SITE CHARACTERIZATION WORK PLAN

for

MIPC Chelsea Facility
PADEP Facility ID No. 634737
920 Cherry Tree Road
Bethel Township, Upper Chichester Township, Aston Township
Delaware County, Pennsylvania

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EXECUTIVE SUMMARY

To meet the objectives of the Order issued by the Pennsylvania Department of Environmental Protection (PADEP) to MIPC, LLC (MIPC) on December 23, 2025, this Site Characterization Work Plan (SCWP) relates to on-site and off-site properties and conveys the primary goals/objectives of ongoing interim measures, product or light non-aqueous phase liquid (LNAPL) recovery, and site characterization and remediation-focused investigation activities for the MIPC facility located at 920 Cherry Tree Road in Aston, Bethel and Upper Chichester Townships, Delaware County, PA (Figure 1). It is intended to provide a status report for response actions and on-site and off-site investigation activities completed and/or planned with an updated summary of findings and accomplishments to date. This SCWP is a dynamic plan that is flexible and subject to modifications and PADEP approval of any revisions or modifications, if warranted, as new information/data becomes available and is interpreted.

A summary of the chronology of the subsurface investigations and ongoing interim remedial measures and site characterization activities are outlined below.

- Recovery through the PADEP-approved water treatment unit began September 13, 2025.
- Soil borings began on November 18, 2025; to date ten investigatory soil borings have been drilled and thirty-eight on-site observation, monitoring and/or recovery wells have been installed. One monitoring well and one soil vapor sampling point have been installed at one off-site property for which MIPC has been given permission to access and conduct investigations. Evidence of gasoline impact was observed in the monitoring well. Detections of a few gasoline compounds are reported in the soil vapor point sample collected on January 23, 2026, but the concentrations are well below the most stringent PADEP Vapor Intrusion (VI) Screening values. Requests for access at eight other nearest neighboring properties to the west of the MIPC facility have been pursued but no further agreements for access to conduct off-site investigations have been reached.
- Evidence of gasoline impacts were observed in borings in the Tank 708 dike area with apparent LNAPL thickness between 3 inches and 1.5 feet in the open borings.
- An Act 2 Notice of Intent to Remediate (NIR) for the release was submitted to the PADEP via the public upload portal on December 30, 2025.
- LNAPL has been observed in twenty-three of the thirty-eight on-site wells installed to date; primarily near the Tank 708 dike and areas west and southwest. LNAPL was observed in the one off-site well that was installed on February 19, 2026.
- Focused interim remedial measures have been conducted since December 5, 2025 to aggressively recover LNAPL and to reduce the mass and potential for further migration of

LNAPL. The primary approach using Vacuum Enhanced Fluid Recovery (VEFR) and other collection/removal methods is ongoing and confirms the potential recoverability of LNAPL (gasoline) as an interim and long-term remedial measure to reduce mass flux and migration potential.

- Delineation of LNAPL and dissolved phase gasoline compounds have been achieved in northerly and southwesterly directions along the MIPC westerly property line. LNAPL delineation has also been achieved to the north, east and south-southeast of Tank 708. A second round of sampling installed wells that do not contain LNAPL was completed the week of February 16, 2026 and will provide a more robust data set to evaluate delineation of the dissolved fraction of gasoline in on-site groundwater.
- Additional soil and groundwater sampling for delineation/remediation purposes is ongoing. Four sonic drill rigs are onsite and scheduled to remain onsite to expand the site investigations and characterization, install additional wells to enhance VEFR and product recovery. When additional off-site access is granted and the investigation can move to the nearest off-site properties, further investigation of subsurface characteristics will occur. This includes delineation of groundwater impacts and advancing vapor intrusion evaluations. If off-site access is not obtained, efforts will be made to explore drilling in rights-of-way and/or at other properties further west of the facility.

Figures 2 and 2A depict the locations of soil borings drilled, the monitoring and recovery wells installed and proposed to be installed, and summarizes the occurrence and distribution of LNAPL based on observations made to date. Product recovery efforts, including VEFR, continue to be directed and enhanced at locations where LNAPL is observed. Attached Table 1 provides construction details, available survey information, and groundwater and product elevations from gauging conducted on February 16, 2026.

Figure 3 depicts the groundwater and top of LNAPL observations taken from the February 16, 2026 well gauging event which represents a "snapshot" of elevations and migration potential. The groundwater results for the initial sampling conducted in December 2025 indicate a dissolved-phase concentration of benzene at one location (MW-4, 3,450 µg/L) that exceeds the PA Act 2 Groundwater Medium Specific Concentrations (MSCs) for a Residential, Used Aquifer (RUA) with Total Dissolved Solids (TDS) <2500. Onsite monitoring wells MW-3 (east), MW-10 (northwest), MW-11 (north), and MW-12 (south) do not have measurable LNAPL, do not have field indications of impact (e.g., PID readings, odors, staining), and do not have compounds of concern present at concentrations above the PA Act 2 Groundwater MSCs for a Residential Used Aquifer (RUA) (TDS <2500).

The site characterization and interim remedial response strategy is being executed as a parallel, concurrent program — implementing focused on-site LNAPL recovery, evaluating potential receptors and investigating exposure pathways potentially affecting off-site receptors, while simultaneously advancing characterization, delineation of LNAPL, impacted soils and dissolved gasoline constituents in groundwater. Collectively, these efforts are providing data to necessary to refine the Conceptual Site Model (CSM) while also supplementing remediation focused pilot-scale performance data to establish a basis for design (well spacing, extraction approach/systems, vapor and liquid controls, and monitoring). The construction and operation of long-term remediation systems toward achieving site cleanup under the Pennsylvania Land Recycling (Act 2) program is anticipated to be initiated in the second quarter of 2026.

In summary, interim remedial measures including VEFR LNAPL recovery initiated on December 5, 2025 and ongoing site characterization activities, continue to be expanded and advanced. To date these efforts have resulted in the following:

- Drilling of soil borings and installation of 35 overburden groundwater wells; 20 with observed LNAPL
- Completion of 41 active VEFR/manual hand-bailing events (as of February 17, 2026) resulting in the removal of approximately 2.580 gallons of LNAPL
- MIPC's removal estimate of 36,500 gallons of LNAPL (based on a graduated cylinder observation approach for LNAPL percentages) via the wastewater treatment unit (WTU)
- Sampling of 15 wells that do not contain LNAPL and analyzing groundwater samples for dissolved gasoline constituents
- Daily fenceline air monitoring since December 30, 2025 (midnight to midnight)
- Offsite drinking water well sampling at 43 homes (plus four non-potable well) in the surrounding community
- Public outreach to 117 property owners/residents
- Requests to 117 property owners to complete well surveys, grant permission to sample private wells (as applicable), 28 receiving offered bottled water (as requested), along with nine requests for site access to the proximate group of potentially affected property owners.
- Installation of one off-site monitoring well and soil vapor point.

This SCWP describes planned tasks and data collection/analysis for characterizing the nature and extent of released gasoline constituents, their fate and transport, potential receptors, and migration and exposure pathways in the environment affected by the release. Site

characterization activities are necessary to support the requirements for and preparation of the Interim Site Characterization Report; the Remedial Investigation Report; the Site-Specific Risk Assessment Report; and the Site-Specific Cleanup Plan and the eventual Act 2 Final Report. Site characterization activities are also critical for refining and enhancing ongoing interim measures and supporting remedial action decision making and implementation. The SCWP is based on the information and data that are currently available. MIPC expects that the nature and scope of the site characterization activities may be refined and supplemented as new data are obtained and interpreted to meet the requirements and objectives of the Act 2 investigation and cleanup submittals. The Department will be notified to seek their approval of the schedule updates and supplemental site characterization activities, if they are needed.

1.0 INTRODUCTION

Langan Engineering and Environmental Services, LLC (Langan) has prepared this Site Characterization Work Plan (SCWP or Plan) on behalf of MIPC, LLC to describe procedures for characterizing gasoline-related impacts in soil, groundwater, and soil vapor at the MIPC Chelsea Facility at 920 Cherry Tree Road, Bethel, Upper Chichester and Aston Townships, Delaware County, Pennsylvania (Site, see Figure 1). The purpose of this Plan is to define the nature and extent of the gasoline release and associated impacts, evaluate potential exposure pathways and receptors, and provide the data needed for PADEP review and subsequent remedy selection and demonstration of attainment of standards under Pennsylvania's Land Recycling Program (Act 2). The approach defined in this Plan will help establish and refine the preliminary Conceptual Site Model (CSM); evaluate actual and potential receptors with emphasis on residential properties along the western boundary; and generate quality data to support remedy selection, cleanup and demonstration of attainment of Act 2 remediation standards.

This Plan is being submitted to the Pennsylvania Department of Environmental Protection (PADEP) in accordance with Part 2.b.iii. of the Administrative Order (Order) issued by PADEP to MIPC on December 23, 2025, and the Remedial Action Implementation Schedule submitted to the PADEP on January 20, 2026 and revised on February 18, 2026. The Order directs MIPC to implement interim remedial actions and to perform a comprehensive environmental investigation and cleanup at the Site – including the identification and sampling of nearby private water supply wells for the presence/absence of gasoline constituents. The work outlined in this Plan will be performed consistent with Act 2 and applicable PADEP technical guidance and regulations,

including Chapter 250 requirements for pathway evaluation and final demonstration of attainment of remediation standards.

Information regarding the interim remedial strategy, approach and methods, including details of the ongoing Vacuum-Enhanced Fluid Recovery (VEFR) and other removal efforts of light non-aqueous phase liquid gasoline (LNAPL) from the subsurface, and an approach for the ongoing evaluation of vapor intrusion pathways are described in the Interim Remedial Action (IRA) Plan and Vapor Intrusion Evaluation Plan (VI Plan) submitted to the PADEP on January 13, 2026.

Information regarding the ongoing on-Site perimeter air monitoring can be found in the Fenceline Perimeter Air Monitoring Sampling Plan (PAMP) submitted to the PADEP on January 13, 2026.

Information regarding the collection, analysis, and reporting of groundwater samples from private drinking water wells located near the Site can be found in the Private Drinking Water Well Sampling and Analysis Plan submitted to the PADEP on February 6, 2026.

This Plan outlines the preliminary CSM, sampling methods, quality assurance/quality control (QA/QC) measures, laboratory analytical methods, data quality and usability assessment, comparison of results to applicable standards, documentation procedures, and a reporting schedule for characterization of the nature and extent of affected environmental media.

2.0 SITE SETTING AND BACKGROUND

Within this section of the SCWP is background information, including a description of the facility and a summary of historical land use.

2.1 General Facility Description

The Site is an approximately 160-acre petroleum distribution facility located at 920 Cherry Tree Road in Delaware County, PA. The facility spans portions of Aston, Bethel, and Upper Chichester Townships and serves as a key intermediate tank farm connecting Monroe Energy's Trainer Refinery to various delivery pipelines and markets. The Site consists of 12 breakout tanks with a total capacity of about 1.7 million barrels of refined petroleum product. The breakout tanks are regulated by the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA) for safety and integrity standards, while air emissions are permitted under PADEP Air Quality regulations.

Supporting infrastructure at the site includes interconnecting pipelines, a pump station, and loading facilities, all dedicated to the storage and transfer of gasoline and other petroleum products. The surrounding land use is primarily residential; notably, some nearby homes (primarily west of the tank farm) rely on private groundwater wells for drinking water, which makes monitoring of groundwater quality a critical concern.

2.2 History of Ownership and Land Use

Petroleum distribution operations at the Chelsea tank farm site date back to the late 1940s, when storage tanks were constructed by Sinclair Refining on what was formerly orchards and farmland primarily owned by Samuel Goodley. Tank 708, which was the source of the recent gasoline release, was constructed by at least 1953 based on a review of historic topographic maps. According to historic maps maintained by MIPC, farm-related structures, namely a dwelling, a barn, two sheds, a coop, and a springhouse, were located within the southwestern portion of the Tank 709 basin. Bezers Run, a tributary of the Marcus Hook Creek, was formerly located east of Chichester Avenue along the western Site boundary.

Throughout the 20th century, the site was operated by predecessor companies in the regional oil industry (likely affiliated with legacy pipeline or refining companies) and was consistently utilized for petroleum product storage and pipeline distribution. In 2012, Monroe Energy, LLC (a subsidiary of Delta Air Lines) acquired the facility and associated pipelines from Phillips 66 as part of the purchase of the Trainer Refinery logistics assets. MIPC, LLC (Monroe Interstate Pipeline Company) was established to own and operate the pipeline network and tank farms including the Aston (Chelsea) Terminal. Under Monroe's ownership, the facility has continued its historical use as a petroleum distribution facility.

The surrounding area has transitioned from rural farmland to a mix of suburban residential developments and commercial/industrial use over time. Many homes in portions of Bethel and Upper Chichester Townships to the west of the Site remain on private well water, despite there being a public water supply main within Chichester Avenue. Parcels adjoining the western Site boundary to the east of Chichester Avenue are generally comprised of 1 to 1.5 acres of land with single-family dwellings located approximately 100 feet east of Chichester Avenue and 250 to 400 feet west of the Site. Most of these dwellings are 1,500 to 2,000 square feet in size and were constructed in the 1950s or 1960s. Detached garages

are located east of the dwellings on some of the properties. For residences that maintain private wells, most are located west of the dwellings.

3.0 PRELIMINARY SOURCE CHARACTERIZATION AND CONCEPTUAL SITE MODEL

The following sections present the preliminary CSM. The purpose of including the preliminary CSM in this SCWP is to provide the current understanding of the Site environmental conditions and characteristics and the processes that appear to influence the fate, transport and movement of gasoline constituents through environmental media. This preliminary CSM incorporates the data collected to date from implementation of the interim remedial actions and environmental investigations and will be refined as additional data are collected and interpreted. A refined CSM will be presented in the interim site characterization report to be submitted to the PADEP in June 2026 and further refined in the subsequent submittals of the site-specific risk assessment report, the site-specific cleanup plan. The Act 2 Final Report will include the final CSM.

3.1 Overview of Release, Interim Corrective Actions, and Investigation Findings to Date

A release of unleaded gasoline was discovered at the Site in August 2025, prompting a series of interim corrective actions and investigations. The release was determined to have occurred from Tank 708, and this tank was decommissioned (i.e., emptied) in early December 2025. As stated in the Order issued by PADEP, MIPC estimated the release to be approximately 9,000 barrels (378,000 gallons). Ongoing subsurface investigations and interim remedial measures conducted to date have included, but are not limited to, the following activities:

- Tank and pipeline integrity evaluations;
- Design, construction and operation of a water treatment system that has operated continuously since September 2025;
- Removal of gasoline via vacuum-enhanced fluid recovery (VEFR), including multi-well extraction using a manifold system;
- Subsurface soil and groundwater investigation that began in November 2025 and remains ongoing;
    - Through February 13, 2026, 35 wells have been installed for groundwater monitoring and/or gasoline recovery.

  - Numerous soil and groundwater samples have been collected and analyzed for characterization and delineation purposes.

- Completion of a geophysical seismic refraction study for subsurface characterization of the soil/weathered bedrock/bedrock interfaces and preliminary CSM development;
- Completion of bail down testing to evaluate LNAPL transmissivity and recoverability;
- Continuous midnight-to-midnight (24-hour) fenceline perimeter air monitoring, which began just after midnight on December 31, 2025, and remains ongoing;
- Off-Site near-source soil gas sampling to assess potential vapor intrusion where access is granted; and
- Identification, sampling and analysis of 43 offsite private wells and offering/supplying bottled water to owners of nearby properties that are not connected to the public water supply.

Updates regarding the above activities are provided in weekly progress reports that MIPC submits to PADEP and the Townships and uploads to their public website.

3.2 Geology and Hydrogeology

Delaware County is underlain by crystalline metamorphic rocks that are mainly comprised of gneisses and schists. The overburden encountered at the Site consists of varying proportions of clay, silt, sand, along with basal cobbles and gravel. Weathered bedrock and saprolite (weathered bedrock that retains its original texture and structure of the bedrock from which it develops, affecting the chemical and physical properties) are encountered at variable depths on-Site.

Interim corrective actions and investigations conducted to date observed depth-to-groundwater ranges from approximately 4 feet to 40 feet below ground surface (bgs). Groundwater elevations provided in the IRA Plan submitted to PADEP on January 13, 2026, indicate that the groundwater flow direction is generally towards the south with observed local and temporal variations in groundwater flow direction inferred.

Groundwater flow is topographically influenced within the weathered gneiss bedrock setting. Subsurface heterogeneity includes silty/sandy lenses or ‘fingers’ that may

preferentially influence flow and movement of gasoline LNAPL and dissolved fractions in groundwater. Migration of LNAPL and dissolved-phase impacts is expected to be variable under the influence of the local differences in soil type/lithology, weathered bedrock surface relief and their associated physical characteristics and properties.

3.3 Interim Extent of LNAPL Impacts

As of February 17, 2026, measured LNAPL is present in 20 of 35 monitoring wells installed at the Site, as summarized in Table 1 and depicted on Figures 2, 2A, and 3. Site observations to date support a CSM in which LNAPL is present in the overburden sandy soils and is observed at/near the soil/weathered bedrock and saprolite interfaces. Indications are that in the saprolite, where structure and texture of the parent rock are retained, the LNAPL potentially accumulates and may preferentially migrate compared to overlying overburden soils. In this setting, bedrock relief (local highs/lows), variability in weathered bedrock/saprolite characteristics and heterogeneity in overburden soils can influence groundwater flow and LNAPL accumulation, producing observed spatial variability in LNAPL occurrence and apparent thickness.

As described in the IRA Plan submitted to the PADEP on January 13, 2026, on-site VEFR has consistently demonstrated measurable reductions in apparent LNAPL thickness and recovery of free product, confirming recoverability and supporting continuation/expansion as an interim remedial measure. The evolving CSM indicates gasoline is preferentially migrating in the subsurface overburden sandy soils and indications to date are that LNAPL occurrence is frequently observed at/near the top of weathered bedrock surface, with LNAPL and dissolved phased groundwater impacts apparently influenced by saprolite and surface topography and physical characteristics.

To date, LNAPL delineation has advanced and been substantially completed to the north, south, and east onsite. LNAPL delineation to the west-southwest remains dependent on offsite access approval. Further delineation efforts will be advanced through targeted step-out locations wherever access can be reasonably obtained (e.g., in roadway rights-of-way and/or at property further westward from the western MIPC property boundary).

The results of ongoing and future groundwater and LNAPL gauging (Section 4.4.2), LNAPL Transmissivity Testing (Section 4.5) and supplemental soil, groundwater and soil vapor investigation and sampling will be provided to the PADEP in regularly required progress

reports and incorporated into the CSM according to the reporting scheduled outlined in the approved Remedial Action Implementation Schedule.

3.4 Interim Extent of Soil Impacts

Langan has and will continue to conduct soil sampling at boring locations to characterize gasoline impacts in unsaturated soil. Soil characterization/sampling procedures are outlined in Section 4.3.

To date, Langan has received analytical results for 43 soil samples collected from borings since subsurface investigations were initiated in November 2025 by a prior consultant and by Langan since the end of December 2025. The compiled analytical results for soil samples collected and validated results received through January 16, 2026 are summarized in Table 3. Relevant and applicable soil MSCs and VI screening criteria are included for comparison in Table 3 and further detailed in Section 6.1.

3.5 Interim Extent of Dissolved Impacts in Groundwater

Groundwater sampling at monitoring wells without measured LNAPL was completed in December 2025 (six wells) and recently during the week of February 16, 2026 (conducted periodically as the monitoring well network is installed to monitor dissolved-phase gasoline impacts). Groundwater characterization/sampling procedures and sample analysis procedures are outlined in Section 4.4.3.

Langan conducted low-flow groundwater sampling for the six wells that at that time had no measurable LNAPL (MW-3, -4, -5, -10, -11 and -12) on December 22 and 23, 2025. A second round of groundwater sampling for the current set of 14 wells that do not contain LNAPL was completed the week of February 16, 2026, and those analytical results are forthcoming. The groundwater samples were analyzed for the PA Petroleum Short List (EPA 8021B/8260D), which includes benzene, ethylbenzene, toluene and xylenes (BTEX).

No exceedances of the PADEP Residential or Non-Residential Groundwater MSCs or VI Screening Values for Groundwater (SV_{GW}) were detected in groundwater samples collected from monitoring wells MW-3, -5, -10, -11 or -12. Benzene was detected in groundwater samples collected from monitoring well MW-4 at a concentration above the PA Groundwater MSCs and SV_{GW}. Ethylbenzene, xylenes, and 1,2,4-trimethylbenzene were also detected in the MW-4 groundwater sample at concentrations above one-tenth of the

SV_{GW}. The results of these groundwater samples were provided in a summary table and laboratory reports to the PADEP as part of the 2nd Weekly Progress Report. Groundwater remediation standards are outlined in Section 6.2. The approximate locations of the existing and proposed monitoring and recovery wells are shown on Figures 2 and 2A.

A second round of low-flow groundwater sampling began on February 18, 2026, and is ongoing to assess dissolved-phase gasoline impacts in recently installed monitoring wells without measurable LNAPL. The results of this sampling and future sampling rounds will be provided to the PADEP and incorporated into the CSM according to the reporting scheduled outlined in Section 7.0.

3.6 Summary of Preliminary Conceptual Site Model

A Conceptual Site Model (CSM) describes physical Site conditions (e.g. geology, hydrogeology, and hydrology) that could relate to the gasoline release and is a model of potential occurrence, distribution, and migration pathways.

The preliminary CSM integrates current information and considerations specific to the gasoline product from Tank 708 that was released. The release migrated primarily southwest as dictated by the physical conditions of the releases and the subsurface hydrogeologic characteristics. The Site hydrogeologic setting consists of overburden soils, weathered bedrock/saprolite overlying fractured crystalline bedrock. Groundwater occurs within the overburden and saprolite regime, and flow is expected to be dominated by more transmissive intervening sandy soil intervals and weathered/saprolite intervals that contain preserved fractures and other remnant structure that are present in the underlying competent bedrock. The observed LNAPL occurrence and distribution is interpreted to be influenced by (i) interconnected sandy soil stringers, weathered/saprolite transmissive horizons and (ii) weathered bedrock surface relief that is conducive to local pooling and lateral spreading along more transmissive intervals. Dissolved-phase gasoline transport is driven by hydraulic gradients and interconnectivity of transmissive intervals. Because apparent LNAPL thickness is influenced by several complicating factors, (e.g. well construction, local variability of geologic conditions, degree of saturation), recoverability and potential mass-flux implications will be more reliably evaluated using repeat gauging, recovery behavior, and LNAPL transmissivity (Tn) testing rather than thickness alone.

4.0 SAMPLING AND ANALYSIS PLAN

The following tasks will be performed on-Site in continuation of the interim remedial actions and ongoing subsurface investigation conducted to date as outlined in Section 3.1:

- Advance soil borings to understand Site geology/hydrogeology and collect/analyze soil samples, as needed, to assess gasoline-related soil impacts.
- Install monitoring wells for groundwater monitoring and/or gasoline recovery.
- Perform Site-wide synoptic water level and LNAPL gauging.
- Collect/analyze groundwater samples via low-flow sampling to assess dissolved-phase gasoline-related impacts.
- Conduct bail down testing to evaluate LNAPL transmissivity and recoverability.
- Conduct additional seismic refraction survey for subsurface characterization and CSM development.

Soil samples will be collected to characterize the vadose zone, the smear zone, and intervals immediately above the water table, including targeted samples where field observations (odor, staining, sheens) and field screening indicate potential gasoline impacts. Groundwater sampling will be conducted using low-flow methods with stabilization criteria for pH, specific conductance, dissolved oxygen, ORP, and turbidity (as applicable). Sampling records will document purge rate, drawdown, stabilization trends, and deviations required by well yield constraints.

Figure 2 indicates the locations of existing and proposed monitoring and recovery wells, soil borings, and a vapor monitoring point at the Site and a neighboring offsite property. Figure 2A depicts the locations of existing and proposed monitoring and recovery wells and soil borings at the Site only. Proposed off-site locations are not included on Figure 2 or Figure 2A. In general, for the nearest properties west of the release area with permission for access, it is proposed to install a monitoring well (approximately +/- 100 feet from the occupied structure) and a soil vapor point at a location that is 30 feet or less from the rear of the occupied structure. Groundwater samples will be collected from installed wells and soil vapor samples will be collected from installed soil vapor points. Samples will be analyzed for the PADEP required list of gasoline constituents.

The following sections provide additional details regarding the key elements of this Plan and the scope of sampling and analysis to be performed.

4.1 Health and Safety

A Site-specific Health and Safety Plan (HASP) consistent with OSHA 29 CFR 1910.120 will be implemented. Field sampling activities performed as part of this Plan will be conducted in a manner consistent with the attached HASP (Appendix A). Field activities will include flammable atmosphere monitoring, PPE selection and escalation criteria, decontamination procedures, emergency response procedures, and worker training requirements.

4.2 Decontamination

Drilling and sampling equipment will be decontaminated before the initiation of field sampling activities and between sampling locations. To prevent cross-contamination between sampling locations, dedicated or disposable sampling materials were and will be used whenever practicable. Where reusable equipment was required, decontamination was performed between wells using a detergent wash, potable water rinse, and final rinse with distilled or deionized water. New nitrile gloves were worn at each sampling location and changed as necessary. Decontamination procedures will be conducted in a manner consistent with the SOPs outlined in Appendix B.

4.3 Soil Characterization

Soil characterization has and will be conducted on-Site and used to obtain data on the horizontal and vertical extent of gasoline impacts, including the identification and delineation of soil or LNAPL that may be a potential vapor intrusion source.

Boring locations will be advanced with the intention of being converted to permanent monitoring wells for purposes of groundwater monitoring and/or gasoline recovery. Boring locations may potentially not be converted to monitoring wells, and in those instances, would be properly sealed, if warranted because of encountering refusal before attaining desired depth or before encountering a sufficient water column or other unforeseen issues with the drill rig. Eight exploratory boring locations (Figures 2 and 2A) were advanced in the initial phase of the subsurface investigation to assist with LNAPL delineation but were not converted to monitoring wells. Details regarding groundwater characterization, including monitoring well installation procedures, are described in Section 4.4.1 and in Appendix B SOPs.

Prior to soil boring advancement, each boring location will be assessed for potential underground utility conflicts. Soil boring locations may be adjusted, based on the utility survey, so that they are more than 3 feet away from identified subsurface utilities.

The first five feet of each boring location will be advanced using "soft dig" techniques that may include hand-augering, air-knifing, and/or vacuum excavation. Hand augers will be equipped with bucket augers that are at least 6 inches long and 3 inches in diameter.

