dry cleaner) provide examples of identifying NAPL triggers.

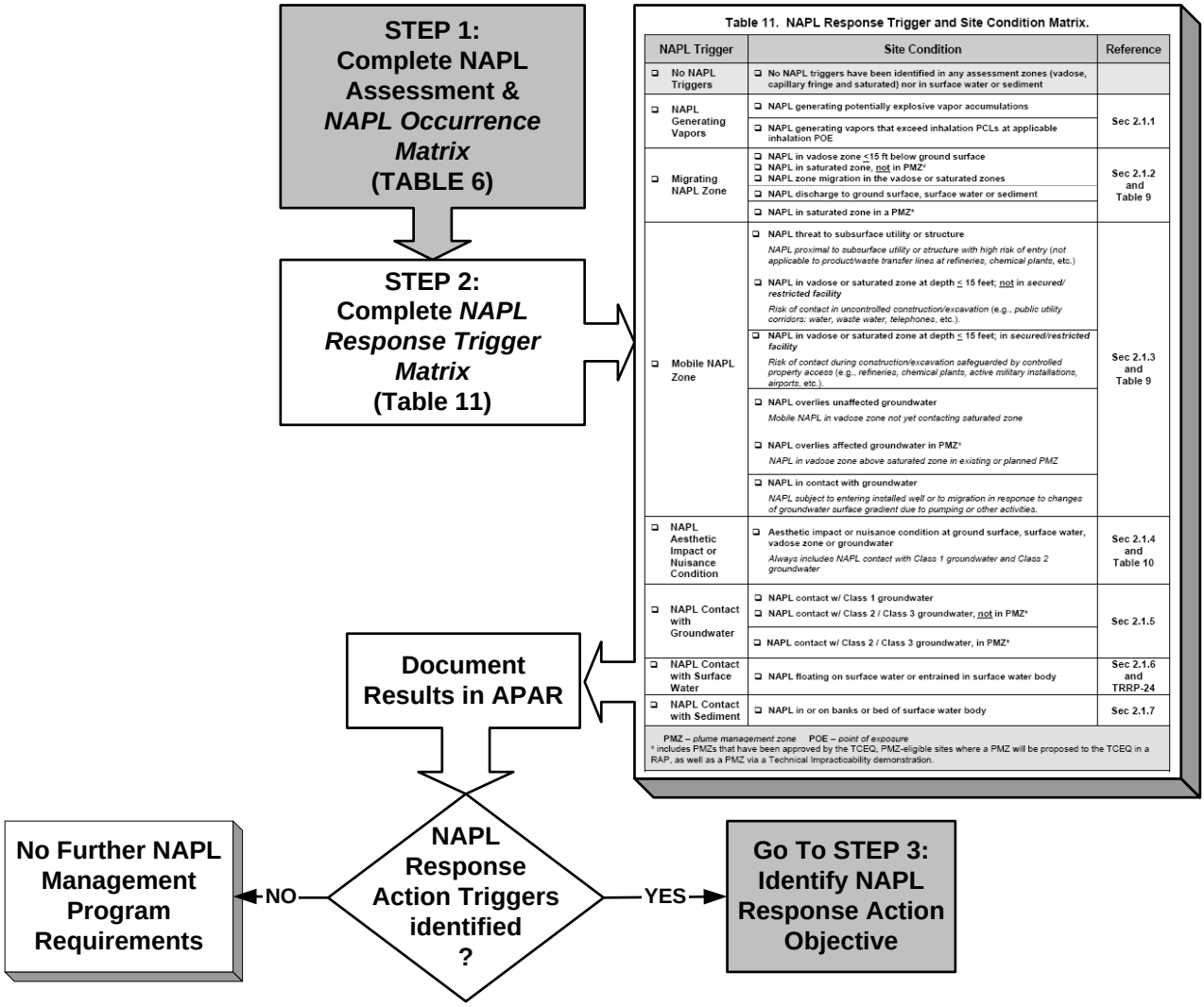

Table 11. NAPL Response Trigger and Site Condition Matrix.

NAPL Trigger	Site Condition	Reference
❑ No NAPL Triggers	❑ No NAPL triggers have been identified in any assessment zones (vadose, capillary fringe and saturated) nor in surface water or sediment	
❑ NAPL Generating Vapors	❑ NAPL generating potentially explosive vapor accumulations	Sec 2.1.1
	❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	
❑ Migrating NAPL Zone	❑ NAPL in vadose zone ≤15 ft below ground surface ❑ NAPL in saturated zone, not in PMZ* ❑ NAPL zone migration in the vadose or saturated zones	Sec 2.1.2 and Table 9
	❑ NAPL discharge to ground surface, surface water or sediment	
	❑ NAPL in saturated zone in a PMZ*	
❑ Mobile NAPL Zone	❑ NAPL threat to subsurface utility or structure *NAPL proximal to subsurface utility or structure with high risk of entry (not applicable to product/waste transfer lines at refineries, chemical plants, etc.)*	Sec 2.1.3 and Table 9
	❑ NAPL in vadose or saturated zone at depth ≤ 15 feet; not in *secured/restricted facility* *Risk of contact in uncontrolled construction/excavation (e.g., public utility corridors: water, waste water, telephones, etc.).*	
	❑ NAPL in vadose or saturated zone at depth ≤ 15 feet; in *secured/restricted facility* *Risk of contact during construction/excavation safeguarded by controlled property access (e.g., refineries, chemical plants, active military installations, airports, etc.).*	
	❑ NAPL overlies unaffected groundwater *Mobile NAPL in vadose zone not yet contacting saturated zone*	
	❑ NAPL overlies affected groundwater in PMZ* *NAPL in vadose zone above saturated zone in existing or planned PMZ*	
	❑ NAPL in contact with groundwater *NAPL subject to entering installed well or to migration in response to changes of groundwater surface gradient due to pumping or other activities.*	
❑ NAPL Aesthetic Impact or Nuisance Condition	❑ Aesthetic impact or nuisance condition at ground surface, surface water, vadose zone or groundwater *Always includes NAPL contact with Class 1 groundwater and Class 2 groundwater*	Sec 2.1.4 and Table 10
❑ NAPL Contact with Groundwater	❑ NAPL contact w/ Class 1 groundwater ❑ NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*	Sec 2.1.5
	❑ NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ*	
❑ NAPL Contact with Surface Water	❑ NAPL floating on surface water or entrained in surface water body	Sec 2.1.6 and TRRP-24
❑ NAPL Contact with Sediment	❑ NAPL in or on banks or bed of surface water body	Sec 2.1.7

PMZ – *plume management zone* POE – *point of exposure*
* includes PMZs that have been approved by the TCEQ, PMZ-eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via a Technical Impracticability demonstration.

Figure 4. Overview of STEP 2: Identify NAPL Response Triggers.

If the NAPL assessment is not sufficient to determine whether a trigger is applicable, either collect the additional NAPL assessment information to properly evaluate the trigger, *or* presume the trigger is applicable. For example, if NAPL is present in the vadose zone, the proper evaluation of triggers must include knowledge of whether the NAPL is mobile or not. If the status of NAPL mobility is not known, then presume it is mobile. Such a presumption can cause NAPL response actions to be taken that could otherwise have been avoided with a better understanding of the NAPL conditions.

2.1 NAPL Response Triggers

Seven NAPL response triggers are used to prompt a risk-based NAPL management response. Table 7 summarizes each trigger and description (see referenced sections for full descriptions).

Table 7. NAPL Response Triggers

NAPL Response Trigger	Description of Trigger	Reference
NAPL Generating Vapors	*NAPL vapor accumulations that are potentially explosive or exceed inhalation PCLs at applicable POE -* $^{Air}Air_{Inh\text{-}V}$	Sec 2.1.1
Migrating NAPL Zone	*NAPL zone is observed to grow or move*	Sec 2.1.2
Mobile NAPL Zone	*NAPL in vadose zone with concentrations exceeding* $Soil_{Res}$	Sec 2.1.3
NAPL Aesthetic Impact or Nuisance Condition	*NAPL causes objectionable characteristics (*e.g.*, taste, odor, color,* etc.*) making a natural resource or soil unsuitable for intended use*	Sec 2.1.4
NAPL Contact with Groundwater	*NAPL is in contact with saturated zone or capillary fringe of a Class 1, 2 or 3 groundwater-bearing unit (GWBU)*	Sec 2.1.5
NAPL Contact with Surface Water	*Liquid with COC concentrations exceeding the aqueous solubility that is in contact with surface water*	Sec 2.1.6
NAPL Contact with Sediment	*Liquid with COC concentrations exceeding the aqueous solubility that has impacted sediments*	Sec 2.1.7

Typically, NAPL that is in soil, in contact with groundwater, surface water, or sediment will constitute at least one of the seven triggers listed in Table 7. *However*, if ***all*** conditions listed below (in Table 8) exist, ***there will not be a NAPL trigger***.

Table 8. Combination of Conditions That Do Not Trigger NAPL Response

NAPL does NOT require management if ALL conditions apply	NAPL is non-toxic for ingestion, inhalation and dermal contact
	NAPL is not causing and will not cause COC concentrations in air or groundwater to exceed PCLs
	NAPL zone is not migrating *and* not mobile in shallow vadose zone
	NAPL is not creating a nuisance or aesthetic impact
	NAPL is not in contact with Class 1 or 2 groundwater, surface water or sediment

The presence of food grade mineral oil in subsurface soil at residual concentrations overlying Class 3 groundwater is an example of the conditions in Table 8 that do not trigger NAPL management. In this example, the NAPL is non-toxic, immobile, relatively insoluble, and in a groundwater situation that is unlikely to result in an aesthetic impact. Therefore, NAPL management is unwarranted. However, such a conclusion must be based on, and consistent with, the results of a complete and proper NAPL assessment (see TCEQ draft guidance document *NAPL Assessment Requirements*).

2.1.1 NAPL Generating Vapors Trigger

This trigger applies to any NAPL occurrence that is generating explosive vapor accumulations in surface or subsurface structures such as underground utility conduits, basements, buildings, storm sewers, and soils in anticipated construction zones. Consider explosive conditions to exist when vapors accumulate to pure-phase or mixed-phase COC concentrations that exceed 25 percent of their lower explosive (flammable) limit (LEL) (see NIOSH LEL values for selected COCs, www.cdc.gov/niosh/npg/).

If another applicable industry, government, or fire protection standard sets the vapor safety trigger at a lower percent LEL (i.e., < 25 percent LEL), that standard should be adopted as the safeguard. Evaluate this trigger any time NAPL is a Class IA, IB, or IC flammable liquid or Class II combustible liquid, and:

- is in proximity to surface or subsurface structures such as those listed above,
- is in proximity to soils within an existing or planned construction zone, or
- is suspected of generating explosive vapor accumulations.

If explosive vapor levels are encountered, assume the concentrations to be immediately dangerous to life and health. Notify the proper safety officials and coordinate with them, as appropriate, to protect human health and safety.

The vapor generation trigger is also applicable to any NAPL occurrence that is generating toxic vapors that are diffusing to the atmosphere in excess of the inhalation PCL at an applicable point of exposure (POE).

2.1.2 Migrating NAPL Zone Trigger

The migrating NAPL zone trigger applies when NAPL is observed in any environmental medium to have lateral or vertical movement or that exhibits an increasing or changing volumetric footprint over time. Examples of such observations include the appearance of NAPL in previously unaffected borings or monitoring wells, or as NAPL seeps to ground surface or into surface water bodies. Cyclic NAPL fluctuations (NAPL presence/absence or thickness changes) in impacted wells that *penetrate* and are completed in the NAPL zone would not be considered evidence of migrating NAPL, but do indicate the presence of *mobile* NAPL (see Sec 2.1.3). See TCEQ draft guidance document *NAPL Assessment Requirements* for additional details on the evaluation of migrating NAPL.

Migrating NAPL zones can use different transport mechanisms to move along pathways that can potentially lead to subsurface structures (e.g., utility conduits, basements, construction excavations, etc.), any environmental exposure medium (e.g., soil, groundwater, ambient air, etc.) or environmental resource (e.g., surface water body, ecological receptor, etc.) resulting in new hazards or increased site risks. Additionally, an increasing NAPL zone footprint will make it more difficult to achieve the Remedy Standard A or B performance requirements.

2.1.3 Mobile NAPL Zone Trigger

The mobile NAPL zone trigger applies *in the vadose zone* when the concentration of a NAPL-forming compound exceeds the unsaturated zone *Theoretical Residual Soil Saturation Limit PCL* ($Soil_{Res}$). A pure- or mixed-phase compound with soil concentrations at or above the $Soil_{Res}$ value (Tier 1 $Soil_{Res}$ = 10,000 mg/kg) is considered to be mobile and has the potential for moving downward through the soil as a separate phase. NAPL also is explicitly mobile when it is observed to migrate in the vadose zone.

Mobile NAPL is capable of impacting previously unaffected environmental media (e.g., groundwater, surface water, etc.) or environmental resources (e.g., ecological receptors). Also, mobile NAPL can flow into construction excavations and utility conduits if disturbed; NAPL can be induced to migrate towards groundwater if penetrated during soil boring activities; or mobile LNAPL can migrate across a

groundwater surface whose slope has changed. Mobile NAPL also can supply a direct source of COCs that can continue to contaminate groundwater or surface water. The extent to which mobile NAPL poses a threat of increased risk to human or environmental exposure is qualified by existing site conditions (see Sec 2.2).

2.1.3.1 Contrast between Migrating NAPL Zone and Mobile NAPL Zone:

The differences between a migrating NAPL zone and a mobile NAPL zone are important to distinguish. In summary: in the vadose zone, all migrating NAPL is mobile, but not all mobile NAPL is migrating. Table 9 summarizes information for the accurate identification of these two triggers.

Table 9. Definition and Contrast of NAPL Zone Triggers

Migrating NAPL Zone ***(Observation-Based)***	❑ **NAPL zone is observed to increase in volume, footprint, or to migrate in any direction** *Examples demonstrating migration:* • NAPL intrudes into previously unaffected wells, soils and/or groundwater • NAPL seeps to land surface; NAPL seeps to surface water bodies
Mobile NAPL (Vadose Zone) ***(Concentration-Based)***	❑ **COC concentration exceeds $Soil_{Res}$ PCL in Vadose Zone** *Examples that imply mobility:* • COC concentration greater than 10,000 mg/kg in vadose zone • NAPL is observed to undergo changes of fluid level in borings, monitoring wells or trenches and other subsurface discontinuities • NAPL flows into borings, monitoring wells, or trenches and other subsurface discontinuities within the NAPL Zone

2.1.4 NAPL Aesthetic Impact or Nuisance Condition Trigger

The NAPL aesthetic impact or nuisance condition trigger applies when NAPL causes a condition that results in an environmental resource being made unfit for use. This trigger applies if the NAPL presents objectionable characteristics (e.g., taste or odor) in the affected environmental medium or via a cross-media exposure pathway.

Table 10 lists examples of NAPL causing, creating, or representing objectionable characteristics.

2.1.5 NAPL Contact with Groundwater Trigger

The NAPL contact with groundwater trigger applies when NAPL is observed or inferred to be in direct contact with a groundwater-bearing unit (GWBU) or its capillary fringe. Typically, this NAPL occurrence can act as the source for an associated dissolved-phase groundwater PCLE zone. This trigger is qualified by site conditions specifying the GWBU class involved and by whether a PMZ has been established for the dissolved PCLE zone (see Table 11).

Table 10. Examples of NAPL Aesthetic or Nuisance Conditions

NAPL Aesthetic Impact or Nuisance Conditions	❑ NAPL is in contact with Class 1 groundwater or is present in a water supply well
	❑ NAPL is producing a taste or odor concern in Class 2 groundwater and the aesthetic impact threatens a water supply well, or the groundwater is the only reasonable source of water for the property [§350.74(f)(3)(B) & (C)]
	❑ NAPL causes complaints of taste, odor, or other objectionable characteristics in water wells OR TCEQ receives complaints of outdoor air odors that are attributable to NAPL
	❑ NAPL pools or NAPL sludges in the upper 10 feet of the soil column (or at ground surface); detrimental effects include degradation of soil integrity [§350.74(i)]
	❑ NAPL in/on surface water and/or the banks or sediment of surface water bodies as visible sheen, globules, etc. [see Sec 3.5.1.1; and *Determining PCLs for Surface Water and Sediment* (RG-366/TRRP-24) for more information]

2.1.6 NAPL Contact with Surface Water Trigger

The NAPL contact with surface water trigger applies to the release of NAPL to surface water. Any observation of NAPL globules, sheen, or NAPL layer in contact with surface water, or inference thereof, constitutes this trigger. (See Sec's 2.1.4 and Sec 3.5.1.1; see also *Determining PCLs for Surface Water and Sediment* [RG-366/TRRP-24] for more information.)

NAPL typically represents a direct toxicity hazard to aquatic, benthic, and other ecological receptors, as well as a potential source of dissolved COC concentrations in the surface water. It also can threaten surface water intakes for water supplies.

2.1.7 NAPL Contact with Sediment Trigger

The NAPL contact with sediment trigger applies when any NAPL impacts surface water sediment (e.g., lake, river, stream, etc.) via a groundwater pathway, a vadose zone pathway, or a direct release to the surface water.

NAPL contact with sediment typically represents a direct toxicity hazard to aquatic, benthic, or other ecological and human receptors and is a potential source of dissolved COCs to surface water.

2.2 NAPL Site Conditions

Site-specific conditions are used to qualify and better define the risk associated with a NAPL occurrence for the purpose of determining the appropriate NAPL management response to a NAPL trigger. Evaluate the site condition at the same time that the NAPL trigger is determined. The applicable NAPL trigger and the site condition are reported together in the NAPL Response Trigger and Site Condition Matrix presented in the APAR and in Table 11.

Table 11. NAPL Response Trigger and Site Condition Matrix.

NAPL Trigger	Site Condition	Reference
❑ **No NAPL Triggers**	❑ **No NAPL triggers have been identified in any assessment zones (vadose, capillary fringe and saturated) nor in surface water or sediment**	
❑ **NAPL Generating Vapors**	❑ **NAPL generating explosive vapor accumulations** ❑ **NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE**	**Sec 2.1.1**
❑ **Migrating NAPL Zone**	❑ **NAPL in vadose zone ≤15 ft below ground surface** ❑ **NAPL in saturated zone, not in PMZ*** ❑ **NAPL zone migration in the vadose or saturated zones** ❑ **NAPL discharge to ground surface, surface water or sediment** ❑ **NAPL in saturated zone in a PMZ***	**Sec 2.1.2 and Table 9**
❑ **Mobile NAPL Zone**	❑ **NAPL threat to subsurface utility or structure** *NAPL proximal to subsurface utility or structure with potential risk of entry* (*not applicable to product/waste transfer lines at refineries, chemical plants*, etc.) ❑ **NAPL in vadose or saturated zone at depth ≤ 15 feet; not in *secured/ restricted facility*** *Risk of contact in uncontrolled construction/excavation* (e.g., *public utility corridors: water, waste water, telephones*, etc.). ❑ **NAPL in vadose or saturated zone at depth ≤ 15 feet; in *secured/restricted facility*** *Risk of contact during construction/excavation safeguarded by controlled property access* (e.g., *refineries, chemical plants, active military installations, airports*, etc.). ❑ **NAPL overlies unaffected groundwater** *Mobile NAPL in vadose zone not yet contacting saturated zone* ❑ **NAPL overlies affected groundwater in PMZ*** *NAPL in vadose zone above saturated zone in existing or planned PMZ* ❑ **NAPL in contact with groundwater** *NAPL subject to entering installed well or to migration in response to changes of groundwater surface gradient due to pumping or other activities.*	**Sec 2.1.3 and Table 9**
❑ **NAPL Aesthetic Impact or Nuisance Condition**	❑ **Aesthetic impact or nuisance condition at ground surface, surface water, vadose zone or groundwater** *Always includes NAPL contact with Class 1 groundwater and Class 2 groundwater*	**Sec 2.1.4 and Table 10**
❑ **NAPL Contact with Groundwater**	❑ **NAPL contact w/ Class 1 groundwater** ❑ **NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*** ❑ **NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ***	**Sec 2.1.5**
❑ **NAPL Contact with Surface Water**	❑ **NAPL floating on surface water or entrained in surface water body**	**Sec 2.1.6 and TRRP-24**
❑ **NAPL Contact with Sediment**	❑ **NAPL in or on banks or bed of surface water body**	**Sec 2.1.7**

PMZ – *plume management zone* **POE** – *point of exposure*
***** includes PMZs that have been approved by the TCEQ, PMZ-eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via a §350.33(f)(3)Technical Impracticability demonstration.

2.3 Complete NAPL Response Trigger and Site Condition Matrix

Document the completion of STEP 2 using the *NAPL Response Trigger and Site Condition Matrix* (Table 11) in the Executive Summary of the APAR. To complete the matrix, check each applicable NAPL trigger and any applicable site conditions for that trigger. If it is determined that NAPL conditions change over time and/or additional triggers are realized to apply, update the matrix and submit it to the TCEQ at that time. If there are no applicable triggers, check the shaded box to indicate no NAPL triggers were identified, and the NAPL management process is terminated. Otherwise, proceed to STEP 3.

3.0 STEP 3: Determine NAPL Response Objectives and Endpoints

STEP 3 comprises the determination and selection of applicable NAPL response endpoints which address the NAPL *response objectives* prompted by the NAPL triggers identified in STEP 2. A NAPL response objective is the performance-based goal that sufficiently manages the threat posed by a NAPL trigger. A NAPL endpoint is the site-specific condition that demonstrates the objective's goal has been achieved. The NAPL trigger is eliminated when all its respective endpoints have been met.

STEP 3 is concluded when the *NAPL Response Endpoint Matrix* (see Table 23) is completed in the APAR and submitted with the design section of the RAP, if required. Exercises in Appendix D (gas station) and Appendix E (dry cleaner) provide examples of determining NAPL response objectives and endpoints.

Figure 5 provides a logic flowchart for fulfilling the STEP 3 requirements.

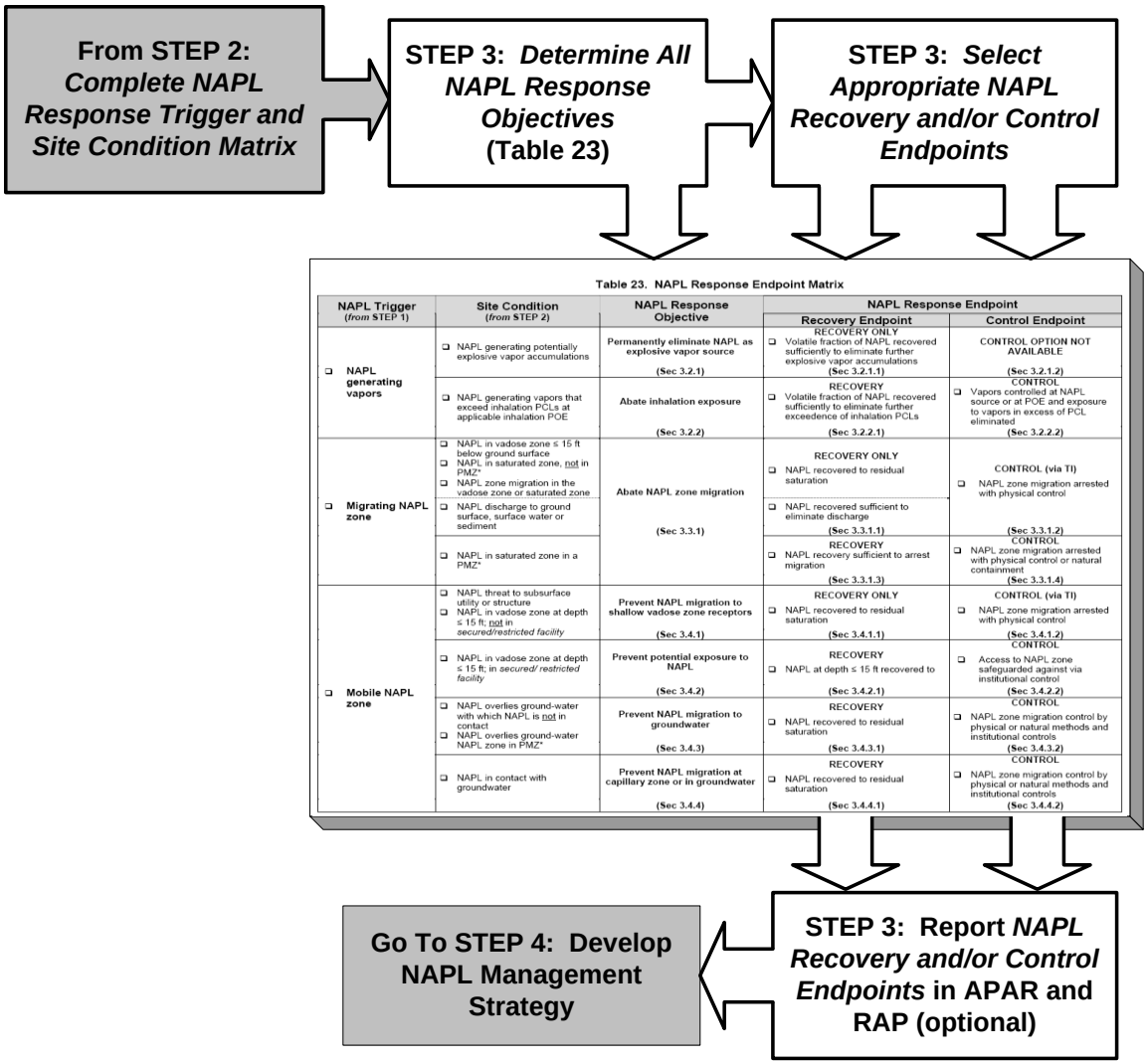

Figure 5. Overview of STEP 3: Determine NAPL Response Objectives and Endpoints.

3.1 NAPL Response Endpoint Types

NAPL response endpoints comprise NAPL *RECOVERY endpoints* and NAPL *CONTROL endpoints*. Table 12 summarizes the different types and characteristics of recovery and control endpoints.

The RECOVERY ONLY endpoint requires that the NAPL response objective be met by NAPL recovery with no control endpoint option available. However, if the RECOVERY ONLY endpoint cannot be achieved *and* the TCEQ concurs with a *Technical Impracticability (TI) Demonstration*, use of the CONTROL (via TI) endpoint may be permitted. See additional information on *TI Demonstrations* in STEP 4 (Section 4.2).

The RECOVERY and CONTROL endpoints may be applied separately or in combination with one another so long as at least one is being pursued. The person has the choice to pursue the recovery or the control endpoint. The decision to select one option over another can depend on considerations not addressed in this document (e.g., cost benefits, time-frame constraints, etc.). However, unless the recovery point is achieved, the control endpoint applies in order that the remaining NAPL is managed properly.

Table 12. NAPL Response Endpoint Types

	NAPL Response Endpoint	Description
NAPL Recovery Endpoints	**RECOVERY ONLY**	• RECOVERY ONLY requires recovery • CONTROL option not available • CONTROL (via TI) available ONLY with approved Technical Impracticability (TI) Demonstration
	RECOVERY	• RECOVERY is optional, based on response objective • RECOVERY may be used in lieu of, or in combination with CONTROL endpoint • RECOVERY is subject to PMZ requirements
NAPL Control Endpoints	**CONTROL**	• CONTROL by physical or natural means in combination with institutional control • CONTROL may be applicable for some triggers by institutional control alone • CONTROL can be combined with RECOVERY endpoint
	CONTROL (via TI)	• CONTROL (via TI) applicable only when RECOVERY ONLY endpoint is demonstrated to be unachievable • CONTROL (via TI) permitted only with approved TI demonstration • CONTROL (via TI) used with institutional control

NAPL response objectives and endpoints differ in accordance with the various triggers and site conditions. Each response objective and endpoint is addressed in this section according to their associated NAPL triggers. For each trigger, the relevant portion of the *NAPL Response Endpoint Matrix* (Table 23**)** is shown and the NAPL response objectives and endpoints are placed in context with the NAPL triggers and the corresponding site conditions. Table 13 is a guide to referencing the location of discussion on the NAPL response objectives and endpoints.

Table 13. STEP 3 Section Reference Key

NAPL Trigger		NAPL Response Objectives	NAPL Response Endpoints
NAPL generating vapors	Sec 3.2 Table 14	3.2.1 - 3.2.2	3.2.1.1 - 3.2.1.2 3.2.2.1 – 3.2.2.2
Migrating NAPL Zone	Sec 3.3 Table 15	3.3.1	3.3.1.1 – 3.3.1.4
Mobile NAPL Zone	Sec 3.4 Table 16	3.4.1 – 3.4.4	3.4.1.1 – 3.4.1.2 3.4.2.1 – 3.4.2.2 3.4.3.1 – 3.4.3.2 3.4.4.1 – 3.4.4.2
NAPL aesthetic impact or nuisance condition	Sec 3.5 Table 17	3.5.1	3.5.1.1 – 3.5.1.2
NAPL contact with groundwater	Sec 3.6 Table 18	3.6.1	3.6.1.1 – 3.6.1.2 3.6.2.1 – 3.6.2.2
NAPL contact with surface water	Sec 3.7 Table 20	3.7.1	3.7.1.1 – 3.7.1.2
NAPL contact with sediment	Sec 3.8 Table 21	3.8.1	3.8.1 – 3.8.2
Special Case: NAPL beneath a Waste Control Unit (WCU)	Sec 3.9 Table 22	3.2.1 3.3.1	3.2.1.1 – 3.2.1.2 3.3.1.1 – 3.3.1.2

3.2 NAPL Generating Vapors Trigger

The NAPL generating vapors trigger has two site condition-specific NAPL response objectives with one RECOVERY ONLY endpoint and one RECOVERY and/or CONTROL endpoint. Table 14 summarizes the NAPL response objectives and endpoints available for the NAPL generating vapors trigger.

Table 14. NAPL Response Objectives and Endpoints for *NAPL Generating Vapors Trigger*

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
		Recovery Endpoint	Control Endpoint
❑ NAPL generating explosive vapor accumulations	**Permanently eliminate NAPL as explosive vapor source** **(Sec 3.2.1)**	**RECOVERY ONLY** ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further explosive vapor accumulations **(Sec 3.2.1.1)**	**CONTROL OPTION NOT AVAILABLE** **(Sec 3.2.1.2)**
❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	**Abate inhalation exposure** **(Sec 3.2.2)**	**RECOVERY** ❑ Volatile fraction of NAPL recovered sufficiently to eliminate vapors that exceed inhalation PCLs **(Sec 3.2.2.1)**	**CONTROL** Vapors controlled at NAPL source or at POE and exposure to vapors that exceed PCLs eliminated **(Sec 3.2.2.2)**

3.2.1 *Response Objective*: Permanently eliminate NAPL as explosive vapor source

Accumulation of explosive vapor is an acute safety hazard that must be controlled at the NAPL source, not just at the point of vapor accumulation. Therefore, the RECOVERY ONLY endpoint is the sole option to effect permanent risk reduction.

3.1.1.1 *Recovery Endpoint*: RECOVERY ONLY:

The RECOVERY ONLY endpoint is achieved when the volatile fraction of the NAPL source of explosive vapor generation has been removed sufficiently to prevent further explosive vapor accumulation. Due to the acute hazard associated with this trigger, the endpoint cannot be achieved by controlling or suppressing vapor at the location of accumulation.

NAPL can be recovered by excavation, liquid extraction, or other effective method, otherwise the *volatile fraction* of the NAPL source can be removed, typically by using vapor extraction. Verify that the volatile fraction of the NAPL has been eliminated using the following:

1. analyze remaining NAPL using appropriate methods, or
2. analyze soil gas concentrations using appropriate methods, and verify with sufficient vapor monitoring events in the threatened structure or construction zone that vapors are not accumulating in excess of 25 percent LEL. (Other applicable authorities may supersede the 25 percent LEL threshold by requiring a lower LEL threshold.)

3.1.1.2 *Control Endpoint*: CONTROL OPTION NOT AVAILABLE:

Use of a control in lieu of NAPL recovery is not an option even with a TI Demonstration. However, pursue an interim control such as a vapor barrier or vapor suppression system as warranted in accordance with §350.1.

3.2.2 *Response Objective*: Abate inhalation exposure

Address NAPL that causes vapor concentrations to exceed inhalation PCLs.

3.2.2.1 *Recovery Endpoint*: RECOVERY:

The RECOVERY endpoint is achieved when the NAPL (or the applicable fractions in the case of mixed NAPL) has been recovered sufficiently to permanently eliminate vapor concentrations that exceed inhalation PCLs at the inhalation POE. The RECOVERY endpoint is consistent with the allowable removal, decontamination, and/or control response actions for a non-NAPL PCLE zone that generates unprotective inhalation exposures.

3.2.2.2 *Control Endpoint*: CONTROL:

The CONTROL endpoint is achieved when the NAPL vapors are controlled physically or naturally at the NAPL zone, at the inhalation POE, or at any effective intervening location such that unprotective inhalation exposures are continuously abated. Any control strategy must be reinforced with an institutional control.

3.3 Migrating NAPL Zone Trigger

The migrating NAPL zone trigger has several associated site conditions and a single NAPL response objective which variously requires RECOVERY ONLY and RECOVERY and/or CONTROL endpoints. Table 15 summarizes responses available for the migrating NAPL zone trigger.

Table 15. NAPL Response Objectives and Endpoints for *Migrating NAPL Zone Trigger*

<table>
<tr><th rowspan="2">Site Condition
(from STEP 2)</th><th rowspan="2">NAPL Response Objective</th><th colspan="2">NAPL Response Endpoint</th></tr>
<tr><th>Recovery Endpoint</th><th>Control Endpoint</th></tr>
<tr><td>❑ NAPL in vadose zone ≤ 15 ft below ground surface
❑ NAPL in saturated zone, not in PMZ
❑ NAPL zone migration in the vadose zone or saturated zone</td><td rowspan="3">Abate NAPL zone migration

(Sec 3.3.1)</td><td>RECOVERY ONLY

❑ NAPL recovered to residual saturation and/or to arrest NAPL migration</td><td rowspan="2">CONTROL (via TI)

❑ NAPL zone migration arrested with physical control

(Sec 3.3.1.2)</td></tr>
<tr><td>❑ NAPL discharge to ground surface, surface water or sediment</td><td>❑ NAPL recovered sufficient to eliminate NAPL discharge

(Sec 3.3.1.1)</td></tr>
<tr><td>❑ NAPL in saturated zone in a PMZ</td><td>RECOVERY

❑ NAPL recovery sufficient to arrest NAPL migration

(Sec 3.3.1.3)</td><td>CONTROL

❑ NAPL zone migration arrested with physical control or natural methods

(Sec 3.3.1.4)</td></tr>
</table>

3.3.1 *Response Objective*: Abate NAPL zone migration

Migrating NAPL can create long-term hazards or nuisance conditions along its travel path. The response objective is to permanently stabilize and prevent migrating NAPL from migrating to and directly impacting additional environmental resources.

3.1.1.3 *Recovery Endpoint*: RECOVERY ONLY:

The RECOVERY ONLY endpoint is achieved when sufficient NAPL is recovered to halt further migration and/or surface or sediment discharge as demonstrated by NAPL monitoring data that show the NAPL zone is no longer migrating. Since the downward migration of a NAPL cannot be prevented by a NAPL control, application of the RECOVERY ONLY endpoint is required for any downward NAPL migration.

Demonstrating compliance with this endpoint may entail long term monitoring when potential NAPL migration rates are slow. Evaluations of NAPL properties, distribution or capillary barriers that contribute to NAPL stability may be conducted to facilitate these decisions.

NOTE: NAPL that is no longer migrating still may have a region of mobile NAPL. Address the mobile NAPL portion in accordance with Sec 3.4 below.

3.1.1.4 *Control Endpoint*: CONTROL (via TI):

The CONTROL (via TI) endpoint is permitted only after the person has determined that the RECOVERY ONLY endpoint for NAPL migration (Sec 3.3.1.1) cannot be achieved and the TCEQ has accepted a TI Demonstration. However, a control remedy may only be employed to abate migration in the context of emergency and abatement actions in accordance with §350.1.

The CONTROL (via TI) endpoint is achieved when a physical control is applied at, or within, the migrating NAPL (e.g., slurry wall along the NAPL perimeter, hydraulic containment, etc.) and subsequent monitoring data demonstrate that further migration is abated with no further increase in the extent of the NAPL zone. The physical control must be reinforced with an institutional control.

3.1.1.5 *Recovery Endpoint*: RECOVERY:

The RECOVERY endpoint is achieved when sufficient NAPL is recovered to abate further NAPL zone migration. This RECOVERY endpoint is allowed in lieu of a RECOVERY ONLY endpoint because the TRRP rule at §350.33(f)(4)(E)(iv) specifies an alternative to allow a control to abate mobile NAPL zone migration within a PMZ.

Unless the NAPL recovery can be demonstrated to have achieved residual saturation concentrations, continue monitoring to verify long-term NAPL zone stability as part of the Remedy Standard B post-response action care requirements for a PMZ. NAPL properties, distribution or capillary barriers that contribute to NAPL zone stability may be evaluated to facilitate the decisions.

3.1.1.6 *Control Endpoint*: CONTROL:

The CONTROL endpoint is achieved when a physical control is applied at or within the migrating NAPL zone (e.g., slurry wall along the NAPL perimeter, hydraulic containment, etc.) and NAPL monitoring data demonstrate NAPL zone migration is abated. An increase in the extent of the NAPL zone is not permitted. The CONTROL option must be reinforced with an institutional control.

3.4 Mobile NAPL Zone Trigger

The mobile NAPL zone trigger has vadose zone site-specific NAPL response objectives variously requiring RECOVERY ONLY or RECOVERY and/or CONTROL endpoints. Table 16 summarizes responses available for the mobile NAPL zone trigger.

3.4.1 *Response Objective*: Prevent mobile NAPL impact to shallow vadose zone receptors

NAPL accumulations in subsurface structures can increase the exposure risk to residents and unprotected workers likely to come in contact with NAPL. Therefore, the response objective is to prevent mobile NAPL from impacting shallow vadose structures such as utility corridors, trenches, conduits or tunnels, building basements, construction excavations, etc. The RECOVERY ONLY endpoint addresses the response objective by eliminating the mobile NAPL and preventing the possibility of it being encountered or induced to flow into the excavation or work zone during routine construction activities.

3.1.1.7 *Recovery Endpoint*: RECOVERY ONLY:

The RECOVERY ONLY endpoint is achieved when NAPL at a depth of 15 feet or less below ground surface or within the typical depth of the local subsurface construction zone or building structure at threat is recovered to residual saturation. Evaluations of NAPL properties, distribution or capillary barriers that contribute to NAPL zone stability may be used to facilitate the determination.

3.1.1.8 *Control Endpoint*: CONTROL (via TI):

The CONTROL (via TI) endpoint is permitted only after it has been determined that the RECOVERY ONLY endpoint for the mobile NAPL zone (Sec 3.4.1.1) cannot be achieved and the TCEQ has accepted a *Technical Impracticability Demonstration*. If accepted, a physical control may be employed to prevent access to the mobile NAPL zone.

The CONTROL (via TI) endpoint is achieved when a combination of a physical control and institutional control is employed. An acceptable physical control provides a physical barrier against human contact with the NAPL. An acceptable institutional control: 1) warns of the NAPL, 2) prohibits excavation into the NAPL zone unless proper safeguards are taken to protect human health and safety from any hazards associated with the NAPL, and 3) requires NAPL removed during any future subsurface activity to be properly handled and managed in accordance with all applicable state and federal rules and regulations.