Borings will be advanced by a licensed well driller via sonic drilling or alternative methods to at least 10 ft below the top of the saturated zone, or otherwise based on observations by the field geologist. Sonic coring will be used where detailed stratigraphic control is required to resolve heterogeneity and to minimize disturbance of LNAPL and smear-zone conditions. Drilling fluids will be minimized/avoided, where feasible, to reduce the potential for product displacement and wellbore skin effects that bias sampling and LNAPL testing.

Soil conditions will be logged continuously from the ground surface to the terminal depth of each boring. Soil conditions to be observed/recorded will include texture, color, moisture content, and odor. Changes in stratigraphy will be noted, and soil will be classified in accordance with the Unified Soil Classification System (USCS). Recovered soil will be screened with a Photoionization Detector (PID) at approximately 6-inch intervals. Soil core logging will be conducted in a manner consistent with the SOPs outlined in Appendix B. A soil boring log will be prepared for each boring noting the date, drilling/sampling method(s), soil descriptions/classifications, depth of first water, PID readings, depths of samples collected for laboratory analysis, and other details. Cross sections will be generated using the soil descriptions/classifications documented in soil boring logs.

Soil samples will be collected and analyzed for gasoline impacts at select boring locations outside of the Tank 708 dike area. Approximately two soil samples will be collected per boring location: one sample from the 6-inch interval with the highest PID reading and one sample from the 6-inch interval immediately above the saturated zone. If there are no indications of gasoline impact, only one sample will be collected from the 6-inch interval immediately above the observed saturated zone. Details regarding soil sample analysis are described in Section 4.10.

4.4 Groundwater Characterization

Groundwater characterization will be conducted on-Site and at offsite properties where access is granted via an executed access agreement. The installation and sampling of groundwater monitoring wells is planned to delineate the horizontal and vertical extent of gasoline impacts to groundwater, including the identification and delineation of groundwater and LNAPL that may be a potential vapor intrusion source.

The planned locations and total depth of the monitoring wells will be based on the locations of identified LNAPL, dissolved-phase concentrations greater than the groundwater screening criteria (Section 6.2), gasoline impacts in soil greater than the soil screening criteria (Section 6.1), lithology identified while logging soil conditions, and structural features identified in the seismic refraction survey. The locations of the planned monitoring wells and/or recovery wells may be adjusted based on the presence of underground utilities and results of the currently ongoing and planned activities identified in the IRA Plan submitted to the PADEP. Additional monitoring wells/recovery wells beyond what is defined in this Plan may be required to complete the groundwater characterization, which will be communicated to the PADEP for their concurrence.

4.4.1 *Monitoring and Recovery Well Installation and Development*

Through February 17, 2026, 35 wells have been installed at the Site for groundwater monitoring and/or gasoline recovery purposes (Figures 2 and 2A). Ten of these wells were installed by a prior consultant and well driller before the start of Langan's activities at the Site. To date, one off-site well has been installed. Approximately 65 additional recovery wells are planned to be installed at the Site in phases to enhance larger-scale gasoline extraction/recovery from the subsurface as part of remedial actions (Figures 2 and 2A). Proposed and existing wells may be used for gasoline recovery and/or may be converted to observation wells as the remediation progress advances. An off-site monitoring well (MW-B) was installed on an adjacent property west of the Site which, at this time, is the lone property with a signed agreement for access to conduct these investigation activities.

Monitoring and recovery wells will be advanced by a licensed well driller via sonic or hollow stem augers drilling methods. Wells will be installed and constructed in a manner consistent with the SOPs provided in Appendix B. They will be constructed with 4-inch diameter schedule 40 PVC screens and risers within a nominal 8-inch

diameter borehole. Each well will be constructed with a 0.01-inch slotted PVC well screen with appropriate screen lengths for the intended use and purpose of the well. The annular space opposite the screen will be filled with #1 filter sand. The top of the well screen will be positioned approximately 10 feet above the approximate water table elevation, which is to be determined from nearby wells and observations made during soil boring advancement and drilling. The filter sand will be emplaced from the bottom of the borehole to approximately 2 – 3 feet above the top of the well screen. A bentonite seal be emplaced to approximately 2 – 3 feet above the filter sand to prevent vertical migration of potential gasoline impacts. Grout will be used to seal the remaining annular space from the top of the bentonite seal to the ground surface. The monitoring wells will be completed with flush-mounted manholes or "stick-up" risers with protective outer steel casings that extend approximately 2 – 3 feet above the ground surface, depending on usage and location. Concrete pads will be set around the flush-mounted manholes and protective outer steel casings. Well PVC risers (inner casings) will be equipped with lockable compression-type well-plugs (j-plugs), and outer protective casings will be equipped with lockable steel lids. Steel and concrete bollards will be installed around wells located in high traffic areas to protect them from damage.

After installation, each well will be developed by the licensed well driller using pumping and surging methods facilitated by a submersible pump, air compressor, or via vacuum truck extraction to remove fine sediment and establish water flow from the formation into the well. Development via submersible pump will be performed using "surge-and-purge" techniques, by moving the pump up and down in the water column during development. Wells will be developed until a clear discharge is achieved, with a minimum of five well volumes of water to be removed.

Existing monitoring wells have been and will continue to be installed and developed in a manner consistent with the procedures outlined above.

4.4.2 *Groundwater Level and LNAPL Gauging*

Synoptic water level and LNAPL gauging have been and will continue to be performed at all installed monitoring wells minimally once per week. Depth to top-of-LNAPL, if present, and top-of-water will be measured to the nearest 0.01 foot from the surveyed reference points using calibrated electronic interface probes. Bottom

depths will be measured from the surveyed reference points the first time a newly installed monitoring well is gauged. Groundwater and LNAPL gauging will be performed in a manner consistent with the SOPs outlined in Appendix B.

The data from these gauging events will be used to assess the presence and thickness of LNAPL across the Site and the movement of groundwater on a Site-wide basis. This assessment will include the preparation of potentiometric surface maps and the computation of horizontal and vertical hydraulic gradients.

4.4.3 *Groundwater Sample Collection*

Monitoring wells without the presence of LNAPL will be sampled to assess the presence and concentration of dissolved-phase gasoline impacts. An initial round of groundwater samples was collected from six monitoring wells on December 22 and 23, 2025. The results of these groundwater samples were provided in a summary table and laboratory reports to the PADEP as part of the 2nd Weekly Progress Report. A second round of low-flow groundwater sampling began on February 18, 2026, and was completed on February 20, 2026 to assess dissolved-phase gasoline impacts in recently installed monitoring wells without measurable LNAPL. In addition to analyzing the groundwater samples for gasoline-related constituents, select sample locations will be analyzed for biogeochemical parameters to assist with remedial decision making.

Groundwater sampling will use low-flow methods where feasible with documented stabilization criteria.

Monitoring wells will be sampled approximately two weeks after installation, when feasible, to allow time for the wells to equilibrate with the surrounding groundwater. Groundwater sampling will be performed in a manner consistent with the SOPs provided in Appendix B, using low flow purging and sampling methodology. Prior to purging, an initial depth to water measurement will be obtained from each well using a calibrated electronic water level sounder. The wells will be purged and sampled using a pre-cleaned bladder pump. New/dedicated pump tubing will be used for each well. During purging, a calibrated multi-parameter water quality meter equipped with a flow-through cell will be used to measure field water quality parameters including temperature, pH, specific conductivity, DO, ORP, and turbidity. Purging will be

performed at a flow rate of 250 mL per minute or less, as indicated in the attached SOP (Appendix B). Reasonable steps should be taken to minimize turbidity, targeting less than 50 nephelometric turbidity units (NTU).

Once purging is complete, samples will be collected directly into the laboratory-provided sample bottles at the same flow rate used for purging. Samples will be labeled and stored on-Site between 2-6°C in a cooler until the laboratory takes possession. Non-dedicated equipment such as water level sounders, water quality meters (and flow-through cells), and bladder pumps will be decontaminated between wells per the SOPs in Appendix B.

4.5 LNAPL Transmissivity Testing

Because apparent LNAPL thickness is influenced by well construction and local subsurface conditions, recoverability and potential mass-flux implications will be evaluated using repeat gauging, recovery behavior, and LNAPL transmissivity (Tn) testing rather than thickness alone. Monitoring wells with measurable LNAPL will be evaluated via transmissivity (Tn) testing (e.g., bail down) under controlled conditions. Interpretation of the testing results will emphasize recoverability and mass flux implications rather than thickness alone.

4.6 Seismic Refraction Survey

A seismic refraction survey was conducted from January 20 – 22, 2026, by Stuby Subsurface Investigations, LLC. Once received, the final report and interpretations will be submitted to the PADEP as part of the ongoing Weekly Progress Reports. Seismic refraction interpretations will be used to constrain the weathered bedrock/bedrock surface model and identify potential structural depressions that can influence groundwater flow and LNAPL pooling and trapping. The interpretations will be incorporated into cross-sections and used as further reasoning for placement of step-out monitoring well locations which will help refine the preliminary Site CSM.

4.7 Location and Elevation Surveying

The horizontal and vertical positions of monitoring well locations will be surveyed by a licensed surveyor. Horizontal positions will be surveyed with respect to the Pennsylvania State Place Coordinate System (South), and vertical elevations will be surveyed with

respect to the North American Datum of 1988. Horizontal positions will be given in northing and easting, and vertical elevations will be given in feet above mean sea level (feet amsl). The survey will include ground surface, top of the inner well casing (at a point marked or to be marked on the well casing), and top of protective outer casing, if present.

4.8 Investigation-Derived Waste

Investigation-derived waste (IDW), such as soil cuttings, purge water, disposable sampling materials, and recovered fluids, will be managed and disposed of in accordance with applicable waste regulations and Site-specific plans. Waste profiling, manifests/receipts, and documentation will be maintained for inclusion in subsequent reporting.

4.9 Quality Assurance / Quality Control

Quality assurance and quality control (QA/QC) measures include the collection and analysis of field duplicates, field blanks, and trip blanks. Field duplicate samples will be collected at a frequency of at least one duplicate sample per 20 samples per environmental media (i.e. groundwater, soil). Field duplicate samples are submitted to the laboratory with no indication as to the associated parent sample (e.g., no reference to parent sample in the sample ID and no time included on label or chain-of-custody). Field blank samples are collected at a frequency of one per day per environmental media. Trip blanks are submitted to the laboratory at a frequency of once per sample shipment. Results of QA/QC samples have been and will continue to be reported to PADEP as part of the ongoing Weekly Progress Reports.

Chain-of-custody documentation was and will be maintained from sample collection through laboratory receipt. Field instruments, including PIDs, interface probes, and water quality meters, were and will be calibrated in accordance with manufacturer specifications prior to use. During data quality review, analytical data were and will be reviewed for completeness, holding times, calibration, and quality control acceptance criteria, as further described in Section 5.0.

4.10 Analytical Methods and Laboratory Analysis

Soil samples collected from soil borings and groundwater samples collected from monitoring wells will be analyzed via Method 8260D for VOCs associated with unleaded gasoline. Analyses will target the PADEP "Short List" of gasoline-related constituents for

unleaded gasoline, which represents the primary compounds of concern for evaluating potential impacts to groundwater and nearby potable water supplies resulting from the gasoline release. The target analyte list will include benzene, toluene, ethylbenzene, total xylenes (BTEX), isopropylbenzene (cumene), methyl tert-butyl ether (MTBE), naphthalene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene. These constituents are characteristic of modern unleaded gasoline formulations. Lead and historical lead scavenger compounds (e.g., 1,2-dibromoethane and 1,2-dichloroethane) are not expected and will not be included in the analytical program, as the released product was new unleaded gasoline.

As described in Section 4.4.3, select groundwater sample locations will be analyzed for biogeochemical parameters to assist with remedial decision making. These parameters include alkalinity (as $CaCO_3$), chloride, sulfate, sulfide, nitrate, nitrite, ammonia, dissolved iron, dissolved manganese, dissolved organic carbon (DOC), methane, ethane, ethene, carbon dioxide. Additional parameters/tests may be considered if supported based on the results of the prior list of parameters. Any supplemental analyses will be presented to the Department for concurrence.

Soil samples have been and are planned to be submitted to SGS North America, Inc. (SGS), and groundwater samples have been and are planned to be submitted to Pace Analytical Services, LLC (Pace). Both laboratories are certified environmental laboratories and maintain appropriate accreditations and quality systems to support regulatory acceptance of analytical data.

Upon receipt at the laboratory, samples have been and will be logged, inspected for container integrity and temperature compliance, and preserved at approximately 4°C until analysis. Internal standards and surrogate compounds will be added to each sample to evaluate analytical performance, recovery, and instrument stability. Laboratory quality control procedures have been and will be implemented in accordance with Method 8260D and will include method blanks, laboratory control samples, and matrix spike/matrix spike duplicate analyses, as applicable. Instrument calibration has been and will be performed using certified reference standards encompassing the full suite of target analytes. Reporting limits have been and are expected to be sufficiently low (generally on the order of sub-microgram per liter concentrations) to allow direct comparison to applicable screening criteria, as further described in Section 5.0.

Laboratory data deliverables will include complete analytical reports and associated quality assurance and quality control documentation. Analytical data produced will be suitable for inclusion in the future Act 2 environmental investigation record and for review by PADEP.

5.0 DATA QUALITY/USEABILITY EVALUATION

Data quality review has been and will be performed in accordance with the applicable USEPA data quality standard operating procedures (SOPs) for data quality review and USEPA's National Functional Guidelines for Organic and Inorganic Data Review. Tier 1 data quality review (the equivalent of USEPA's Stage 2A validation) was and will be performed to evaluate and verify the quality of data that are used in support of delineation, decision end points and /or evaluation of environmental risk.

Langan Tier 1 data quality review is based on completeness and compliance checks of sample-related QA results including:

- Holding times;
- Sample preservation;
- Blank results (method, trip, and field blanks);
- Surrogate recovery compounds and extracted internal standards (as applicable);
- Laboratory Control Sample (LCS) and LCS Duplicate (LCSD) recoveries and Relative Percent Differences (RPDs);
- Field duplicate RPDs

Data Usability Assessments (DUAs) have been and will be prepared by a Langan data quality assessor and reviewed by the Langan Quality Assurance Manager (QAM) before issuance. Copies of the DUAs completed to date are provided as Appendix F. The DUA presents the results of data quality review, including a summary assessment of laboratory data packages, sample preservation and chain-of-custody procedures, and a summary assessment of precision, accuracy, representativeness, comparability, and completeness for each analytical method. The DUAs for samples collected as part of the December 2025 and January 2026 sampling activities conclude that all data are considered usable, as qualified. In addition, completeness, defined as the percentage of analytical results that are judged to be valid, is 100%.

6.0 SELECTION OF SOIL & GROUNDWATER STANDARDS & VI SCREENING VALUES

Analytical results obtained from soil and groundwater characterization activities, as described in Sections 4.3 and 4.4, respectively, will be evaluated by comparison to relevant and applicable Pennsylvania Land Recycling and Environmental Remediation Standards Act (Act 2) for soil, and groundwater, and the PADEP vapor intrusion criteria to assess potential on- and off-Site gasoline impacts and determine whether further actions are warranted. As referenced by the December 5, 2025 Notice of Intent to Remediate field by MIPC, the intent is to demonstrate attainment of a combination of the Statewide Health and Site-Specific standards available under the Act 2 program. Pennsylvania's Act 2 Statewide Health Standards are established scientifically based, uniform, numerical targets known as medium-specific concentrations (MSCs) for soil and groundwater that protect human health and the environment and apply to residential and non-residential land uses. MSCs define acceptable levels of contaminants of concern based on toxicity and potential exposure. Site-Specific Standards (SSS) require a more in-depth risk-based analysis to support a more flexible, risk-based approach to soil and groundwater remediation that tailor cleanup efforts toward mitigating actual site risks, consistent with intended land use, and site-specific characteristics.

PADEP Vapor Intrusion (VI) screening values for soil and groundwater are used to evaluate if volatile organic compounds (VOCs – in this instance specifically, gasoline related) pose an indoor air risk. These VI screening values are derived from toxicological data and applied as screening levels and not cleanup standards to determine if further VI assessment is warranted.

The SWH, site-specific standards and VI screening values will be applied in combination in evaluating analytical data for affected media and to evaluate potential and actual risks to human health and the environment that form a basis for final site cleanup under the requirements of the Administrative Order and the Act 2 Program.

6.1 Soil MSCs

The following sections discuss the screening levels that will be used to evaluate the presence and relative magnitude of gasoline-related constituents in soil.

6.1.1 *PADEP Direct Contact and Soil-to-Groundwater MSCs for Soil*

Langan has and will continue to compare soil sample results from on-Site boring locations to the PADEP Non-Residential MSCs in accordance with the PADEP Act 2

Land Recycling Program. The applicable Non-Residential MSCs for soil consist of direct contact values for surface soil (0-2 feet bgs), direct contact for subsurface soil (2-15 feet bgs), and soil-to-groundwater values for unsaturated soil in a used aquifer containing less than or equal to 2,500 mg/l total dissolved solids (TDS).

The PADEP Non-Residential Direct Contact MSC for surface soil (0-2 feet bgs) are:

- Benzene: 280 mg/kg
- Toluene: 10,000 mg/kg
- Ethylbenzene: 880 mg/kg
- Xylene (total): 7,900 mg/kg
- Isopropylbenzene (Cumene): 10,000 mg/kg
- MTBE: 8,500 mg/kg
- Naphthalene: 66 mg/kg
- 1,2,4-Trimethylbenzene: 4,700 mg/kg
- 1,3,5-Trimethylbenzene: 4,700 mg/kg

The PADEP Non-Residential Direct Contact MSC for subsurface soil (2-15 feet bgs) are:

- Benzene: 330 mg/kg
- Toluene: 10,000 mg/kg
- Ethylbenzene: 1,000 mg/kg
- Xylene (total): 9,100 mg/kg
- Isopropylbenzene (Cumene): 10,000 mg/kg
- MTBE: 9,800 mg/kg
- Naphthalene: 77 mg/kg
- 1,2,4-Trimethylbenzene: 5,400 mg/kg
- 1,3,5-Trimethylbenzene: 5,400 mg/kg

The PADEP Non-Residential Soil-to-Groundwater MSC for unsaturated soil in a used aquifer with TDS less than or equal to 2,500 mg/l are:

- Benzene: 0.5 mg/kg
- Toluene: 100 mg/kg
- Ethylbenzene: 70 mg/kg
- Xylene (total): 1,000 mg/kg
- Isopropylbenzene (Cumene): 2,500 mg/kg
- MTBE: 2 mg/kg

- Naphthalene: 25 mg/kg
- 1,2,4-Trimethylbenzene: 300 mg/kg
- 1,3,5-Trimethylbenzene: 93 mg/kg

Langan will compare soil sample results from borings advanced on off-Site, residential properties to the PADEP Residential Direct Contact Medium-Specific Concentrations (MSCs) in accordance with the PADEP Act 2 Land Recycling Program.

The PADEP Residential Direct Contact MSC for soil (0-15 feet bgs) are:

- Benzene: 57 mg/kg
- Toluene: 10,000 mg/kg
- Ethylbenzene: 180 mg/kg
- Xylene (total): 1,900 mg/kg
- Isopropylbenzene (Cumene): 7,600 mg/kg
- MTBE: 1,700 mg/kg
- Naphthalene: 13 mg/kg
- 1,2,4-Trimethylbenzene: 1,100 mg/kg
- 1,3,5-Trimethylbenzene: 1,100 mg/kg

6.1.2 *PADEP Vapor Intrusion Screening Values for Soil*

Langan has and will continue to compare soil sample results from on-Site boring locations to one-tenth of the PADEP Non-Residential Soil Statewide Health Standards (SHS) Vapor Intrusion (VI) Screening Values for Soil (SV_{SOIL}) in accordance with the PADEP Act 2 Land Recycling Program Technical Guidance Manual for Vapor Intrusion.

One-tenth of the PADEP Non-Residential SHS VI SV_{SOIL} are:

- Benzene: 0.013 mg/kg
- Toluene: 4.4 mg/kg
- Ethylbenzene: 4.6 mg/kg
- Xylene (total): 99 mg/kg
- Isopropylbenzene (Cumene): 250 mg/kg
- MTBE: 0.14 mg/kg
- Naphthalene: 2.5 mg/kg

- 1,2,4-Trimethylbenzene: 30 mg/kg
- 1,3,5-Trimethylbenzene: 9.3 mg/kg

Langan will compare soil sample results from borings advanced on off-Site, residential properties to the PADEP Residential Soil SHS VI Screening Values for Soil (SV_{SOIL}) in accordance with the PADEP Act 2 Land Recycling Program Technical Guidance Manual for Vapor Intrusion.

One-tenth of the PADEP Residential SHS VI SV_{SOIL} are:

- Benzene: 0.013 mg/kg
- Toluene: 4.4 mg/kg
- Ethylbenzene: 4.6 mg/kg
- Xylene (total): 99 mg/kg
- Isopropylbenzene (Cumene): 60 mg/kg
- MTBE: 0.028 mg/kg
- Naphthalene: 2.5 mg/kg
- 1,2,4-Trimethylbenzene: 7.3 mg/kg
- 1,3,5-Trimethylbenzene: 2.3 mg/kg

6.2 Groundwater MSCs

The following sections discuss the groundwater MSCs that will be used to evaluate the presence and relative magnitude of gasoline-related constituents in groundwater.

6.2.1 *PADEP MSC for Groundwater in a Used Aquifer, TDS ≤2,500 mg/l*

Langan has and will continue to compare groundwater sample results from monitoring wells to the PADEP Residential and Non-Residential MSC for regulated substances contained in groundwater in an aquifer used or currently planned to be used for drinking water containing less than or equal to 2,500 mg/l TDS.

The PADEP Residential MSC for groundwater in a used aquifer with TDS less than or equal to 2,500 mg/l are:

- Benzene: 5 microgram per liter (µg/L)
- Toluene: 1,000 µg/L
- Ethylbenzene: 700 µg/L

- Xylenes (total): 10,000 µg/L
- Isopropylbenzene (Cumene): 840 µg/L
- MTBE: 20 µg/L
- Naphthalene: 100 µg/L
- 1,2,4-Trimethylbenzene: 130 µg/L
- 1,3,5-Trimethylbenzene: 130 µg/L

The PADEP Non-Residential MSC for groundwater in a used aquifer with TDS less than or equal to 2,500 mg/l are:

- Benzene: 5 µg/L
- Toluene: 1,000 µg/L
- Ethylbenzene: 700 µg/L
- Xylenes (total): 10,000 µg/L
- Isopropylbenzene (Cumene): 3,500 µg/L
- MTBE: 20 µg/L
- Naphthalene: 100 µg/L
- 1,2,4-Trimethylbenzene: 530 µg/L
- 1,3,5-Trimethylbenzene: 530 µg/L

6.2.2 *PADEP Vapor Intrusion Screening Values for Groundwater*

Langan has and will continue to compare groundwater results from monitoring wells to one-tenth of the PADEP Act 2 Residential and Non-Residential Site-Specific Standard (SSS) VI Screening Values for Groundwater (SV_{GW}) in accordance with the PADEP Act 2 Land Recycling Program Technical Guidance Manual for Vapor Intrusion.

One-tenth of the PADEP Residential SSS VI SV_{GW} are:

- Benzene: 2.3 µg/L
- Toluene: 3,400 µg/L
- Ethylbenzene: 70 µg/L
- Xylene (total): 1,000 µg/L
- Isopropylbenzene (Cumene): 190 µg/L
- MTBE: 630 µg/L
- Naphthalene: 10 µg/L
- 1,2,4-Trimethylbenzene: 51 µg/L

- 1,3,5-Trimethylbenzene: 36 µg/L

One-tenth of the PADEP Non-Residential SSS VI SV_{GW} are:

- Benzene: 35 µg/L
- Toluene: 43,000 µg/L
- Ethylbenzene: 86 µg/L
- Xylene (total): 1,200 µg/L
- Isopropylbenzene (Cumene): 2,400 µg/L
- MTBE: 9,600 µg/L
- Naphthalene: 130 µg/L
- 1,2,4-Trimethylbenzene: 640 µg/L
- 1,3,5-Trimethylbenzene: 450 µg/L

6.3 Treatment of Non-Detects and Reporting Limits

Results reported as non-detect (ND) will be considered compliant with screening criteria provided that the associated laboratory method detection limits or reporting limits are below the applicable screening levels.

Qualified detections (e.g., estimated values reported with laboratory qualifiers) will be evaluated on a case-by-case basis, considering the magnitude of the concentration relative to applicable screening levels and the associated quality control information.

6.4 Interpretation and Response Considerations

Analytical results below applicable screening levels will be considered indicative of groundwater and soil quality with respect to gasoline-related constituents. Detections below screening criteria may be noted for trend evaluation but will not, by themselves, trigger response actions.

If any constituent is detected at a concentration exceeding an applicable screening level, the result will be further evaluated in coordination with PADEP to determine appropriate next steps.

7.0 REPORTING SCHEDULE

As required by the Order, MIPC has been and will continue to submit to PADEP weekly progress reports (per Part 1.f.) containing a summary of well installations completed to date and soil and groundwater characterization results as they are received.

Following data quality review (see Section 5.0), letters transmitting the results of soil and groundwater characterization samples collected by MIPC/Langan from a residence's property will be prepared and mailed via USPS certified or priority mail to each property owner within two weeks of sample collection. An excerpt of the laboratory analytical report containing the results for the characterization samples will be appended to each results transmittal.

Quarterly remedial action progress reports will be submitted beginning 90 days after the Order's issuance, in accordance with Part 2.b.xi of the Order. The weekly and quarterly progress reports have and will continue to summarize soil and groundwater characterization efforts, well installation and sampling activities, and analytical results including data comparison to applicable screening criteria.

A Site Characterization Report (SCR) will be submitted to the PADEP following the implementation of this SCWP. The SCR will summarize soil and groundwater characterization activities and delineation of gasoline-impacts according to the screening criteria described herein.

A remedial investigation report (RIR) pursuant to the PADEP Order and Act 2 Land Recycling Program will also be submitted to the PADEP under separate cover in accordance with the implementation schedule submitted to the PADEP on January 20, 2026 (submitted revised on February 18, 2026). The Act 2 RIR will also include relevant information and updates regarding soil and groundwater characterization sampling and analysis plan described herein.