Table 16. NAPL Response Objectives and Endpoints for Mobile NAPL Zone Trigger

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint Types	
		Recovery Endpoint	Control Endpoint
❑ Mobile NAPL threat to subsurface utility or structure ❑ Mobile NAPL in vadose zone at depth ≤ 15 ft; not in *secured/restricted facility*	**Prevent mobile NAPL impact to shallow vadose zone receptors** **(Sec 3.4.1)**	**RECOVERY ONLY** ❑ NAPL recovered to residual saturation **(Sec 3.4.1.1)**	**CONTROL (via TI)** ❑ Access to NAPL zone prevented using physical control **(Sec 3.4.1.2)**
❑ Mobile NAPL in vadose zone at depth ≤ 15 ft; in *secured/restricted facility*	**Prevent potential exposure to mobile NAPL** **(Sec 3.4.2)**	**RECOVERY** ❑ NAPL recovered to residual saturation **(Sec 3.4.2.1)**	**CONTROL** ❑ Exposure to NAPL zone prevented via institutional control **(Sec 3.4.2.2)**
❑ Mobile NAPL overlies groundwater with which NAPL is not in contact ❑ Mobile NAPL overlies groundwater NAPL zone in PMZ	**Prevent NAPL migration to groundwater** **(Sec 3.4.3)**	**RECOVERY** ❑ NAPL recovered to residual saturation **(Sec 3.4.3.1)**	**CONTROL** ❑ NAPL zone migration control by physical or natural methods and institutional controls **(Sec 3.4.3.2)**
❑ Mobile NAPL in contact with groundwater	**Prevent disturbance of mobile NAPL that could induce migration** **(Sec 3.4.4)**	**RECOVERY** ❑ NAPL recovered to residual saturation **(Sec 3.4.4.1)**	**CONTROL** ❑ Disturbance of mobile NAPL zone prevented by institutional controls **(Sec 3.4.4.2)**

3.4.2 *Response Objective*: Prevent potential exposure to mobile NAPL

This response action applies to exposure to NAPL that is onsite at a secure or restricted facility—such as at a refinery or chemical plant—or any subsurface excavation or construction that is controlled by a facility work permit process that can be anticipated and planned for.

3.4.2.1 *Recovery Endpoint*: RECOVERY:

The RECOVERY endpoint is achieved when sufficient NAPL is recovered to prevent mobile NAPL from impacting anticipated work or construction zones in the vadose zone within 15 feet of the ground surface.

3.4.2.2 *Control Endpoint: CONTROL:*

The CONTROL endpoint is achieved when an institutional control is applied to a work site that could be threatened by a mobile NAPL zone and at which the consideration for protection of workers is anticipated. The CONTROL option must be reinforced by an institutional control. An acceptable institutional control: 1) warns of the NAPL, 2) prohibits excavation into the NAPL zone unless proper safeguards are taken to protect human health and safety from any hazards associated with the NAPL, 3) prohibits disturbance of a physical control by excavation unless proper safeguards are taken to protect human health and safety from any hazards associated with the NAPL, and 4) requires any NAPL removed during any future subsurface activity to be properly handled and managed in accordance with all applicable state and federal rules and regulations.

3.4.3 *Response Objective*: Prevent NAPL migration to groundwater

The potential for mobile NAPL in the vadose zone to continue migrating to or to be induced to migrate to an underlying GWBU must be prevented. This response objective allows for the use of the RECOVERY and/or CONTROL endpoint options.

3.4.3.1 *Recovery Endpoint: RECOVERY:*

The RECOVERY endpoint is achieved when sufficient mobile NAPL is recovered to reduce NAPL concentrations throughout the NAPL zone to levels that are below the residual saturation, thereby eliminating the potential for, or actual migration of, NAPL to a GWBU.

3.4.3.2 *Control Endpoint*: CONTROL

The CONTROL endpoint is achieved when the mobile NAPL zone is prevented from actively migrating and an institutional control is applied to give advance notice of the mobile NAPL zone so precautions can be taken to minimize the potential for subsurface activity to destabilize any remaining mobile NAPL zone that could induce migration.

An acceptable institutional control: 1) warns of the NAPL, 2) prohibits access to drilling/excavation into or through the NAPL zone unless actions are taken to prevent the possibility of migration of the underlying groundwater, and 3) requires any NAPL removed during any future subsurface activity to be properly handled and managed in accordance with all applicable state and federal rules and regulations.

3.4.4 *Response Objective*: Prevent disturbance of mobile NAPL that could induce migration

This response objective applies to mobile NAPL at the capillary zone or in the saturated zone that is not migrating, but which could be induced to migrate by altering the site hydraulics through groundwater pumping (e.g., increasing the water table gradient, changing the groundwater flow path direction, drilling through to deeper GWBUs, etc.). Such remobilized NAPL migration can result in increased threat of impact to groundwater receptors. This response objective allows for the use of the RECOVERY and/or CONTROL endpoint options.

3.4.4.1 *Recovery Endpoint*: RECOVERY

The RECOVERY endpoint is achieved when sufficient mobile NAPL is recovered to reduce NAPL concentrations throughout the NAPL zone to levels that are below the residual saturation, thereby eliminating the potential for, or actual migration of, NAPL.

3.4.4.2 *Control Endpoint*: CONTROL

The CONTROL endpoint is achieved when an institutional control is applied to give advance notice of the mobile NAPL zone so that precautions can be taken to minimize the potential for subsurface activity that could destabilize the mobile NAPL zone and induced migration.

An acceptable institutional control: 1) warns of the mobile NAPL, 2) prohibits groundwater pumping in the affected GWBU and/or drilling/excavation into or through the mobile NAPL zone unless actions are taken to prevent the possibility of migration to underlying GWBUs, and 3) requires any NAPL removed during any future subsurface activity to be properly handled and managed in accordance with all applicable state and federal rules and regulations.

3.5 NAPL Aesthetic Impact or Nuisance Condition Trigger

The NAPL aesthetic impact or nuisance condition trigger comprises numerous situations that can impair an environmental medium or resource (see Table 10). The response objective for this trigger allows for the RECOVERY and/or CONTROL endpoint option. Table 17 summarizes responses available for the NAPL aesthetic impact or nuisance condition trigger.

Table 17. NAPL Response Objectives and Endpoints for *NAPL Aesthetic Impact or Nuisance Condition Trigger*

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
		Recovery Endpoint	Control Endpoint
❑ Aesthetic or nuisance condition at ground surface, surface water, vadose zone or groundwater	**Eliminate NAPL aesthetic impact or nuisance condition** **(Sec 3.5.1)**	**RECOVERY** ❑ Recover NAPL sufficient to eliminate aesthetic/ nuisance condition **(Sec 3.5.1.1)**	**CONTROL** ❑ Aesthetic impact or nuisance condition abated with physical control at NAPL zone and/or at POE **(Sec 3.5.1.2)**

3.5.1 *Response Objective*: Eliminate NAPL aesthetic impact or nuisance condition

Eliminate NAPL responsible for an aesthetic impact or a nuisance condition (see Table 10).

3.5.1.1 Recovery Endpoint: RECOVERY

The RECOVERY endpoint is achieved when sufficient NAPL is recovered to permanently eliminate the aesthetic impact or nuisance condition at the NAPL zone and/or the applicable point of exposure (POE) and can be implemented in conjunction with a physical control to mitigate the offensive condition.

3.5.1.2 Control Endpoint: CONTROL

The CONTROL endpoint is achieved when the person demonstrates that a physical control applied at either the NAPL zone or the point of aesthetic impact or nuisance condition has mitigated the offensive condition. An institutional control is established to protect placement of the physical control.

3.6 NAPL Contact with Groundwater Trigger

NAPL response objectives for the NAPL contact with groundwater trigger are consistent with the groundwater response actions required by §350.33(f) of the TRRP rule for the dissolved-phase groundwater PCLE zone. The default response objective is to restore the groundwater throughout the dissolved groundwater PCLE zone to the critical PCL. However, for affected Class 2 and Class 3 groundwater, there is the potential alternative to manage the groundwater PCLE zone in a PMZ in lieu of restoration. Therefore, site conditions associated with this trigger determine the applicability of using the RECOVERY ONLY or the RECOVERY and/or CONTROL options that are available. Table 18 summarizes the NAPL responses for this trigger.

3.6.1 *Response Objective*: Groundwater restoration

The soluble NAPL fraction that acts as the source of a dissolved-phase groundwater PCLE zone must be recovered to the extent that the groundwater PCLE zone is restored. Restoration of the groundwater PCLE zone is required for any of the following:

- affected Class 1 groundwater
- PMZ is not proposed
- proposed PMZ is not approved by the TCEQ

rule-required performance objectives and requirements for an approved PMZ could not be satisfactorily achieved (i.e.,failure to obtain landowner consent for the required institutional control is a common example of inability to meet rule requirements)

Table 18. NAPL Response Objectives and Endpoints for *NAPL Contact with Groundwater Trigger*

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
		Recovery Endpoint	Control Endpoint
❑ NAPL contact w/ Class 1 groundwater ❑ NAPL contact w/ Class 2 / Class 3 groundwater not in PMZ	**Groundwater restoration** **(Sec 3.6.1)**	**RECOVERY ONLY** ❑ Recover soluble NAPL fraction sufficient to eliminate source contributions to GW PCLE zone **(Sec 3.6.1.1)**	**CONTROL (via TI)** ❑ Control soluble NAPL fraction sufficient to create stable (or shrinking) PCLE zone **(Sec 3.6.1.2)**
❑ NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ	**Compliance with PMZ performance criteria at NAPL zone** **(Sec 3.6.2)**	**RECOVERY** ❑ Recover readily recoverable NAPL fraction **(Sec 3.6.2.1)**	**(only address recovery endpoint, if applicable)** **(Sec 3.6.2.2)**

3.6.11 Recovery Endpoint: RECOVERY ONLY

The RECOVERY ONLY endpoint is achieved when the soluble fraction of the NAPL zone is recovered sufficiently to stop further sourcing of the dissolved-phase groundwater PCLE zone. The endpoint meets the response objective for groundwater restoration by removing the active source of the dissolved-phase groundwater PCLE zone.

3.6.1.2 Control Endpoint: CONTROL (via TI)

The CONTROL (via TI) endpoint is achieved when the soluble fraction of the NAPL zone is controlled by physical or natural means at the NAPL source zone such that the dissolved-phase groundwater PCLE zone is stable (or shrinking) and the PCLE performance objectives for the TI-based PMZ can be met.

The CONTROL (via TI) endpoint may only be employed when the RECOVERY ONLY endpoint is demonstrated to be unable to achieve the required groundwater restoration. The CONTROL (via TI) option is available only after a formal *TI Demonstration* that addresses *both* the NAPL zone *and* the groundwater PCLE zone has been accepted by the TCEQ. If the TI demonstration is approved by the TCEQ, the person is allowed to establish a PMZ for the portion of the NAPL zone and groundwater PCLE zone that is technically impracticable to restore (i.e., the TI zone).

3.6.2 *Response Objective*: Compliance with PMZ performance criteria at NAPL zone

Per rule, compliance with applicable PMZ performance criteria must be maintained at the NAPL zone. NAPL in a PMZ which contain COCs in excess of PCLs must be reduced (recovered) to the *extent practicable* [§350.33(f)(4)(E)]. This means that the NAPL would pose a health threat should human or ecological exposure occur. Five NAPL-related PMZ performance criteria are specified in the rule to determine if adequate NAPL reduction has occurred (before or after NAPL recovery) and are listed in Table 19. The first four PMZ NAPL zone performance criteria *are addressed by other NAPL triggers discussed above* and endpoints for achieving and maintaining PMZ compliance are found in the associated sections (see Table 19 for summary).

Table 19. PMZ NAPL Zone Extent Practicable Performance Criteria

PMZ NAPL Zone Performance Criteria	Applicable NAPL Triggers	Applicable NAPL Response Objectives
❑ **No explosive conditions generated by the NAPL**	NAPL generating vapors (Sec 3.2)	Permanently eliminate NAPL as explosive vapor source (Sec 3.2.1)
❑ **Meet critical PCLs**	NAPL generating vapors (Sec 3.2)	Abate inhalation exposure (Sec 3.2.2)
❑ **No NAPL zone migration**	Migrating NAPL zone (Sec 3.3)	Abate NAPL zone migration (Sec 3.3.1)
❑ **No NAPL discharges to environment**	Migrating NAPL zone (Sec 3.3)	Abate NAPL zone migration (Sec 3.3.1)
	Mobile NAPL zone (Sec 3.4)	Prevent NAPL migration to shallow vadose zone receptors (Sec 3.4.1)
❑ **Recover readily recoverable NAPL**	NAPL contact with GW creating dissolved PCLE zone (Sec 3.6)	Ensure compliance of NAPL zone in PMZ (Sec 3.6.2)

The fifth criterion, removal of *readily recoverable* NAPL, is used to satisfy the *extent practicable* reduction requirement while accommodating the flexibility provided in the rule to demonstrate that remaining NAPL (before or after recovery) does not pose a long term threat to human health and the environment. This response objective only has a RECOVERY endpoint.

3.6.2.1 Recovery Endpoint: RECOVERY

The RECOVERY endpoint is achieved when the *readily recoverable* fraction of the NAPL zone has been removed. Readily recoverable NAPL is defined as the NAPL fraction whose removal can be accomplished by an appropriately designed and properly maintained recovery system based on a *conventional technology* (see Appendix B for definition of conventional technology). The endpoint is achieved when the ability of the recovery system to feasibly remove NAPL has reached its practicable extent.

The application of the readily recoverable endpoint depends on the potential for conventional technology recovery at the site. The determination of whether readily recoverable NAPL exists at a site is made using *NAPL Management TOOL A* (Appendix A). Figure 6 shows the logic-decision flowchart for the applicability of the readily recoverable removal endpoint. NAPL recovery is subject to the reasonable time frame requirements in §350.33(b). For discussion of time frames, see *Application of Remedy Standards A and B* (RG-366/TRRP-28). *The presence or absence of readily recoverable NAPL should be re-evaluated in the course of each PMZ monitoring event.*

3.6.2.2 Control Endpoint: (Only address recovery endpoint, if applicable)

A separate specific CONTROL endpoint does not exist for this response objective because all control requirements associated with a PMZ are in place. The NAPL control response is implicitly addressed by its inclusion within the PMZ (see Table 19).

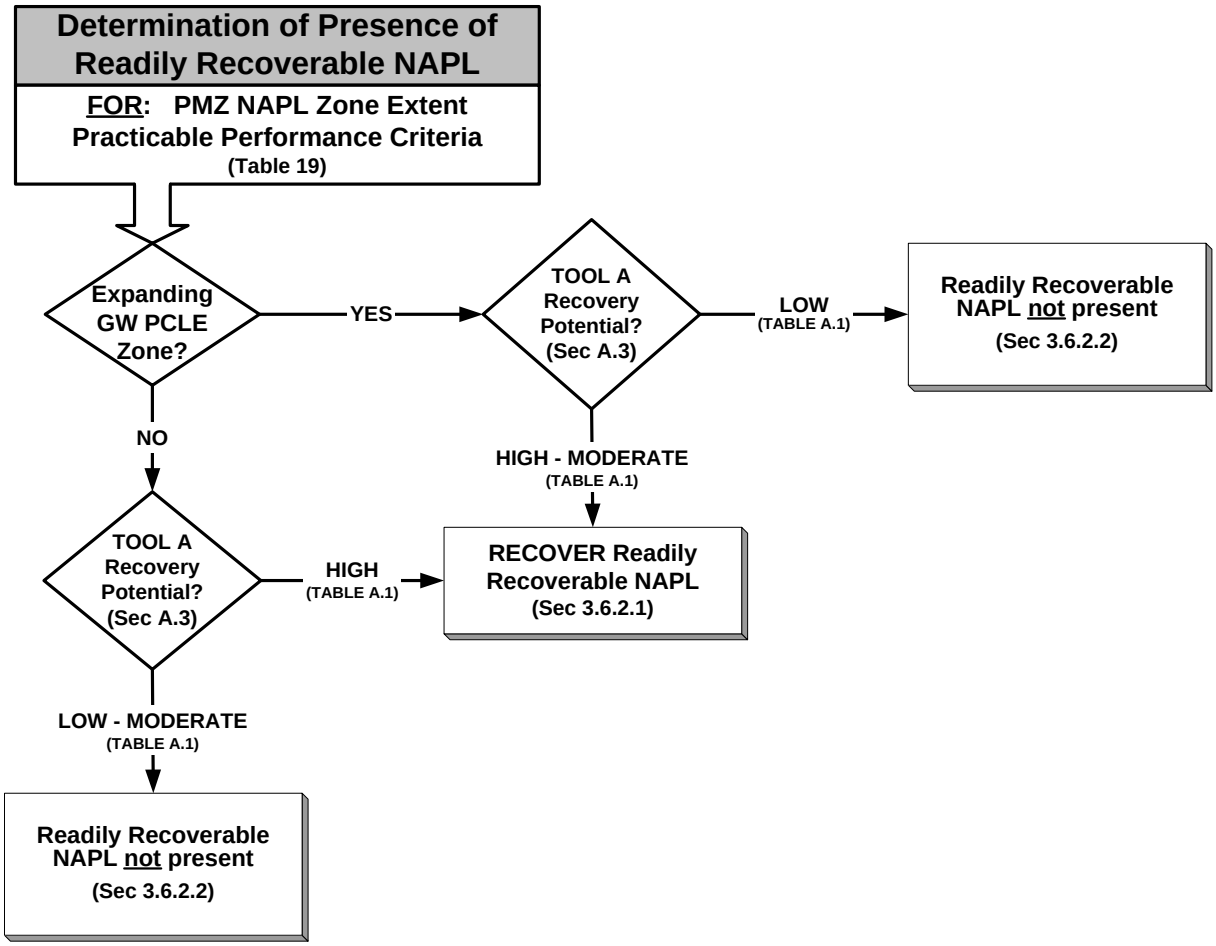

Figure 6. Determination of Presence of Readily Recoverable NAPL in a PMZ.

3.7 NAPL Contact with Surface Water Trigger

The NAPL contact with surface water trigger for impacts of surface water by NAPL has a NAPL response objective that requires a RECOVERY ONLY endpoint. Table 20 summarizes the response objective and endpoints.

3.7.1 *Response Objective*: Eliminate NAPL in contact with surface water

NAPL in contact with surface water, floating or otherwise, requires the RECOVERY ONLY endpoint. The control endpoint option is *not* allowed for this response objective.

Table 20. NAPL Response Objectives and Endpoints for *NAPL Contact with Surface Water Trigger*

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
		Recovery Endpoint	Control Endpoint
❑ NAPL floating on surface water or entrained in surface water body	**Eliminate NAPL in contact with surface water** (Sec 3.7.1)	**RECOVERY ONLY** ❑ Recover NAPL on or in surface water (Sec 3.7.1.1)	**CONTROL OPTION NOT AVAILABLE** (Sec 3.7.1.2)

3.7.1.1 Recovery Endpoint: RECOVERY ONLY

The RECOVERY ONLY endpoint is achieved when NAPL has been removed from the surface water body.

3.7.1.2 *Control Endpoint*: CONTROL OPTION NOT AVAILABLE

No control endpoint is applicable or allowed. The NAPL response objective must be addressed with the RECOVERY ONLY endpoint (Sec 3.7.1.1). However, an interim emergency or abatement control for containment purposes should be pursued as warranted in accordance with §350.1.

3.8 NAPL Contact with Sediment Trigger

The *NAPL Contact with Sediment Trigger* for NAPL that has impacted sediment has a response objective that requires NAPL and the associated sediment to be abated for the purpose of preventing direct human or ecological contact using the RECOVERY ONLY endpoint, or if approved the CONTROL (via TI) endpoint. Table 21 summarizes the response objective and the applicable endpoints.