8.0 REFERENCES

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Langan Engineering and Environmental Services, LLC. February 3, 2026. Weekly Progress Report #6. MIPC Chelsea Facility, Aston, PA. *[Previously Submitted to PADEP]*

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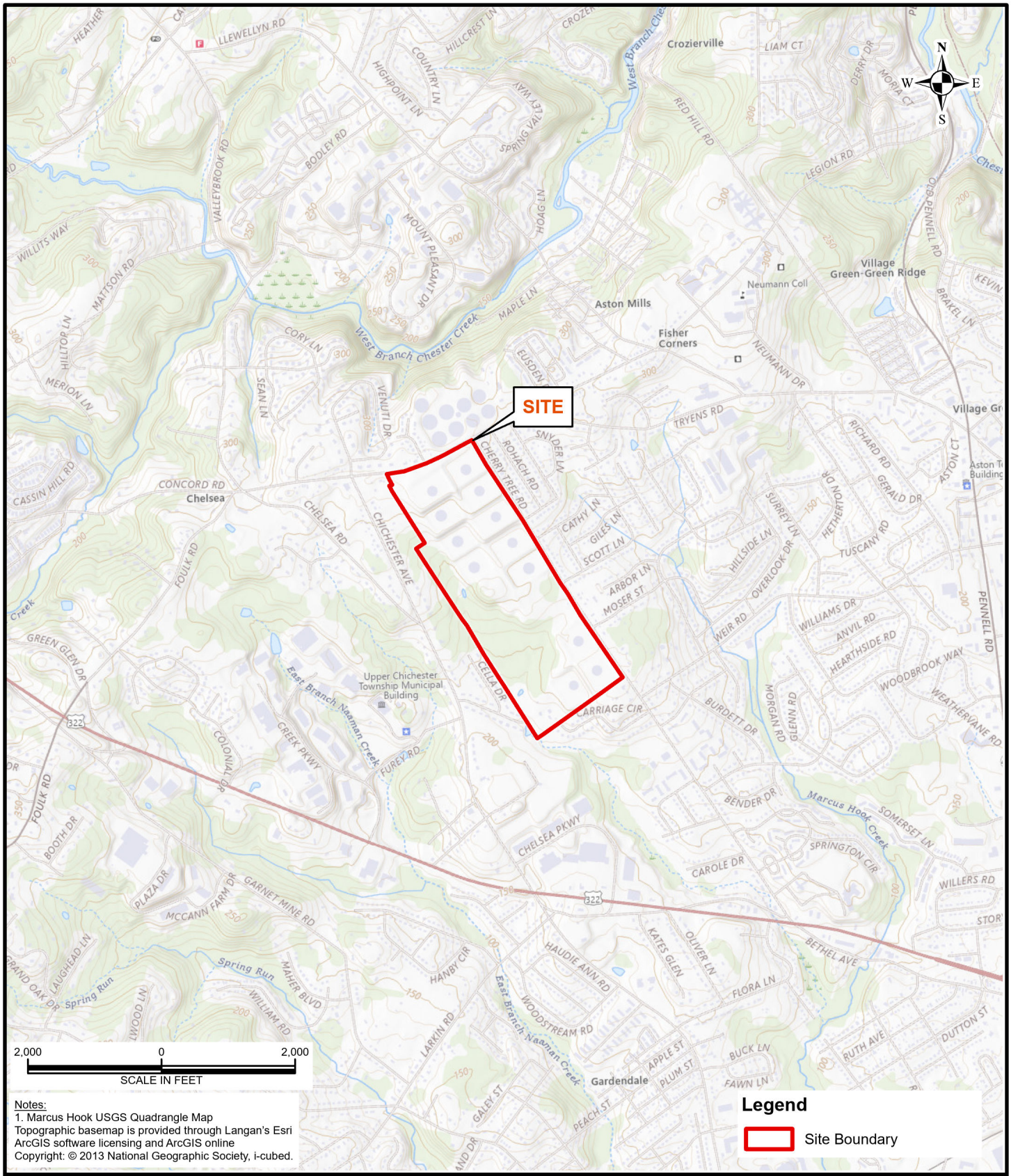
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PADEP. November 20, 2021. Act 2 Vapor Intrusion Screening Value Tables. https://www.pa.gov/agencies/dep/programs-and-services/land/land-recycling-program/standards-guidance-and-procedures/guidance-and-technical-tools/vapor-intrusion

FIGURES



Notes:
1. Marcus Hook USGS Quadrangle Map Topographic basemap is provided through Langan's Esri ArcGIS software licensing and ArcGIS online Copyright: © 2013 National Geographic Society, i-cubed.

Legend

Site Boundary

LANGAN

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Project

MIPC CHELSEA FACILITY

920 CHERRY TREE ROAD
ASTON TOWNSHIP
COUNTY STATE

Drawing Title

SITE LOCATION MAP

Project No. 220240201	Figure 1
Date 1/12/2026	
Scale 1"=2,000'	
Drawn By CH	

© 2026 Langan

Path: \\langan.com\data\PH\data2\220240201\Project Data\ArcGIS\APRX\220240201\220240201.aprx Date: 1/12/2026 User: challman Time: 9:21 AM



Legend

- Approximate Initial Investigation Exploratory Soil Boring Location
- Proposed Monitoring Well Location
- Approximate Monitoring Well Location
- Proposed Recovery Well Location
- Approximate Soil Vapor Monitoring Location
- Pending Site Access
- Recovery Well Installation Phase Boundaries
- Site Boundary
- Structure
- Stream
- Parcel Boundary

Notes:
Green Sample ID – No LNAPL Encountered in Well/Boring
Pink Sample ID – LNAPL Encountered in Well/Boring

1. All site feature locations are approximate.
2. Imagery provided through Langan's subscription to Nearmap.com. Flown 10/6/2025.
3. Parcel boundaries are provided by the Delaware County Office of Data and Mapping Innovation (ODMI).
4. Monitoring well and soil boring locations per survey data provided by Environsure.
5. Streams and waterbodies are provided by the National Hydrography Dataset (NHD).
6. Structure outlines provided by the Federal Emergency Management Agency (FEMA) Geospatial Response Office and Oak Ridge National Laboratory (ORNL).

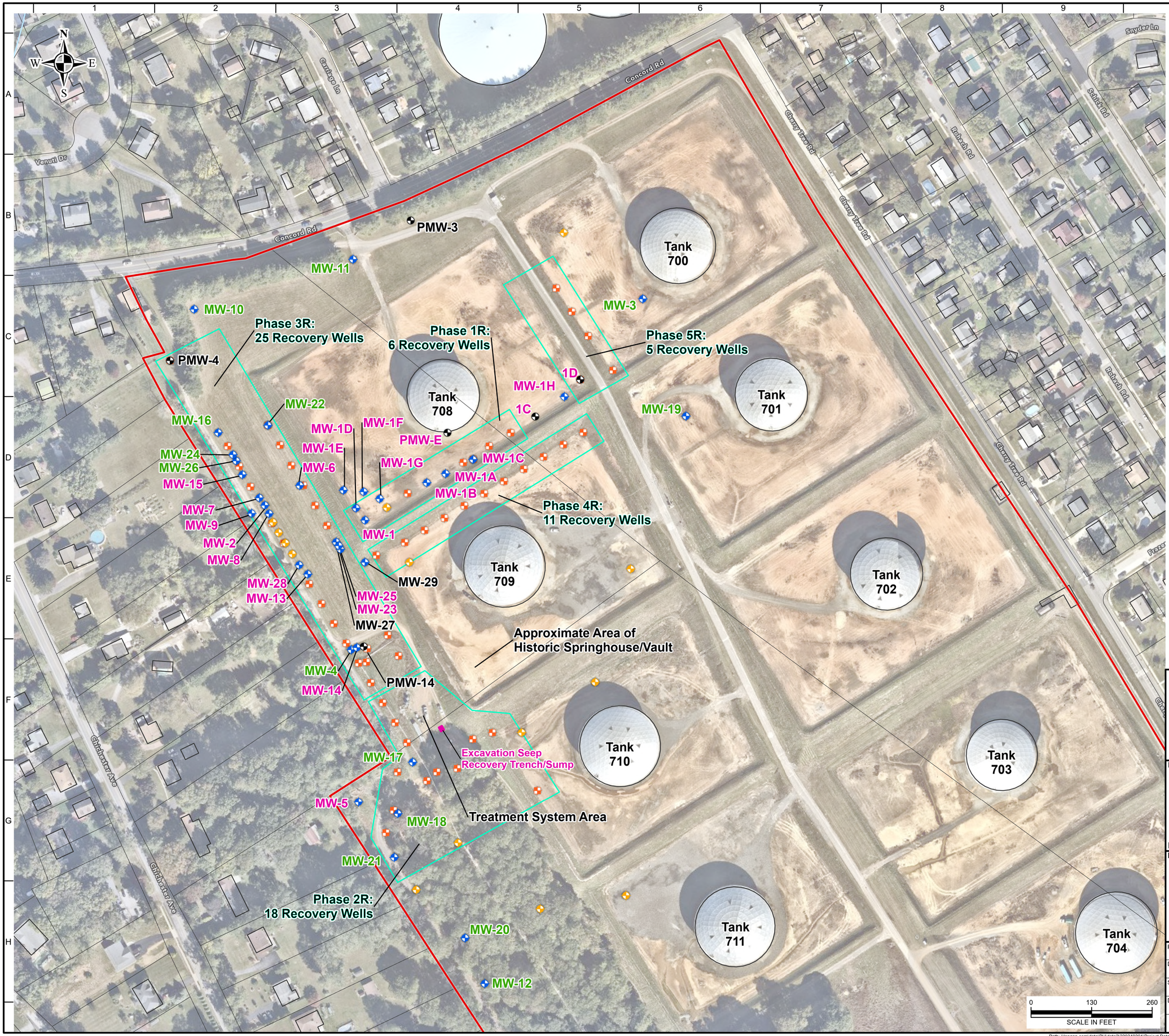
LANGAN
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Project
MIPC CHELSEA FACILITY
920 CHERRY TREE ROAD
ASTON TOWNSHIP
DELAWARE COUNTY PENNSYLVANIA

Drawing Title
EXISTING AND PROPOSED WELL INSTALLATIONS

Project No. 220240201	Figure 2
Date 2/19/2026	
Scale 1"=130'	
Drawn By CH	

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Legend

- Approximate Intial Investigation Exploratory Soil Boring Location
- Proposed Monitoring Well Location
- Approximate Monitoring Well Location
- Proposed Recovery Well Location
- Recovery Well Installation Phase Boundaries
- Site Boundary
- Structure
- Stream
- Parcel Boundary

Notes:
Green Sample ID – No LNAPL Encountered in Well/Boring
Pink Sample ID – LNAPL Encountered in Well/Boring

1. All site feature locations are approximate.
2. Imagery provided through Langan's subscription to Nearmap.com. Flown 10/9/2025.
3. Parcel boundaries are provided by the Delaware County Office of Data and Mapping Innovation (ODMI).
4. Monitoring well and soil boring locations per survey data provided by Envirosure.
5. Streams and waterbodies are provided by the National Hydrography Dataset (NHD).
6. Structure outlines provided by the Federal Emergency Management Agency (FEMA) Geospatial Response Office and Oak Ridge National Laboratory (ORNL).

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Project

MIPC CHELSEA FACILITY

920 CHERRY TREE ROAD
ASTON TOWNSHIP

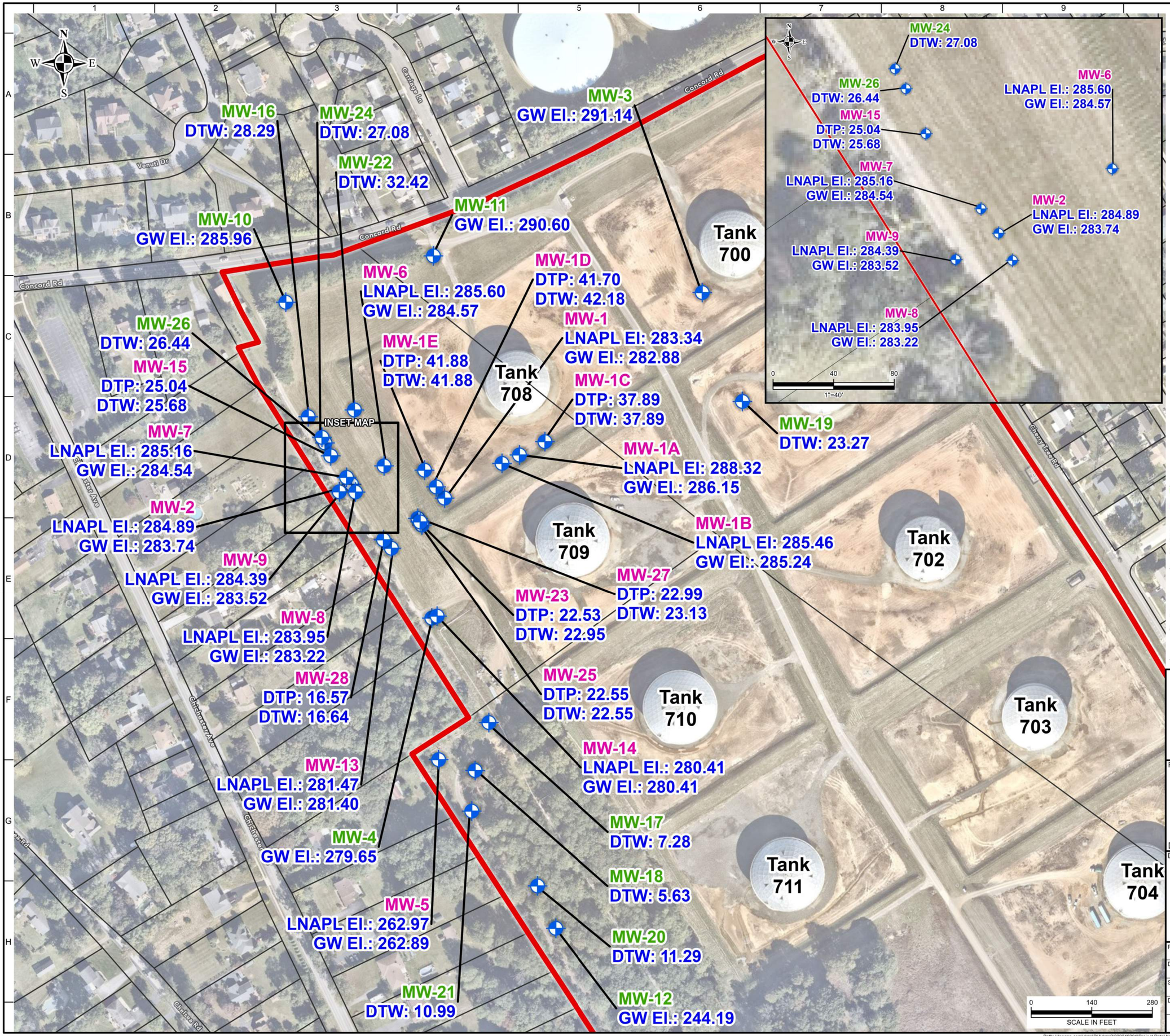
DELAWARE COUNTY PENNSYLVANIA

Drawing Title

ONSITE EXISTING AND PROPOSED WELL INSTALLATIONS

Project No. 220240201	Figure 2A
Date 2/20/2026	
Scale 1"=130'	
Drawn By CH	

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Legend

- Approximate Monitoring Well Location and ID
- Site Boundary
- Parcel Boundary

Notes:
Green Sample ID – No LNAPL Encountered in Well/Boring
Pink Sample ID – LNAPL Encountered in Well/Boring

1. All site feature locations are approximate.
2. Imagery provided through Langan's subscription to Nearmap.com. Flown 10/9/2025.
3. Parcel boundaries are provided by the Delaware County Office of Data and Mapping Innovation (ODMI).
4. Per US EPA guidance, depth-to-groundwater has been corrected to account for presence of gasoline Light Non-Aqueous Phase Liquid (LNAPL) using the formula: Corrected Depth-to-Water = Measured Depth-to-Water - (Product Thickness x Specific Gravity of Product). A specific gravity of 0.7 was used for gasoline product.
5. Product elevation and groundwater elevation are measured in ft NAVD 88.
6. For wells not yet surveyed, depth-to-LNAPL (DTP), where encountered, and corrected depth-to-groundwater (DTW) and are reported as feet below top of casing.

ft - feet

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MIPC CHELSEA FACILITY

920 CHERRY TREE ROAD
ASTON TOWNSHIP
DELAWARE COUNTY PENNSYLVANIA

Drawing Title

GROUNDWATER GAUGING DATA - FEBRUARY 16, 2026

Project No. 220240201	Figure 3
Date 2/19/2026	
Scale 1"=140'	
Drawn By CH	

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TABLES

Table 1
Well Construction and Groundwater Gauging Data Summary
MIPC Chelsea Facility
920 Cherry Tree Road, Aston Township, Delaware County, Pennsylvania 19014
Project No.: 220240201

Date 2/16/2026
Site MIPC Chelsea Facility - Aston, PA
Personnel Zayne Aniszewski

Well ID	Well Construction								Gauging Data				Survey Elevations			
	Driller	Date Well Installed	PVC Casing Diameter (inches)	Surface Completion	Top of Screen Depth (ft bgs)	Bottom of Screen Depth (ft bgs)	Screen Length (ft)	Total Well Depth (ft bgs)	Depth to Product (ft btoc)	Depth to Water (ft btoc)	Apparent Product Thickness (ft)	Corrected Depth to Groundwater (ft btoc)*	TOC Survey Elevation (ft NAVD 88)	Bottom of Well Elevation (ft NAVD 88)	Product Elevation (ft NAVD 88)	Groundwater Elevation (ft NAVD 88)
MW-1	Eichelbergers	11/25/2025	2	Stick-up Casing	25	45	20	45	41.99	43.54	1.55	42.46	325.33	280.33	283.34	282.88
MW-1A	Eichelbergers	12/22/2025	4	Stick-up Casing	26	46	20	46	36.62	43.86	7.24	38.79	324.94	278.94	288.32	286.15
MW-1B	Eichelbergers	12/17/2025	4	Stick-up Casing	27	47	20	47	39.48	40.20	0.72	39.70	324.94	277.94	285.46	285.24
MW-1C	Summit	2/5/2026	4	Stick-up Casing	25.5	50.5	25	50.5	37.89	37.90	0.01	37.89	NS	NS	NS	NS
MW-1D	Summit	2/9/2026	4	Stick-up Casing	30.3	50.3	20	50.3	41.70	43.29	1.59	42.18	NS	NS	NS	NS
MW-1E	Summit	2/11/2026	4	Stick-up Casing	30	50	20	50	41.88	41.89	0.01	41.88	NS	NS	NS	NS
MW-1F	Summit	2/13/2026	4	Stick-up Casing	30	50	20	50	NP	42.32	NP	NA	NS	NS	NS	NS
MW-2	Eichelbergers	12/3/2025	4	Stick-up Casing	11	31	20	31	22.30	26.13	3.83	23.45	307.19	276.19	284.89	283.74
MW-3	Eichelbergers	12/5/2025	2	Stick-up Casing	21	41	20	41	NP	28.94	NP	NA	320.08	279.08	NP	291.14
MW-4	Eichelbergers	12/8/2025	4	Flushmount	4	24	20	24	NP	5.20	NP	NA	284.85	260.85	NP	279.65
MW-5	Eichelbergers	12/9/2025	4	Flushmount	3	15	12	15	5.71	5.79	0.08	5.73	268.68	253.68	262.97	262.89
MW-6	Eichelbergers	12/10/2025	4	Flushmount	14	34	20	34	26.85	30.29	3.44	27.88	312.45	278.45	285.6	284.57
MW-7	Eichelbergers	12/11/2025	4	Stick-up Casing	10	30	20	30	22.62	24.69	2.07	23.24	307.78	277.78	285.16	284.54
MW-8	Eichelbergers	12/15/2025	4	Stick-up Casing	10.5	30.5	20	30.5	22.42	24.85	2.43	23.15	306.37	275.87	283.95	283.22
MW-9	AWT	12/16/2025	4	Stick-up Casing	10.5	30.5	20	30.5	23.01	25.90	2.89	23.88	307.40	276.90	284.39	283.52
MW-10	AWT	12/17/2025	4	Stick-up Casing	22	42	20	42	NP	38.40	NP	NA	324.36	282.36	NP	285.96
MW-11	AWT	12/19/2025	4	Stick-up Casing	19	39	20	39	NP	41.18	NP	NA	331.78	292.78	NP	290.60
MW-12	AWT	12/20/2025	4	Stick-up Casing	3	15	12	15	NP	9.74	NP	NA	253.93	238.93	NP	244.19
MW-13	AWT	12/20/2025	4	Stick-up Casing	10	30	20	30	16.32	16.56	0.24	16.39	297.79	267.79	281.47	281.40
MW-14	EPI	1/14/2026	4	Stick-up Casing	3	15	12	15	6.18	6.19	0.01	6.18	286.59	271.59	280.41	280.41
MW-15	AWT	1/16/2026	4	Stick-up Casing	15	37	22	37	25.04	27.18	2.14	25.68	NS	NS	NS	NS
MW-16	AWT	1/20/2026	4	Stick-up Casing	15	40	25	40	NP	28.29	NP	NA	NS	NS	NS	NS
MW-17	AWT	1/23/2026	4	Stick-up Casing	4.5	19.5	15	19.5	NP	7.28	NP	NA	NS	NS	NS	NS
MW-18	AWT	1/28/2026	4	Stick-up Casing	5	20	15	20	NP	5.63	NP	NA	NS	NS	NS	NS
MW-19	Summit	1/29/2026	4	Stick-up Casing	15	30	15	30	NP	23.27	NP	NA	NS	NS	NS	NS
MW-20	AWT	2/2/2026	4	Stick-up Casing	5	20	15	20	NP	11.29	NP	NA	NS	NS	NS	NS
MW-21	AWT	2/3/2026	4	Stick-up Casing	5	19	14	19	NP	10.99	NP	NA	NS	NS	NS	NS
MW-22	Cascade	2/4/2026	4	Stick-up Casing	30	50	20	50	NP	32.42	NP	NA	NS	NS	NS	NS
MW-23	AWT	2/5/2026	4	Stick-up Casing	5	30	25	30	22.53	23.94	1.41	22.95	NS	NS	NS	NS
MW-24	Cascade	2/6/2026	4	Stick-up Casing	15	36	21	36	NP	27.08	NP	NA	NS	NS	NS	NS
MW-25	AWT	2/9/2026	4	Stick-up Casing	15	35	20	35	22.55	22.56	0.01	22.55	NS	NS	NS	NS
MW-26	Cascade	2/10/2026	4	Stick-up Casing	15	35	20	35	NP	26.44	NP	NA	NS	NS	NS	NS
MW-27	AWT	2/10/2026	4	Stick-up Casing	15	35	20	35	22.99	23.47	0.48	23.13	NS	NS	NS	NS
MW-28	Cascade	2/11/2026	4	Stick-up Casing	8.5	28.5	20	28.5	16.57	16.80	0.23	16.64	NS	NS	NS	NS
MW-29	AWT	2/13/2026	4	Stick-up Casing	10	34	24	34	20.97	22.75	1.78	21.50	NS	NS	NS	NS

Notes:

bgs	Below ground surface	NAVD 88	North American Vertical Datum of 1988	NP	No product
btoc	Below top of casing	NA	Not applicable	NS	Not surveyed
ft	Feet	NG	Not gauged	TOC	Top of casing
ID	Identification	NM	Not measured		

Survey data was collected on December 18, 2025, and January 16, 2026.

* Per US EPA guidance, depth-to-groundwater has been corrected to account for presence of gasoline Light Non-Aqueous Phase Liquid (LNAPL) using the formula: Corrected Depth-to-Water = Measured Depth-to-Water - (Product Thickness x Specific Gravity of Product). A specific gravity of 0.7 was used for gasoline product.