Table 21. NAPL Response Objectives and Endpoints for *NAPL Contact with Sediment Trigger*

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
		Recovery Endpoint	Control Endpoint
❑ NAPL in or on banks or bed of surface water body	**Prevent NAPL in sediment from contacting surface water *and* direct human or ecological receptor contact with NAPL** **(Sec 3.8.1)**	**RECOVERY ONLY** ❑ Recover NAPL to sediment PCLs at applicable POE **(Sec 3.8.1.1)**	**CONTROL (via TI)** ❑ Isolate NAPL zone from surface water bodies and receptors using physical control **(Sec 3.8.1.2)**

3.8.1 *Response Objective*: Prevent NAPL in sediment from contacting surface water *and* direct human or ecological receptor contact with NAPL

NAPL occurring in sediment that has, or could come in contact with surface water, floating or otherwise, requires the RECOVERY ONLY endpoint. The control endpoint option is *not* allowed for this response objective.

3.8.1.1 Recovery Endpoint: RECOVERY ONLY

The RECOVERY ONLY endpoint is achieved when NAPL has been recovered from the greater depth of: 1) the upper one foot of sediment or 2) the sediment depth above which sediment is likely to be dredged or reasonably expected to be eroded during storm events plus one foot in depth. *Additionally*, all deeper NAPL must be recovered to residual saturation.

Potential ecological impacts from the recovery may warrant deviation from this RECOVERY ONLY endpoint in a site-specific situation. Contact TCEQ ecological risk assessors or TCEQ natural resource trustees about such matters.

3.8.1.2 Control Endpoint: CONTROL (via TI)

The CONTROL (via TI) endpoint is achieved when a physical control isolates the NAPL zone from the surface water and effectively prevents direct human or ecological receptor contact. The control endpoint is allowable only after the RECOVERY ONLY endpoint has been formally demonstrated technically impracticable in a TCEQ-approved TI demonstration (unless a deviation is deemed appropriate—contact TCEQ ecological risk assessors or TCEQ natural resource trustees regarding details). An interim emergency or abatement action for containment purposes should be pursued as warranted in accordance with §350.1.

3.9 Special Case: NAPL Beneath a Waste Control Unit (WCU)

A WCU is a municipal or industrial solid waste landfill (including RCRA-regulated units closed as landfills) with a liner system and an engineered cap that has been closed pursuant to an approved closure plan, previous regulations, or will be closed pursuant to an approved RAP. No groundwater POEs are considered to exist within the footprint of a WCU (Figure 7). Only two triggers and response objectives apply to WCUs; they are the *NAPL Generating Vapors Trigger* and the *Migrating NAPL Zone Trigger* (summarized in Table 22).

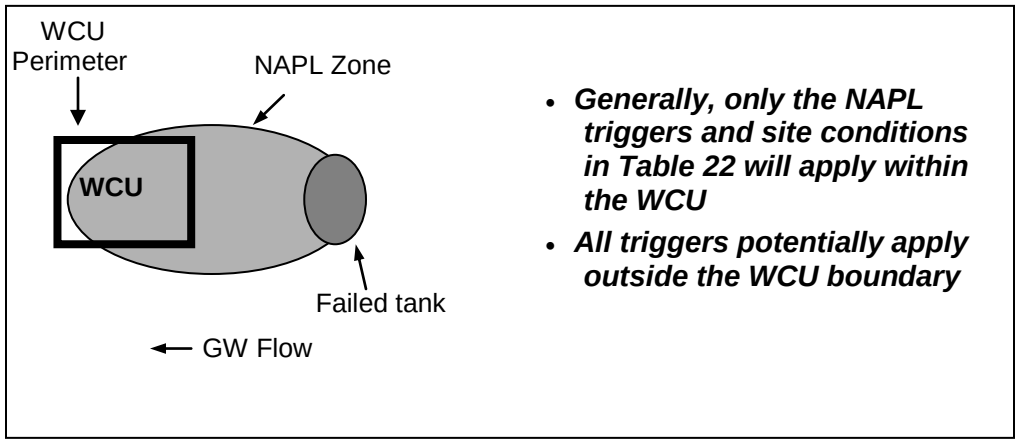

Figure 7. Map View of NAPL Groundwater PCLE Zone Extending Beneath a WCU.

These two triggers generally apply beneath the footprint of a WCU. However, all NAPL triggers potentially apply at and beyond the perimeter of the WCU as projected down into the groundwater. In the example presented in Figure 7, NAPL recovery and/or control is only required for the portion of the NAPL that is present outside the perimeter of the WCU *unless* NAPL recovery beneath the WCU is the only action that will result in response objectives to be met beyond the perimeter of the WCU. The use of the WCU exemption must be proposed in a RAP. See TCEQ guidance document *Soil and Groundwater Response Objectives* (RG-366/TRRP-29) for additional information on WCUs.

Table 22. NAPL Triggers, Response Objectives and Endpoints Applicable to WCUs

Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Reponse Endpoint	
		Recovery Endpoint	Control Endpoint
***NAPL Generating Vapors Trigger* (Sec 3.2; Table 14)**			
❑ NAPL generating potentially explosive vapor accumulations	**Permanently eliminate NAPL as explosive vapor source** **(Sec 3.2.1)**	**RECOVERY ONLY** ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further explosive vapor accumulations **(Sec 3.2.1.1)**	**CONTROL OPTION NOT AVAILABLE** **(Sec 3.2.1.2)**
❑ NAPL generating explosive vapors that exceed inhalation PCLs at applicable inhalation POE	**Abate inhalation exposure** **(Sec 3.2.2)**	**RECOVERY** ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further exceedance of inhalation PCLs **(Sec 3.2.2.1)**	**CONTROL** ❑ Vapors controlled at NAPL source or at POE and exposure to vapors in excess of PCL eliminated **(Sec 3.2.2.2)**
Migrating NAPL Zone Trigger (Sec 3.3; Table 15)			
❑ NAPL zone migration in the vadose or saturated zone	**Abate NAPL zone migration** **(Sec 3.3.1)**	**RECOVERY ONLY** ❑ NAPL recovered to residual saturation **(Sec 3.3.1.1)**	**CONTROL (via TI)** ❑ NAPL zone migration arrested with physical control ❑ **(Sec 3.3.1.2)**

3.10 Complete the *NAPL Response Endpoint Matrix* (Table 23)

The *NAPL Management Endpoint Matrix* (Table 23) is used to document the site-specific NAPL triggers, site conditions, response objectives and endpoints for submittal with the APAR, RAP and RACR, as applicable. The *Endpoint Matrix* assembles and summarizes the NAPL assessment information collected in STEP 1, the applicable NAPL triggers and site conditions identified in STEP 2, and the NAPL response objectives and associated management endpoints selected in STEP 3 (above).

STEP 3 is completed when all applicable information from STEP 1 through STEP 3 has been properly checked in Table 23 for inclusion in an approved RAP.

Table 23. NAPL Response Endpoint Matrix

NAPL Trigger (*from* STEP 2)	Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
			Recovery Endpoint	Control Endpoint
❑ **NAPL generating vapors** **Sec 2.1.1**	❑ NAPL generating explosive vapor accumulations	**Permanently eliminate NAPL as explosive vapor source** **(Sec 3.2.1)**	**RECOVERY ONLY** ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further explosive vapor accumulations **(Sec 3.2.1.1)**	**CONTROL OPTION NOT AVAILABLE** **(Sec 3.2.1.2)**
	❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	**Abate inhalation exposure** **(Sec 3.2.2)**	**RECOVERY** ❑ Volatile fraction of NAPL recovered sufficiently to eliminate vapors that exceed inhalation PCLs **(Sec 3.2.2.1)**	**CONTROL** ❑ Vapors controlled at NAPL source or at POE and exposure to vapors that exceed PCLs eliminated **(Sec 3.2.2.2)**
❑ **Migrating NAPL zone** **Sec 2.1.2**	❑ NAPL in vadose zone ≤ 15 ft below ground surface ❑ NAPL in saturated zone, <u>not</u> in PMZ* ❑ NAPL zone migration in the vadose zone or saturated zone	**Abate NAPL zone migration** **(Sec 3.3.1)**	**RECOVERY ONLY** ❑ NAPL recovered to residual saturation and/or to arrest migration	**CONTROL (via TI)** ❑ NAPL zone migration arrested with physical control **(Sec 3.3.1.2)**
	❑ NAPL discharge to ground surface, surface water or sediment		❑ NAPL recovered sufficient to eliminate NAPL discharge **(Sec 3.3.1.1)**	
	❑ NAPL in saturated zone in a PMZ*		**RECOVERY** ❑ NAPL recovery sufficient to arrest NAPL migration **(Sec 3.3.1.3)**	**CONTROL** ❑ NAPL zone migration arrested with physical control or natural methods **(Sec 3.3.1.4)**
❑ **Mobile NAPL zone** **Sec 2.1.3**	❑ Mobile NAPL threat to subsurface utility or structure ❑ Mobile NAPL in vadose zone at depth ≤ 15 ft; <u>not</u> in *secured/ restricted facility*	**Prevent mobile NAPL impact to shallow vadose zone receptors** **(Sec 3.4.1)**	**RECOVERY ONLY** ❑ NAPL recovered to residual saturation **(Sec 3.4.1.1)**	**CONTROL (via TI)** ❑ Access to NAPL zone prevented using physical control **(Sec 3.4.1.2)**
	❑ Mobile NAPL in vadose zone at depth ≤ 15 ft; in *secured/ restricted facility*	**Prevent potential exposure to mobile NAPL** **(Sec 3.4.2)**	**RECOVERY** ❑ NAPL recovered to residual saturation **(Sec 3.4.2.1)**	**CONTROL** ❑ Exposure to NAPL zone prevented via institutional control **(Sec 3.4.2.2)**
	❑ Mobile NAPL overlies ground-water with which NAPL is <u>not</u> in contact ❑ Mobile NAPL overlies ground-water NAPL zone in PMZ*	**Prevent NAPL migration to groundwater** **(Sec 3.4.3)**	**RECOVERY** ❑ NAPL recovered to residual saturation **(Sec 3.4.3.1)**	**CONTROL** ❑ NAPL zone migration control by physical or natural methods and institutional controls **(Sec 3.4.3.2)**
	❑ Mobile NAPL in contact with groundwater	**Prevent disturbance of mobile NAPL that could induce migration** **(Sec 3.4.4)**	**RECOVERY** ❑ NAPL recovered to residual saturation **(Sec 3.4.4.1)**	**CONTROL** ❑ Disturbance of mobile NAPL zone prevented via institutional control **(Sec 3.4.4.2)**

Table 23. NAPL Response Endpoint Matrix (continued)

NAPL Trigger (*from* STEP 2)	Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
			Recovery Endpoint	Control Endpoint
❑ **NAPL Aesthetic Impact or Nuisance Condition** **Sec 2.1.4**	❑ Aesthetic or nuisance condition at ground surface, surface water, vadose zone or groundwater	**Eliminate NAPL aesthetic impact or nuisance condition** **(Sec 3.5.1)**	**RECOVERY** ❑ Recover NAPL sufficient to eliminate aesthetic or nuisance condition **(Sec 3.5.1.1)**	**CONTROL** ❑ Aesthetic impact or nuisance condition abated with physical control at NAPL zone and/or at POE **(Sec 3.5.1.2)**
❑ **NAPL Contact with Groundwater** **Sec 2.1.5**	❑ NAPL contact w/ Class 1 groundwater ❑ NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*	**Groundwater restoration** **(Sec 3.6.1)**	**RECOVERY ONLY** ❑ Recover soluble NAPL fraction sufficient to eliminate source contributions of NAPL to GW PCLE zone **(Sec 3.6.1.1)**	**CONTROL (via TI)** ❑ Control soluble NAPL fraction sufficient to create stable (or shrinking) PCLE zone **(Sec 3.6.1.2)**
	❑ NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ*	**Ensure compliance of NAPL zone in PMZ** **(Sec 3.6.2)**	**RECOVERY** ❑ Recover readily recoverable NAPL fraction** **(Sec 3.6.2.1)**	**(only address recovery endpoint, if applicable)** **(Sec 3.6.2.2)**
❑ **NAPL contact with Surface Water** **Sec 2.1.6**	❑ NAPL floating on surface water or entrained in surface water body	**Eliminate NAPL in contact with surface water** **(Sec 3.7.1)**	**RECOVERY ONLY** ❑ Recover NAPL on or in surface water **(Sec 3.7.1.1)**	**CONTROL OPTION NOT AVAILABLE** **(Sec 3.7.1.2)**
❑ **NAPL contact with Sediment** **Sec 2.1.7**	❑ NAPL in or on banks or bed of surface water body	**Prevent NAPL in sediment from contacting surface water *and* direct human or ecological receptor contact with NAPL** **(Sec 3.8.1)**	**RECOVERY ONLY*** ❑ Recover NAPL to sediment PCLs at applicable POE **(Sec 3.8.1.1)**	**CONTROL (via TI)** ❑ Isolate NAPL zone from surface water bodies and receptors using physical control **(Sec 3.8.1.2)**

LEL- *lower explosive limit* **PCL** – *protective concentration limit* **PMZ** – *plume management zone* **POE** – *point of exposure* **TI** – *technical impracticability demonstration*

*** The PMZ reference includes PMZs that have been approved by the TCEQ, PMZ eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via TI demonstration.**

**** For the PMZ situation, the applicability of the readily recoverable circumstance must be determined and recovery must occur if it is applicable (see Table 19 and Figure 6 and associated explanatory text).**

***** Potential ecological impacts from NAPL recovery actions may warrant deviation from this RECOVERY ONLY endpoint on a site-specific basis. Inquire with TCEQ.**

4.0 STEP 4: Develop NAPL Management Strategy

STEP 4 is the development of the NAPL Management Strategy. The strategy comprises the comprehensive site-specific response action plan by which the person intends to achieve the endpoint(s) for each applicable trigger (STEP 3). The *NAPL strategy is integrated with all other non-NAPL response actions* (i.e., remove, decontaminate, and/or control the PCLE zones) required for the affected property.

Figure 8 summarizes the basic elements that may be used to develop the NAPL strategy. The contributing NAPL strategy elements should be selected by comparing the relevant recovery and/or control endpoints set from STEP 3 for each applicable trigger associated with a NAPL occurrence (e.g., NAPL in vadose zone). Identify the endpoint that, if achieved, will satisfy the others. Determine the fewest endpoints capable of addressing all applicable response objectives for that NAPL occurrence. Evaluate the most appropriate NAPL recovery and/or control response action that will achieve the endpoint. Consider both conventional and alternative NAPL recovery technologies as appropriate. Repeat the process for each NAPL occurrence. Exercises in Appendix D (gas station) and Appendix E (dry cleaner) provide examples for the development of integrated NAPL strategies.

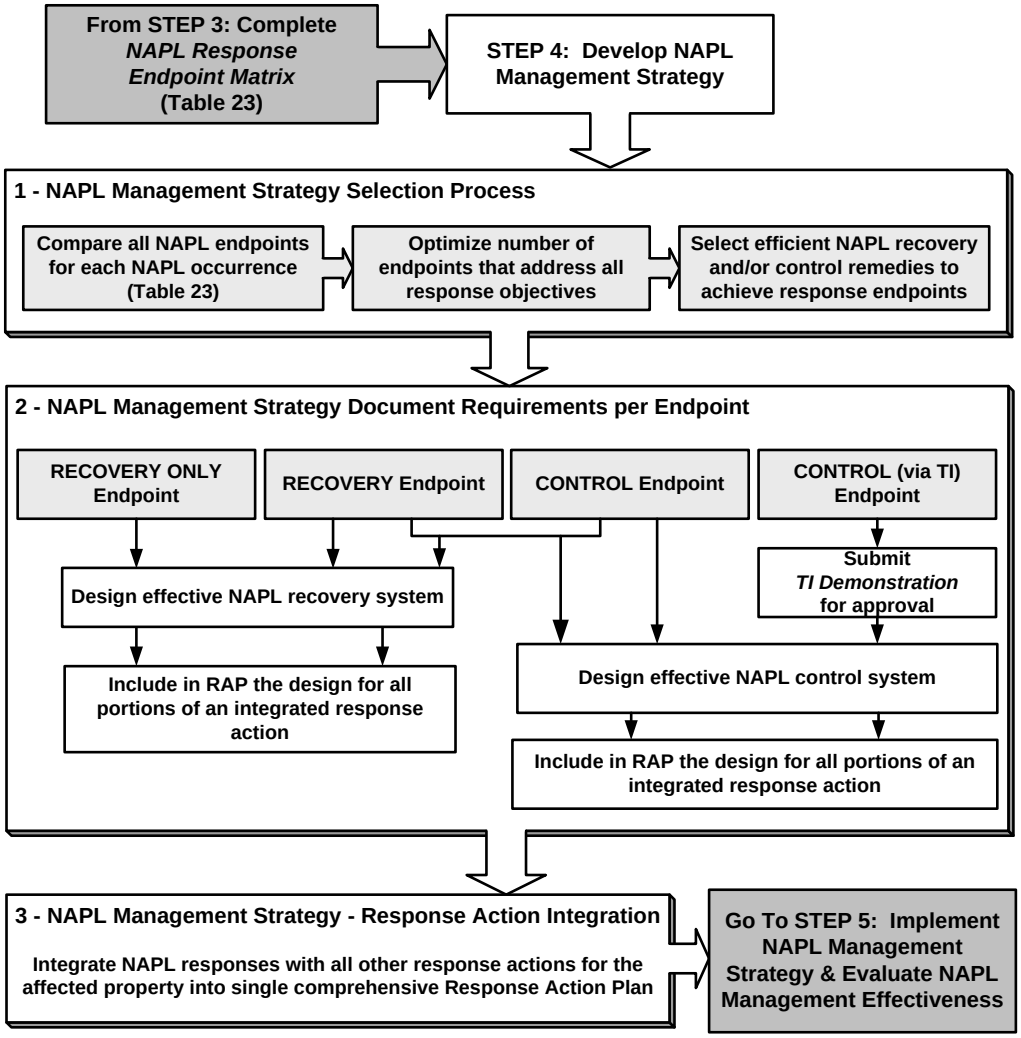

Figure 8. Overview of STEP 4: Develop NAPL Management Strategy.

4.1 Administrative Process

Table 24 summarizes the reporting requirements associated with the NAPL strategy. If only NAPL recovery response actions are to be taken (i.e., no control response action is to be taken for the NAPL or for any PCLE zone at the affected property), then the NAPL recovery action may be self-implemented under Remedy Standard A. In such a case, submit a SIN to the TCEQ 10 days in advance of self-implementing the NAPL recovery. No RAP is required under Remedy Standard A unless the person chooses to submit a RAP for TCEQ approval (Table 24).

In contrast, if an integrated remedy includes either a NAPL control, or other PCLE zone, control response action, then all NAPL recovery and/or control response actions are included in a RAP for TCEQ approval. Upon approval, the response action proceeds under Remedy Standard B and cannot be self-implemented. Physical or natural controls must be reinforced with the filing of an institutional control, and there is the potential for post response action care requirements (e.g., monitoring, operation and maintenance, and financial assurance) to ensure the long-term protectiveness of the physical control.

Table 24. Summary of NAPL Response Actions and Remedy Standards

	Remedy Standard A (SIN Required) Submit to TCEQ (and respective regional office) 10 days prior to implementation of response action.	**Remedy Standard B (RAP Required)** Submit RAP for TCEQ approval *prior to initiating any control response action*..If pursuing a NAPL TI demonstration, submit it with RAP.
RECOVERY ONLY	✓ **(unless submitting RAP)**	✓
RECOVERY	✓ **(unless submitting RAP)**	✓
CONTROL	**N/A**	✓
CONTROL (via TI)	**N/A**	✓
N/A = Remedy Standard A not available with CONTROL response action associated with ANY aspect of an integrated response action approach		

A RAP for NAPL response actions must have incorporated into it the specific elements listed in Table 25. These four elements are generally applicable to all RAPs, but are presented here in the NAPL context. These elements should be specifically addressed in terms of the NAPL zone, as well as in terms of any other PCLE zones. See TCEQ guidance documents *Evaluating Remedy Effectiveness* (draft RG-366/TRRP-31), *Application of Remedy Standards A and B* (RG-366/TRRP-28), *Soil and Groundwater Response Objectives* (RG-366/TRRP-29), and the *Response Action Plan* form (10326/RAP) for further information on response action performance requirements, planning a response action, and preparation of a RAP.