Table 2
Well Construction Summary and Rationale
MIPC Chelsea Facility
920 Cherry Tree Road, Aston Township, Delaware County, Pennsylvania 19014
Project No.: 220240201

Well ID	Well Construction					Survey Elevations		Measureable LNAPL Present?	Rationale
	Driller	Date Well Installed	PVC Casing Diameter (inches)	Screen Length (ft)	Total Well Depth (ft bgs)	TOC Survey Elevation (ft NAVD 88)	Ground Surface Elevation (ft NAVD 88)		
Tank 708 Dike Area Recovery Wells									
MW-1	Eichelbergers	11/25/2025	2	20	45	325.33	322.71	Yes	LNAPL Recovery
MW-1A	Eichelbergers	12/22/2025	4	20	46	324.94	322.82	Yes	LNAPL Recovery
MW-1B	Eichelbergers	12/17/2025	4	20	47	324.94	322.85	Yes	LNAPL Recovery
MW-1C	Summit	2/5/2026	4	25	50.5	NS	NS	Yes	LNAPL Recovery
MW-1D	Summit	2/9/2026	4	20	50.3	NS	NS	Yes	LNAPL Recovery
MW-1E	Summit	2/11/2026	4	20	50	NS	NS	Yes	LNAPL Recovery
MW-1F	Summit	2/13/2026	4	20	50	NS	NS	Yes	LNAPL Recovery
Western Boundary Core Recovery Wells									
MW-2	Eichelbergers	12/3/2025	4	20	31	307.19	305.24	Yes	LNAPL Recovery
MW-7	Eichelbergers	12/11/2025	4	20	30	307.78	306.05	Yes	LNAPL Recovery
MW-8	Eichelbergers	12/15/2025	4	20	30.5	306.37	304.51	Yes	LNAPL Recovery
MW-9	AWT	12/16/2025	4	20	30.5	307.40	305.10	Yes	LNAPL Recovery
Potential Recovery Wells									
MW-6	Eichelbergers	12/10/2025	4	20	34	312.45	312.76	Yes	LNAPL Recovery
MW-13	AWT	12/20/2025	4	20	30	297.79	294.96	Yes	LNAPL Recovery
MW-14	EPI	1/14/2026	4	12	15	286.59	285.84	Yes	LNAPL Recovery
MW-15	AWT	1/16/2026	4	22	37	NS	NS	Yes	LNAPL Recovery
MW-23	AWT	2/5/2026	4	25	30	NS	NS	Yes	LNAPL Recovery
MW-25	AWT	2/9/2026	4	20	35	NS	NS	Yes	LNAPL Recovery
MW-27	AWT	2/10/2026	4	20	35	NS	NS	Yes	LNAPL Recovery
MW-28	Cascade	2/11/2026	4	20	28.5	NS	NS	Yes	LNAPL Recovery
MW-29	AWT	2/13/2026	4	10	34	NS	NS	Yes	LNAPL Recovery
Delineation Wells									
MW-3	Eichelbergers	12/5/2025	2	20	41	320.08	317.67	No	Eastern LNAPL Delineation
MW-5	Eichelbergers	12/9/2025	4	12	15	268.68	269.13	No	Southern LNAPL Delineation
MW-10	AWT	12/17/2025	4	20	42	324.36	321.92	No	Northern LNAPL Delineation
MW-12	AWT	12/20/2025	4	12	15	253.93	251.07	No	Southern LNAPL Delineation
MW-16	AWT	1/20/2026	4	25	40	NS	NS	No	Western LNAPL Delineation
MW-18	AWT	1/28/2026	4	15	20	NS	NS	No	Southern LNAPL Delineation
MW-19	Summit	1/29/2026	4	15	30	NS	NS	No	Eastern LNAPL Delineation
MW-20	AWT	2/2/2026	4	15	20	NS	NS	No	Southern LNAPL Delineation
MW-21	AWT	2/3/2026	4	14	19	NS	NS	No	Southern LNAPL Delineation
Dissolved-Phase Monitoring / LNAPL Delineation Wells									
MW-4	Eichelbergers	12/8/2025	4	20	24	284.85	285.28	No	Southern LNAPL Delineation / Dissolved-Phase Monitoring
MW-11	AWT	12/19/2025	4	20	39	331.78	328.80	No	Northern LNAPL Delineation / Dissolved-Phase Monitoring
MW-16	AWT	1/20/2026	4	25	40	NS	NS	No	Western LNAPL Delineation / Dissolved-Phase Monitoring
MW-17	AWT	1/23/2026	4	15	19.5	NS	NS	No	Southern LNAPL Delineation / Dissolved-Phase Monitoring
MW-22	Cascade	2/4/2026	4	20	50	NS	NS	No	Northwestern LNAPL Delineation / Dissolved-Phase Monitoring
MW-24	Cascade	2/6/2026	4	21	36	NS	NS	No	Northwestern LNAPL Delineation / Dissolved-Phase Monitoring
MW-26	Cascade	2/10/2026	4	20	35	NS	NS	No	Northwestern LNAPL Delineation / Dissolved-Phase Monitoring

Notes:
bgs = below ground surface
btoc = below top of casing
ft = feet
ID = identification
NAVD 88 = North American Vertical Datum of 1988
NA = not applicable / not available
NS = not surveyed
TOC = top of casing

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	MW-2					MW-2					PMW-1					PMW-1					PMW-1A				
					Sample Name	MW-2_19.5-20					MW-2_21.5-22					PMW-1_29-30					PMW-1_32-35					PMW-1A_28-29				
					Sample Date	12/04/2025					12/04/2025					11/19/2025					11/19/2025					11/19/2025				
					Sample Depth	19.5-20					21.5-22					29-30					32-35					28-29				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	270		0.98	4.3	2000	2.9		0.024	0.11	50	0.071	J	0.021	0.09	50	160		0.27	1.2	500	27		0.045	0.19	100
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	80		1.1	4.3	2000	0.86		0.026	0.11	50	ND	U	0.022	0.09	50	44		0.29	1.2	500	8		0.048	0.19	100
Benzene	71-43-2	330	0.5	0.013	mg/kg	**140**		*0.86*	*4.3*	2000	**7.7**		*0.021*	*0.11*	50	0.2		*0.018*	*0.09*	50	**55**		*0.24*	*1.2*	500	**3.5**		*0.039*	*0.19*	100
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	**130**		1.3	4.3	2000	1.8		0.032	0.11	50	0.07	J	0.027	0.09	50	**76**		0.35	1.2	500	11		0.058	0.19	100
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	12		1.4	4.3	2000	0.13		0.034	0.11	50	ND	U	0.029	0.09	50	7.3		0.38	1.2	500	1.2		0.062	0.19	100
Naphthalene	91-20-3	77	25	2.5	mg/kg	**61**		*3.8*	*4.3*	2000	0.43		0.093	0.11	50	ND	U	0.079	0.09	50	13		1	1.2	500	2.4		0.17	0.19	100
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	*0.91*	*4.3*	2000	ND	U	0.023	0.11	50	ND	U	0.019	0.09	50	ND	U	*0.25*	*1.2*	500	ND	U	0.041	*0.19*	100
Toluene	108-88-3	10000	100	4.4	mg/kg	**770**		1.1	4.3	2000	17		0.026	0.11	50	0.72		0.022	0.09	50	**370**		0.29	1.2	500	40		0.048	0.19	100
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	850		1.2	8.5	2000	12		0.03	0.21	50	0.41		0.025	0.18	50	500		0.33	2.3	500	76		0.054	0.39	100
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					NA					NA					NA				

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	PMW-1A					PMW-1B					PMW-1B					PMW-1C					PMW-1C				
					Sample Name	PMW-1A_31-32					PMW-1B_28-29					PMW-1B_31-32					PMW-1C_25-26					PMW-1C_32-33				
					Sample Date	11/19/2025					11/19/2025					11/19/2025					11/20/2025					11/20/2025				
					Sample Depth	31-32					28-29					31-32					25-26					32-33				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	**350**		0.51	2.2	1000	ND	U	0.023	0.1	50	0.14		0.028	0.12	50	0.11	J	0.031	0.14	50	0.3		0.023	0.1	50
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	**99**		0.56	2.2	1000	ND	U	0.025	0.1	50	ND	U	0.03	0.12	50	ND	U	0.034	0.14	50	0.071	J	0.025	0.1	50
Benzene	71-43-2	330	0.5	0.013	mg/kg	**30**		*0.45*	*2.2*	1000	ND	U	*0.021*	*0.1*	50	0.14		*0.025*	*0.12*	50	**0.63**		*0.028*	*0.14*	50	**4.9**		*0.02*	*0.1*	50
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	**140**		0.67	2.2	1000	ND	U	0.03	0.1	50	0.067	J	0.036	0.12	50	0.096	J	0.041	0.14	50	0.46		0.03	0.1	50
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	16		0.71	2.2	1000	ND	U	0.032	0.1	50	ND	U	0.039	0.12	50	ND	U	0.044	0.14	50	ND	U	0.032	0.1	50
Naphthalene	91-20-3	77	25	2.5	mg/kg	19		2	2.2	1000	ND	U	0.089	0.1	50	ND	U	0.11	0.12	50	ND	U	0.12	0.14	50	0.12		0.088	0.1	50
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	*0.48*	*2.2*	1000	ND	U	0.022	0.1	50	ND	U	0.026	0.12	50	ND	U	0.029	0.14	50	ND	U	0.021	0.1	50
Toluene	108-88-3	10000	100	4.4	mg/kg	**390**		0.56	2.2	1000	ND	U	0.025	0.1	50	0.47		0.03	0.12	50	1.1		0.034	0.14	50	8.3		0.025	0.1	50
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	920		0.63	4.5	1000	0.032	J	0.028	0.2	50	0.45		0.034	0.24	50	0.57		0.038	0.27	50	2.8		0.028	0.2	50
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					NA					NA					NA				

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	PMW-1D					PMW-1D					PMW-1E					PMW-1E					PMW-1F				
					Sample Name	PMW-1D_30-31					PMW-1D_31-32					PMW-1E_SHALLOW					PMW-1E_DEEP					PMW-1F_SHALLOW				
					Sample Date	11/20/2025					11/20/2025					11/21/2025					11/21/2025					11/21/2025				
					Sample Depth	30-31					31-32					28-29					31-32					24-25				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	ND	U	0.026	0.11	50	0.11	J	0.03	0.13	50	16		0.033	0.14	50	4		0.033	0.14	50	ND	U	0.028	0.12	50
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	ND	U	0.029	0.11	50	ND	U	0.033	0.13	50	4.3		0.036	0.14	50	1.1		0.036	0.14	50	ND	U	0.03	0.12	50
Benzene	71-43-2	330	0.5	0.013	mg/kg	ND	U	*0.023*	*0.11*	50	0.18		*0.027*	*0.13*	50	**16**		*0.029*	*0.14*	50	**10**		*0.029*	*0.14*	50	ND	U	*0.024*	*0.12*	50
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	ND	U	0.034	0.11	50	0.067	J	0.039	0.13	50	9.4		0.043	0.14	50	1.9		0.043	0.14	50	ND	U	0.036	0.12	50
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.037	0.11	50	ND	U	0.042	0.13	50	0.81		0.046	0.14	50	0.19		0.046	0.14	50	ND	U	0.039	0.12	50
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.1	0.11	50	ND	U	0.12	0.13	50	0.96		0.13	0.14	50	0.6		0.13	0.14	50	ND	U	0.11	0.12	50
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.025	0.11	50	ND	U	0.028	0.13	50	ND	U	0.031	0.14	50	ND	U	0.03	0.14	50	ND	U	0.026	0.12	50
Toluene	108-88-3	10000	100	4.4	mg/kg	ND	U	0.029	0.11	50	0.5		0.033	0.13	50	57		0.036	0.14	50	17		0.036	0.14	50	ND	U	0.03	0.12	50
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	ND	U	0.032	0.23	50	0.36		0.037	0.26	50	58		0.04	0.29	50	12		0.04	0.28	50	ND	U	0.034	0.24	50
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					NA					NA					NA				

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	PMW-1F					PMW-1G					PMW-1G					PMW-3					PMW-3				
					Sample Name	PMW-1F_DEEP					PMW-1G_SHALLOW					PMW-1G_DEEP					PMW-3_16-16.5					PMW-3_17-17.5				
					Sample Date	11/21/2025					11/24/2025					11/24/2025					12/04/2025					12/04/2025				
					Sample Depth	30-31					29-30					31-32					16-16.5					17-17.5				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	ND	U	0.025	0.11	50	ND	U	0.025	0.11	50	23		0.047	0.21	100	ND	U	0.027	0.12	50	ND	U	0.024	0.1	50
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	ND	U	0.027	0.11	50	ND	U	0.028	0.11	50	7.2		0.051	0.21	100	ND	U	0.03	0.12	50	ND	U	0.026	0.1	50
Benzene	71-43-2	330	0.5	0.013	mg/kg	ND	U	*0.022*	*0.11*	50	0.023	J	*0.022*	*0.11*	50	**10**		*0.042*	*0.21*	100	ND	U	*0.024*	*0.12*	50	ND	U	*0.021*	*0.1*	50
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	ND	U	0.033	0.11	50	ND	U	0.033	0.11	50	13		0.062	0.21	100	ND	U	0.036	0.12	50	ND	U	0.031	0.1	50
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.035	0.11	50	ND	U	0.035	0.11	50	1.3		0.066	0.21	100	ND	U	0.038	0.12	50	ND	U	0.033	0.1	50
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.096	0.11	50	ND	U	0.097	0.11	50	1.9		0.18	0.21	100	ND	U	0.1	0.12	50	ND	U	0.092	0.1	50
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.023	0.11	50	ND	U	0.024	0.11	50	ND	U	0.044	*0.21*	100	ND	U	0.025	0.12	50	ND	U	0.022	0.1	50
Toluene	108-88-3	10000	100	4.4	mg/kg	ND	U	0.027	0.11	50	0.061	J	0.028	0.11	50	60		0.051	0.21	100	ND	U	0.03	0.12	50	ND	U	0.026	0.1	50
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	ND	U	0.03	0.22	50	ND	U	0.031	0.22	50	88		0.058	0.41	100	ND	U	0.033	0.24	50	ND	U	0.029	0.21	50
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					NA					NA					NA				

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	PMW-4					PMW-4					PMW-4A (MW-4)					PMW-4A (MW-4)					PMW-4B (MW-5)				
					Sample Name	PMW-4_15.5-16					PMW-4_17.5-18					PMW-4A_10-10.5					PMW-4A_12.5-13					PMW-4B_4.5-5				
					Sample Date	12/04/2025					12/04/2025					12/08/2025					12/08/2025					12/09/2025				
					Sample Depth	15.5-16					17.5-18					10-10.5					12.5-13					4.5-5				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	ND	U	0.023	0.1	50	ND	U	0.022	0.096	50	ND	U	0.034	0.15	50	ND	U	0.027	0.12	50	ND	U	0.021	0.093	50
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	ND	U	0.025	0.1	50	ND	U	0.024	0.096	50	ND	U	0.036	0.15	50	ND	U	0.029	0.12	50	ND	U	0.023	0.093	50
Benzene	71-43-2	330	0.5	0.013	mg/kg	ND	U	*0.02*	*0.1*	50	ND	U	*0.019*	*0.096*	50	ND	U	*0.029*	*0.15*	50	ND	U	*0.023*	*0.12*	50	ND	U	*0.019*	*0.093*	50
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	ND	U	0.03	0.1	50	ND	U	0.029	0.096	50	ND	U	0.044	0.15	50	ND	U	0.035	0.12	50	ND	U	0.028	0.093	50
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.032	0.1	50	ND	U	0.031	0.096	50	ND	U	0.047	0.15	50	ND	U	0.037	0.12	50	ND	U	0.03	0.093	50
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.089	0.1	50	ND	U	0.084	0.096	50	ND	U	0.13	0.15	50	ND	U	0.1	0.12	50	ND	U	0.082	0.093	50
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.022	0.1	50	ND	U	0.02	0.096	50	ND	U	0.031	*0.15*	50	ND	U	0.025	0.12	50	ND	U	0.02	0.093	50
Toluene	108-88-3	10000	100	4.4	mg/kg	ND	U	0.025	0.1	50	ND	U	0.024	0.096	50	ND	U	0.036	0.15	50	ND	U	0.029	0.12	50	ND	U	0.023	0.093	50
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	ND	U	0.028	0.2	50	ND	U	0.027	0.19	50	ND	U	0.041	0.29	50	ND	U	0.032	0.23	50	ND	U	0.026	0.19	50
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					NA					NA					NA				

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	PMW-4B (MW-5)					PMW-4C					PMW-4C					PMW-4D					PMW-4D				
					Sample Name	PMW-4B_6.5-7					PMW-4C_12-12.5					PMW-4C_26.5-27					PMW-4D_12.5-13					PMW-4D_16.5-17				
					Sample Date	12/09/2025					12/09/2025					12/09/2025					12/11/2025					12/11/2025				
					Sample Depth	6.5-7					12-12.5					26.5-27					12.5-13					16.5-17				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	ND	U	0.022	0.094	50	ND	U	0.023	0.1	50	1.7		0.031	0.13	50	ND	U	0.033	0.15	50	25		0.06	0.26	100
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	ND	U	0.024	0.094	50	ND	U	0.025	0.1	50	0.52		0.033	0.13	50	ND	U	0.036	0.15	50	7.4		0.066	0.26	100
Benzene	71-43-2	330	0.5	0.013	mg/kg	ND	U	*0.019*	*0.094*	50	ND	U	*0.02*	*0.1*	50	**3.1**		*0.027*	*0.13*	50	ND	U	*0.029*	*0.15*	50	0.36		*0.053*	*0.26*	100
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	ND	U	0.028	0.094	50	ND	U	0.03	0.1	50	0.93		0.04	0.13	50	ND	U	0.044	0.15	50	7.6		0.079	0.26	100
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.03	0.094	50	ND	U	0.032	0.1	50	0.076	J	0.043	0.13	50	ND	U	0.047	0.15	50	1		0.084	0.26	100
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.083	0.094	50	ND	U	0.089	0.1	50	ND	U	0.12	0.13	50	ND	U	0.13	0.15	50	1.6		0.23	0.26	100
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.02	0.094	50	ND	U	0.022	0.1	50	ND	U	0.029	0.13	50	ND	U	0.031	*0.15*	50	ND	U	0.056	*0.26*	100
Toluene	108-88-3	10000	100	4.4	mg/kg	ND	U	0.024	0.094	50	ND	U	0.025	0.1	50	7.2		0.033	0.13	50	ND	U	0.036	0.15	50	12		0.066	0.26	100
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	ND	U	0.026	0.19	50	ND	U	0.028	0.2	50	5.8		0.037	0.27	50	ND	U	0.041	0.29	50	55		0.074	0.53	100
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					NA					NA					NA				

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	PMW-4E					PMW-4E					SB-MW-9					SB-MW-9				
					Sample Name	PMW-4E_13.5-14					PMW-4E_15.5-16					SB-MW-9_16.0					SB-MW-9_16.5				
					Sample Date	12/12/2025					12/12/2025					12/15/2025					12/15/2025				
					Sample Depth	13.5-14					15.5-16					16-16.5					16.5-17				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																									
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	ND	U	0.027	0.12	50	ND	U	0.027	0.12	50	ND	U	0.00072	0.0029	1	ND	U	0.00078	0.0031	1
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	ND	U	0.03	0.12	50	ND	U	0.03	0.12	50	ND	U	0.00062	0.0029	1	ND	U	0.00067	0.0031	1
Benzene	71-43-2	330	0.5	0.013	mg/kg	ND	U	*0.024*	*0.12*	50	0.028	J	*0.024*	*0.12*	50	0.001		0.00066	0.00072	1	ND	U	0.00071	0.00078	1
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	ND	U	0.036	0.12	50	ND	U	0.035	0.12	50	ND	U	0.00066	0.0014	1	ND	U	0.0007	0.0016	1
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.038	0.12	50	ND	U	0.038	0.12	50	ND	U	0.0021	0.0029	1	ND	U	0.0022	0.0031	1
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.1	0.12	50	ND	U	0.1	0.12	50	ND	U	0.0036	0.0072	1	ND	U	0.0039	0.0078	1
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.025	0.12	50	ND	U	0.025	0.12	50	ND	U	0.00068	0.0014	1	ND	U	0.00073	0.0016	1
Toluene	108-88-3	10000	100	4.4	mg/kg	ND	U	0.03	0.12	50	0.067	J	0.03	0.12	50	0.0037		0.00076	0.0014	1	0.0015	J	0.00082	0.0016	1
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	ND	U	0.033	0.24	50	ND	U	0.033	0.24	50	0.0018		0.00066	0.0014	1	ND	U	0.00071	0.0016	1
General Chemistry																									
Solids, Percent	SOLID	NS	NS	NS	Percent	NA					NA					63.9			0	1	63			0	1

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	SB-MW-10					SB-MW-10					SB-MW-11					SB-MW-12					SB-MW-13				
					Sample Name	SB-MW-10_28					SB-MW-10_31					SB-MW-11_33					SB-MW-12_5.5					SB-MW-13_12				
					Sample Date	12/17/2025					12/17/2025					12/18/2025					12/19/2025					12/20/2025				
					Sample Depth	28-28.5					31-31.5					33-33.5					5.5-6					12-12.5				
					Saturation	Unsaturated					Unsaturated					Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																													
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	ND	U	0.00065	0.0026	1	0.002		0.00048	0.0019	1	ND	U	0.00052	0.0021	1	ND	U	0.00053	0.0021	1	11.6		0.099	0.4	1
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	ND	U	0.00056	0.0026	1	0.00057	J	0.00042	0.0019	1	ND	U	0.00045	0.0021	1	ND	U	0.00045	0.0021	1	3.34		0.085	0.4	1
Benzene	71-43-2	330	0.5	0.013	mg/kg	ND	U	0.0006	0.00065	1	ND	U	0.00044	0.00048	1	0.00092		0.00047	0.00052	1	ND	U	0.00048	0.00053	1	**20.1**		*0.09*	*0.099*	1
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	ND	U	0.00059	0.0013	1	0.00069	J	0.00044	0.00097	1	ND	U	0.00047	0.001	1	ND	U	0.00048	0.0011	1	7.64		0.09	0.2	1
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.0019	0.0026	1	ND	U	0.0014	0.0019	1	ND	U	0.0015	0.0021	1	ND	U	0.0015	0.0021	1	0.6		0.28	0.4	1
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.0033	0.0065	1	ND	U	0.0024	0.0048	1	ND	U	0.0026	0.0052	1	ND	U	0.0026	0.0053	1	0.62	J	0.49	0.99	1
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.00061	0.0013	1	ND	U	0.00045	0.00097	1	ND	U	0.00049	0.001	1	ND	U	0.00049	0.0011	1	ND	U	0.093	*0.2*	1
Toluene	108-88-3	10000	100	4.4	mg/kg	ND	U	0.00069	0.0013	1	0.0018		0.00051	0.00097	1	ND	U	0.00055	0.001	1	ND	U	0.00055	0.0011	1	57.6		1	2	1
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	ND	U	0.0006	0.0013	1	0.0043		0.00044	0.00097	1	ND	U	0.00048	0.001	1	ND	U	0.00048	0.0011	1	45.5		0.091	0.2	1
General Chemistry																													
Solids, Percent	SOLID	NS	NS	NS	Percent	70.8			0	1	83.5			0	1	82.8			0	1	79			0	1	62.2			0	1

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Analyte	CAS Number	PADEP Non-Residential Direct Contact MSC (2-15 Ft)	PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated	PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values	Location	SB-MW-14					SB-MW-14					SB-MW-15				
					Sample Name	SB-MW-14_11					SB-MW-14_12					SB-MW-15_20.5				
					Sample Date	01/13/2026					01/13/2026					01/16/2026				
					Sample Depth	11-11.5					12-12.5					20.5-21				
					Saturation	Unsaturated					Unsaturated					Unsaturated				
					Unit	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF	Result	Q	MDL	RL	DF
Volatile Organic Compounds																				
1,2,4-Trimethylbenzene	95-63-6	5400	300	30	mg/kg	0.0093		0.00068	0.0027	1	0.0304		0.00053	0.0021	1	9.28		0.09	0.36	1
1,3,5-Trimethylbenzene	108-67-8	5400	93	9.3	mg/kg	0.0021	J	0.00059	0.0027	1	0.0069		0.00046	0.0021	1	2.73		0.079	0.36	1
Benzene	71-43-2	330	0.5	0.013	mg/kg	0.201		0.00062	0.00068	1	**0.66**		*0.052*	*0.057*	1	**2.77**		*0.083*	*0.09*	1
Ethylbenzene	100-41-4	1000	70	4.6	mg/kg	0.0151		0.00062	0.0014	1	0.0529		0.00048	0.0011	1	4.94		0.083	0.18	1
Isopropylbenzene (Cumene)	98-82-8	10000	2500	250	mg/kg	ND	U	0.0019	0.0027	1	ND	U	0.0015	0.0021	1	0.456		0.26	0.36	1
Naphthalene	91-20-3	77	25	2.5	mg/kg	ND	U	0.0034	0.0068	1	0.0045	J	0.0026	0.0053	1	0.563	J	0.47	0.9	1
Tert-Butyl Methyl Ether (MTBE)	1634-04-4	9800	2	0.14	mg/kg	ND	U	0.00064	0.0014	1	ND	U	0.0005	0.0011	1	ND	U	0.083	*0.18*	1
Toluene	108-88-3	10000	100	4.4	mg/kg	0.255		0.00072	0.0014	1	0.678		0.06	0.11	1	20.1		0.094	0.18	1
Total Xylenes	1330-20-7	9100	1000	99	mg/kg	0.112		0.00062	0.0014	1	0.39		0.00048	0.0011	1	31.1		0.083	0.18	1
General Chemistry																				
Solids, Percent	SOLID	NS	NS	NS	Percent	73.4			0	1	92.8			0	1	64.2		0	0	1

See notes on last pate.

Table 3
Soil Sample Analytical Results Summary
MIPC Chelsea Facility
920 Cherry Tree Rd, Aston, PA
Langan Project No.: 220240201

Notes:
Soil samples were compared to the PADEP MSCs and Vapor Intrusion Screening Values (1/10th) (November 2021)
PADEP - Pennsylvania Department of Environmental Protection
MSC - Medium Specific Concentrations
SHS - Statewide Health Standards (PA Act 2 Program)
TDS - Total Dissolved Solids
CAS - Chemical Abstract Service
NS - No standard
mg/kg - Milligrams per kilogram
ND - Not detected
Q - Qualifier
MDL - Method detection limit
RL - Reporting Limit
DF - Dilution factor

Qualifiers:
J – The analyte was positively identified and the associated numerical value is the approximate concentration of the analyte in the sample.
U – The analyte was analyzed for, but was not detected at a level greater than or equal to the level of the RL or the sample concentration for results impacted by blank contamination.

Exceedance Summary:
10 - Result exceeds PADEP Non-Residential Direct Contact (2-15 Ft)
10 - Result exceeds PADEP Non-Residential Soil to Groundwater MSC Used Aquifer TDS <=2500 mg/l Unsaturated
10 - Result exceeds PADEP Non-Residential Soil SHS Vapor Intrusion 1/10 Screening Values
10 - MDL or RL greater than the applicable standard

APPENDICES

Appendix A

Health and Safety Plan

HEALTH AND SAFETY PLAN
MIPC CHELSEA FACILITY

920 Cherry Tree Road
Aston, Delaware County, PA 19014

Prepared for:

MIPC Petrol Distribution Terminal- Chelsea Facility
920 Cherry Tree Road
Aston, Delaware County, PA 19014

Prepared by:

Langan Engineering and Environmental Services, LLC
1818 Market Street, Suite 3300
Philadelphia, Pennsylvania 19103

Ver. R3
February 20, 2025
Project Number: 220240201

Health and Safety Plan (HASP) Revision Log

Date	Draft Identification or Revision Number	Description	Author
December 5, 2025	Original		Ryan Hall
January 9, 2026	R1	Updated HASP to align with Langan's Oil & Gas Program	Daniel Danehy
February 9, 2026	R2	Updated text establishing work exclusion zones (6.9) and breathing-zone monitoring in active work areas (8.2)	Jean-Paul Antoine, Daniel Danehy
February 20, 2026	R3	Added section 9.3 – Half-face respirator requirements when working near WTU; included references to the Lone Worker Policy for Perimeter Air Monitoring (2.9), included as Appendix X	Daniel Danehy

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***** Items to be posted prominently on site or made readily available to personnel.

1.0 INTRODUCTION

Langan Engineering and Environmental Services, LLC (Langan) is committed to providing a safe and healthful work environment. Langan's goal is to be SAFE (Stay Accident Free Everyday), meaning that we strive to complete every project without injury, illness, property damage, or environmental damage. Safety must always take precedence over expediency. No phase of the planned operation is more important than accident prevention. As such, high standards have been followed in developing the safety program for this project. Through adherence to the safety program, careful planning, and a positive safety attitude by workers; Langan asserts that the safety of people and property is of the utmost importance.

This Health and Safety Plan (HASP) has been developed by Langan to comply with Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.120(b)(4), *Hazardous Waste Operations and Emergency Response*, and Langan policies/procedures, and the *Langan-MIPC Health, Safety and Environment (HSE) Program Plan*. In addition, Langan will comply with federal, state, and local regulations as applicable to the project. Compliance with this HASP is required of all Langan personnel and subcontractors.

The management of the day-to-day site activities and implementation of this HASP in the field is the responsibility of the site Health and Safety Officer (HSO). Assistance in the implementation of this HASP can also be obtained from the Langan Health and Safety Manager (HSM). The content of this HASP may change or undergo revision based upon additional information made available to health and safety personnel, monitoring results, or changes in the scope of work.

2.0 EMERGENCY RESPONSE PLAN

2.1 General

This Emergency Response Plan has been developed as part of the HASP to address management of emergency situations such as injury or chemical exposure to personnel; fire or explosion; environmental release; security threat, or serious weather conditions. In all cases, reference **Table 1** for the emergency notification master contact list.

In the event of an incident or injury, responding employees must assure personal safety and security at the site, then immediately contact the Langan Incident/Injury Hotline at 1-800-9LANGAN ext. 4699 following an incident or near miss to support notifications and emergency response outlined in Figure 1.2.2.

Responsibilities

2.2.1 Site Emergency Coordinator - The HSO, or his/her alternate, will serve as the Site Emergency Coordinator and shall implement emergency procedures whenever conditions warrant such action. The Site Emergency Coordinator will be responsible for assuring the evacuation, emergency treatment, emergency transport of site personnel, and notification of emergency units and the appropriate management staff. Emergency response instructions will be provided by the HSO as part of every employee's training prior to the start of work.

2.2.2 Employees - All employees at the site will be familiar with emergency response procedures for this work location.

2.3 Emergency Medical Treatment

Personnel Injury - In case of injury to personnel, Langan or subcontractor site personnel with first aid / CPR / AED training will immediately administer emergency first aid.. The ambulance/rescue squad will also be contacted as necessary. Some situations may require transport of the injured parties to the closest emergency medical facility. Therefore, maps/directions to the nearest hospital are provided as **Figure 2** and **Figure 3**. **Figure 2** and **Figure 3** will either be posted at the site, or will be made readily available to all personnel all of the time.

In emergency cases requiring first aid treatment, including the use of a defibrillator, use

shall be provided by a trained/designated first aid responder and treatment shall start within 4 minutes. Employees who are injured and need to be transported to the hospital shall be assessed and stabilized by a medical professional within one hour and admitted to and receive medical care within 4 hours. If the project team is not able to meet response times, Langan's Corporate HSM, Langan Principal-in-Charge, and the Client Owner must approve the response plan.

Personnel Exposure – If there is exposure to a chemical, follow procedures on the corresponding Safety Data Sheet (SDS) attached to **Appendix E** and seek emergency medical attention/poison control: if warranted based on the severity of the exposure. The following provides general emergency first aid procedures for chemical exposure.

Skin Contact:	Use ample amounts of soap and water. Wash/rinse affected areas thoroughly, then provide appropriate medical attention. Rinse eyes with water for at least 15 minutes.
Inhalation:	Move to fresh air and/or, if necessary decontaminate and transport to emergency medical facility or request the assistance of emergency medical professionals.
Ingestion:	Decontaminate and transport to emergency medical facility or request assistance of medical professionals.
Puncture/Laceration:	Decontaminate, if possible, and transport to emergency medical facility or request the assistance of emergency medical professionals.

2.4 Non-Emergency Medical Treatment

In case of injury to personnel, which is not a medical emergency the employee will contact WorkCare at (1-888-449-7787). WorkCare provides access 24 hours / 7 days a week to experienced occupational health nurses and physicians who confer with employees at the onset of a work-related injury or illness. WorkCare will provide over the phone injury

treatment or direct employees to medical treatment by third party provider, if appropriate.

2.5 Nearest Medical Assistance

The address and telephone number of the nearest hospital/emergency care facility:

Riddle Hospital (Main Line Health)
1068 W Baltimore Pike, Media, PA 19063
(484) 227-9400

Address and telephone number of the nearest urgent care facility with occupational medicine services:

AFC Aston
5024 Pennell Road, Aston, PA 19014
(484) 766-3502

Map with directions to the hospital/emergency care facility are shown in as **Figure 2** and **Figure 3**. This information will either be posted prominently at the site or will be available to all personnel all of the time. Further, all field personnel, including the HSO, will know the directions to the hospital.

2.6 Emergency Contacts/Notification System

Emergency telephone numbers are summarized in **Table 1**. This list is to be included with the site first aid kit and readily available to all personnel at all times. Langan requires that all property damage, environmental releases, injuries of any personnel (Langan employees, subcontractors, property owner, site visitors, etc.), and near misses associated with the field activities be reported on the Incident Injury Report located in **Appendix C** and to **Langan's Incident/Injury Hotline at (973-560-4699)** as soon as possible following the incident. In the event of a work-related Injury or Illness contact WorkCare at 1-888-449-7787.

2.7 Evacuation

In the event of an emergency situation, an air horn or vehicle horn should be sounded three times indicating the initiation of evacuation procedures. Loud voice command, if

appropriate, can be used. All personnel will evacuate and assemble at the site entrance or designated muster point. No one, except the emergency responders, will be allowed to proceed into the area once the emergency signal has been given. The Site Emergency Coordinator will ensure that access for emergency equipment is provided and that all sources of combustion (e.g., operating machinery, etc.) have been shut down once the alarm has been sounded. Wind direction will be taken into consideration for evacuation plans. Evacuation plans will be discussed at the initial Site-Specific Training and as needed at the regular safety briefings.

In all situations, when an on-site emergency results in an evacuation, personnel shall not re-enter until:

- The conditions resulting in the emergency have been corrected.
- The hazards have been reassessed.
- This HASP has been reviewed.
- Site personnel have been briefed on any changes to this HASP.

2.8 The Buddy System

When working in teams of two or more, workers will use the "buddy system" for all work activities to ensure that rapid assistance can be provided in the event of an emergency. Work groups will be organized so workers can remain close together and maintain visual contact with one another. Workers using the "buddy system" have the following responsibilities:

- Provide his/her partner with assistance.
- Observe his/her partner for signs of chemical or heat exposure.
- Periodically check the integrity of his/her partner's PPE.
- Notify the HSO or other site personnel if emergency service is needed.

2.9 Lone Worker Policy

In situations where perimeter air monitoring may be conducted by a single worker, personnel must follow the *Langan Lone Worker Policy for Perimeter Air Monitoring*. This

policy establishes requirements for lone-work authorization, check-in intervals, communication methods, escalation procedures, and safety controls to ensure that work performed without a buddy can still be conducted safely and in compliance with project HSSE expectations. The Lone Worker Policy is included as **Appendix X**.

2.10 Fire or Explosion

Appropriate fire extinguishers should be made available at the site for trained personnel to use on fires in their initial stage without endangering the safety and health of those nearby. If the use of fire extinguishers will not extinguish the fire, immediately notify the fire department or call 911, sound the evacuation signal, and then evacuate the area, assembling at the site entrance to be accounted for and to receive further instruction. Fire extinguishers will be checked monthly or as needed to ensure that they are in proper operating condition. A record of fire extinguisher checks will be notated on a tag attached to the fire extinguisher and an inspection log will be updated and maintained for all Health and Safety equipment (i.e. first aid kits, eye wash, AED) to ensure all equipment is in working order and good condition.

2.11 Explosive Atmospheres

Langan employees are prohibited from entering or conducting work in a confined space where immediately Dangerous to Life and Health (IDLH) conditions are present. IDLH concentrations of potential chemical contaminants are provided on **Table 2.**

Areas where an explosive atmosphere exist should not be entered until appropriate testing has deemed the area safe for entry and confined space entry procedures have been followed. For explosive atmospheres such as excavation operations, a multi-gas meter equipped for monitoring of VOCs, H_2S, LEL, O_2, and CO with a remote sensing head should be used.

For LEL readings between 0% to <10%; continue to work and continue to monitor atmosphere. For reading $\geq$10% of the LEL; evacuate the area.

2.12 Oxygen Deficient Atmospheres

Langan employees are prohibited from entering or conducting work in a confined space

where IDLH conditions, such as an oxygen-deficient atmosphere, are present. An oxygen-deficient atmosphere is defined as an atmosphere containing less than 19.5% oxygen.

Areas where oxygen deficient atmospheres exist should not be entered until appropriate testing has deemed the area safe for entry and confined space entry procedures have been followed. Prior to entering any space where an oxygen deficiency may exist, an oxygen meter will be used to test for adequate oxygen levels. Decisions will be based on oxygen concentrations as follows:

Oxygen Concentration	**Decision**
20.8%	Continue Operations
< 20.8%	Continuous Monitoring
< 19.5%	Stop Work/Do not Enter, withdraw from work area; notify HSM & PM
> 22%	Stop Work/Do not Enter, withdraw from work area; notify HSM & PM

2.13 Spills/Leaks

In the event of accidental spillage, the following spill response protocol will be implemented as follows:

- Immediately stop work and move up-wind of the spill.
- Administer first aid to injured personnel and call 911 if necessary.
- Notify the Langan HSO immediately of the spill. The HSO will notify the project manager who will notify the client and all appropriate outside agencies.
- If possible and safe to do, gather data regarding material spilled, location, quantity spilled, injuries and environmental impacts.
- An exclusion zone will be set up, informing and warning all site personnel of the hazard(s).
- Complete an Incident Injury Report and notify Langan's Incident/Injury Hotline at (973-560-4699) as soon as possible following the incident.

2.14 Adverse Weather Conditions

In the event of severe weather (rain, snow, sleet, heat, etc.), conditions will be assessed

on site to determine if the work can proceed safely. If it is determined that the weather poses a significant hazard, site operations will be stopped and rescheduled. Some of the items to be considered prior to determining if work should continue include:

- Potential for heat stress and heat-related injuries.
- Potential for cold stress and cold-related injuries.
- Treacherous weather-related working conditions.
- Limited visibility.

2.15 Underground Utilities Strike

In the event a utility is encountered or disturbed during subsurface work, follow these procedures:

- Immediately stop work;
- Leave the work area and retreat to a safe area;
- Call 911, if necessary;
- Contact the client representative and owner and operator of the property; and
- Immediately notify the Langan PM, HSO and Langan Incident/Injury Hotline.

2.16 Documentation

Employees are required to contact WorkCare at (1-888-449-7787) to document incidents/injuries which are not medical emergencies. Following an incident or near miss, unless emergency medical treatment is required, either the employee, coworker or supervisor must contact the Langan Incident/Injury Hotline at (973-560-4699) and the client representative to report the incident or near miss. For emergencies involving personnel injury and/or exposure, the HSO and affected employee will complete an Incident Injury Report located in **Appendix C** and submit to Langan's H&S Department as soon as possible following the incident.

3.0 SITE LOCATION AND BACKGROUND

3.1 Location

The site is located at 920 Cherry Tree Road Aston, Delaware County, PA 19014. The site area is approximately 154 acres and is bounded by Concord Road followed by private residences and the Chester Water Authority bulk storage facility to the north, Cherry Tree

Road followed by private residences to the east, private residences along Chichester Avenue to the west, and private residences along Cella Drive, Bernard Street, and Carriage Circle to the south.

3.2 Background

The Chelsea Tank farm is a refined petroleum pipeline (SIC 4613) transportation facility, which consists of break-out tanks, pipelines, storage tanks, and a manifold area. There are two (2) incoming and four (4) outgoing transportation pipelines, twelve (12) aboveground break-out tanks, two (2) aboveground storage tanks, four (4) transformers, and pipeline manifold/ distribution system. The site is owned and occupied by MIPC, and acts as a major storage hub for Monroe Energy's distribution network. All on-site buildings are currently in use for administration, storage, and/or maintenance operations. The property has a large tank farm designed for bulk storage of gasoline, diesel, and jet fuel. Integrated with breakout tanks and pipeline systems for efficient transfer. It is connected via 51 miles of pipeline to Monroe's Trainer Refinery and other terminals. This terminal supports regional fuel supply and logistics for the Philadelphia area and beyond

3.3 Summary of Work Tasks

Task 1: LNAPL Recovery via VEFR

Truck, tank, and vacuum system shall be suitable for pure-phase hydrocarbon service (flammable liquids). All vacuum truck operations in hydrocarbon service shall include proper bonding and grounding of the truck, hoses, and any connected equipment to mitigate static charge accumulation and reduce the risk of ignition. Subcontractor shall provide and use suitable grounding/bonding cables and clamps in accordance with industry practices and applicable NFPA guidance (e.g., NFPA 30 and NFPA 77) whenever loading, unloading, or transferring flammable liquids or vapors. Vapors will be continuously monitored using a 5-gas meter.

Fluids will be extracted from monitoring wells using a vacuum truck. Groundwater and product will be removed from each well through an adjustable stinger pipe set approximately six inches below the groundwater-product interface In order to avoid the

smearing of LNAPL to deeper levels within the aquifer, and not to exceed the lowest seasonal groundwater level. Vacuum will be applied to each well at successively increasing levels to observe the response of product recovery with increasing vacuum levels. Fluids will then be extracted from each well at a vacuum level that produces the highest rate of recovery without completely evacuating each well.

o During the VEFR event, groundwater elevation measurements will be collected. Gauging will continue following the VEFR to record the recovery rates of the wells.

o Using an interface probe, LNAPL thickness measurements will be collected at the beginning and end of the test to evaluate the impact of the VEFR. LNAPL measurements will not be collected during the test to minimize interruptions of the VEFR.

o Following the VEFR, water level and product thickness measurements will be collected.

o Recovered fluids will be containerized for characterization (if needed) and disposed of in compliance with applicable regulations.

Task 2: Soil Borings and Monitoring Well Installations

Exploratory soil borings will be advanced using a Geoprobe drilling rig, using either direct-push or hollow-stem auger methods. If groundwater is encountered within a boring location at the target locations/depths, a groundwater well may be installed. Langan will perform characterization testing on soils, groundwater, and/or LNAPL encountered during well installation.

Prior to drilling, locations will be cleared of utilities and obstructions using soft-dig techniques including using a hand auger, air-knife, AirSpade soil excavation unit, or soil vacuum to 5 feet bgs. The soft dig will be completed at each boring location. If needed, Langan will direct the driller to remove asphalt or concrete to advance soft dig locations.

Soils retrieved from each boring will be continuously logged and screened for volatile organic compounds (VOCs) using a calibrated photoionization detector (PID). Soil

lithology, PID readings, and field observations will be recorded on soil boring logs. At each location, a soil sample for chemical analysis may be collected from the 6-inch depth interval corresponding to the highest PID reading or the greatest visual indication of impact (i.e., staining). If no indication of impact is observed based on PID screening, visual or olfactory observations, the sample will be collected from the depth interval immediately above the water table.

If groundwater is encountered at the target locations/depths, a groundwater well may be installed. Wells will be installed and developed using an intrinsically-safe pump, and Langan will measure depth to groundwater prior to and following well development. A groundwater grab sample may be collected at a future date. Presence/absence of light non-aqueous phase liquid (LNAPL) will also be recorded. If LNAPL is present, a sample of the LNAPL may be collected, and a groundwater sample will not be collected.

Level D PPE, modified to include drilling safety considerations (e.g. hard hat, safety glasses, hearing protection) and MIPC requirements (e.g. fire-resistant coveralls) is assumed; however, if action levels for gases are exceeded as detected by the relevant screening equipment, Level C protection will be donned.

Task 3: Private Well Sampling

At MIPC's discretion or as required by regulators, private water wells will be sampled and submitted for laboratory analysis of select volatile and semi-volatile organic compounds. Specifically, samples will be analyzed via Method 524.2 for Unleaded Gasoline analytes, as listed in Table IV-9 of the PA Storage Tank Program Guidance, Document ID No. 253-

0300-100. These analytes include:

- Benzene
- Toluene
- Ethyl Benzene
- Total Xylenes
- Methyl tert-Butyl Ether
- Cumene (Isopropylbenzene)
- Naphthalene
- Trimethyl benzene, 1,2,4-
- Trimethyl benzene, 1,3,5-

4.0 IDENTIFICATION OF KEY PERSONNEL/HEALTH AND SAFETY PERSONNEL

The following briefly describes the health and safety (H&S) designations and general responsibilities that may be employed for this site. The personnel titles have been established to accommodate the project needs and requirements and insure the safe conduct of site activities. The H&S personnel requirements for a given work location are based upon the proposed site activities.

4.1 Langan Project Manager (PM)

The Langan Project Manager (PM) is **Jeff Smith**. Their responsibilities include:

- Confirming that this HASP is developed and approved prior to on-site activities.
- Confirming that all the tasks in the project are performed in a manner consistent with Langan's Corporate Health and Safety Program and this HASP.

4.2 Langan Corporate Health and Safety Manager (HSM)

The Langan Corporate Health and Safety Manager (HSM) and dedicated project HSE Manager is **Tony Moffa**. His responsibilities include:

- Updating the Health and Safety Program.
- Assisting the site Health and Safety Officer (HSO) with development and revisions of the HASP.
- Assisting the HSO in the implementation of this HASP and conducting Jobsite Safety Inspections and assisting with communication of results and correction of shortcomings found.

- Maintaining records on personnel including medical evaluation results, training, certifications, and Incident/Injury reports

4.3 Langan Site Health & Safety Officer (HSO)

The Langan Site HSO will rotate and potential HSOs are listed on Table 1 and will be identified on the Safe Work Certificate (SWC). The Site HSO is an HSE Critical Role, which is defined as a job that can impact significantly on the execution of an HSE CRITICAL ACTIVITY at the front line operational or planning/supervisory level. The Site HSO responsibilities include:

- Participating in the development and implementation of this HASP.
- The management of the day-to-day site activities and implementation of this HASP in the field
- Conducting Tailgate Safety Meetings and Jobsite Safety Inspections and correcting any shortcomings in a timely manner.
- Confirming that proper PPE is available, worn by employees and properly stored and maintained.
- Controlling entry into and exit from the site contaminated areas or zones.
- Monitoring employees for signs of stress, such as heat stress, fatigue, and cold exposure.
- Monitoring site hazards and conditions.
- Knowing (and relaying that all site personnel also know) emergency procedures, evacuation routes, and the telephone numbers of the ambulance, local hospital, poison control center, fire department, and police department.
- Resolving conflicts that may arise concerning safety requirements and working conditions.
- Reporting all incidents, injuries and near misses to the Langan Incident/Injury Hotline and WorkCare immediately and the client representative.
- Confirming permits are signed prior to the start of any permitted activities and closed out at the end of each day.

4.4 Subcontractor Responsibilities

Each subcontractor shall develop and implement their own HASP, which identifies a lead individual responsible for H&S compliance for each of their employees, lower-tier

subcontractors, and consultants. The subcontractor's HASP will be at least as stringent as this Langan HASP. The subcontractor must be familiar with and abide by the requirements outlined in their own HASP. A subcontractor may elect to adopt Langan's HASP as its own provided that it has given written notification to Langan, but where Langan's HASP excludes provisions pertinent to the subcontractor's work (i.e., confined space entry); the subcontractor must provide written addendums to this HASP. Additionally, the subcontractor must:

- Confirm their employees are trained in the use of all appropriate PPE for the tasks involved;
- Notify Langan of any hazardous material brought onto the job site or site related area, the hazards associated with the material, and must provide a SDS for the material;
- Have knowledge of, understand, and abide by all current federal, state, and local health and safety regulations pertinent to the work;
- Ensure their employees have received current training in the appropriate levels of 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response* (HAZWOPER) and other training required for site work;
- Confirm their employees have been medically cleared to work and to wear a respirator, if necessary;
- Confirm their employees have been fit-tested within the year on the type respirator they will wear.
- Truck, tank, and vacuum system shall be **suitable for pure-phase hydrocarbon service** (flammable liquids). All vacuum truck operations in hydrocarbon service shall include **proper bonding and grounding** of the truck, hoses, and any connected equipment to mitigate static charge accumulation and reduce the risk of ignition. Subcontractor shall provide and use suitable grounding/bonding cables and clamps in accordance with industry practices and applicable NFPA guidance (e.g., NFPA 30 and NFPA 77) whenever loading, unloading, or transferring flammable liquids or vapors.
    - Comply with, at minimum:
        - NFPA 30 – Flammable and Combustible Liquids Code
        - NFPA 385 – Tank Vehicles for Flammable and Combustible Liquids

- 49 CFR (DOT hazardous materials / tank vehicle requirements, as applicable)
- OSHA 29 CFR 1910 (including noise and PPE)
- Applicable federal, state, local, and plant safety and environmental requirements
- **Appendix J** VEFR Minimum Technical Requirements

5.0 GENERAL HAZARD MANAGEMENT

This section provides an assessment of the general hazards that may be encountered during field work activities at the site through a task-by-task risk analysis. Potential hazards are addressed below

5.1 Chemical Exposure Hazards

Known and suspected chemical contaminant hazards that could be encountered during site operations are detailed in **Table 2, Part A**. A complete inventory of SDSs for chemical products used on site can be found in **Appendix E**.

5.2 Physical Hazards

Physical hazards, which may be encountered during site operations for this project, are detailed in Table 2 Part B. Site activities will be conducted in accordance with the safety procedures outlined in Langan's *Corporate Health and Safety Plan* and the *Langan-MICP HSE Program Plan*. For ease of reference, relevant sections of these documents have been reproduced int eh following appendices:

- Lifting and hoisting (**Appendix K**). Lifting and hoisting is not planned as part of the scope of the project. The trigger for considering an activity a "lifting" or "hoisting" operation will be using equipment to suspend, by way of cables, chains, straps, or other similar materials, any object such that the bottom of an object that is more than 4 feet above the ground surface. If such suspension is necessary, work will stop and the Langan HSO and persons involved in the lifting activity will use the materials in **Appendix K** to plan the lift appropriately before work is allowed to proceed.
- Heat Illness Prevention Plan (**Appendix M**; this appendix also incorporates additional standards to satisfy heat illness prevention requirements by California OSHA)
- Cold exposure (**Appendix N**)
- Driving (**Section 6.7** and **Appendix P**)

- Ladder Use (**Appendix W**)

5.3 Biological Hazards

Biological hazards, which may be encountered during site operations for this project, are detailed in **Table 2 Part B**.

6.0 SAFE WORK PRACTICES AND HAZARD IDENTIFICATION

GENERAL HAZARD MANAGEMENT

6.1 Permit to Work System

All activities will be performed under a daily Safe Work Certificate (SWC; **Appendix H**). The SWC must be completed each day before beginning work. Approval flow of SWCs depends upon an activity's risk rating on Langan's Hazard Analysis Matrix (HAM; **Table 5**). The HSO may issue SWCs for low- and medium-risk activities. Prior approval from the Langan PM and/or Corporate HSM is needed before a SWC is issued for significant- and high-risk activities. Subcontractor supervisors are responsible for understanding and signing off on daily SWCs before beginning work. The levels of permit approval are identified on the SWC Approval Flow Chart in **Appendix I**.

SWCs may not be authorized for multiple shifts or days. SWCs cannot be changed in the field without re-submittal and full approval.

Work plans must be formally communicated to the HSO, at a minimum, before the activity starts. Before beginning daily site activities, the HSO must confirm that the site and vehicle(s) have been inspected, that site conditions conform to the SWC, that it is safe to start work, and that the SWC and applicable attachments have been signed. After work is completed or suspended, permits must be closed out and completion of the work must be communicated to the affected personnel.

6.2 Tailgate Safety Briefings

Before starting work each day or as needed, the Langan HSO will conduct a brief tailgate safety briefing meeting to assist site personnel in conducting their activities safely. Tailgate meetings will be documented in **Appendix H**. Briefings will include the following:

- Scope of work for the day,
- Review of safety information relevant to planned tasks and environmental conditions
- New activities/task being conducted;
- Results of Jobsite Safety Inspection Checklist;
- Changes in work practices;
- Safe work practices; and
- Discussion and remedies for noted or observed deficiencies.

The Tailgate Safety Briefing should include a focused discussion utilizing the Take 5 – STEPS process (see Section 6.5 below) and a discussion of site-specific conditions and emergency procedures. Further, a twilight toolbox meeting will be held at the conclusion of field activities for the day, to review any safety or progress related items, discuss the following days proposed activities, and closure of the SWC, located in Section 7 - Permit Close-Out.

6.3 Job Safety Analysis

A Job Safety Analysis (JSA) is a process to identify existing and potential hazards associated with each job or task so these hazards can be eliminated, controlled or minimized. JSAs will be reviewed at the beginning of each work day, when an employee begins a new task or moves to a new location. JSAs must be developed and reviewed by all parties involved. A blank JSA form and documentation of completed JSAs are in **Appendix G**.

6.4 Take 5 -STEPS Worksite Hazard Management Program

Langan has implemented a Worksite Hazard Management System, known as Take 5 - STEPS, which stands for:

Stop, what has changed?

Think about task

Evaluate hazards

Plan approach

Start task safely

The Take 5 system is used for hazard recognition and mitigation and is summarized on the Take 5 card. The Take 5 – STEPS system is to be used before, during or upon completion of work, to promote discussion and guide hazard identification.

6.5 Behavior-Based Safety

Langan has implemented a Behavior Based Safety Program known as BASE: Behavior Awareness – Safety Engagement. The BASE program assists Langan employees by increasing safety of operations by positively influencing the behavior of all employees involved, through a process of observation, coaching and communication. Employees are expected to participate in the observation process by conducting observations of employee work behaviors. Observations should provide direct, measurable information on employees' work practices, identifying both safe and unsafe behaviors. BASE field forms can be found in **Appendix O**.

BASE observations by all field team members will help identify safe and unsafe trends that are present at the Site. Unsafe trends will be addressed and associated hazards will be mitigated by either additional PPE that is fit for the task or improved work practices. Site personnel (Langan and subcontractors) will complete one BASE observation per person on location per day.

6.6 Driver Safety and Journey Management Planning

Langan employees are required to follow Langan's Driver Safety Policy. All Langan employees and subcontractors will follow a First Move Forward policy. The First Move Forward Policy requires vehicle operators to park their vehicles while onsite such that the first movement of the vehicle will be in the forward direction. All drivers will follow the resources provided in Section IV of the Langan *Corporate Health and Safety Plan*. More information regarding transportation of unauthorized passengers, management of safe driver training, and other responsibilities is provided in **Appendix P**.

Spotters will be utilized, when necessary, for equipment travelling in tight quarters, near hazards (e.g. power lines), obstructions, or backing up. Spotters must be a competent person in understanding vehicle blind spots, communicate using radio communication or approved hand signals, shall be positioned with ample distance between the vehicle and hazard, and wearing the site-specific PPE (class 1 or class 2 safety vest with reflective tape).

Driving-related incidents are some of the most prevalent on Langan projects, as driving hazards are present on every project and vehicle incidents pose a more likely risk of serious injury than any other jobsite hazard. Therefore, a written Journey Management Plan (JMP) is required in the following situations:

- The commute to a project location is greater than 4.5 hours round-trip;
- A commute of any duration for any staff's first commute to the Site;
- Langan personnel will be hauling a trailer; or
- A transportation contractor will haul multiple trips from the site during a short period of time. JMPs will be approved and sent to the transportation contractor prior to the beginning of trucking, and will be verified the JMP is with the driver on site.

The JMP document must be:

- Completed prior to beginning the journey;
- Discussed/agreed with drivers before the journey (or daily, during the tailgate safety meeting, for multiple days of soil hauling); and
- Kept in the vehicle during the journey.