4.2 Technical Impracticability (TI) Demonstrations for NAPL Recovery Endpoints

A NAPL TI Demonstration is required to be submitted when: 1) a RECOVERY ONLY response action is demonstrated to be incapable of achieving its respective endpoint (see *NAPL Response Effectiveness* [draft RG-366/TRRP-31A]), or 2) when recovery must be resorted to because of an inability to file the required institutional control for a control response action AND that respective recovery endpoint cannot be achieved [§350.111(c)].

A NAPL TI demonstration is applicable to NAPL in soil, groundwater, and sediment, although TI demonstrations are only specifically discussed in the rule in the context of groundwater [§350.33(f)(3)].

Table 25. Summary of Requirements for RAPs

	RAP Section	Description
Response Action Plan Requirements	**Response Action Objectives**	Declaration of planned NAPL recovery and/or control endpoints(s)
	Response Action Design	Proposed engineering design for NAPL recovery and/or control system(s)
	Response Action Performance	Method by which NAPL recovery or control system performance is to be evaluated
	Response Action Implementation Schedule	Schedule for implementing proposed NAPL management strategy

4.2.1 Minimum Requirements for NAPL TI Demonstrations

Acceptance and approval of a NAPL TI demonstration requires a determination that an appropriately engineered NAPL recovery system has become ineffective. An appropriately engineered NAPL recovery system design is based on the specific site conditions and NAPL occurrence and is one that is implemented in a manner that maximizes the potential for achieving the recovery endpoint. A NAPL TI demonstration must include a technically rigorous analysis and evaluation leading to a quantitative conclusion that recovery is not, or no longer, feasible.

A conventional technology can always be deployed to attempt to reach a RECOVERY ONLY endpoint. However, before concluding that a RECOVERY ONLY endpoint is technically impracticable, an alternative technology must be evaluated and typically deployed, at least on a pilot-test scale. Appendix A describes qualitative tools to screen for the potential efficacy of using a conventional technology and a strategy to follow in deciding and sequencing technologies. Appendix B discusses conventional and alternative technologies and gives examples of those types of technologies. Appendix C (TOOL B) provides information useful for performing presumptive screens on the applicability of conventional NAPL recovery technologies based on some site characteristics.

In cases when a NAPL CONTROL option is available, consider the long-term costs and time commitments for operating and maintaining a physical control and the financial assurance (if applicable) during the post-response action care phase. The NAPL RECOVERY option may significantly reduce long-term costs, expedite achievement of a “no further action” status for the remediation project, or enhance the value or marketability of the property.

Submit a TI demonstration in the RAP that proposes the CONTROL (via TI) endpoint remedy. TCEQ approval of the TI demonstration always must be obtained *before* implementing a CONTROL (via TI) response.

Table 26 summarizes the components of a formal NAPL TI Demonstration.

Table 26. Components of a RECOVERY ONLY TI Demonstration

	Description	Data Requirements
TI Demonstration Applicability	TI demonstration applicability pertains only to the inability of meeting RECOVERY ONLY endpoints or institutional control requirements. Applicability extends only to specific portions of the NAPL zone(s) for which achieving the RECOVERY ONLY endpoint(s) can be demonstrated to be technically impracticable.	• Applicable NAPL endpoints • Applicable NAPL occurrences
NAPL Zone Applicability	The NAPL zone, or portion thereof, for which the TI demonstration is intended must be fully assessed and delineated.	• NAPL zones plotted in map(s) and cross sections • Dimensions of NAPL zone(s) • Affected groundwater-bearing units (for the TI zone, if applicable) • PCLE zone maps for all affected media
Site Conceptual Model	The TI demonstration must be appropriate to the site conceptual model (STEP 1). The TI demonstration must persuasively conclude that the recovery response action cannot meet the recovery endpoint.	• Site geology and hydrology • Observed and theoretical NAPL zone migration pathways • NAPL source history • NAPL characteristics and occurrences
Evaluation of Conventional and/or Alternative NAPL Recovery Efforts	The TI demonstration must be based on a technically rigorous analysis of time-series data collected during the operation of the alternative technology recovery system, OR a technically rigorous analysis of data from an appropriate on-site pilot test and modeling study that demonstrates the endpoint cannot be achieved via alternative technology recovery efforts alone.	• Cumulative mass recovered versus time data • Concentration reduction versus time data • Operation and maintenance expenditure records • Economic analysis

5.0 TEP 5: Implement NAPL Management Strategy and Evaluate NAPL Response Effectiveness

STEP 5 comprises the implementation of the NAPL management strategy and the evaluation of progress and effectiveness of the response action. Evaluating the effectiveness is essential. The intent of the evaluation is to provide tools that can facilitate an efficient course toward achieving an endpoint, or prompt the recognition that following the same course will not result in achieving the endpoint.

Implement the integrated response action developed in STEP 4. Thereafter, collect appropriate effectiveness data no less frequently than each scheduled monitoring event for the purpose of:

- determining the ability of a NAPL response action to achieve the endpoint
- confirming that a NAPL endpoint has been achieved
- selecting appropriate real-time NAPL response action monitoring methods
- collecting NAPL response action performance data
- determining the point at which the use of one NAPL response action technology should shift to a different technology
- evaluating the appropriate NAPL response action data for use in developing an acceptable TI demonstration

Re-evaluate recovery endpoint attainment after each monitoring event. For example, determine the presence or absence of readily recoverable NAPL in a PMZ at each data collection opportunity, where applicable.

TCEQ guidance document *NAPL Response Action Effectiveness* (draft RG-366/TRRP-31A) provides evaluation techniques and analytical methods by which demonstrations of effectiveness can be made.

APPENDIX A: NAPL Management TOOL A

A. TOOL A — Qualitative Screen for Conventional NAPL Recovery Technologies

NAPL Management TOOL A can be used as a *qualitative* screen for evaluating the general efficacy of conventional NAPL recovery technology for some site conditions. TOOL A is used for two purposes: 1) as a starting point for considering the potential for NAPL recoverability of a conventional technology during the development of an effective NAPL recovery system (Sec A.2), and 2) as the evaluation by which the presence of readily recoverable NAPL is determined (Sec A.3).

NAPL Management TOOL A is presented in Table A.1. TOOL A incorporates physical site conditions and a simple scoring system based on the conditions' relative propensity to facilitate NAPL recovery.

Table A.1. TOOL A (Qualitative Screen for Potential of Conventional NAPL Recovery Technologies)

Potential for NAPL Recovery by Conventional Technologies

1. by SOIL TYPE

Clay - Silt	Silt - Sand	Sand - Gravel	SCORE
-1	0	+1	

+

2. by MAX TRUE NAPL THICKNESS

< 2 in	2 in - 12 in	> 12 in	
-1	0	+1	

+

3. by NAPL VISCOSITY

HIGH (mixed-phase DNAPL PCBs, coal tar)	MEDIUM (heavy refined petroleum (e.g., no. 6 fuel oil)	LOW (light refined petroleum (e.g., gasoline)	
-1	0	+1	

+

4. by NAPL OCCURRENCE

LOW (in saturated zone with double porosity)	MEDIUM (in other saturated zone)	HIGH (in coarse-grained capillary fringe)	
-1	0	+1	

Potential for NAPL Recovery by Conventional Technology	TOTAL SCORE
HIGH: recovery likely	+2 to +4
MODERATE: recovery possible	-1 to +1
LOW: consider alternative tech	-4 to -2

⇦ TOTAL SCORE

A.1 NAPL Management TOOL A—Scoring

TOOL A (Table A.1) is a qualitative evaluation of the characteristics of four different conditions associated with a NAPL occurrence. The four conditions represent physical parameters that directly affect the potential for NAPL recoverability. A positive value for a given characteristic indicates that the condition is favorable for NAPL migration, and thus has a higher potential for recovery by a conventional technology. Conversely, a negative value for a characteristic is indicative of a condition that is not favorable for NAPL migration and which has a lower potential for recovery by a conventional technology.

TOOL A is scored by selecting the appropriate characteristic for each condition and summing them in the right column (Table A.1). The NAPL recovery potential is determined from the value of the total score.

A.2 NAPL Management TOOL A—Potential for NAPL Recoverability by Conventional Technologies

TOOL A is used to perform a qualitative screen for the purpose of providing a starting point from which to evaluate the potential effectiveness of conventional technologies for a NAPL occurrence. When a TOOL A score (Sec A.1) indicates conditions of a NAPL occurrence have a low potential for recovery using a conventional technology and recovery is necessary or desired by the person, an alternative NAPL recovery technology should be considered. Figure A.1 summarizes the decision-logic for use of TOOL A.

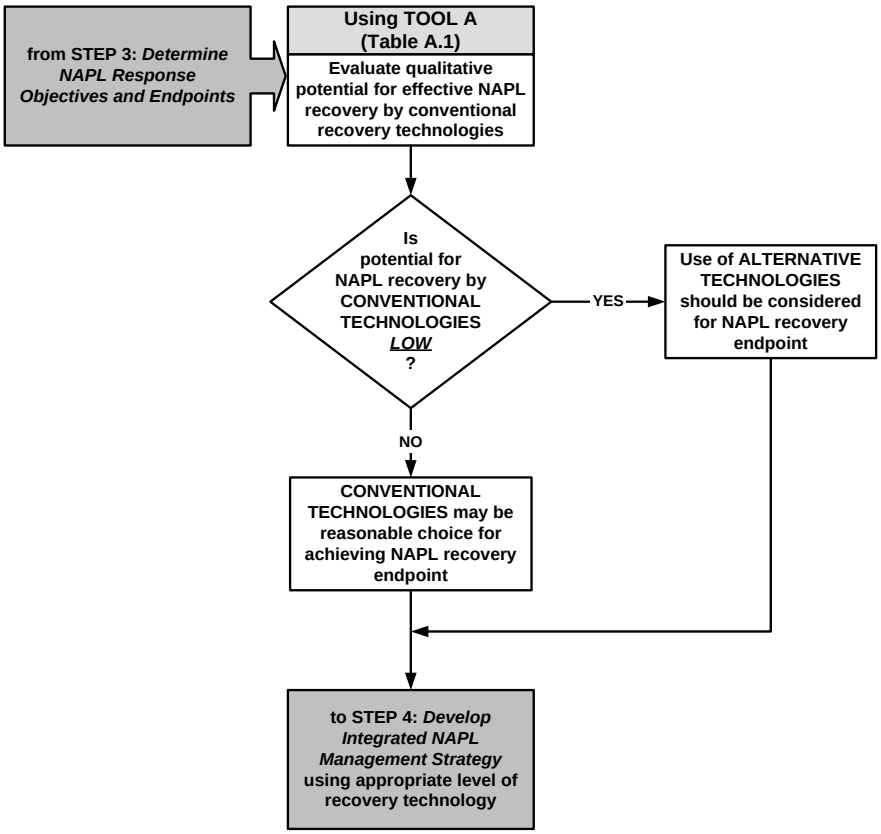

Figure A.1. Use of TOOL A: Screen for Potential of Conventional NAPL Recovery Technology.

A.3 NAPL Management TOOL A—Readily Recoverable NAPL

TOOL A also is used to determine the presence of readily recoverable NAPL (Sec 3.6.2.1). Score TOOL A as described in Section A.1 and determine the potential for recovery by conventional technology (LOW, MODERATE or HIGH). Use the resulting recoverability potential level in Figure 6 (Sec 3.6.2.1) to evaluate the presence of readily recoverable NAPL.

APPENDIX B: Conventional vs. Alternative NAPL Recovery Technologies

Conventional NAPL recovery technologies typically comprise standard "off-the-shelf" components which facilitate a modular-system design approach that takes advantage of readily available equipment. Such systems often cost less to construct, maintain and operate. The variety of available system components allow conventional recovery systems to be more readily matched to requirements imposed by the actual site conditions. The use of alternative NAPL recovery technologies at sites that are not conducive to effective recovery by conventional technologies often requires significant design development—including system pilot testing—before an effective system can be implemented. Expect the additional design and testing costs to be expected to be higher than those of conventional technology systems, but in such cases, alternative NAPL recovery technologies may be the sole means by which mandatory NAPL recovery requirements can be fulfilled.

This section defines the contrast between conventional and alternative NAPL recovery technologies as the terms apply throughout this guidance document.

B.1 Conventional NAPL Recovery Technologies

Conventional NAPL recovery technologies are considered to be those which remove NAPL by exploiting the following physical properties:

- **Hydraulic**: removal of NAPL via direct pumping of liquid-phase NAPL and/or NAPL plus groundwater.
- **Vapor phase**: removal of NAPL via extraction of volatile NAPL by induced vacuum pressure and flow.

Many conventional NAPL recovery technology configurations create effective recovery by exploiting both the hydraulic and vapor phase properties of a NAPL and the site conditions. Conventional NAPL recovery technologies are most effective for NAPL in the vadose zone and at the capillary fringe.

Table B.1 summarizes various common conventional NAPL recovery technologies.

B.2 Alternative NAPL Recovery Technologies

Alternative NAPL recovery technologies rely primarily on transforming NAPL chemistry or altering site conditions and should be considered for use in NAPL recovery when conventional technologies are unable to meet recovery endpoints. A summary of some alternative NAPL recovery technologies appears in Table B.2. However, the list is not complete as new technologies are tested routinely.

Implementation of these technologies generally requires more design and testing effort than that typically required for conventional technologies. Pilot testing of alternative NAPL recovery systems often is commensurate with the site-specific engineering design process and may be necessary prior to completing the submitted RAP design. Therefore, the design process can be technically challenging and requires the involvement of qualified professionals experienced with the technology.

Table B.1. Summary of Conventional NAPL Recovery Technologies

Technology	System Description / Configuration	Recovery Products
Soil vapor extraction (SVE)	Extraction well(s) set in vadose zone, one low-(or hi-) vacuum pump recovers volatile NAPL	VP LNAPL and VP DNAPL
Floating LNAPL extraction (FLE)	LNAPL skimming pump with LNAPL inlet set at water-NAPL interface	LNAPL
Shallow liquid-only (total fluids) extraction (SLE)	Single submersible pump set *shallow* in saturated zone	GW + LNAPL (undifferentiated)
Deep liquid-only (total fluids) extraction (DLE)	Single submersible pump set *deep* in saturated zone	GW + DNAPL (undifferentiated)
Dual-pump liquid extraction (DPLE)	Two submersible pumps; one set below water table to create groundwater drawdown, second pump set at water-NAPL interface to recover NAPL	GW and LNAPL (separated)
Low-vacuum dual phase extraction (LVE)	One submersible pump set below water table, one low-vacuum pump with suction-tube set above cone of depression low vacuum = 2 – 12 in Hg	GW + LNAPL (undifferentiated) VP LNAPL and VP DNAPL (separated from liquids)
Hi-vacuum dual phase extraction (HVE)	One submersible pump set below water table, one hi-vacuum pump with suction-tube set above cone of depression high vacuum = 18 – 26 in Hg	GW + LNAPL and DNAPL (undifferentiated) VP LNAPL and VP DNAPL (separated from liquids)
Two-phase extraction (*i.e.*, Bioslurp) (TPE)	Single high-vacuum pump, suction-tube set at air-liquid interface; high vacuum = 18 – 26 in Hg	GW + LNAPL (undifferentiated) VP LNAPL and VP DNAPL (separated from liquids)

GW - *groundwater* **VP** - *vapor phase* **LNAPL** - *light non-aqueous phase liquid* **DNAPL** - *dense non-aqueous phase liquid* **in Hg** – *pressure, inches of mercury*

Table B.2. Examples of Alternative NAPL Recovery Technologies

Technology	System Description	Target NAPLs
Soil flushing	Alcohol, cosolvents, and/or surfactants are flushed through NAPL zone to solublize and mobilize NAPL; flushate and groundwater are recovered via extraction downgradient	NAPL in saturated zone
***In situ* oxidation**	Oxidizing compound (e.g., potassium permanganate, hydrogen peroxide) introduced into the NAPL zone chemically destroys NAPL; system is flushed with water and extracted	NAPL in saturated zone
Electrical heating + SVE	Vadose NAPL zone temperature is increased via resistance (Joule) heating, radio frequency heating, etc.; NAPL is volatized and mobilized; vapor is removed using soil vapor extraction, and then treated	Volatile and semi-volatile NAPL in fine-grained (and coarser) vadose zone
Air sparging + SVE	Air injected in the saturated zone below NAPL zone causes NAPL to partition into air phase which is transported into vadose zone where vapor is extracted via SVE system and treated	NAPL in saturated zone
Steam injection + SVE	Steam is injected into the NAPL zone to vaporize and mobilize NAPL which is recovered by soil vapor extraction system and treated	NAPL in medium – coarse unsaturated zone
Electrokinetics	A DC electrical field is established in NAPL zone that induces water and NAPL zone migration to recovery area; NAPL can be made to migrate through a treatment zone	NAPL in fine-grained soils

APPENDIX C: Quantitative and Qualitative Screens for TI Demonstrations

TI demonstrations require the submission of rigorous quantitative analyses. The use of different *quantitative screens* may provide appropriate corroborative support to a TI demonstration and are essential to facilitating its acceptance by the TCEQ. This section offers two examples of tools that can be used as presumptive screens. Qualitative NAPL recovery TOOL B and an example quantitative NAPL recovery screening tool are intended to guide, not to replace engineering analysis or design.

Many more technical strategies and methods exist that may be applied to making successful TI demonstrations, but they are not discussed here. See TCEQ guidance document *NAPL Response Action Effectiveness* (draft RG-366/TRRP-31A) for additional details.

C.1 Recovery Technology Screening Tools

The effectiveness of a conventional NAPL recovery technology may be *estimated* by use of qualitative and quantitative NAPL recovery screening tools. The use of the two NAPL recovery technology screening tools is intended to provide decision-making guidance for determining whether a conventional NAPL recovery technology may be a more appropriate choice than implementing an alternative NAPL recovery technology.

TOOL B: Qualitative Conventional NAPL Recovery Technology Matrix

TOOL B is a qualitative means to evaluate the potential applicability of different conventional NAPL recovery technologies (Table C.1). TOOL B is intended for guidance purposes and is not to be used as a replacement for engineering judgment or design.

Begin using TOOL B by finding the row that contains the applicable site-specific NAPL occurrence (from STEP 1) then compare to available site-specific values for various parameters and site conditions in the column labeled Condition(s) Favorable for Conventional Recovery. When actual site data match a range of values for recovery criterion parameters and site conditions, go to the next column for one or more corresponding conventional NAPL recovery technologies demonstrated to be successful in recovering NAPL from a similar NAPL occurrence.

If site conditions for a given NAPL occurrence are outside the range favorable for conventional recovery, then give consideration to the implementation of an alternative NAPL recovery technology.

Example of Quantitative Screen for Conventional NAPL Recovery System

Quantitative NAPL recovery screens include numerical model simulations that can be used to determine how effective a NAPL recovery system may be. An example of a quantitative NAPL recovery screen follows.

This *example* is designed to determine the effectiveness of a conventional total-fluids submersible pump recovery system for a range of petroleum products and hydraulic conductivities at petroleum product NAPL sites. The example screen was developed specifically for certain site conditions using the numerical model *ARMOS* (ES&T, 1994) with system configuration and site-specific assumptions. Among these are:

- petroleum hydrocarbon contamination, *and*
- a single submersible total-fluids recovery pump, *using*
- a submersible pump inlet set at depth of 3 feet below static water level.