Drivers must not alter the route designated in the JMP unless preapproved by the HSO or PM. In some cases, it may make sense to identify an alternate route in the JMP. JMPs will be prepared in accordance with the Langan JMP policy. A JMP template is included in **Appendix P**.

Vehicles other than those used only for commuting will be inspected daily. Vehicle inspections will be documented using the Vehicle Inspection Form included in **Appendix P**. Heavy equipment will be inspected daily by the contractor responsible for the equipment before beginning work, and the inspections will be documented on the contractor's inspection forms. Heavy equipment maintenance will be addressed promptly and proactively.

If a vehicle or piece of equipment is damaged, it will be immediately called off rent and replaced. Damaged vehicles or equipment will not be used for site work.

To support Langan's goal of reducing mileage and driving exposure by 10%, the following measures will be implemented:

- Combine trips where possible;
- Select nearby facilities for soil disposal, imported fill, and lodgings;
- Carpool where appropriate;
- Staff the project using local personnel to the extent practicable; and
- Where project staffing using local personnel is infeasible, reduce driving exposure by using alternative forms of transportation such as flying.

6.7 Life-Saving Rules

Compliance with the International Association of Oil & Gas Producers (IOGP) Life-Saving Rules is mandatory for the Langan Team. Failure to comply with any Life-Saving Rule, or encouraging or tolerating rule-breaking will result in disciplinary action. The Life-Saving Rules are:

- Obtain authorization before overriding or disabling safety controls
- Obtain authorization before entering a confined space
- Follow safe driving rules
- Verify isolation and zero energy before work begins
- Control flammables and ignition sources
- Keep yourself and others out of the line of fire
- Plan lifting operations and control the area
- Work with a valid permit when required
- Protect yourself against a fall when working at heights

6.8 Safe Work Practices

Standing orders for day to day safe work practices to be followed while onsite by Langan employees and subcontractors are included as **Appendix A**. Field personnel will follow safe work practices for. In the event that Langan's or the subcontractor's safe work practices are contradictory, the more stringent practices will be followed.

6.9 BIG3

Langan has identified specific conditions that create high-potential incidents. These conditions include line-of-fire, dropped objects, and line strikes and are collectively referred to as the BIG3. Site-specific risk mitigation measures for the BIG3 are as follows:

Applicable Tasks:

- Driving around the Site

- Equipment and material delivery
- Hand work
- Magnetometer and EM Survey
- Direct push and Sonic drilling
- Monitoring well installation
- Environmental soil sampling
- VEFR
- Well gauging and bailing product

General Mitigations

- Discussion of hazards during site-specific orientation with workers
- Review and update JSAs before beginning a task and whenever site conditions change
- Daily vehicle and equipment inspections
- Confirm open PA One-Call ticket prior to any ground disturbance.
- Confirm with existing utility plans that no utilities are present. Ensure that both utility markout results are reviewed
- Utilize the TAKE-5 last-minute risk assessment to evaluate changing conditions or before starting a task

Line of Fire

Risk – Pinch points, individuals being hit by equipment or instruments from equipment.

Implement the following methods to minimize Line of Fire incidents:

- Inspect equipment prior to operation. Ensure there is no evidence of equipment weakness (leaked hoses, frayed pull lines, damaged augers) ensuring equipment will not break under operational stressors or pressure.
- Identify pinch points prior to equipment operation.
- Identify, and test, emergency shutoff controls on equipment.
- Establish clear exclusion zones for active work areas with caution tape, cones, temporary fencing where practicable, marking paint, or signs with an established visitor control point. Only authorized personnel with appropriate PPE and a site-specific safety briefing will be permitted within the controlled area; any visitors (including property owners/representatives) will be escorted at all times and kept outside the exclusion zone unless specifically approved by the HSO and the Site Supervisor.
- Establish responsibility for maintaining the exclusion zone. Employees should not enter or exit the zone without permission from the exclusion zone attendant.

- Establish responsibility for signaling the equipment operator (the spotter). The spotter should be the only person to signal the operator during normal operation. Ideally, this person will also be the exclusion zone attendant.
- Establish communication between spotter, operator, and ground staff outside of the exclusion zone (hand signals or radio communication).
- Stay out of the way of equipment during mobilization. Never position yourself within the swing radius or travel path of equipment while in operation.
- Seek and obtain eye contact and the "hands-off" signal from equipment operators prior to collecting soil from stockpiles / excavator bucket, approaching soil stockpiles / excavator bucket, and when approaching operating equipment in general, even after the spotter has cleared you for entry into the exclusion zone.
- Utilize spotter or exclusion zone and attendant when backing with a skid steer is required.
- Never position yourself under on the blind side of a truck being loaded.
- Never position yourself within the fall zone of a dump truck when it has its bed raised.
- Never position yourself behind a truck that is backing.
- Always de-energize heavy equipment with all hydraulic components resting on the ground.
- Consult weather conditions daily. If rainfall is anticipated assess road and access conditions to determine if the roads will be unsafe to travel.

Dropped Objects

Risk – An object dropped from height and striking someone or damaging equipment or property.

- A drop hazard is defined as any tool, material or object that has an opportunity to fall from elevation to a lower level causing potential for damage to property, injury or death.
- During the office and warehouse maintenance and restoration, items will need to be removed from warehouse shelving and disposed of to allow for disinfection and pressure washing. During performance of this task, and when soil is loaded or unloaded from trucks, items may need to be lifted more than five feet about the ground. Outside of these tasks, there is no need within the current scope of work for tools or material to be raised more than 5 ft above the ground. Mitigations for the loading and unloading of fill and shelved items are discussed in the section above of line of fire.

- In general, mitigations for dropped objects at the site would be to reduce the need for anything to be raised above the ground if possible, wear hard hats while clearing out the warehouse shelving, tether tools if working at heights, establish clear exclusion zones, and comply with exclusion zones.

Line Strikes

Risk – Striking aboveground or subsurface utilities or lines. Implement the following methods to minimize utility strikes:

- Overhead lines:
  - Mark locations of overhead lines with signs.
  - Where crossing beneath overhead lines can be avoided, establish physical barriers to prevent equipment from traveling beneath the lines.
  - Where crossing beneath overhead lines cannot be avoided, establish a warning guideline at a safe distance away from the overhead lines. Equipment must be able to travel beneath the warning guideline to avoid striking overhead lines.
  - Use spotters to verify sufficient distance between equipment and overhead lines.
  - Two overhead lines are present at the site where personnel and equipment may pass during this scope of work. One line is present at the office on the west side, and another is present over the frac tank area
- Subsurface lines:
  - Mark locations of subsurface lines with paint, pin flags, or signs when working in the vicinity
  - Hand clear all subsurface borings to a minimum of 5 feet below ground surface (ft bgs) before beginning drilling activities
  - Confirm equipment is appropriately rated to cross over subsurface lines, if the equipment is too heavy, appropriately rated matting must be used and a crossing agreement in place with the subsurface line owner

6.10 Health and Safety Equipment Inspections

Health and safety equipment that has the potential to expire or no longer is suitable for use after a certain date must be inspected weekly or monthly and documented on a tracking form and a tag affixed to the piece of equipment. **Appendix V** contains an

example tracking form for weekly and monthly equipment inspections.

Equipment that is to be inspected weekly includes first aid kits and eye wash stations. First aid kits will be inspected weekly to verify that they are appropriately stocked, that supplies are not expired, and that the kits are easily accessible. First aid kits should be weatherproof and contain individually sealed packages of supplies.

Eye wash stations will be checked weekly to determine if flushing fluid needs to be changed or supplemented as stated in ANSI Z358.1-2014. The inspection shall ensure the eye wash is easily accessible and is in proper functioning order.

Equipment that is to be inspected monthly includes fire extinguishers and automated external defibrillators (AED). Fire extinguishers will be inspected monthly to verify that they are properly charged, in good condition, easily accessible, and not expired. Expired or non-functioning fire extinguishers must either be repaired according to the manufacturer's recommendations or removed from service and replaced.

AEDs will be inspected monthly to ensure they are easily accessible, have adequate charge, and have not surpassed their expiration date or calibration.

6.11 Disciplinary Action

Any behaviors or actions on the part of site personnel that jeopardize the safety of others or are deemed harmful to human health and the environment will result in the immediate removal of those individuals from the project.

6.12 Chemical Exposure Hazards

Known and suspected chemical contaminant hazards that could be encountered during site operations are detailed in Table 2, Part A. A complete inventory of safety data sheets (SDS) for chemical products used on site can be found in **Appendix E**.

6.13 Task-By-Task Risk Analysis

Through information gathering, inspection, and monitoring; hazards that are potentially present have been determined for each specific task described in **Table 2**. This table provides a summary of chemical, physical and Biological hazards that could potentially be encountered by personnel during each task effort.

7.0 TRAINING & MEDICAL CLEARANCE REQUIREMENTS

The general training and medical clearance requirements for Langan personnel are discussed in the following sections.

7.1 Project Training

Completion of an initial 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training program as detailed in OSHA's 29 CFR 1910.120(e) is required for all employees who will perform work in areas where the potential for a toxic exposure exists. Annual eight-hour refresher training is also required to maintain competencies to ensure a safe work environment.

Completion of any client specific training is required prior to the start of field work and field implementation. Client specific training may include training required for the project that is provided by Langan and/or the Client. Training records are maintained by Langan's H&S Department.

7.2 Site Specific Training

MIPC-required health-and-safety training is required prior to completing field activities. Training occurs in the administrative building. Flame resistant (FR) coveralls are required in addition to Level D PPE. Training will be provided to specifically address the activities, procedures, monitoring, and equipment for site operations at the beginning of each field mobilization and the beginning of each discrete phase of work. The training will include the site and facility layout, hazards, and emergency services at the site, and will detail all the provisions contained within this HASP.

7.3 Medical Surveillance/Fitness For Duty

All personnel who will be performing field work involving potential exposure to toxic and hazardous substances will be required to have passed an initial baseline medical examination, with follow-up medical exams thereafter, consistent with 29 CFR 1910.120(f). Medical evaluations will be performed by, or under the direction of, a physician board-certified in occupational medicine. Personnel who may be required to perform work while wearing a respirator must receive medical clearance as required under CFR 1910.134(e), *Respiratory Protection*. Results of medical evaluations are maintained by Langan's H&S Department.

Onsite personnel have the option of completing a brief Medical Data Sheet (**Appendix R**)

which will be kept in a designated area in the project office. This data sheet will accompany any Langan personnel when medical assistance is needed or if transport to hospital facilities is required.

7.4 Short-Service Employee

A Short-Service Employee (SSE) is defined as any new Langan employee. A new employee is considered an SSE as follows:

- A new employee new to the industry is considered an SSE for six months.
- A new employee with experience in the industry is considered an SSE for three months.

Each SSE will be assigned a mentor to provide guidance in developing and understanding safe and proper work practices. The SSE will be accompanied at all times by their mentor. The ratio of SSE members in a given work crew shall remain under 20% unless prior written approval is obtained from Langan management. Langan's SSE program and forms are attached as **Appendix Q**.

Each subcontractor of Langan will be required to maintain an SSE program that is at least as stringent as the Langan policy. Each subcontractor will be required to notify the Langan HSO or PM in writing before assigning SSEs to work at the site.

8.0 AIR MONITORING

8.1 General

In many instances, it will be necessary to monitor the atmospheric conditions during on-site work activities to identify and quantify airborne contaminants; to assist in defining work zones; and, to determine the level of work protection needed. Air monitoring will be performed wherever the possibility of worker exposure to hazardous substances exists. Air monitoring will be performed at the worker's breathing zone. Upgrades/downgrades to personal protective equipment (PPE) will be made based on air monitoring results in the breathing zone. The air monitoring device will be calibrated daily and readings will be recorded in the field log or in **Appendix D**.

8.2 Action Levels

A 5-gas multimeter with **Photoionization Detector (PID)** will be used to evaluate action levels during investigation activities. **Table 3** provides a summary explanation of available monitoring equipment. The %-gas meter will be capable of measuring, VOCs, CO, O2, LEL, H2S. **Table 3** provides a summary explanation of available monitoring equipment.

Breathing zone readings should be taken at the start of work in all areas each day, as well as during the field activities, and frequently whenever strong odors are detected. Before any field activities commence, the background levels of the site will be monitored and recorded away from the areas of potential contamination to representative conditions. Continuous monitoring is required during intrusive work. Instrumentation Action levels for monitored gases based on 5-gas readings are provided in **Table 4**.

Work will be stopped immediately and crews will remove themselves to fresh air if workers are experiencing potential acute physical symptoms of exposure such as irritation, nausea, drowsiness or headache. Work will not recommence in the area until reasoning for exposure is determined and appropriate control measures have been taken.

In addition to breathing-zone monitoring at the active work area, the field team will perform periodic perimeter sweeps with calibrated direct-reading instrumentation (e.g., 5-gas/PID) at a reasonable offset beyond the immediate work zone to verify conditions remain protective and to support work-zone management. Sweep locations, visitor presence, weather / wind conditions, and results will be documented in the field log, and monitoring frequency will be increased during active advancement/development or if conditions change. If uncontrolled access cannot be maintained or monitoring results approach / exceed HASP action levels, the team will pause work / TAKE5, expand the controlled area, implement additional controls, and upgrade PPE / respiratory protection as required; stop-work authority will be exercised until conditions and security/access are confirmed acceptable.

9.0 PERRSONAL PROTECTIVE EQUIPMENT (PPE)

9.1 Levels of Protection

Langan will provide PPE to workers to protect them from the specific hazards they are likely to encounter on-site. Selection of the appropriate PPE must take into consideration:

(1) identification of the hazards or suspected hazards; (2) potential exposure routes; and, (3) the performance of the PPE construction (materials and seams) in providing a barrier to these hazards.

Based on anticipated site conditions and the proposed work activities to be performed at the site, **Level D** modified is recommended as PPE should be determined by a site specific risk assessment. The upgrading/downgrading of the level of protection will be based on continuous air monitoring results as described in Section 7 or based off of the potential exposure to chemicals. The decision to modify standard PPE will be made by the site HSO after conferring with the site project manager. The levels of protection are described below.

Upgrading Levels of PPE

If site conditions warrant an increase in PPE protection, a Stop Work will be initiated and Site conditions will be evaluated, a Management of Change (MOC) will be initiated, and this HASP will be revised. Level D Modified is the same as Level D for respiratory protection, but the skin protection is increased to that of level C and includes chemical resistant clothing. Level C is used when the concentrations and types of airborne substances are known and the criteria for using air purifying respirators are met.

PPE Program

An effective PPE inspection program includes the following five parts:

- Inspection and operational testing of equipment received from the factory or distributor;
- Inspection of equipment as it is issued to workers;
- Inspection after use or training and prior to maintenance;
- Periodic inspection of stored equipment; and
- Periodic inspection when a question arises concerning the appropriateness of the selected equipment, or when problems with similar equipment arise.

Level D Protection

Level D is used when no respiratory protection is required and minimal skin protection is needed (used for nuisance contamination only). The following conditions suggest a need

for Level D protection:

- The atmosphere contains no known hazard; and
- Work functions preclude splashes, immersion, or the potential for unexpected inhalation of or contact with hazardous levels of any chemicals.

The following constitutes Level D equipment; it may be used as appropriate:

- **Coveralls (Flame Resistant [FR])**
- Gloves (as applicable, specific to task).
- Boots/shoes, chemical-resistant steel toe and shank
- Boots, outer, chemical-resistant (disposable) (optional – as applicable).
- Safety glasses or chemical splash goggles (as applicable)
- Hard hat (as applicable)
- Escape mask (optional – as applicable)
- Face shield (optional – as applicable).

Level D Modified

Level D Modified is the same as Level D for respiratory protection, but the skin protection is increased to that of level C.

Level C Protection

Level C is used when the concentrations and types of airborne substances are known and the criteria for using air purifying respirators are met. The following conditions suggest a need for Level C protection:

- The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect or be absorbed through any exposed skin;
- The types of air contaminants have been identified, concentrations measured, and an air-purifying respirator is available that can remove the contaminants; and

The following constitutes Level C equipment; it may be used as appropriate.

- Full-face or half-mask, air purifying respirators (NIOSH approved).

- Hooded chemical-resistant clothing (overalls; two-piece chemical-splash suit; disposable chemical-resistant overalls)
- Coveralls (optional – as applicable).
- Gloves, outer, chemical-resistant.
- Gloves, inner, chemical-resistant.
- Boots (outer), chemical-resistant steel toe and shank (optional – as applicable).
- Boot-covers, outer, chemical-resistant (disposable) (optional – as applicable).
- Hard hat (optional – as applicable).
- Face shield (optional – as applicable).
- Escape mask (optional – as applicable).

9.2 Respirator Fit-Test

Langan employees who may be exposed to hazardous substances at the work site are in possession of a full or half face-piece air-purifying respirator, appropriate cartridges and have been successfully fit-tested within the past year. Fit-test records are maintained by Langan's H&S Department.

9.3 Respiratory Protection Requirements for Work Near the Water Treatment Unit

Due to intermittent elevated vapor conditions in and around the Water Treatment Unit (WTU) and the potential for acute exposure, respiratory protection shall be required only when air monitoring thresholds exceed:

- **5.0 ppm** VOC on the PID, and/or
- **1.0 ppm** on the benzene meter.

All Langan personnel entering the WTU work zone must evaluate conditions using both a PID and a benzene monitor prior to crossing into the WTU-designated area. If either threshold is exceeded, personnel shall don a half-face air-purifying respirator (APR) equipped with organic vapor/P100 cartridges (unless otherwise specified).

This requirement applies to all activities conducted within or adjacent to the WTU. Personnel must remain in respiratory protection until monitoring confirms levels are below both thresholds.

WTU Area Work Requirements

When air monitoring indicates concentrations above the respirator-trigger thresholds (≥5 ppm VOC or ≥1 ppm benzene):

- A half-face APR is mandatory before crossing into the WTU-designated work zone, including but not limited to:
  - S-1 LNAPL thickness gauging
  - S-1 LNAPL vacuum extraction
- Personnel must be medically cleared for respirator use in accordance with 29 CFR 1910.134.
- Personnel must be fit-tested annually for the specific make and model of respirator used.
- Air monitoring must be performed continuously or at intervals appropriate to task duration and vapor variability.

Langan will coordinate and oversee all vac-truck support activities associated with S-1 sump gauging and cleanouts near the WTU. Responsibilities include:

- Confirming respirator use is enforced when monitoring thresholds are exceeded.
- Coordinating vac-truck mobilization and operations.
- Confirming vac-truck personnel comply with all site PPE, respiratory protection, and safety requirements.
- Managing and documenting air monitoring during sump and WTU-adjacent activities.
- Confirm proper bonding and grounding procedures for all hydrocarbon-related operations.

10 SITE CONTROL

10.1 Site Communications Plan

Verbal communication and two-way radios will be the primary method of communication used at the site. A Starlink system will be available near the primary work area for communication assistance.

If use of verbal communication or radios is not practicable, hand signals will be used. Hand signals will be covered prior to the start of jobsite work or during tailgate safety meetings.

Hand Signal	Meaning
Hand gripping throat	Out of air; cannot breathe
Grip partners wrists or place both hands around waist	Leave immediately without debate

Hands on top of head	Need assistance
Thumbs up	OK; I'm alright; I understand
Thumbs down	No; negative
Simulated "stick" break with fists	Take a break; stop work

A satellite phone will be located in the vehicle of the HSO or his or her designee, as appropriate. In case of an emergency, if members of the work team do not have cell phone reception, the HSO or his or her designee will use the satellite phone to notify emergency responders.

Use of cell phones onsite will be limited to cell phone areas designated by the HSO.

10.2 Work Zones

The need to formally establish specific work zones (Support, Contamination Reduction, and Exclusion Zones) during site activities will be determined by the HSO. A general description of these work zones is provided in **Figure 5**. It is important for the safety of all concerned that appropriate barriers (cones, wooden horses, plastic fencing etc.) are in place to keep vehicles and pedestrians away from the Work Zone.

10.3 Standing Orders/Safe Work Practices

The standing orders, which consist of a description of safe work practices that must always be followed while onsite by Langan employees and subcontractors, are shown in **Appendix A**. The HSO has the responsibility for enforcing these practices. The standing orders will be posted prominently at the site, or are made available to all personnel at all times. Those who do not abide by these safe work practices will be removed from the site.

10.4 The Buddy System

When working in teams of two or more, workers will use the "buddy system" for all work activities to ensure that rapid assistance can be provided in the event of an emergency. This requires work groups to be organized such that workers can remain close together and maintain visual contact with one another. Workers using the "buddy system" have the following responsibilities:

- Provide his/her partner with assistance.
- Observe his/her partner for signs of chemical or heat exposure.
- Periodically check the integrity of his/her partner's PPE.

- Notify the HSO or other site personnel if emergency service is needed.

10.5 Site Security

Unauthorized personnel shall not be permitted to access work areas. Security measures may include, but are not limited to, employee background checks, drug and alcohol screening and requirement for employees to obtain Transportation Worker Identification Credential (TWIC).

Site visitors will be escorted by a Langan employee. Visitors are required to sign in at the site office and must don appropriate PPE for the site areas they are to enter.

10.6 Underground Utilities

The following safe work practices should be followed before and during subsurface work:

- Obtain available utility drawings from the property owner/client or operator.
- Provide utility drawings to the subcontractors.
- In the field, mark the proposed area of subsurface disturbance (when possible).
- Ensure that the one-call (811) system or state utility hotline in your area has been notified.
- Engage two private utility locators to conduct independent sweeps of the subsurface disturbance areas.
- Ensure that utilities are marked before beginning subsurface work.
- Discuss subsurface work locations with the owner/client and subcontractor.
- Obtain approval from the owner/client and operators for proposed subsurface work locations.
- Use safe digging procedures when applicable.
- Stay at least 10 feet from all equipment performing subsurface work.

10.7 Site Safety Inspection and Hazard Hunt

The Langan HSO or alternate will conduct daily checks of the work area at the beginning and end of each work shift at a minimum. More frequently checks may be required to ensure safe work conditions. The HSO or alternate must complete the Jobsite Safety Inspection Checklist, found in **Appendix F**, at least weekly or before completion of work, whichever is shorter. Any deficiencies shall be discussed during the daily tailgate meeting and shared with the PM and HSM, if needed.

At least once per week, the Langan HSO or alternate will lead site personnel in a hazard hunt. A hazard hunt is defined as a proactive assessment for hazards. To conduct a hazard hunt, personnel will critically examine the work environment and step out of their day-to-day routine to identify potential hazards. Results of hazard hunts will be documented on JSA and SWC forms.

10.8 Hand and Power Tools

All hand and power tools and similar equipment shall be maintained in a safe operating condition. All power tools must be inspected initially and prior to each use. Damaged tools shall be tagged and removed immediately from service or repaired. Tools shall be used only for the purpose for which they were designed. All users must be properly trained in their safe operation.

10.9 Stop Work Authority

Langan employees have the authority to stop work of Langan employees and subcontractors when they believe an unsafe condition exists. All project staff are encouraged to exercise "stop work authority" as part of Langan's safety culture.

The following steps shall be taken by Langan employees when performing work with Langan co-workers and Langan subcontractors within a work zone at a site and an unsafe condition is observed.

- When an employee observes an unsafe condition, a Stop Work Intervention shall be immediately initiated with the person(s) potentially at risk.
- The Stop Work Intervention shall be coordinated through the Langan HSO onsite.
- All affected personnel in the work zone shall immediately be notified of the Stop Work Intervention. If necessary, associated work activities should be stopped and persons should be removed from the area.
- All affected personnel shall discuss and gain agreement on the cause of the Stop Work Intervention.
- Every attempt shall be made to resolve the cause of the Stop Work Intervention prior to the resumption of work.
- If the cause of the Stop Work Intervention cannot be resolved immediately, then work shall be suspended until proper resolution is achieved.
- All Stop Work Interventions and associated details shall be documented and

reported to the PM and HSM, if needed.

11 DECONTAMINATION PLAN

11.1 General

Some equipment contamination is anticipated during the site inspection phase. In the event that equipment is contaminated, all personnel, equipment, and samples leaving the contaminated area of the site must be decontaminated. Decontamination for this operation is achieved through physical removal and chemical detoxification/disinfection/sterilization. The first step in decontamination, however, is prevention, and standard operating procedures have been established meant to minimize contact with wastes, including work habits that minimize contact with wastes are stressed and disposable equipment, where appropriate, will be used.

11.2 Decontamination Procedures

Standard decontamination procedures will be used as described in **Appendix B**.

11.3 Disposal of Decontamination Wastes

Waste solutions generated during decontamination procedures shall be contained, collected, and stored in drums or other appropriate containers and labeled for proper disposal. It is assumed that fluids extracted will be managed on site. In the event that liquids must be transported for disposal, the container will be properly sealed and labeled prior to shipment for proper off-site disposal.

12 MANAGEMENT OF CHANGE

Management of change (MOC) as described in *Appendix L of the Contract HSE Plan* is a best practice intended to ensure that safety, health, and environmental risks are reviewed and addressed when there are personnel, physical, and procedural changes. The MOC form can be found in **Appendix S**. The general MOC steps are outlined below.

- The Langan employee who notices the change shall notify the Langan senior project manager.
- The Langan PM will alert the MIPC PM immediately of any changes to the HSE/ERP prior to generation of the MOC.
- The Langan employee who identifies the change should complete the MOC form with

the help of the Project Manager.

- The MOC Coordinator assigns Langan employees to an evaluation team to review the MOC authorization form, provide comments, and approve or deny the MOC before forwarding the form to the Authorizer.
- The Principal-In-Charge of the project reviews the MOC authorization form following the evaluation team's approval and approves or denies the MOC, then forwards the form to the MOC Coordinator and the H&S Department.
- The MOC Coordinator is responsible for notifying MIPC PM, all employees, subcontractors, and contractors that may be affected by the approved MOC of the proposed changes and any necessary measures to mitigate HSE impacts.
- The MOC coordinator is responsible for implementing the change identified in the MOC in accordance with the implementation timeline in the MOC Authorization Form.

13.0 PERMITTED ACTIVITIES

General work permits (Safe Work Certificates, or SWC) are required for all work, and are to be completed daily. In addition to work covered by SWC's, there are specific work operations which pose higher risk (as determined by the RAM rating) and demand more specific planning and permitting. These operations, which are covered in *Section 5.10 of the Contract HSE Plan*, are outlined in the sections below. All permitted activities from the *Contract HSE Plan* are referenced to comprehensively cover any potential work activities, however due to the nature of the project some of the activities may not be applicable.

13.1 Simultaneous Operations

SIMOPs are not anticipated during the sonic drilling phase of the project.