Table C.1. TOOL B Qualitative Conventional NAPL Recovery Technology Matrix

NAPL Occurrence (from TABLE 1.6)		Condition(s) Favorable for Conventional Recovery	Conventional NAPL Recovery Technologies	References
NAPL in vadose zone	NAPL in permeable vadose zone	COC vapor pressure > 0.5 mm Hg	SVE	USACE, 1995
	NAPL in impermeable vadose zone	COC vapor pressure > 0.5 mm Hg Vadose zone air permeability > 10^{-10} cm^2	SVE	USACE, 1995
		H' > 0.01 H > 2.46 x 10^{-4} atm·m^3/mol	SVE	USEPA. 1997
NAPL at capillary fringe	LNAPL at water table and/or capillary fringe	Low K : 10^{-3} $cm/_{sec}$ > K_w > 10^{-5} $cm/_{sec}$ True NAPL thickness > 15 cm NAPL kinematic viscosity < 10 centistoke	Vacuum-enhanced LNAPL recovery	USACE, 1999
		Single pump GW depression Diaphragm pump: 2" well; K > 10^{-4} $cm/_s$ Centrifugal pump: 2" well; K > 5x10^{-3} $cm/_s$	SLE Depth to GW < 30'	Suthersan, 1997
			SLE	USEPA, 1996a
		Submersible pump: 4" well; K > 10^{-2} $cm/_s$ Pneumatic pumps: top filling: 4" well; K > 10^{-3} $cm/_s$ product only: 4" well; K > 10^{-4} $cm/_s$	DLE	USEPA, 1996b
		Low K : 10^{-3} $cm/_{sec}$ > K_w > 10^{-5} $cm/_{sec}$ (lower with secondary porosity) T ≤ 500 gpd/ft LNAPL kinematic viscosity < 10 centistoke heterogeneous (interbedded) sediments limited saturated thickness	TPE	Suthersan, 1997 USACE, 1999 USEPA, 1996b USEPA, 1999
	Petroleum HCs at water table and/or capillary fringe	Use TOOL A Appendix A	Total fluids extraction	Appendix A
NAPL in saturated zone	DNAPL in saturated zone	DNAPL exists in moderate- to high-permeability matrix and/or in pool	GW extraction	Pankow and Cherry, 1996
		Conventional recovery of DNAPL at the base of shallow saturated zones may be enhanced using horizontal well technology	GW extraction	USEPA, 1994
		DNAPL existing at depths less than 50 ft bgs are reachable by excavated interceptor/recovery trenches	GW extraction	USEPA, 1994
		DNAPL recovery most effective for: well yield > 1 gpm/well saturated thickness > 10 ft	GW extraction	USEPA, 2005
NAPL in fractured rock and karst	L/DNAPL in saturated / unsaturated rock	Low K sediments with secondary porosity Low permeability fractured systems	TPE	Suthersan, 1997
SLE - *shallow liquid-only extraction*, **SVE** - *soil vapor extraction*, **TPE** - *two-phased extraction*				

Figure C.1 summarizes the results of numerous model simulations configured for different fuel viscosities, hydraulic conductivities, product thicknesses, and recovery system drawdown that are combined with assumptions of what constitutes recovery *effectiveness* at this site.

Figure C.1 can be used as follows: 1) select the applicable LNAPL product curve and 2) plot the point that approximates the true NAPL thickness and the hydraulic conductivity of the unit in which the NAPL is found. If the plotted point is on the right-hand side of the product curve LNAPL is recoverable using the total fluids system configuration described above. Otherwise, another conventional or alternative technology should be considered for NAPL recovery.

NOTE: If the system configuration (described above) is implemented and becomes ineffective in removing NAPL prior to satisfying the applicable endpoint(s), implementation of a different NAPL recovery system may be necessary.

Quantitative screens such as the one described here cannot be used as the basis for a TI demonstration. TI demonstrations require actual recovery system operation and/or pilot test data.

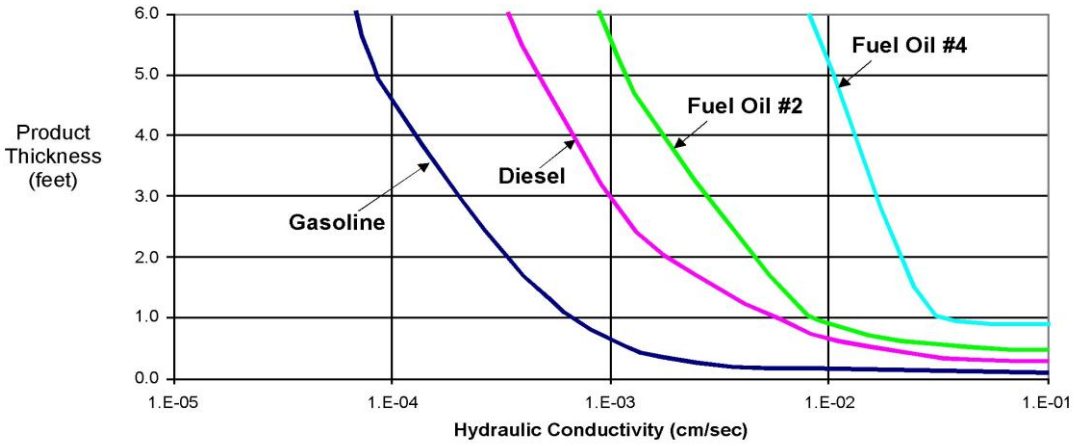

Figure C.1. *Example* Quantitative Screen for Conventional NAPL Recovery System. (EXAMPLE:NOT FOR ACTUAL USE. SITE-SPECIFIC MODELS MUST BE DEVELOPED.)

APPENDIX D: Example Problem 1 — Gas Station LPST Release

Example Problem 1 demonstrates the application of the TRRP risk-based NAPL management paradigm to a hypothetical leaking petroleum storage tank (LPST) release at a gas station.

D.1 STEP 1 — Conduct NAPL Assessment

Figure D.1 shows the surface and subsurface conditions at and around an LPST release at a gas station. The original LPST was replaced with a new, compliant tank and plumbing. According to the documented site history, the facility had always dispensed petroleum products. While gasoline remained the primary product sold, diesel fuel had once been sold briefly and then discontinued. Both fuels are NAPLs having specific gravities less than that of water (SG < 1) and are classified as light non-aqueous phase liquids (LNAPLs). An affected property assessment was performed at the site which included LNAPL assessment methods and techniques described in TCEQ draft guidance document *NAPL Assessment Requirements*.

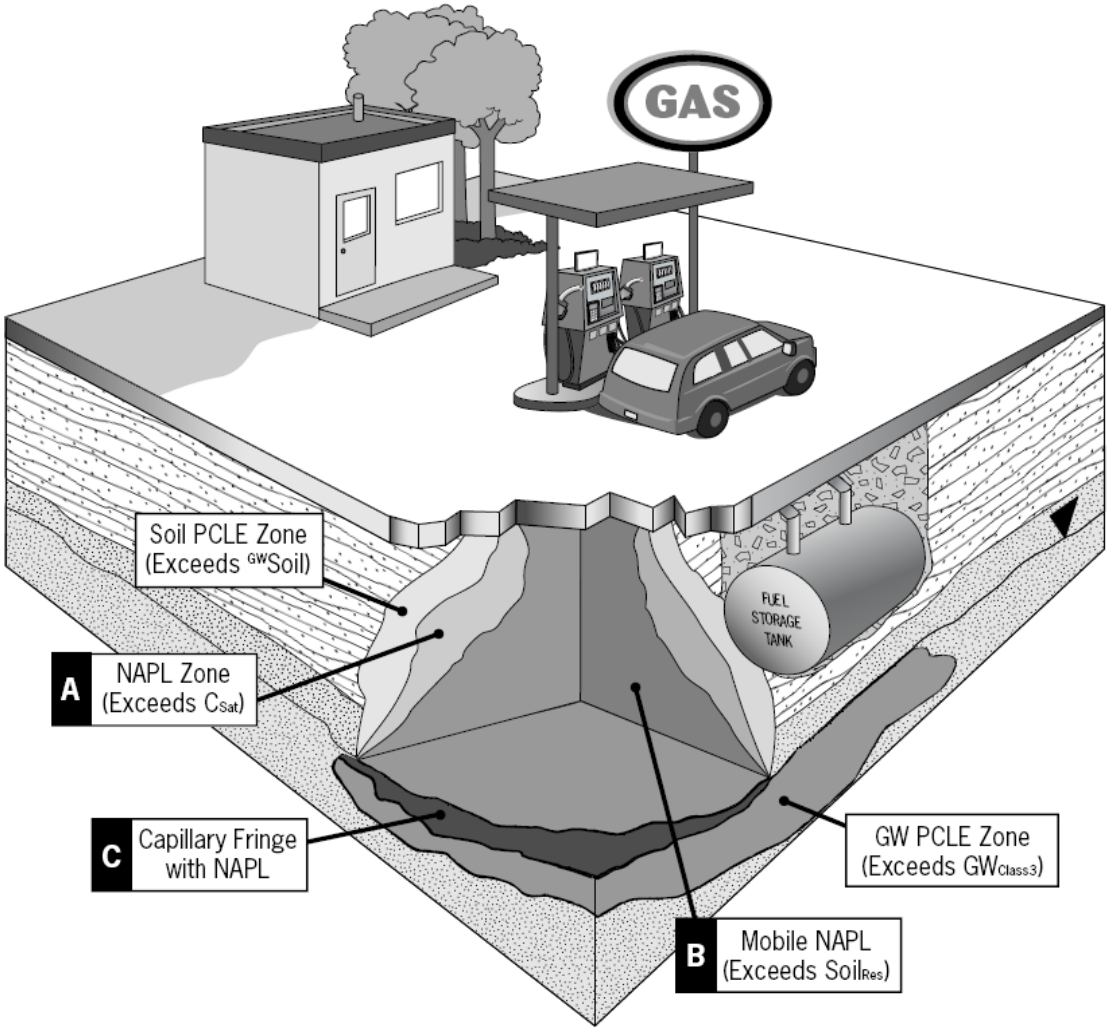

Figure D.1. Results of NAPL Assessment for Example Problem 1.

Figure D.1 depicts the assessment zones and environmental media that were affected by the LNAPL release. The affected property assessment revealed the presence of TPH and BTEX compounds in the vadose zone and at the capillary fringe. The underlying GWBU was determined to be Class 3 using methods and techniques described in TCEQ guidance document *Groundwater Classification* (RG-366/TRRP-8). Although dissolved BTEX concentrations were detected in the groundwater, no direct or indirect evidence of NAPL was detected in the saturated zone.

D.1.1 Site PCL Concerns

Assessment of the vadose zone indicated evidence of a TPH release. Consequently, soil concentrations of the TPH aliphatic and aromatic compounds were measured using the analytical method TCEQ 1006. Soil concentrations of the BTEX suite of compounds also were determined. The soil concentrations of the TPH aromatic and aliphatic fractions indicated gasoline was the only product released. Some of the soil TPH fraction concentrations and soil BTEX concentrations exceeded their respective $^{GW}Soil_{Class\ 3}$, creating a soil PCLE zone.

Assessment of the Class 3 GWBU revealed a groundwater COC plume comprised of dissolved TPH fractions and BTEX compounds that exceeded their respective $^{GW}GW_{Class\ 3}$. The dissolved TPH and BTEX groundwater PCLE zone was shown to have migrated in the direction of the groundwater gradient.

Results of the PCL assessment are summarized in Table D.1.

D.1.2 Site NAPL Concerns

In the vadose zone, some soil total TPH concentrations exceed their Tier 2 C_{sat} values and define the NAPL zone **A**. Within the NAPL zone, some soil total TPH concentrations exceed the Tier 1 $Soil_{Res}$ value (10,000 mg/kg) that defines the mobile NAPL zone **B**.

At the capillary fringe, approximately 1 inch (true NAPL thickness) was observed, indicating NAPL contact with the Class 3 groundwater **C**.

Results of the NAPL assessment are summarized in Table D.1.

Table D.1. Example Problem 1 — Summary of NAPL Assessment Results

Subsurface Site Conditions	*Vadose Zone*: unconsolidated silty sand *Saturated Zone*: unconsolidated sand comprising an unconfined Class 3 GWBU		
Depth to GW	~ 20 ft below ground surface		
NAPL type	Gasoline (TCEQ-1006)		
Max NAPL Thickness	1 inch (true thickness)		
Site PCL Concerns	Soil	$^{GW}Soil_{Class\ 3}$ - soil PCLE zone	
	Groundwater	$^{GW}GW_{Class\ 3}$ - groundwater PCLE zone <u>not</u> expanding	
Site NAPL Concerns	Vadose Zone	**A**	Soil concentrations exceed Tier 2 C_{sat} - NAPL zone
		B	Soil concentrations exceed Tier 1 $Soil_{Res}$ - mobile NAPL zone
	Capillary Fringe	**C**	~ 1 inch NAPL at capillary fringe - NAPL contact with groundwater
NAPL Occurrences	Vadose Zone	NAPL in unconsolidated sandy silt soil	
	Capillary Fringe	NAPL detected at capillary fringe, in contact with groundwater; approx. 1 inch maximum true thickness	

STEP 1 ends with the completion of the *NAPL Occurrence Matrix* in the APAR. In this example, NAPL has been found only in the vadose zone and at the capillary fringe. The *NAPL Occurrence Matrix* is completed by checking off each applicable NAPL occurrence (Table D.2).

Table D.2. Example Problem 1 — Completed NAPL Occurrence Matrix (Table 6)

	NAPL Occurrence	Description
NAPL in vadose zone	❑ **No NAPL in vadose zone**	There is no direct or indirect evidence of NAPL in the vadose zone
	☑ **NAPL in/on soil**	NAPL detected in or on unsaturated, unconsolidated clay-, silt-, sand-, and/or gravel-dominated soils
	❑ **NAPL in fractured clay**	NAPL detected in fractures of unsaturated fine-grained soils
	❑ **NAPL in fractured or porous rock**	NAPL detected in unsaturated lithologic material
	❑ **NAPL in karst**	NAPL detected in unsaturated karst environment
NAPL in saturated zone or capillary fringe	❑ **No NAPL in saturated zone or capillary fringe**	There is no direct or indirect evidence of NAPL in the saturated zone or capillary fringe
	☑ **NAPL at capillary fringe**	NAPL detected at capillary fringe (in contact with groundwater)
	❑ **NAPL in saturated soil**	NAPL detected in saturated unconsolidated clay-, silt-, sand- and/or gravel-dominated soils
	❑ **NAPL in saturated fractured clay**	NAPL detected in fractures of saturated fine-grained soil or other double-porosity soils
	❑ **NAPL in saturated fractured or porous rock**	NAPL detected in saturated lithologic material
	❑ **NAPL in saturated karst**	NAPL detected in karst environment within the saturated zone
NAPL in surface water / sediment	☑ **No NAPL in surface water or sediment**	There is no direct or indirect evidence of NAPL in surface water or sediment
	❑ **NAPL in surface water**	NAPL observed in contact with surface water
	❑ **NAPL in sediment**	NAPL detected or observed in sediment

D.2 STEP 2 — Identify NAPL Response Triggers and Site Conditions

In STEP 2, data collected during the affected property assessment are reviewed to identify *all* applicable NAPL triggers and site conditions. The data collected during the STEP 1 NAPL assessment are compared against all potential NAPL triggers and site conditions in the *NAPL Trigger and Site Condition Matrix*.

Table D.3 summarizes the applicable NAPL triggers and site conditions found.

STEP 2 is completed after all applicable triggers are checked off on the *NAPL Response Trigger and Site Condition Matrix* (Table D.4) and submitted with the Executive Summary of the *APAR*.

D.3 STEP 3 — Determine NAPL Response Objectives and Endpoints

In STEP 3, determine the NAPL response objectives and the response endpoints that are available for, and which address, each applicable NAPL trigger (from STEP 2). The NAPL response objectives and available endpoint options are determined in the *NAPL Response Endpoint Matrix* (Table D.5). The

NAPL response endpoint matrix is used by reading across the rows containing the applicable NAPL triggers and site conditions. The completed NAPL response endpoint matrix for Example 1 is presented in Table D.5.

Table D.3 Example Problem 1 — Summary of NAPL Response Triggers and Site Conditions

NAPL Response Triggers		Site Conditions	
Mobile NAPL Zone	*Tier 1 mixed –phase concentrations exceed 10,000 mg/Kg (residual saturation).*	**NAPL in contact with groundwater**	*NAPL zone in vadose extends to groundwater*
NAPL Contact with Groundwater	*C_{sat} concentrations are exceeded, or NAPL is observed at the capillary fringe, the capillary fringe is considered in contact with ground water*	**NAPL Contact with Class 2 / Class 3 groundwater**	*NAPL observed at capillary fringe*
		Site is PMZ-eligible	*Requisite institutional controls are obtainable*

D.4 STEP 4 — Develop NAPL Management Strategy

In STEP 4, develop an *integrated* and *comprehensive* strategy for addressing the applicable NAPL triggers and all other exceedances associated with the gasoline release. The first step in the development of an overall site strategy is to inventory all concerns that require response action.

Recall that the site in Example Problem 1 is PMZ-eligible. Table D.6 summarizes the inventory of response action concerns and available options for Example Problem 1.

Determine the extent of the NAPL response by evaluating whether readily recoverable NAPL is present at site. Table D.7 shows TOOL A with the scoring calculation completed and a MODERATE potential for conventional recovery indicated.

From Figure 6 (Sec 3.6.2.1), a MODERATE NAPL recovery potential and a groundwater PCLE zone that is not expanding (from Table D.1) indicates readily recoverable NAPL is not present at site. This means that the RECOVERY endpoint is not applicable for the NAPL contact with groundwater trigger.

From the inventory of possible response actions in Table D.6, the control option is available for the remaining NAPL and PCLE concerns. Should the control options be pursued exclusively, the post-response action care monitoring includes the NAPL zone in the capillary fringe and the groundwater PCLE zone and any changes are documented.

Pursuit of any control option that relies on engineering controls requires a RAP that includes an engineering design appropriate for effective NAPL zone and/or groundwater PCLE zone control systems. If the NAPL zone recovery endpoint option(s) and/or the groundwater PCLE zone decontamination option are/is desired in lieu of, or in conjunction with, the control response action, the RAP must include engineering designs for effective NAPL recovery and/or groundwater decontamination systems, as applicable.

Table D.4 Example Problem 1 — NAPL Response Trigger and Site Condition Matrix (Table 11)

NAPL Trigger	Site Condition	Reference
❑ No NAPL Triggers	❑ No NAPL triggers have been identified in any assessment zones (vadose, capillary fringe and saturated) nor in surface water or sediment	
❑ NAPL Generating Vapors	❑ NAPL generating potentially explosive vapor accumulations ❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	Sec 2.1.1
❑ Migrating NAPL Zone	❑ NAPL in vadose zone ≤15 ft below ground surface ❑ NAPL in saturated zone, not in PMZ* ❑ NAPL zone migration in the vadose or saturated zones	Sec 2.1.2 and Table 9
	❑ NAPL discharge to ground surface, surface water or sediment	
	❑ NAPL in saturated zone in a PMZ*	
☑ **Mobile NAPL Zone**	❑ NAPL threat to subsurface utility or structure *NAPL proximal to subsurface utility or structure with high risk of entry (not applicable to product/waste transfer lines at refineries, chemical plants*, etc.)	Sec 2.1.3 and Table 9
	❑ NAPL in vadose or saturated zone at depth ≤ 15 feet; not in ***secured/ restricted facility*** *Risk of contact in uncontrolled construction/excavation* (e.g., *public utility corridors: water, waste water, telephones*, etc.).	
	❑ NAPL in vadose or saturated zone at depth ≤ 15 feet; in ***secured/restricted facility*** *Risk of contact during construction/excavation safeguarded by controlled property access* (e.g., *refineries, chemical plants, active military installations, airports*, etc.).	
	❑ NAPL overlies unaffected groundwater *Mobile NAPL in vadose zone not yet contacting saturated zone*	
	☑ **NAPL overlies affected groundwater in PMZ*** *NAPL in vadose zone above saturated zone in existing or planned PMZ*	
	☑ **NAPL in contact with groundwater** *NAPL subject to entering installed well or to migration in response to changes of groundwater surface gradient due to pumping or other activities.*	
❑ NAPL Aesthetic Impact or Nuisance Condition	❑ Aesthetic impact or nuisance condition at ground surface, surface water, vadose zone or groundwater *Always includes NAPL contact with Class 1 groundwater and Class 2 groundwater*	Sec 2.1.4 and Table 10
☑ **NAPL Contact with Groundwater**	❑ NAPL contact w/ Class 1 groundwater ❑ NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*	Sec 2.1.5
	☑ **NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ***	
❑ NAPL Contact with Surface Water	❑ NAPL floating on surface water or entrained in surface water body	Sec 2.1.6 and TRRP-24
❑ NAPL Contact with Sediment	❑ NAPL in or on banks or bed of surface water body	Sec 2.1.7

PMZ – *plume management zone* **POE** – *point of exposure*
***** includes PMZs that have been approved by the TCEQ, PMZ-eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via a Technical Impracticability demonstration.