Section 5.10.7 of the Contract HSE Plan outlines simultaneous operations (SIMOPs) as when there is potential for multiple work scopes to interfere with one another when executed simultaneously in the same or adjacent work areas. If SIMOPs risks are identified, SIMOPs planning is completed for upcoming activities by identifying areas and systems affected. The SIMOPs planning is communicated to the person in charge (SIMOPs coordinator). A pre-work meeting with all parties involved will occur to identify a work schedule, communicate planned tasks, and implement any necessary controls prior to the beginning of work. Meetings will occur between work parties throughout the SIMOPs activities. The pre-work meeting will determine if SIMOPs are:

- Prohibited (no SIMOPs activities will occur, requires additional planning),

- Controlled (SIMOPs activities can occur under controlled circumstances), or
- Acceptable (SIMOPs activities will not directly interfere with each work scope).
- The PTW system will govern SIMOPs activities and will be communicated to work parties utilizing proper signage, barricades, and/or permit boards. If the PTW conditions cannot be met, the activity will be cancelled, rescheduled, or specific site controls will be implemented to meet the PTW requirements. The SIMOPs Permit Attachment is included in *Appendix P of the Contract HSE Plan*.

13.2 Hot Work

Section 5.10.3 of the Contract HSE Plan outlines hot work operations when there is work that involves electric or gas welding, cutting, brazing, or similar flame-or spark-producing operations.

13.3 Lifting and Hoisting

Section 5.10.4 of the Contract HSE Plan outlines lifting and hoisting operations when there is work that involves use of the mechanized equipment, including cranes, derricks, or forklifts, to lift or suspend loads. The following risk assessment and mitigation planning tools are required before lifting may take place:

- Completion of a JSA specific to the lifting activity being conducted;
- Preparation of a lift plan appropriate to the level of risk (**Appendix K**);
- Completion of "10 Questions for a Safe Lift" (**Appendix K**);
- Completion of an OSHA Hoisting/Rigging Permit for critical lifts and L&H operations conducted with a mobile crane (**Appendix K**);
- Identification of personnel holding key roles in the lifting activity and verification of their competency (**Appendix K**);
- Erection of signs and barriers to designate the exclusion zone; and
- Completion of a pre-work safety meeting attended by all personnel involved in the lift. The pre-work safety meeting will review the items listed above at a minimum.

13.4 CONFINED SPACE ENTRY

A confined space has limited or restricted means for entry or exit and is not designed for continuous occupancy. Confined spaces include, but are not limited to, tanks, vessels, silos, storage bins, hoppers, vaults, pits, manholes, tunnels, equipment housings, ductwork, pipelines, etc. Confined spaces **will not** be entered by Langan personnel, nor subcontractors during the project.

14 FATIGUE MANAGEMENT

Fatigue can be a contributing factor in work-related incidents and injuries and can negatively affect an employee's health and safety in the workplace and at home. Langan has developed a Fatigue Risk Management Program to provide guidance on how to identify, avoid, manage and control fatigue in employees to reduce the impacts on employee safety.

14.1 Overview

Fatigue is the feeling of tiredness, exhaustion or the need to rest because you lack energy or strength. The causes of fatigue can be attributed to factors including overwork, poor sleep habits, anxiety and poor physical health. Illnesses, such as the common cold and flu, can also cause fatigue. Other factors that can contribute to fatigue include:

- Duration of work shifts,
- Time between work shifts,
- Time of day work shift times are scheduled,
- Ability to sleep and the quality of that sleep,
- Work load and responsibilities,
- Mental and physical work demands,
- Ability to deal with work and personal stress, and
- Working environment.

14.2 Employee Responsibilities

Employees are responsible for adhering to the following measures to prevent and reduce the potential for fatigue:

- Schedule and take breaks for water, rest and food.
    - Minimum one 15-minute break for every three work hours.
    - Minimum one half-hour break after six work hours.
    - More frequent breaks may be required depending on work tasks and working conditions.
- Follow limitations on work hours.
- Ensure sufficient sleep is obtained before the start of a work shift.
- Avoid chronic use of over-the-counter drugs, prescription medication or other products that may affect the ability to perform work safely.
- Stop work when a safety concern is created by fatigue, which can impair an employee's ability to work safely.

- Maintain a healthy balance between work and personal life.
- Use ergonomically friendly equipment when appropriate.
- Report fatigue and lack of mental acuity to Langan management.

14.3 Management Responsibilities

The Langan HSO and PM are responsible for adhering to the following measures to prevent and reduce the potential for fatigue in employees:

- Complete a Fatigue Risk Management Plan for high risk activities.
- Limit the work shift to 14 hours, including breaks.
- Ensure that employees are trained in managing fatigue.
- Ensure the availability of adequate work breaks.
- Rotate jobs or work shifts to avoid repetition and maintain awareness.
- Ensure that ergonomically friendly equipment is available when needed.
- Monitor employees for signs of fatigue (lethargic behavior, diminished physical abilities, sleepiness).
- Relieve employees of work duties to allow them adequate rest when signs of fatigue are exhibited or reported.
- Periodically analyze and review work tasks to control fatigue.
- Stop work when a safety concern is observed or reported by employee.

14.4 Fatigue Risk Management Plan

A Fatigue Risk Management Plan shall be completed by the Langan HSO or PM when the potential for high-risk activities has been identified or assigned to specific employees and/or positions. The plan shall include the following at a minimum:

- Work Time Limits – Maximum work hours per day/week/month. (Include driving time to and from work location).
- Shift rotation/rosters - Where possible, establish shift rosters ahead of time and avoid sudden changes of shifts to allow employees to plan rest time.
- Breaks - There shall be a 15 minute rest break and a 30 minute meal break with a break generally taken every three hours.
- Supervision - Appropriate supervision or additional employees during times of low alertness.

14.5 Training

Training in fatigue management will be provided to Langan employees before their initial work assignments and annually thereafter. Training will include the following topics, at a minimum:

- Employees' responsibilities.
- Management responsibilities.
- Recognition of fatigue.
- Effects and symptoms of fatigue.
- Causes and contributing factors of fatigue.
- Fatigue Risk Management Plan.
- Prevention of fatigue.
- Notification procedures.

Employees must demonstrate understanding in the topics covered in the training. Employees who do not demonstrate comprehension of the training material will be retrained. Training records including the name of the employee, type of training and date of training are maintained by Langan's H&S Department.

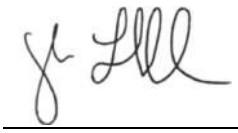
15 SUBCONTRACTOR HEALTH AND SAFETY PROCEDURES

Copies of subcontractor health and safety documents and work procedures were provided to Langan for review and are in conformance with Langan's Corporate HASP and Contract HSE Program Plan.

16 HASP ACKNOWLEDGEMENT FORM

Langan field personnel and subcontractors will sign this HASP Compliance Agreement indicating that they have become familiar with this HASP and that they understand it and agree to abide by it.

LANGAN PERSONNEL



20 February 2026

John Loeffel, Project Manager — Date



20 February 2026

Daniel Danehy, Project Health and Safety Manager — Date

Printed Name	Signature	Company	Date

Printed Name	Signature	Company	Date

TABLES

TABLE 1

Emergency Notification Contact Information

ORGANIZATION	CONTACT	TELEPHONE
Local Police Department	Aston Township Police Department Address: 1 New Road, Aston, PA 19014 Website: astonpd.org	Emergency: Dial 911 Non-Emergency: (610) 497-2633
Local Fire Department	Aston Township Fire Department (Station 17) Address: 2900 Dutton Mill Road, Aston, PA 19014 Website: atfd17.com	Emergency: Dial 911 Non-Emergency: (610) 494-6771
Ambulance/Rescue Squad	Aston Township Fire Department – EMS Division Address: 2900 Dutton Mill Road, Aston, PA 19014 Website: atfd17.com/ems	Emergency: Dial 911 Non-Emergency Phone: (610) 494-6771
WorkCare Incident Intervention (occupational nurse hotline)	Operator	888-449-7787
Hospital	Riddle Hospital (Main Line Health)	484-227-9400
Occupational Health Clinic	AFC Urgent Care Aston	484-766-3502
Delaware County Sheriffs	Non-emergency Dispatch	610-891-4296
Langan Incident / Injury Hotline	Operator	1-800-9LANGAN Ext. #4699
Langan Project Manager	Jeff Smith Cortney Savidge John Loeffel	215-694-7549 (cell) 610-202-9523 (cell) 201-779-8039 (cell)
Langan Health and Safety Manager (HSM) (dedicated project HSE Manager)	Tony Moffa	215-756-2523 (cell)
Langan Site Health and Safety Officer (HSO) (Site HSE Critical Role)	John Loeffel Daniel Danehy Zayne Aniszewski Jean-Paul Antoine	201-779-8039 (cell) 215-606-7966 (cell) 412-956-2546 (cell) 832-208-7398 (cell)
Langan Field Personnel with First Aid/CPR/AED Training	John Loeffel Daniel Danehy Zayne Aniszewski Jean-Paul Antoine Ryan Hall Paige Monyak Justin Longo Nathan Carpenter	201-779-8039 (cell) 215-606-7966 (cell) 412-956-2546 (cell) 832-208-7398 (cell) 551-497-9024 (cell) 215-845-8975 973-560-4953 412-335-6113 (cell)

Client Contact	Melissa Turchi Environmental Specialist Monroe Energy, LLC Caroline Kerr Regulatory Compliance Lead, MIPC LLC. Christine Shorokey Vice President & General Manager, MIPC, LLC	Office: 610-364-8536 Cell: 445-230-9644 Melissa.Turchi@monroe-energy.com Office: (484) 816-3305 Cell: (610) 389-7043 Caroline.Kerr@monroe-energy.com NA
MIPC Operator	Operator	
National Response Center (NRC)	Operator	800-424-8802
Pennsylvania Emergency Management Agency (PEMA)	Operator	717-651-2001
PADEP 24/7 hotline	Operator	800-541-2050
Chemical Transportation Emergency Center (Chemtrec)	Operator	800-424-9300
Center for Disease Control (CDC)	Operator	404-645-3355
EPA (RCRA Superfund Hotline)	Operator	800-424-9346
TSCA Hotline	Operator	202-554-1404
Poison Control Center	Operator	800-222-1222

Immediately following an incident or near miss, unless emergency medical treatment is required, either the employee or a coworker must contact the Langan Incident/Injury Hotline at 1-(800)-9LANGAN (ext: #4699).

In the event of a work-related Injury or Illness contact WorkCare at 1-888-449-7787

TABLE 2

TASK RISK ANALYSES

A. CONTAMINANT HAZARDS OF CONCERN

Task	Contaminant	Monitoring Device	PEL/IDLH	Source of Concentration on Site	Route of Exposure	Symptoms	First Aid
1, 2, & 3	Benzene	PID	1 ppm (PEL)	Soil / Groundwater	Inh, Abs,	Irrit eyes, skin, nose, resp sys; dizz; head, nau, staggered gait; anor, lass; derm; bone marrow depress; [carc]	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Medical attn. immed.
1, 2, & 3	Ethyl Benzene	PID	Ca, 500 ppm (IDLH)	Soil / Groundwater	Ing, Con	Irrit eyes, skin, muc memb; head; derm; narco, coma	Eye: Irrigate immediately Skin: Water flush immediately Breath: Respiratory support Swallow: Medical attn. immed.
1, 2, & 3	Toluene	PID	100 ppm (PEL)	Soil / Groundwater	Inh, Ing,	Irrit eyes, nose; lass, conf, euph, dizz, head; dilated pupils, lac; anxi, musc ftg, insom; pares; derm; liver, kidney damage	Eye: Irrigate immediately Skin: Soap wash promptly Breath: Respiratory support Swallow: Medical attn. immed.
1, 2, & 3	Xylenes	PID	800 ppm (IDLH)	Soil / Groundwater	Con	Irrit eyes, skin, nose, throat; dizz, excitement, drow, inco, staggering gait, corn vacuolization; anor, nau, vomit, abdom pain; derm	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Medical attn. immed
1, 2, & 3	Benzo(a)anthracene (represents other PAHs)	PID	0.2 mg/m^3 (PEL) 0.1 mg/m^3 (REL)	Groundwater	Inh, Abs, Ing, Con	Irrit eyes, skin, nose, resp sys;	Eye: Irrigate immediately Skin: Water flush immediately Breath: Respiratory support Swallow: Medical attn.

EXPLANATION OF ABBREVIATIONS

PID = Photoionization Detector
Inh = Inhalation
Abs = Skin absorbtion
Ing = Ingestion
Con = Skin and/or eye contact
PEL = Permissable Exposure Limit (8-hour Time Weighted Average
IDLH = Immediately Dangerous to Life and Health
LEL = Lower Explosive Limit
ppm = part per million
TLV = Threshold Limit Value
abdom = abdominal
anor = anorexia
arrhy = arrhythmia
card = cardiac
Ca = Considered by NIOSH to be potential occupational carcinogen
[carc] = potential occupational carcinogen
CNS = central nervous system
depres = depressant/depression
derm= dermititis
dizz = dizziness
drow = drowsiness
tg = fatigue
gidd = giddiness
inco = incoordination
inj = injury
lass = lassitude (weakness, exhaustion)
muc memb = mucous membrane
nau = nausea
pares = paresthesia
som = somnolence (sleepiness, unnatural drowsiness)
verti = vertigo
vis dist = visual disturbance

B. PHYSICAL & BIOLOGICAL HAZARDS OF CONCERN

Task	Hazard	Description	Control Measures	First Aid
1, 2, & 3	Skin contact with contaminant	Sample spills on skin; splashes in eyes.	Wear proper PPE; follow safe work practices	See "A" above
1, 2, & 3	Lacerations, abrasions, punctures	Several types of this injury could occur from carrying out this task	Wear proper PPE; follow safe work practices	Refer to National Safety Council (NSC) "Emergency First Aid Guide" enclosed
1, 2, & 3	Inhalation	Opening wells, purging and sampling exposes sampler	Follow air monitoring plan; wear respirator	See "A" above.
1, 2, & 3	Lifting	Improper lifting/carrying of equipment and materials causing strains.	Follow safe lifting and general material handling techniques	Refer to NSC "Emergency First Aid Guide" enclosed
1, 2, & 3	Slips, trips, and falls	Any number of injuries could occur from slips, trips, and falls in carrying out this task	Good housekeeping at site, constant awareness and focus on the task	Refer to NSC "Emergency First Aid Guide" enclosed
1, 2, & 3	Bites and stings	Bee stings; dog, tick, snake bites	Wear proper PPE, be watchful, follow safe work practices	See pages 115-121 of NSC manual
1 & 2	Noise	Drill rig/ Bosch hammer drill	Wear hearing protection	-
1, 2, & 3	Driving To/From location	Vehicle incidents, fatigue, aggressive driving.	Obey all posted traffic signage, following distance, Take frequent breaks,	
1, 2, & 3	Cold Related Injuries	Hypothermia, Frostbite, Trench foot	Dress in layers, Move to a heated area, Take frequent breaks, Change socks, Stay Hydrated, Avoid caffeinated drinks	Refer to NSC "Emergency First Aid Guide" enclosed
1, 2, & 3	Pinch Points	Equipment installation, moving lifts, pipe connections, conveyors, etc.	Use caution, wear work gloves where necessary	Seek medical attention as required
1, 2, & 3	Vehicle traffic / Heavy Equipment Operation	Vehicles unable to see workers on site, operation of heavy equipment in tight spaces, equipment failure, malfunctioning alarms	Wear proper PPE, especially visibility vest; use a buddy system to look for traffic; rope off area of work with cones and caution tape or devices at points of hazard, maintain safe distance from construction activities and equipment	Seek medical attention as required

1 & 2	Excavator/Drill Rig/Construction Equipment	Struck by heavy equipment	Maintain safe distance and visual contact with operator	Refer to NSC "Emergency First Aid Guide" enclosed
1, 2 & 3	Heat Related Injuries	Heat Stress/Exhaustion/Cramps	Drink plenty of water, stay hydrated, take frequent breaks in a cool/shaded area, conduct working during cooler times of the day if possible	Refer to NSC "Emergency First Aid Guide" enclosed
1 & 2	Underground/overhead utilities	Subsurface probing tool makes contact with underground object; overhead pipes	Follow mark-out policy and all drilling safe practices	Refer to NSC "Emergency First Aid Guide" enclosed

TABLE 3
Summary of Monitoring Equipment

Instrument	Operation Parameters
Photoionization Detector (PID)	**Hazard Monitored:** Many organic and some inorganic gases and vapors. **Application:** Detects total concentration of many organic and some inorganic gases and vapors. Some identification of compounds is possible if more than one probe is measured. **Detection Method:** Ionizes molecules using UV radiation; produces a current that is proportional to the number of ions. **General Care/Maintenance:** Recharge or replace battery. Regularly clean lamp window. Regularly clean and maintain the instrument and accessories. **Typical Operating Time:** 10 hours. 5 hours with strip chart recorder.
Additional equipment (if needed, based on site conditions)	
Combustible Gas Indicator (CGI)	**Hazard Monitored:** Combustible gases and vapors. **Application:** Measures the concentration of combustible gas or vapor. **Detection Method:** A filament, usually made of platinum, is heated by burning the combustible gas or vapor. The increase in heat is measured. Gases and vapors are ionized in a flame. A current is produced in proportion to the number of carbon atoms present. **General Care/Maintenance:** Recharge or replace battery. Calibrate immediately before use. **Typical Operating Time:** Can be used for as long as the battery lasts, or for the recommended interval between calibrations, whichever is less.
Flame Ionization Detector (FID) with Gas Chromatography Option *(i.e., Foxboro Organic Vapor Analyzer (OVA))*	**Hazard Monitored:** Many organic gases and vapors (approved areas only). **Application:** In survey mode, detects the concentration of many organic gases and vapors. In gas chromatography (GC) mode, identifies and measures specific compounds. In survey mode, all the organic compounds are ionized and detected at the same time. In GC mode, volatile species are separated. **General Care/Maintenance:** Recharge or replace battery. Monitor fuel and/or combustion air supply gauges. Perform routine maintenance as described in the manual. Check for leaks. **Typical Operating Time:** 8 hours; 3 hours with strip chart recorder.
Potable Infrared (IR) Spectrophotometer	**Hazard Monitored:** Many gases and vapors. **Application:** Measures concentration of many gases and vapors in air. Designed to quantify one or two component mixtures. **Detection Method:** Passes different frequencies of IR through the sample. The frequencies absorbed are specific for each compound. **General Care/Maintenance:** As specified by the manufacturer.
Direct Reading Colorimetric Indicator Tube	**Hazard Monitored:** Specific gas and vapors. **Application:** Measures concentration of specific gases and vapors. **Detection Method:** The compound reacts with the indicator chemical in the tube, producing a stain whose length or color change is proportional to the compound's concentration.

Instrument	Operation Parameters
	General Care/Maintenance: Do not use a previously opened tube even if the indicator chemical is not stained. Check pump for leaks before and after use. Refrigerate before use to maintain a shelf life of about 2 years. Check expiration dates of tubes. Calibrate pump volume at least quarterly. Avoid rough handling which may cause channeling.
Aerosol Monitor	**Hazard Monitored:** Airborne particulate (dust, mist, fume) concentrations **Application:** Measures total concentration of semi-volatile organic compounds, PCBs, and metals. **Detection Method:** Based on light-scattering properties of particulate matter. Using an internal pump, air sample is drawn into the sensing volume where near infrared light scattering is used to detect particles. **General Care/Maintenance:** As specified by the mfr. Also, the instrument must be calibrated with particulates of a size and refractive index similar to those to be measured in the ambient air.
Monitox	**Hazard Monitored:** Gases and vapors. **Application:** Measures specific gases and vapors. **Detection Method:** Electrochemical sensor relatively specific for the chemical species in question. **General Care/Maintenance:** Moisten sponge before use; check the function switch; change the battery when needed.
Gamma Radiation Survey Instrument	**Hazard Monitored:** Gamma Radiation. **Application:** Environmental radiation monitor. **Detection Method:** Scintillation detector. **General Care/Maintenance:** Must be calibrated annually at a specialized facility. **Typical Operating Time:** Can be used for as long as the battery lasts, or for the recommended interval between calibrations, whichever is less.

TABLE 4

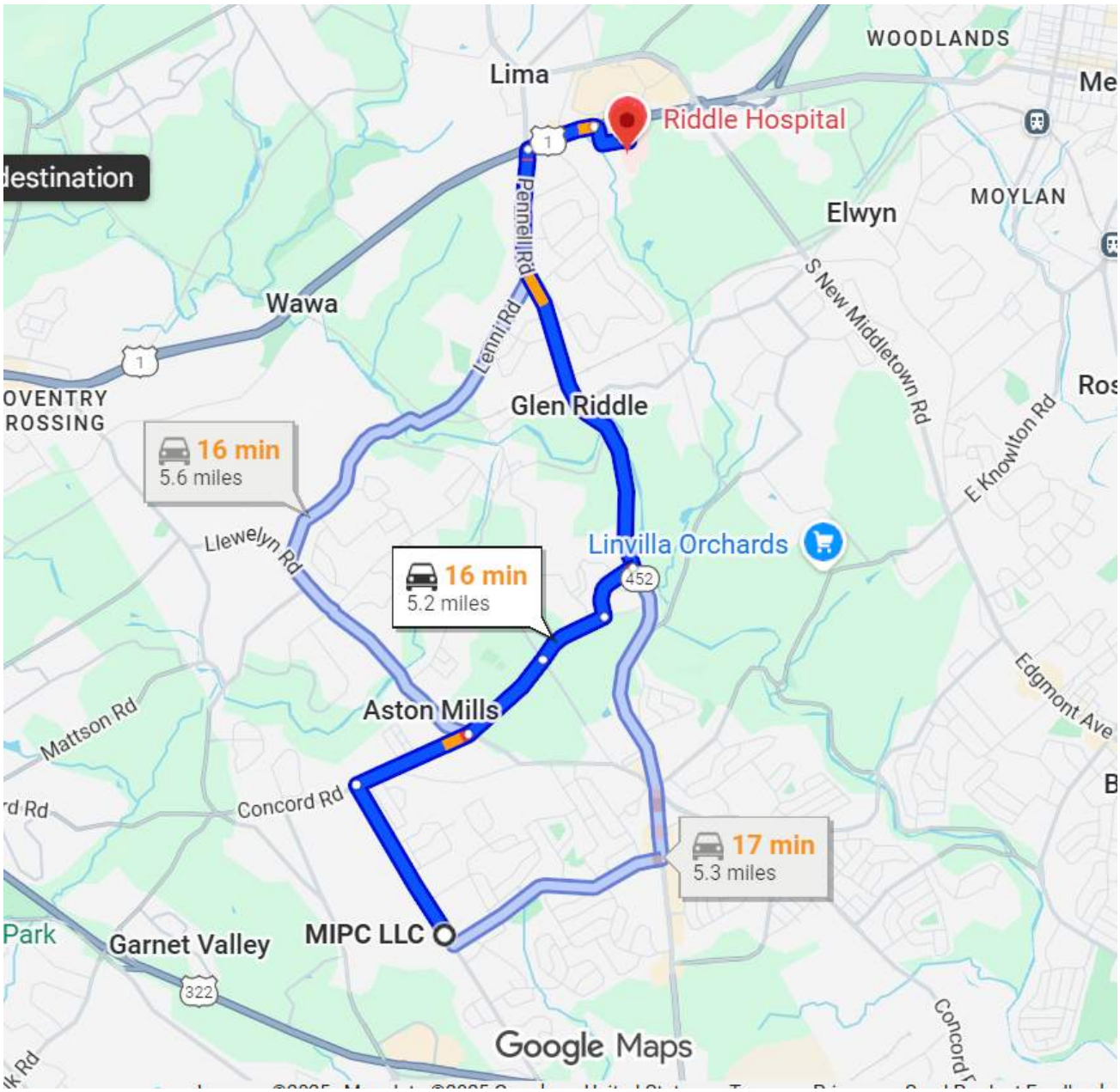
INSTRUMENTATION ACTION LEVELS
Below levels are based using Benzene as the COC and use of a Full Face Respirator.

Photoionization Detector Action Levels	**Action Required**
Background to 1 ppm	No respirator; no further action required
> 1 ppm but < 5 ppm for < 5 minutes	1. Temporarily discontinue all activities and evaluate potential causes of the excessive readings. If these levels persist and cannot be mitigated (i.e., by slowing drilling or excavation activities), contact HSO to review conditions and determine source and appropriate response action. 2. If PID readings remain above 1 ppm, temporarily discontinue work and upgrade to Level C protection (Full-Face Respirator Required). 3. If sustained PID readings fall below 1 ppm, downgrading to Level D protection may be permitted.
> 5 ppm but < 50 ppm for > 5 minutes	1. Discontinue all work; all workers shall move to an area upwind of the jobsite. 2. Evaluate potential causes of the excessive readings and allow work area to vent until VOC concentrations fall below 5 ppm. 3. Level C protection (Full-Face Respirator Required) will continue to be used until PID readings fall below 1 ppm.
> 50 ppm	Evacuate the work area

Notes:
1. 1 ppm level based on OSHA Permissible Exposure Limit (PEL) for benzene.
2. 5 ppm level based on OSHA Short Term Exposure Limit (STEL) maximum exposure for benzene for any 15 minute period.
3. 50 ppm level based on the Maximum Use Concertation (MUC) for a full-face respirator or NIOSH Immediately Dangerous to Life and Health (IDLH) for benzene. (The lower value will be used).