Table D.5. Example Problem 1: NAPL Response Endpoint Matrix (Table 23)

NAPL Trigger (from STEP 1)	Site Condition (from STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
			Recovery Endpoint	Control Endpoint
❑ NAPL generating vapors	❑ NAPL generating potentially explosive vapor accumulations	Permanently eliminate NAPL as explosive vapor source (Sec 3.2.1)	RECOVERY ONLY ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further explosive vapor accumulations (Sec 3.2.1.1)	CONTROL OPTION NOT AVAILABLE (Sec 3.2.1.2)
	❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	Abate inhalation exposure (Sec 3.2.2)	RECOVERY ❑ Volatile fraction of NAPL recovered sufficiently to eliminate vapors that exceed of inhalation PCLs (Sec 3.2.2.1)	CONTROL ❑ Vapors controlled at NAPL source or at POE and exposure to vapors that exceed PCLs (Sec 3.2.2.2)
❑ Migrating NAPL zone	❑ NAPL in vadose zone ≤ 15 ft below ground surface ❑ NAPL in saturated zone, not in PMZ* ❑ NAPL zone migration in the vadose zone or saturated zone	Abate NAPL zone migration (Sec 3.3.1)	RECOVERY ONLY ❑ NAPL recovered to residual saturation and/or to arrest migration	CONTROL (via TI) ❑ NAPL zone migration arrested with physical control (Sec 3.3.1.2)
	❑ NAPL discharge to ground surface, surface water or sediment		❑ NAPL recovered sufficient to eliminate NAPL discharge (Sec 3.3.1.1)	
	❑ NAPL in saturated zone in a PMZ*		RECOVERY ❑ NAPL recovery sufficient to arrest NAPL migration (Sec 3.3.1.3)	CONTROL ❑ NAPL zone migration arrested with physical control or natural methods (Sec 3.3.1.4)
☑ **Mobile NAPL zone**	❑ Mobile NAPL threat to subsurface utility or structure ❑ Mobile NAPL in vadose zone at depth ≤ 15 ft; not in *secured/restricted facility*	Prevent mobile NAPL impact to shallow vadose zone receptors (Sec 3.4.1)	RECOVERY ONLY ❑ NAPL recovered to residual saturation (Sec 3.4.1.1)	CONTROL (via TI) ❑ Access to NAPL zone prevented using physical control (Sec 3.4.1.2)
	❑ Mobile NAPL in vadose zone at depth ≤ 15 ft; in *secured/ restricted facility*	Prevent potential exposure to mobile NAPL (Sec 3.4.2)	RECOVERY ❑ NAPL recovered to residual saturation (Sec 3.4.2.1)	CONTROL ❑ Exposure to NAPL zone prevented via institutional control (Sec 3.4.2.2)
	❑ Mobile NAPL overlies ground-water with which NAPL is not in contact ☑ Mobile NAPL overlies ground-water NAPL zone in PMZ*	**Prevent NAPL migration to groundwater (Sec 3.4.3)**	**RECOVERY** ❑ NAPL recovered to residual saturation (Sec 3.4.3.1)	**CONTROL** ❑ NAPL zone migration control by physical or natural methods and institutional controls (Sec 3.4.3.2)
	☑ Mobile NAPL in contact with groundwater	**Prevent NAPL disturbance of mobile NAPL that could induce (Sec 3.4.4)**	**RECOVERY** ❑ NAPL recovered to residual saturation (Sec 3.4.4.1)	**CONTROL** ❑ NAPL zone migration control by physical or natural methods and institutional controls (Sec 3.4.4.2)

Table D.5. Example Problem 1: NAPL Response Endpoint Matrix (Table 23) (continued)

NAPL Trigger (*from* STEP 1)	Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
			Recovery Endpoint	Control Endpoint
❑ **NAPL Aesthetic Impact or Nuisance Condition**	❑ Aesthetic or nuisance condition at ground surface, surface water, vadose zone or groundwater	**Eliminate NAPL aesthetic impact or nuisance condition** (Sec 3.5.1)	**RECOVERY** ❑ Recover NAPL sufficient to eliminate aesthetic or nuisance condition (Sec 3.5.1.1)	**CONTROL** ❑ Aesthetic impact or nuisance condition abated with physical control at NAPL zone and/or at POE (Sec 3.5.1.2)
☑ **NAPL Contact with Groundwater**	❑ NAPL contact w/ Class 1 groundwater ❑ NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*	**Groundwater restoration** (Sec 3.6.1)	**RECOVERY ONLY** ❑ Recover NAPL sufficient to eliminate source contributions of NAPL GW PCLE zone (Sec 3.6.1.1)	**CONTROL (via TI)** ❑ Control soluble NAPL fraction sufficient to create stable (or shrinking) PCLE zone (Sec 3.6.1.2)
	❑ NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ*	**Ensure compliance of NAPL zone in PMZ** (Sec 3.6.2)	**RECOVERY** ☑ Recover readily recoverable NAPL fraction** (Sec 3.6.2.1)	**(only address recovery endpoint, if applicable)** (Sec 3.6.2.2)
❑ **NAPL contact with Surface water**	❑ NAPL floating on surface water or entrained in surface water body	**Eliminate NAPL in contact with surface water** (Sec 3.7.1)	**RECOVERY ONLY** ❑ Recover NAPL on or in surface water (Sec 3.7.1.1)	**CONTROL OPTION NOT AVAILABLE** (Sec 3.7.1.2)
❑ **NAPL contact with Sediment**	❑ NAPL in or on banks or bed of surface water body	**Prevent NAPL in sediment from contacting surface water *and* direct human or ecological receptor contact with NAPL** (Sec 3.8.1)	**RECOVERY ONLY*** ❑ Recover NAPL to critical sediment PCLs at applicable POE (Sec 3.8.1.1)	**CONTROL (via TI)** ❑ Isolate NAPL zone from surface water bodies and receptors using physical control (Sec 3.8.1.2)

LEL- *lower explosive limit* **PCL –** *protective concentration limit* **PMZ –** *plume management zone* **POE –** *point of exposure* **TI –** *technical impracticability demonstration*

*** The PMZ reference includes PMZs that have been approved by the TCEQ, PMZ eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via TI demonstration.**
**** For the PMZ situation, the applicability of the readily recoverable circumstance must be determined and recovery must occur if it is applicable (see Table 19 and Figure 6 and associated explanatory text).**
***** Potential ecological impacts from NAPL recovery actions may warrant deviation from this RECOVERY ONLY endpoint on a site-specific basis. Inquire with TCEQ.**

Table D.6. Example Problem 1: Summary Inventory of Response Actions and Options

NAPL Trigger	Condition	Objective	NAPL Response Options	
			Recovery	Control*
Mobile NAPL Zone	NAPL overlies groundwater	Prevent NAPL migration to groundwater	Recover vadose zone NAPL to residual saturation ($Soil_{Res}$)	Control of mobile NAPL option available
	NAPL in contact w/ groundwater	Prevent NAPL migration at capillary fringe		
NAPL Contact with Groundwater	NAPL contact with Class 3 groundwater; in PMZ*	Ensure compliance of NAPL zone in PMZ*	Recover *readily recoverable* NAPL	N/A
PCLE Zones	**PCL**	**Objective**	**PCLE Zone Options**	
			Decontamination	**Control***
Soil	^{GW}Soil	Prevent soil leachate from affecting groundwater	Decontamination to PCL is optional*	Control option available since site is PMZ-eligible
Groundwater	$^{GW}GW_{Class\ 3}$	Ensure groundwater complies with PMZ requirements	Decontamination to PCL to ensure compliance with PMZ requirements	
* PMZ-eligibility allows the control option (Remedy Standard B)				

D.5 STEP 5 — Implement NAPL Management Strategy and Evaluate NAPL Response Effectiveness

For STEP 5, assess the effectiveness of the NAPL response action and monitor for changes in NAPL condition or distribution. If the groundwater PCLE zone is observed to expand during post response action care monitoring, the original RAP is subject to reconsideration and modification.
Similarly, if over time, the maximum true NAPL thickness is observed to increase to more than 2 inches, the recalculation of the NAPL recovery potential score will change to +2 and the status of the site will change to having readily recoverable NAPL. Such a change in status constitutes a change in the NAPL response endpoint and prompts NAPL recovery that continues until the true NAPL thickness is less than 2 inches, when readily recoverable NAPL is no longer present.

Table D.7. Example Problem 1: TOOL A – for Readily Recoverable NAPL

Potential for NAPL Recovery by Conventional Technologies

1. by SOIL TYPE

Clay - Silt	Silt - Sand	Sand - Gravel	SCORE
-1	0	+1	0

2. by MAX TRUE NAPL THICKNESS +

< 2 in	2 in - 12 in	> 12 in	
-1	0	+1	-1

3. by NAPL VISCOSITY +

HIGH (mixed-phase DNAPL PCBs, coal tar)	MEDIUM (heavy refined petroleum (e.g., no. 6 fuel oil)	LOW (light refined petroleum (e.g., gasoline)	
-1	0	+1	+1

4. by NAPL OCCURRENCE +

LOW (in saturated zone with double porosity)	MEDIUM (in other saturated zone)	HIGH (in coarse-grained capillary fringe)	
-1	0	+1	+1

Potential for NAPL Recovery by Conventional Technology	TOTAL SCORE
HIGH: recovery likely	+2 to +4
MODERATE: recovery possible	-1 to +1
LOW: consider alternative tech	-4 to -2

⇦ +1

TOTAL SCORE

APPENDIX E: Example Problem 2 — Dry Cleaner Operation

Example Problem 2 demonstrates the application of the TRRP risk-based NAPL management paradigm to a hypothetical solvent release associated with a dry cleaner operation.

E.1 STEP 1 — Conduct NAPL Assessment

Figure E.1 shows the surface and subsurface conditions at and around a dry cleaner operation that had a leaking solvent storage tank. The original solvent storage tank was replaced with a new tank and plumbing. The long-existing dry cleaner began its operation using the solvent trichloroethylene (TCE), later switching to the solvent perchloroethylene (PCE). Both TCE and PCE have specific gravities greater than that of water (SG > 1) and are classified as dense non-aqueous phase liquids (DNAPLs). An affected property assessment was performed at the site that included DNAPL assessment methods and techniques described in TCEQ draft guidance document *NAPL Assessment Requirements*.

Figure E.1 depicts the assessments zones and the environmental media that were affected by the DNAPL release. The underlying GWBU was determined to be Class 3 using methods and techniques described in TCEQ guidance document *Groundwater Classification* (RG-366/TRRP-8). The affected property assessment revealed that concentrations of both TCE and PCE were found in the vadose zone, at the capillary fringe, in the saturated zone, at the ground surface and in surface water. Because the assessment documented the release of both TCE and PCE, it was concluded that a release had continued for a period of time that extended back to when TCE was in use. The results of the site assessment are summarized in Table E.1.

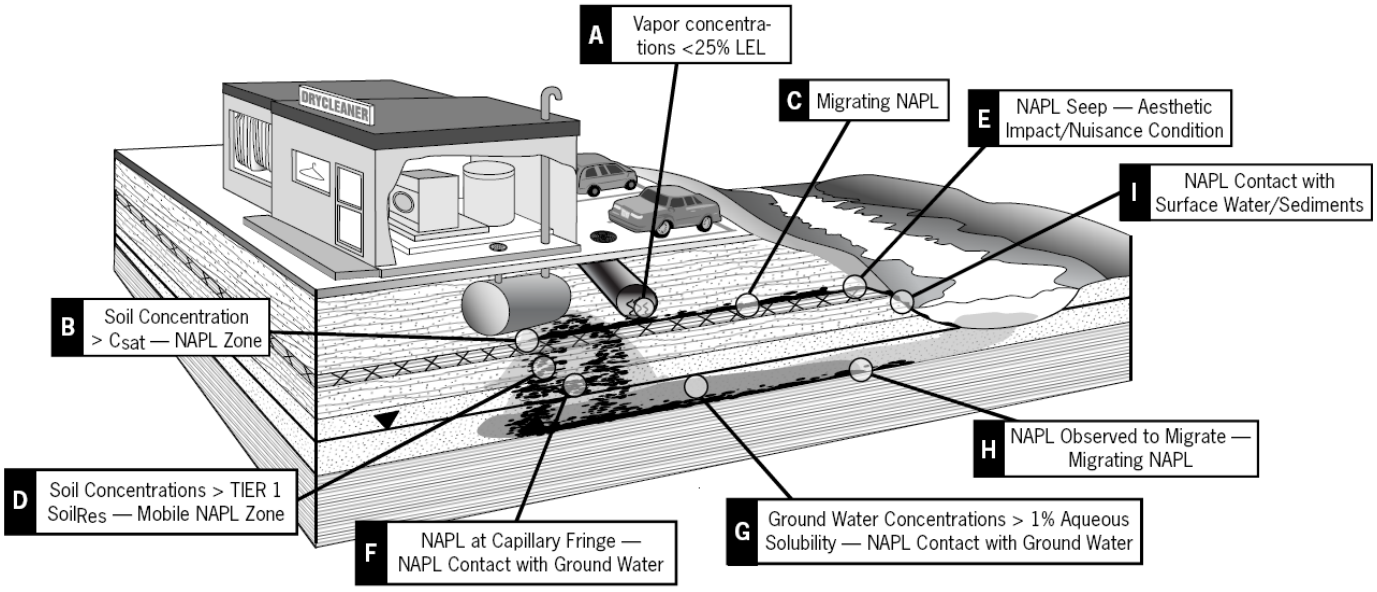

Figure E.1. Results of NAPL Assessment for Example Problem 2.

E.1.1 Site PCL Concerns

Soil TCE and PCE concentrations in the vadose zone beneath and next to the former solvent storage tank exceeded the $^{GW}Soil_{Class\ 3}$ and a soil PCLE zone was delineated. A seep was observed at the nearby stream bank at which soil concentrations were found to exceed the $^{SW}Soil$.

COC concentrations in the underlying Class 3 GWBU exceeded the $^{GW}GW_{Class\ 3}$ and a groundwater PCLE zone was delineated. Groundwater COC concentrations also were found to exceed the ^{SW}GW for the nearby stream.

Finally, stream sediment was found to have been impacted and COC concentrations in that medium were found to exceed the ^{SW}Sed.

Table E.1. Example Problem 2 — Summary of NAPL Assessment Results

Subsurface Site Conditions	*Vadose Zone*: unconsolidated silty sand with an intercalated layer of fractured clay *Saturated Zone*: unconsolidated sand comprising an unconfined GWBU and thin capillary fringe, base of aquifer underlain by non-transmissive clay layer (thickness unknown) *Groundwater*: Class 3		
Depth to GW	~ 15 ft below ground surface		
NAPL type	PCE and TCE (DNAPL)		
Site PCL Concerns	Soil		Soil concentrations exceed $^{GW}Soil$ - soil PCLE zone
			Soil concentrations exceed $^{SW}Soil$ - soil PCLE zone
	Groundwater		Groundwater concentrations exceed $^{GW}GW_{Class\ 3}$ - GW PCLE zone
			Groundwater concentrations exceed ^{SW}GW - GW PCLE zone
	Surface Water / Sediment		Sediment concentrations exceed ^{SW}Sed - sediment PCLE zone
Site NAPL Concerns	Vadose Zone	**A**	Vapor concentrations < 25% LEL - NAPL generating vapors
		B	Soil concentrations exceed Tier 2 C_{sat} - NAPL zone
		C	NAPL observed to migrate on clay layer - migrating NAPL zone
		D	Soil concentrations exceed Tier 1 $Soil_{Res}$ - mobile NAPL zone
		E	NAPL seep at soil surface - aesthetic impact / nuisance condition
	Capillary Fringe	**F**	Concentrations exceed Tier 2 C_{sat} - NAPL contact with groundwater
	Groundwater	**G**	Groundwater concentrations exceed 1% aqueous solubility - NAPL contact with groundwater
		H	NAPL observed to migrate - migrating NAPL zone
	Surface Water / Sediments	**I**	NAPL observed in surface water and sediments - NAPL contact with surface water / sediments
NAPL Occurrences	Vadose Zone		NAPL zone delineated in unconsolidated sandy silt soil
	Capillary Fringe		NAPL zone delineated at capillary fringe, in contact with groundwater
	Saturated Zone		NAPL zone delineated in the GWBU, contact with groundwater
	Surface Water / Sediment		NAPL observed in surface water; NAPL detected in sediment

E.1.2 Site NAPL Concerns

Concurrent with the PCL assessment, a NAPL assessment was performed to determine the full vertical extent of the solvent impact at the site per guidance in Section 1.0 and using methods described in TCEQ draft guidance document *NAPL Assessment Requirements*. The results of the NAPL assessment are summarized in Table E.1. Figure E.1 provides a visual reference of the results.

In the vadose zone, some soil COC concentrations exceed Tier 2 C_{sat} values and define the extent of the NAPL zone **B**. Some soil COC concentrations inside the NAPL zone exceed the Tier 1 $Soil_{Res}$ value and define the extent of the mobile NAPL zone **D**. NAPL was found to have accumulated on top of the fractured clay layer and was observed to flow into the borehole, thus constituting migrating NAPL **C**. Portions of this migrating NAPL are intersected by a shallow subsurface sewer line that was found to contain vapor concentrations that did not exceed the 25 percent LEL **A** and the conditions were determined not to be potentially explosive. Additionally, the vapor ambient air inhalation PCL was not exceeded.

The migrating NAPL within the mobile NAPL zone was found to be seeping from the top of the fractured clay at the point it terminates at the stream bank, causing aesthetic impact and/or nuisance conditions **E**. The assessment further revealed that NAPL had migrated through the fractured clay layer beneath which the NAPL zone continues **B** and regions of mobile NAPL **D** also were observed.

The vertical assessment was extended to the capillary fringe to where NAPL zone migration was found to have continued and where the NAPL zone is considered in to be in contact with groundwater **F**.

Since TCE and PCE are DNAPLs (more dense than water), the subsurface assessment was necessarily extended into the saturated zone to its basal clay layer for the purpose of determining the DNAPL distribution in the groundwater. Borings advanced throughout the GWBU to the base of the aquifer were converted to monitoring wells appropriately located and screened for a DNAPL groundwater assessment. While no "pools" of DNAPL were expected to have been encountered, numerous groundwater samples had COC concentrations that exceeded their 1 percent effective aqueous solubility concentration (see TCEQ draft guidance document *NAPL Assessment Requirements*). Groundwater solvent concentrations were determined to be greater at the bottom of the aquifer than at the top, and the portion of the GWBU containing COC concentrations that exceed their 1% effective aqueous solubility concentration defined the groundwater NAPL zone **G**. The delineation of the groundwater NAPL zone indicated that it migrated from the source area down-dip along the base of the aquifer to its intersection with the stream and, in lieu of contrary evidence, was considered still to be the zone of migrating NAPL **H**.

At the stream, small amounts of NAPL were directly observed (see TCEQ draft guidance document *NAPL Assessment Requirements*) in the surface water and sediments in the area where the groundwater NAPL zone discharges to it. Here, NAPL contacts surface water and sediment **I**.

The results of the NAPL assessment are summarized in Table E.1.

E.1.3 Complete the NAPL Occurrence Matrix

STEP 1 ends with the completion of the *NAPL Occurrence Matrix* in the APAR (Executive Summary). The *NAPL Occurrence Matrix* is completed by checking off each applicable NAPL occurrence as determined in the NAPL assessment described in Section E.1.2. Table E.2 is the *NAPL Occurrence Matrix* completed for this example problem.

Table E.2 Example Problem 2 — Completed NAPL Occurrence Matrix (Table 6)

	NAPL Occurrence	Description
NAPL in vadose zone	❑ **No NAPL in vadose zone**	There is no direct or indirect evidence of NAPL in the vadose zone
	☑ **NAPL in/on soil**	NAPL detected in or on unsaturated, unconsolidated clay-, silt-, sand-, and/or gravel-dominated soils
	☑ **NAPL in fractured clay**	NAPL detected in fractures of unsaturated fine-grained soils
	❑ **NAPL in fractured or porous rock**	NAPL detected in unsaturated lithologic material
	❑ **NAPL in karst**	NAPL detected in unsaturated karst environment
NAPL in saturated zone or capillary fringe	❑ **No NAPL in saturated zone or capillary fringe**	There is no direct or indirect evidence of NAPL in the saturated zone or capillary fringe
	☑ **NAPL at capillary fringe**	NAPL detected at capillary fringe (in contact with groundwater)
	☑ **NAPL in saturated soil**	NAPL detected in saturated unconsolidated clay-, silt-, sand- and/or gravel-dominated soils
	❑ **NAPL in saturated fractured clay**	NAPL detected in fractures of saturated fine-grained soil or other double-porosity soils
	❑ **NAPL in saturated fractured or porous rock**	NAPL detected in saturated lithologic material
	❑ **NAPL in saturated karst**	NAPL detected in karst environment within the saturated zone
NAPL in surface water / sediment	❑ **No NAPL in surface water or sediment**	**There is no direct or indirect evidence of NAPL in surface water or sediment**
	☑ **NAPL in surface water**	NAPL observed in contact with surface water
	☑ **NAPL in sediment**	NAPL detected or observed in sediment

E.2 STEP 2 — Identify NAPL Response Triggers

In STEP 2, data collected during the affected property assessment are reviewed to identify *all* applicable NAPL triggers and site conditions. The data collected during the STEP 1 NAPL assessment are compared against all potential NAPL triggers and site conditions in the *NAPL Trigger and Site Condition Matrix* (Table 11). Table E.3 summarizes the applicable NAPL triggers and site conditions found in this example problem.

STEP 2 is completed after all applicable triggers are checked off on the *NAPL Response Trigger and Site Condition Matrix* (Table E.3) and submitted with the Executive Summary of the *APAR*.

E.3 STEP 3 — Determine NAPL Response Objectives and Endpoints

In STEP 3, determine the NAPL response objectives and the response endpoints that are available for, and which address, each applicable NAPL trigger (from STEP 2). The NAPL response objectives and available endpoint options are determined in the *NAPL Response Endpoint Matrix* (Table 23). The NAPL response endpoint matrix is used by reading across the rows containing the applicable NAPL triggers and site conditions. The completed NAPL response endpoint matrix for Example 2 is presented in Table E.4.

Table E.3 Example Problem 2 — NAPL Response Trigger and Site Condition Matrix (Table 11)

NAPL Trigger	Site Condition	Reference
❑ No NAPL Triggers	❑ No NAPL triggers have been identified in any assessment zones (vadose, capillary fringe and saturated) nor in surface water or sediment	
❑ NAPL Generating Vapors	❑ NAPL generating potentially explosive vapor accumulations	Sec 2.1.1
	❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	
☑ Migrating NAPL Zone	❑ NAPL in vadose zone ≤15 ft below ground surface ☑ NAPL in saturated zone, not in PMZ* ☑ NAPL zone migration in the vadose or saturated zones	Sec 2.1.2 and Table 9
	☑ NAPL discharge to ground surface, surface water or sediment	
	❑ NAPL in saturated zone in a PMZ*	
☑ Mobile NAPL Zone	☑ NAPL threat to subsurface utility or structure *NAPL proximal to subsurface utility or structure with high risk of entry* (*not applicable to product/waste transfer lines at refineries, chemical plants*, etc.)	Sec 2.1.3 and Table 9
	☑ NAPL in vadose or saturated zone at depth ≤ 15 feet; not in *secured/ restricted facility* *Risk of contact in uncontrolled construction/excavation* (e.g., *public utility corridors: water, waste water, telephones*, etc.).	
	❑ NAPL in vadose or saturated zone at depth ≤ 15 feet; in *secured/restricted facility* *Risk of contact during construction/excavation safeguarded by controlled property access* (e.g., *refineries, chemical plants, active military installations, airports*, etc.).	
	❑ NAPL overlies unaffected groundwater *Mobile NAPL in vadose zone not yet contacting saturated zone*	
	❑ NAPL overlies affected groundwater in PMZ* *NAPL in vadose zone above saturated zone in existing or planned PMZ*	
	☑ NAPL in contact with groundwater *NAPL subject to entering installed well or to migration in response to changes of groundwater surface gradient due to pumping or other activities.*	
☑ NAPL Aesthetic Impact or Nuisance Condition	☑ Aesthetic impact or nuisance condition at ground surface, surface water, vadose zone or groundwater *Always includes NAPL contact with Class 1 groundwater and Class 2 groundwater*	Sec 2.1.4 and Table 10
☑ NAPL Contact with Groundwater	❑ NAPL contact w/ Class 1 groundwater ☑ NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*	Sec 2.1.5
	❑ NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ*	
☑ NAPL Contact with Surface Water	☑ NAPL floating on surface water or entrained in surface water body	Sec 2.1.6 and TRRP-24
☑ NAPL Contact with Sediment	☑ NAPL in or on banks or bed of surface water body	Sec 2.1.7

PMZ – *plume management zone* **POE** – *point of exposure*
***** includes PMZs that have been approved by the TCEQ, PMZ-eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via a Technical Impracticability demonstration.

Table E.4 Example Problem 2 — NAPL Response Endpoint Matrix (Table 23)

NAPL Trigger (*from* STEP 1)	Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
			Recovery Endpoint	Control Endpoint
❑ NAPL generating vapors	❑ NAPL generating potentially explosive vapor accumulations	Permanently eliminate NAPL as explosive vapor source (Sec 3.2.1)	RECOVERY ONLY ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further explosive vapor accumulations (Sec 3.2.1.1)	CONTROL OPTION NOT AVAILABLE (Sec 3.2.1.2)
	❑ NAPL generating vapors that exceed inhalation PCLs at applicable inhalation POE	Abate inhalation exposure (Sec 3.2.2)	RECOVERY ❑ Volatile fraction of NAPL recovered sufficiently to eliminate further exceedence of inhalation PCLs (Sec 3.2.2.1)	CONTROL ❑ Vapors controlled at NAPL source or at POE and exposure to vapors in excess of PCL eliminated (Sec 3.2.2.2)
☑ **Migrating NAPL zone**	☑ NAPL in vadose zone ≤ 15 ft below ground surface ☑ NAPL in saturated zone, not in PMZ* ☑ NAPL zone migration in the vadose zone or saturated zone	**Abate NAPL zone migration (Sec 3.3.1)**	**RECOVERY ONLY** ☑ **NAPL recovered to residual saturation**	CONTROL (via TI) ❑ NAPL zone migration arrested with physical control (Sec 3.3.1.2)
	☑ NAPL discharge to ground surface, surface water or sediment		☑ **NAPL recovered sufficient to eliminate discharge (Sec 3.3.1.1)**	
	❑ NAPL in saturated zone in a PMZ*		RECOVERY ❑ NAPL recovery sufficient to arrest migration (Sec 3.3.1.3)	CONTROL ❑ NAPL zone migration arrested with physical control or natural containment (Sec 3.3.1.4)
☑ **Mobile NAPL zone**	☑ NAPL threat to subsurface utility or structure ❑ NAPL in vadose zone at depth ≤ 15 ft; not in *secured/restricted facility*	**Prevent NAPL migration to shallow vadose zone receptors (Sec 3.4.1)**	**RECOVERY ONLY** ☑ **NAPL recovered to residual saturation (Sec 3.4.1.1)**	CONTROL (via TI) ❑ NAPL zone migration arrested with physical control (Sec 3.4.1.2)
	❑ NAPL in vadose zone at depth ≤ 15 ft; in *secured/ restricted facility*	Prevent potential exposure to NAPL (Sec 3.4.2)	RECOVERY ❑ NAPL at depth ≤ 15 ft recovered to (Sec 3.4.2.1)	CONTROL ❑ Access to NAPL zone safeguarded against via institutional control (Sec 3.4.2.2)
	❑ NAPL overlies groundwater with which NAPL is not in contact ❑ NAPL overlies ground-water NAPL zone in PMZ*	Prevent NAPL migration to groundwater (Sec 3.4.3)	RECOVERY NAPL recovered to residual saturation (Sec 3.4.3.1)	CONTROL ❑ NAPL zone migration control by physical or natural methods and institutional controls (Sec 3.4.3.2)
	☑ NAPL in contact with groundwater	**Prevent NAPL migration at capillary zone or in groundwater (Sec 3.4.4)**	**RECOVERY** ☑ **NAPL recovered to residual saturation (Sec 3.4.4.1)**	**CONTROL** ☑ **NAPL zone migration control by physical or natural methods and institutional controls (Sec 3.4.4.2)**

Table E.4 Example Problem 2 — NAPL Response Endpoint Matrix (continued) (Table 23)

NAPL Trigger (*from* STEP 1)	Site Condition (*from* STEP 2)	NAPL Response Objective	NAPL Response Endpoint	
			Recovery Endpoint	Control Endpoint
☑ **NAPL Aesthetic Impact or Nuisance Condition**	☑ Aesthetic or nuisance condition at ground surface, surface water, vadose zone or groundwater	**Eliminate NAPL aesthetic impact or nuisance condition** **(Sec 3.5.1)**	**RECOVERY** ☑ Recover NAPL sufficient to eliminate aesthetic/ nuisance condition **(Sec 3.5.1.1)**	**CONTROL** Aesthetic impact or nuisance condition abated with physical control at NAPL zone and/or at POE **(Sec 3.5.1.2)**
☑ **NAPL Contact with Groundwater**	❑ NAPL contact w/ Class 1 groundwater ☑ NAPL contact w/ Class 2 / Class 3 groundwater, not in PMZ*	**Groundwater restoration** **(Sec 3.6.1)**	**RECOVERY ONLY** ☑ Recover NAPL sufficient to eliminate source contributions to GW PCLE zone **(Sec 3.6.1.1)**	**CONTROL (via TI)** ❑ Control soluble NAPL fraction sufficient to create stable (or shrinking) PCLE zone **(Sec 3.6.1.2)**
	❑ NAPL contact w/ Class 2 / Class 3 groundwater, in PMZ*	**Ensure compliance of NAPL zone in PMZ** **(Sec 3.6.2)**	**RECOVERY** ❑ Recover readily recoverable NAPL fraction** **(Sec 3.6.2.1)**	**N/A** ❑ All other applicable (RECOVERY) / CONTROL endpoints are already enforced **(Sec 3.6.2.2)**
☑ **NAPL contact with Surface water**	☑ NAPL floating on surface water or entrained in surface water body	**Eliminate NAPL in contact with surface water** **(Sec 3.7.1)**	**RECOVERY ONLY** ☑ Recover NAPL on or in surface water **(Sec 3.7.1.1)**	**CONTROL OPTION NOT AVAILABLE** **(Sec 3.7.1.2)**
☑ **NAPL contact with Sediment**	☑ NAPL in or on banks or bed of surface water body	**Prevent: 1) NAPL in sediment from contacting surface water *and* 2) direct human or ecological receptor contact with NAPL** **(Sec 3.8.1)**	**RECOVERY ONLY*** ☑ Recover NAPL to critical sediment PCLs at applicable POE **(Sec 3.8.1.1)**	**CONTROL (via TI)** ❑ Isolate NAPL zone from surface water bodies and receptors using physical control **(Sec 3.8.1.2)**

LEL- *lower explosive limit* **PCL** – *protective concentration limit* PMZ – *plume management zone* POE – *point of exposure* TI – *technical impracticability demonstration*

* The PMZ reference includes PMZs that have been approved by the TCEQ, PMZ eligible sites where a PMZ will be proposed to the TCEQ in a RAP, as well as a PMZ via TI demonstration.

** For the PMZ situation, the applicability of the readily recoverable circumstance must be determined and recovery must occur if it is applicable (see Table 11 and Figure 8 and associated explanatory text).

*** Potential ecological impacts from NAPL recovery actions may warrant deviation form this RECOVERY ONLY endpoint on a site-specific basis. Inquire with TCEQ.

E.4 STEP 4 – Develop NAPL Management Strategy

In STEP 4, develop an *integrated* and *comprehensive* strategy for addressing COC concentrations that exceed applicable PCLs and violate applicable NAPL triggers associated with the solvent release. The first step in the development of an overall site strategy is to inventory all concerns that require response action.

E.4.1 Inventory PCL Concerns

Table E.5 summarizes the inventory of PCL concerns determined in the previous steps. Response actions for the inventory of PCL concerns should be developed in accordance with TRRP regulatory guidance documents *Application of Remedy Standards A and B* (RG-366/TRRP-28), *Soil and Groundwater Response Objectives* (RG-366/TRRP-29) and *Evaluating Remedy Effectiveness* (draft RG-366/TRRP-31).

Recall that the site in Example Problem 2 is not PMZ-eligible as currently depicted because of the continuing NAPL migration and surface seep. Table E.5 summarizes the inventory of PCL response action concerns and available options for Example Problem 2.

Table E.5 - Example Problem 2: Summary Inventory of PCL Response Actions and Options

PCL Concerns	PCL Exceeded	Response Objective	PCLE Zone Options	
			Decontamination	Control
Soil	^{GW}Soil	Reduce soil concentrations to be protective of groundwater / surface water	Remove or decontaminate soil to PCLs	**Control option not available since site is not PMZ-eligible**
	^{SW}Soil			
Groundwater	$^{GW}GW_{Class\ 3}$	Reduce groundwater concentrations to protective levels	Decontaminate groundwater to PCLs	
	^{SW}GW			
Surface Water / Sediment	^{SW}Sed	Reduce sediment concentrations to protective levels	Decontaminate sediment to PCL	

E.4.2 Inventory NAPL Concerns

The inventory of NAPL concerns that require response actions are summarized in Table E.6. In this example, some NAPL recovery must be pursued to satisfy various NAPL response actions. However, an appropriately designed NAPL recovery plan for the vadose zone could address the NAPL vapor, NAPL migration, and mobile NAPL concerns simultaneously. Similarly, an appropriately designed NAPL recovery plan for the saturated zone could address the NAPL migration, NAPL discharge to surface water and sediment, NAPL source of groundwater contamination, and NAPL impact to surface water and sediment. The mobile NAPL trigger may be addressed by control as may the NAPL aesthetic impact or nuisance condition.

Table E.6 — Example Problem 2: Summary Inventory of NAPL Response Actions and Options

NAPL Triggers	Site Condition	NAPL Response Objective	NAPL Response Options	
			Recovery	Control
Migrating NAPL Zone	Migrating NAPL in shallow vadose zone and saturated zone	Abate NAPL zone migration	Recover NAPL to residual saturation	**Control by TI only**
	NAPL discharge to surface water / sediment		Recover NAPL to eliminate discharge	
Mobile NAPL Zone	NAPL threat to shallow vadose structure	Prevent migration to shallow vadose receptor	Recover NAPL to residual saturation	**Control by TI only**
	NAPL contact with groundwater	Prevent migration at capillary fringe or groundwater		Control to prevent migration potential
NAPL aesthetic impact / nuisance condition	NAPL visible in sediment and surface water	Eliminate NAPL aesthetic impact / nuisance condition	Recover NAPL to eliminate aesthetic or nuisance condition	Control to eliminate aesthetic impact or nuisance condition
NAPL contact with groundwater	NAPL contact with Class 3 groundwater; no PMZ	Groundwater restoration	Recover NAPL sufficient to eliminate source of groundwater contamination	**Control by TI only**
NAPL contact with surface water	NAPL in surface water	Eliminate NAPL in surface water	Eliminate source of NAPL to surface water	**Control option not available**
NAPL contact with sediment	NAPL in sediments	Prevent NAPL contact with sediment and receptors	Recover/decontaminate to sediment critical PCL	**Control option not available**

E.5 STEP 5 – Implement NAPL Management Strategy and Evaluate NAPL Management Effectiveness

In STEP 5, assess the effectiveness of the NAPL response action and monitor for changes in NAPL condition or distribution. If the groundwater PCLE zone is observed to expand during post response care monitoring, the original RAP is subject to reconsideration and modification.

Pursuit of any control option that relies on engineering controls requires a RAP that incudes engineering designs for effective NAPL zone and/or groundwater PCLE zone control systems. If the NAPL zone recovery endpoint option(s) and/or the groundwater PCLE zone decontamination option is desired in lieu of, or in conjunction with, the control response action, the RAP must include engineering plans for a NAPL recovery and/or groundwater decontamination system that is designed to be more effective.

In the event that the endpoint for a RECOVERY ONLY NAPL trigger (see Table E.4) cannot be attained using the original technology, the response action should be redesigned using a different engineered technology until effective NAPL removal is exhausted. Once the response action has reached this point, an appeal may be allowed to pursue the Control (via TI) endpoint, at which time a rigorous *Technical Impracticability Demonstration* may be submitted for TCEQ approval.

APPENDIX F: References

ES&T, 1994 *Areal Multiphase Organic Simulator for Free Phase Hydrocarbon Migration and Recovery: ARMOS*, ES&T, Blacksburg, Va.

NIOSH, 2005 *Pocket Guide to Chemical Hazards*, US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH Publication No. 2005-149.

Pankow J. F. and Cherry J. A 1996 *Dense Chlorinated Solvents and Other DNAPLs in Groundwater*, Waterloo Press, Waterloo, Ontario, 522 pp.

Suthersan S.S., 1997 *Remediation Engineering: Design Concepts*, CRC Press, Boca Raton, FL, 362 pp.

USACE, 1995 *Soil Vapor Extraction and Bioventing*, Engineering Manual No. 1110-1-4001, U.S. Army Corps of Engineers, Department of the Army, Washington, DC.

USACE, 1999 *Multiphase Extraction*, Engineering Manual No. 1110-1-4010, U.S. Army Corps of Engineers, Department of the Army, Washington, DC.

USEPA, 1994 *Manual: Alternative Methods for Fluid Delivery and Recovery*, EPA 625/R-94/003, US Environmental Protection Agency, ORD, Cincinnati, OH.

USEPA, 1996a *Hydrogeologic Characterization of Fractured Rock Formations: A Guide for Groundwater Remediators*, EPA 600/S-96/001, National Risk Management Research Laboratory, Cincinnati, OH, 12 pp.

USEPA, 1996b *How to Effectively Recover Free Product at Leaking Underground Storage Tank Sites*, EPA 510/R-96/001, OSWER, US Environmental Protection Agency, Washington D.C.

USEPA, 1997 *Engineering Forum Issue Paper: Soil Vapor Extraction Implementation Experiences*, EPA 540/F-95/030, OSWER, US Environmental Protection Agency, Washington D.C., 10 pp.

USEPA, 1999 *Multi-Phase Extraction: State-of-the-Practice*, EPA 542/R-99/004, OSWER, US Environmental Protection Agency, Washington D.C.

USEPA, 2005 *Cost-Effective Design of Pump and Treat Systems*, EPA 542/R-05/008, OSWER, US Environmental Protection Agency, Washington D.C.