FIGURE 1

FIGURE 2:
HOSPITAL MAP & DIRECTIONS



MIPC LLC

920 Cherry Tree Rd, Aston Township, PA 19014

- Take Cherry Tree Rd to Convent Rd in Aston Township

  4 min (1.4 mi)

- Continue on Convent Rd to PA-452 N/Pennell Rd

  4 min (1.2 mi)

- Continue on PA-452 N/Pennell Rd to Middletown Township

  5 min (2.4 mi)

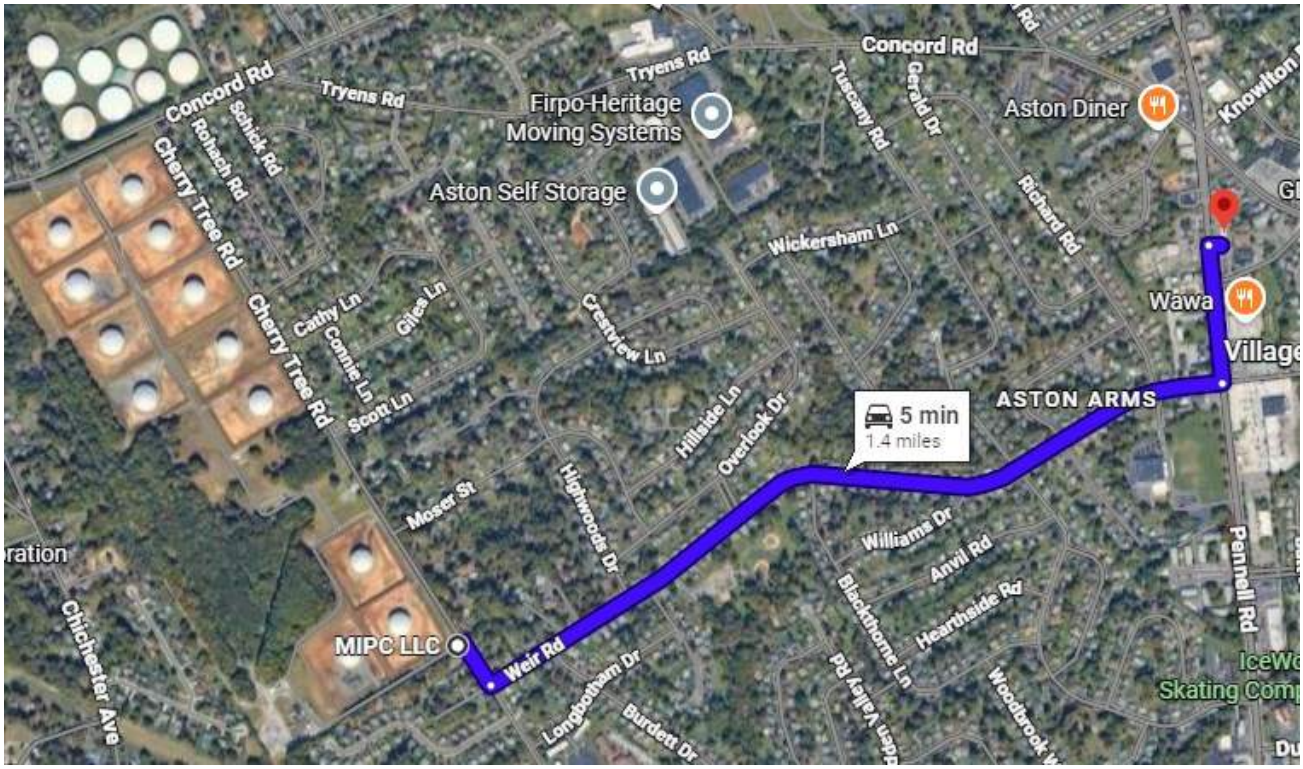
- Drive to your destination

  1 min (0.2 mi)

Main Line HealthCare Family Medicine at Riddle Hospital

Riddle Hospital, Health Center 2, 1088 W Baltimore Pike Suite 2301, Media, PA 19063

FIGURE 3:
URGENT CARE MAP & DIRECTIONS



from MIPC LLC, 920 Cherry Tree Rd, Aston Tow...
to AFC Urgent Care Aston, 5024 Pennell Rd, Ast...

5 min (1.4 miles)

via Weir Rd

Fastest route, the usual traffic

MIPC LLC

920 Cherry Tree Rd, Aston Township, PA 19014, United States

Head toward Cherry Tree Rd
Restricted usage road

43 ft

Turn right onto Cherry Tree Rd

364 ft

Turn left onto Weir Rd

1.1 mi

Turn left onto Pennell Rd

0.2 mi

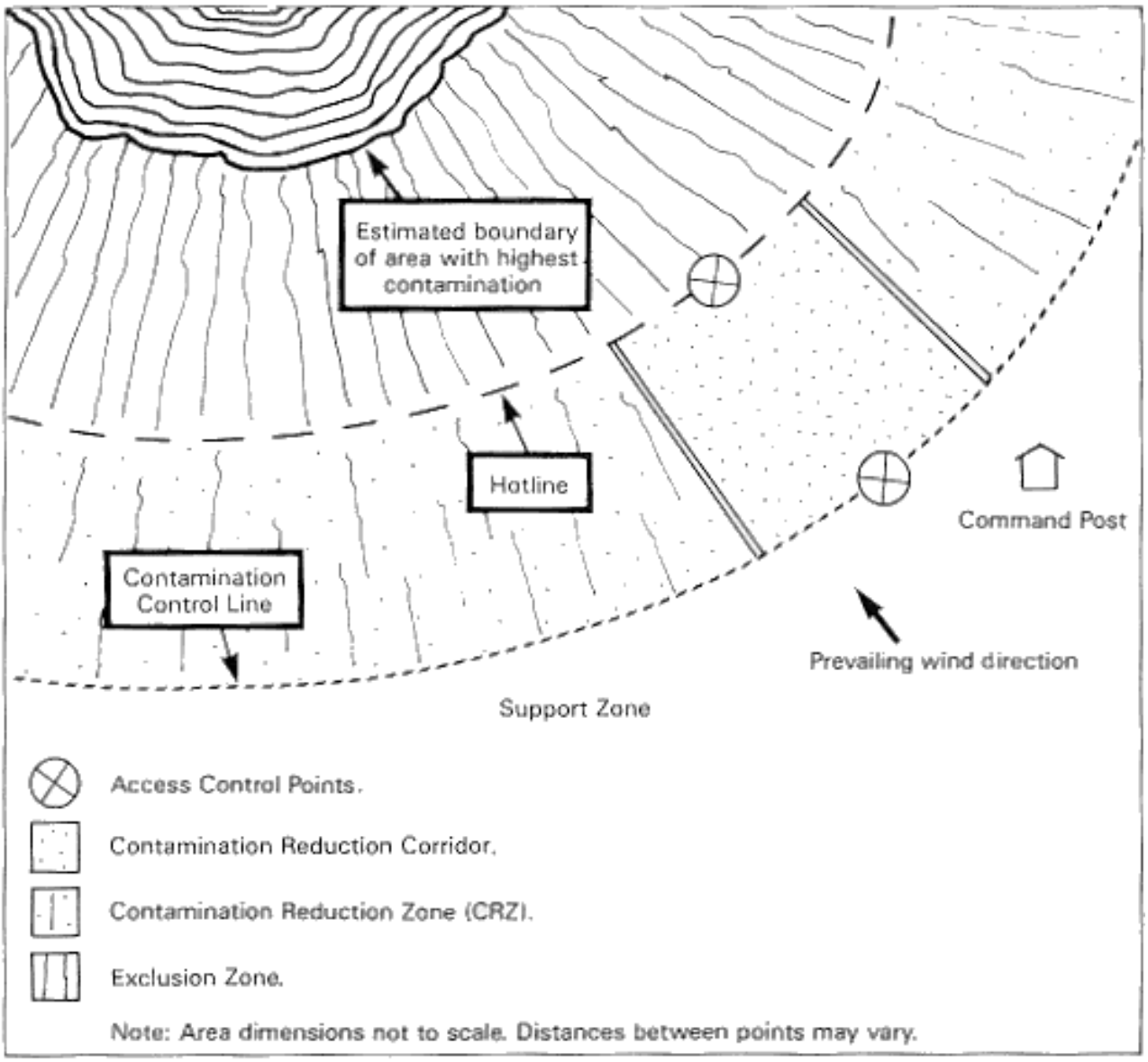
Turn right
Destination will be on the left

89 ft

AFC Urgent Care Aston

5024 Pennell Rd, Aston Township, PA 19014, United States

FIGURE 4:
GENERIC MAP OF SITE WORK ZONES



Map Source: NIOSH/OSHA/USCG/EPA "Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities", October 1985.

Notes:

1. This is not a site-specific map, but a conceptual map depicting a typical layout of work zones at a generic hazardous waste site.
2. See the following text for descriptions of the work zones delineated on the map.

Delineation of Work Zones

Work zones are used to prevent or reduce the migration of contamination. The three recommended contiguous zones are provided below.

- Zone 1: Exclusion Zone
- Zone 2: Contamination Reduction Zone
- Zone 3: Support Zone

Less stringent site control and decontamination procedures may be used if more definitive information is available on the types of substances involved, their locations, and the hazards they present.

Zone 1: Exclusion Zone

The Exclusion Zone is the zone where contamination may exist. An entry and exit checkpoint must be established at the periphery of the Exclusion Zone to regulate the flow of personnel and equipment into and out of the zone.

The outer boundary of this zone, the Hotline, is initially established by visually surveying the area and determining where hazardous substances, drainage, leachate, or spilled material may be located, and whether any discolorations are visible, or from data from the initial site survey.

Additional factors that should be considered include:

- The distances needed to prevent fire or an explosion from affecting personnel outside the zone;
- The physical area necessary to conduct site operations; and,
- The potential for contaminants to be blown from the area.

The Hotline must be physically marked or fenced. The boundary may be modified and adjusted as more information becomes available.

All personnel within the Exclusion Zone must wear the required level of personal protective equipment established in the Health & Safety Plan.

Zone 2: Contamination Reduction Zone

The Contamination Reduction Zone is located between the Exclusion Zone and the Support Zone and provides a transition between contaminated and clean zones. It serves as a buffer to reduce the probability of the clean zone becoming contaminated. Within the Contamination Reduction Zone lies the Contamination Reduction Corridor. This corridor begins at the boundary of the Exclusion Zone and is the area where the decontamination stations are established. Exit from the Exclusion Zone must always be through a decontamination station.

The size and location of the Contamination Reduction Corridor depends on the wind direction (up or side wind), the number of stations in the decontamination procedure, the overall dimension of work control zones, and the amount of space available at the site. An area of 75 by 15 feet should be

adequate for most corridors.

Personnel in the Contamination Reduction Corridor must wear the personal protective equipment designated for the decontamination crew. Another corridor may be required for the entrance and exit of heavy equipment needing decontamination.

Access to the Contamination Reduction Corridor should be limited to personnel wearing the appropriate protection and activities should be limited to decontamination.

Factors to consider when organizing the Contamination Reduction Corridor and selecting decontaminants include:

- The extent and type of hazard expected;
- Explosive potential;
- Meteorological conditions;
- Topography;
- Levels of protection; and
- Availability of equipment and supplies.

Zone 3: Support Zone

The Support Zone is considered to be a non-contaminated or clean area. Support equipment (command post, equipment trailer, etc.) shall be located in the zone and traffic shall be restricted to authorized response personnel. Normal work clothes are appropriate within this zone; potentially contaminated personnel clothing, equipment, and samples must be left in the Contamination Reduction Zone until they are decontaminated.

The location of the command post and other support facilities in the Support Zone depends on the factors below.

1. Accessibility - The topography, available open space, and the locations of highways and railroad tracks.

2. Wind Direction - The support facilities shall be located upwind of the Exclusion Zone. Shifts in wind direction and other conditions may be such that an ideal location determined on the basis of wind direction alone does not exist.

3. Resources - There should be adequate roads, power lines, water, and shelter.

Area Dimensions

The distance, size and shape of each zone must be based on conditions specific to each site. Distances between zone boundaries should be sufficient to allow room for the necessary operations,

provide adequate distances to prevent the spread of contaminants, and eliminate the possibility of injury due to explosion or fire. Long-term operations should involve developing reasonable methods to determine if material is being transferred between zones and to assist in modifying site boundaries.

The following criteria shall be considered in establishing area dimensions and boundary distances:

1. Physical and topographical features of the site;
2. Weather conditions;
3. Field/laboratory measurements of air contaminants and environmental samples;
4. Air dispersion calculations;
5. Potential for explosion and flying debris;
6. Physical, chemical, toxicological, and other characteristics of the substances present;
7. Cleanup activities required;
8. Potential for fire;
9. Area needed to conduct operations;
10. Decontamination procedures;
11. Dimensions of contaminated area; and,
12. Potential for exposure.

APPENDIX A
Standing Orders

STANDING ORDERS

GENERAL

- Utilize Stop Work Authority when warranted.
- No smoking, eating, or drinking in this work zone.
- Upon leaving the work zone, personnel will thoroughly wash their hands and face.
- Minimize contact with contaminated materials through proper planning of work areas and decontamination areas, and by following proper procedures. Do not place equipment on the ground. Do not sit on contaminated materials.
- No open flames in the work zone.
- Only properly trained and equipped personnel are permitted to work in potentially contaminated areas.
- Always use the appropriate level of personal protective equipment (PPE).
- Maintain close contact with your buddy in the work zone
- Contaminated material will be contained in the Exclusion Zone (EZ).
- Report any unusual conditions.
- Work areas will be kept clear and uncluttered. Debris and other slip, trip, and fall hazards will be removed as frequently as possible.
- The number of personnel and equipment in the work zone will be kept to an essential minimum.
- Be alert to the symptoms of fatigue and heat/cold stress, and their effects on the normal caution and judgment of personnel.
- Conflicting situations which may arise concerning safety requirements and working conditions must be addressed and resolved quickly by the site HSO.

TOOLS AND HEAVY EQUIPMENT

- Do not, under any circumstances, enter or ride in or on any backhoe bucket, materials hoist, or any other device not specifically designed to carrying passengers.
- Loose-fitting clothing or loose long hair is prohibited around moving machinery.
- Ensure that heavy equipment operators and all other personnel in the work zone are using the same hand signals to communicate.
- Drilling/excavating within 10 feet in any direction of overhead power lines is prohibited.
- The locations of all underground utilities must be identified and marked out prior to initiating any subsurface activities.
- Check to insure that the equipment operator has lowered all blades and buckets to the ground before shutting off the vehicle.
- If the equipment has an emergency stop device, have the operator show all personnel its location and how to activate it.
- Help the operator ensure adequate clearances when the equipment must negotiate in tight quarters; serve as a signalman to direct backing as necessary.
- Ensure that all heavy equipment that is used in the Exclusion Zone is kept in that zone until the job is done, and that such equipment is completely decontaminated before moving it into the clean area of the work zone.
- Samplers must not reach into or get near rotating equipment such as the drill rig. If personnel must work near any tools that could rotate, the equipment operator must completely shut down the rig prior to initiating such work. It may be necessary to use a remote sampling device.

APPENDIX B
Decontamination Procedures

PERSONNEL DECONTAMINATION

LEVEL C DECONTAMINATION

Station 1:	Equipment Drop	1. Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths. Segregation at the drop reduces the probability of cross contamination. During hot weather operations, cool down stations may be set up within this area.
Station 2:	Outer Garment, Boots, and Gloves Wash and Rinse	2. Scrub outer boots, outer gloves and chemical-resistant splash suit with decon solution or detergent and water. Rinse off using copious amounts of water.
Station 3:	Outer Boot and Glove Removal	3. Remove outer boots and gloves. Deposit in container with plastic liner.
Station 4:	Canister or Mask Change	4. If worker leaves Exclusion Zone to change canister (or mask), this is the last step in the decontamination procedure. Worker's canister is exchanged, new outer gloves and boot covers donned, joints taped, and worker returns to duty.
Station 5:	Boot, Gloves and Outer Garment Removal	5. Boots, chemical-resistant splash suit, inner gloves removed and deposited in separate containers lined with plastic.
Station 6:	Facepiece Removal	6. Facepiece is removed (avoid touching face with fingers). Facepiece deposited on plastic sheets.
Station 7:	Field Wash	7. Hands and face are thoroughly washed. Shower as soon as possible.

LEVEL D DECONTAMINATION

Station 1:	Equipment Drop	1. Deposit equipment used on-site (tools, sampling devices and containers, monitoring instruments, radios, clipboards, etc.) on plastic drop cloths. Segregation at the drop reduces the probability of cross contamination. During hot weather operations, cool down stations may be set up within this area.
Station 2:	Outer Garment, Boots, and Gloves Wash and Rinse	2. Scrub outer boots, outer gloves and chemical-resistant splash suit with decon solution or detergent and water. Rinse off using copious amounts of water.
Station 3:	Outer Boot and Glove Removal	3. Remove outer boots and gloves. Deposit in container with plastic liner.
Station 4:	Boot, Gloves and Outer Garment Removal	4. Boots, chemical-resistant splash suit, inner gloves removed and deposited in separate containers lined with plastic.
Station 5:	Field Wash	5. Hands and face are thoroughly washed. Shower as soon as possible.

EQUIPMENT DECONTAMINATION

GENERAL:

Equipment to be decontaminated during the project may include tools, monitoring equipment, respirators, sampling containers, laboratory equipment and drilling equipment.

All decontamination will be done by personnel in protective gear, appropriate for the level of decontamination, as determined by the site HSO. The decontamination work tasks will be split or rotated among support and work crews.

Depending on site conditions, backhoe and pumps may be decontaminated over a portable decontamination pad to contain wash water; or, wash water may be allowed to run off into a storm sewer system. Equipment needed may include a steam generator with high-pressure water, empty drums, screens, screen support structures, and shovels. Drums will be used to hold contaminated wash water pumped from the lined pit. These drums will be labeled as such.

Miscellaneous tools and equipment will be dropped into a plastic pail, tub, or other container. They will be brushed off and rinsed with a detergent solution, and finally rinsed with clean water.

MONITORING EQUIPMENT:

Monitoring equipment will be protected as much as possible from contamination by draping, masking, or otherwise covering as much of the instruments as possible with plastic without hindering the operation of the unit. The HNu or OVA meter, for example, can be placed in a clear plastic bag, which allows reading of the scale and operation of knobs. The probes can be partially wrapped keeping the sensor tip and discharge port clear.

The contaminated equipment will be taken from the drop area and the protective coverings removed and disposed in the appropriate containers. Any dirt or obvious contamination will be brushed or wiped with a disposable paper wipe.

RESPIRATORS:

Respirators will be cleaned and disinfected after every use. Taken from the drop area, the masks (with the cartridges removed and disposed of with other used disposable gear) will be immersed in a cleaning solution and scrubbed gently with a soft brush, followed by a rinse in plain warm water, and then allowed to air dry. In the morning, new cartridges will be installed. Personnel will inspect their own masks for serviceability prior to donning them. And, once the mask is on, the wearer will check the respirator for leakage using the negative and positive pressure fit check techniques.

APPENDIX C
Incident, Injury, & Near Miss Report Form

INCIDENT/ INJURY REPORT
LANGAN ENGINEERING & ENVIRONMENTAL SERVICES

(Complete and return to Tony Moffa in the Doylestown Office)

Affected Employee Name: _____ Date: _____

Incident type: ☐ Injury ☐ Report Only/No Injury
☐ Near Miss ☐ Other: _____

EMPLOYEE INFORMATION (Person completing Form)

Employee Name: _____ Employee No: _____

Title: _____ Office Location: _____

Length of time employed or date of hire: _____

Mailing address: _____

_____

Sex: M ☐ F ☐ Birth date: _____

Business phone & extension: _____ Residence/cell phone: _____

ACCIDENT INFORMATION

Project: _____ Project #: _____

Date & time of incident: _____ Time work started & ended: _____

Site location: _____

Incident Type: Possible Exposure ☐ Exposure ☐ Physical Injury ☐

Names of person(s) who witnessed the incident: _____

Exact location incident occurred:

Describe work being done:

Describe what affected employee was doing prior to the incident occurring:

Describe in detail how the incident occurred:

Nature of the incident (List the parts of the body affected):

Person(s) to whom incident was reported (Time and Date):

List the names of other persons affected during this incident:

Possible causes of the incident (equipment, unsafe work practices, lack of PPE, etc):

Weather conditions during incident:

MEDICAL CARE INFORMATION

Did affected employee receive medical care? Yes ☐ No ☐

If Yes, when and where was medical care received:

Provide name of facility (hospital, clinic, etc):

Length of stay at the facility?

Did the employee miss any work time? Yes ☐ No ☐ Undetermined ☐

Date employee last worked: Date employee returned to work:

Has the employee returned to work? Yes ☐ No ☐

Does the employee have any work limitations or restrictions from the injury? : Yes ☐ No ☐

If Yes, please describe:

Did the exposure/injury result in permanent disability? Yes ☐ No ☐ Unknown ☐

If Yes, please describe:

HEALTH & SAFETY INFORMATION

Was the operation being conducted under an established site specific Health and Safety Plan?
Yes ☐ No ☐ Not Applicable: ☐

Describe protective equipment and clothing used by the employee:

Did any limitations in safety equipment or protective clothing contribute to or affect exposure / injury? If so, explain:

Employee Signature Date

Langan Representative Date

LANGAN

Near Miss Report
Health and Safety

A Near-Miss is an incident which did not result in property damage or employee injury, but potentially could have under different circumstances. Near-Miss Reporting is the process of identifying and preventing an unsafe act or condition before it causes property damage or employee injury. *All near misses must be reported to the Health and Safety Department using this form.*

Near Miss Information

Check all that apply:

☐ Unsafe Condition ☐ Unsafe Act/ Behavior

☐ Unsafe Equipment ☐ Unsafe Use of Equipment

Location/ Project #: _____ Date/Time: _____

Description of Near Miss (Who, What, Where, When & How):

Causes (Why it happened):

Corrective Action (How can this be prevented in the future?):

Submitted By: _____ Date: _____

Reviewed by (Health and Safety Department Use Only)

Name: _____ Date: _____

NMR #: _____

Langan Incident/ Injury Hotline: 201.398.4699

Form: HS13-01

APPENDIX D
Calibration Log

DATE:_____ **PROJECT:**_____

CALIBRATION LOG

Date & Time	Inst Type	Inst #	Media	Initial Reading	Span #	Calib Reading	Performed By:

APPENDIX E
Safety Data Sheets (SDS)

Product Safety Information Sheet

Document:	9030165	Date of revision:	21.11.2025
Version:	11/2025	Supersedes:	Version 10/2025
Format:	Dräger-Tubes™ and MicroTubes (which are not classified as dangerous goods!)_PSIS_EN.doc	Status:	released

1. Identification of the substance/preparation and of the company/undertaking

1.1 Identification of the substance or preparation:

Trade name: **Dräger-Tubes™ and MicroTubes (which are not classified as dangerous goods!)**
Part nos. : various (see section 1.5)

1.2 Use of the substance/preparation:

Detection of gases, measuring of gas concentrations.

1.3 Company/undertaking name:

Dräger Safety AG & Co. KGaA
Revalstr. 1
D-23560 Lübeck
Telephone number +49 451/882-0
Fax number +49 451/882-2080
Contact for information: Dräger Global EHS Management
Telephone number +49 451/882-5997

1.4 Emergency telephone: **+49 451/882-2395**

1.5 Relevant products:

Part-No.	Trade name	Part-No.	Trade name
6726665	Acetaldehyde 100/a	8610080	MT Carbon monoxide 2-1000 ppm
6722101	Acetic Acid 5/a	8610090	MT Hydrochloric acid 0.5-25 ppm
CH22901	Acetone 100/b	8610100	MT Formaldehyde 0,15-3 ppm
8103381	Acetone 40/a	8610110	MT Sulfur dioxide 0.05-5 ppm
8101121	Acid Test	8610120	MT Nitrogen dioxide 0.25-25 ppm
8103701	Acrylonitrile 0,2/a	8610130	MT Ammonia 1-100 ppm
8101141	Active Tube for Formaldehyde 0.2A	8610190	MT Carbon dioxide 200-50000 ppm
3740290	Alcohol 10/a	8610200	MT Ethylene Oxide 25-250 ppb
8101061	Amine Test	8610220	MT Hydrogen sulfide 100-2000 ppm
8101711	Ammonia 0.25/a	8610230	MT Vinyl chloride 0.1-10 ppm
CH31901	Ammonia 0.5 %/a	8610250	MT Toluene 10-1000 ppm
6733231	Ammonia 2/a	8610260	MT Xylene 10-1000 ppm
8101301	Ammonia 20/a-D	8610270	MT Petroleum Hydrocarbons 10-3000 ppm
8103301	Ammonia 3/a	8610280	MT Benzol 10-100 ppm
CH20501	Ammonia 5/a	8610290	MT Demo
8101941	Ammonia 5/b	8610300	MT 1,3-Butadiene 0.5-25 ppm
6733171	Aniline 0.5/a	8610320	MT Trichlorethylene 0.25-50 ppm
CH25001	Arsine 0.05/a	8610330	MT Acetic Acid 2-50 ppm
6718801	Benzene 5/a	8610340	MT Phosgene 10-1000 ppb
8101161	Butadiene 10/a-D	8610350	MT Mercury 0,005-0,25 mg/m³
8103861	n-Butanol 10/a	8610360	MT Mercaptane 50-6000 ppb
CH23501	Carbon Dioxide 0.1 %/a	8610380	MT Alcohol 10-5000 ppm
CH31401	Carbon Dioxide 0.5 %/a	8610400	MT Phosphine 50-5000 ppb
CH25101	Carbon Dioxide 1 %/a	8610430	MT Ozone 10-1000 ppb
8101051	Carbon Dioxide 1 %/a-D	8610460	MT 1,3-Butadiene 25-500 ppb
8101811	Carbon Dioxide 100/a	8610470	MT Acetone 25-5000 ppm
6728521	Carbon Dioxide 100/a-P	8610510	MT Methylene Chloride 10-500 ppm
CH20301	Carbon Dioxide 5 %/A	8610520	MT Hydrocyanic acid 0,5-50 ppm
8101891	Carbon Disulphide 3/a	8610530	MT MTBE 2-200 ppm
CH23201	Carbon Disulphide 30/a		

CH24101	Carbon Pre-Tube	8610540	MT Formaldehyde 5-150 ppb
8101021	Carbon Tetrachloride 1/a	8610050	MT Hydrogen Sulfide 0.1-50 ppm
8103140	CDS Set I	8610060	MT Nitrous fumes 0,5-25 ppm
8103200	CDS Set V	8610580	MT Ethylene oxide 0.25-10 ppm
8103230	CDS Training-Kit I	8610600	MT Benzene 1-150 ppb
8103240	CDS Training-Kit V	8103071	Natural Gas odorization, tert.-Butyl mercaptan (TBM)
CH24301	Chlorine 0.2/a	CH19501	Nickel Tetracarbonyl 0.1/a
CH20701	Chlorine 50/a	6728311	Nitric Acid 1/a
8103491	Chlorine Dioxide 0.025/a	8103631	Nitrogen Dioxide 0.1/a
6728761	Chlorobenzene 5/a	8101111	Nitrogen Dioxide 10/a-D
6718601	Chloroformates 0.2/b	6719101	Nitrogen Dioxide 2/c
8103421	Chloropicrin 0.1/a	8103661	Nitrous Fumes 0,2/a
6718901	Chloroprene 5/a	CH31001	Nitrous Fumes 2/a
6728681	Chromic Acid 0.1/a	3706171	Nitrous Fumes 20/b
6728791	Cyanide 2/a	8103941	Nitrous Fumes 50/b
CH19801	Cyanogen Chloride 0.25/a	CH31201	Olefines 0.05 % /a
8103671	Cyclohexane 40/a	CH26303	Organic Arsenic Compounds
6728931	Cyclohexylamine 2/a	CH25903	Organic Basic Nitrogen Compounds
8103475	Diesel Fuel	6733181	Ozone 0.05/b
6730501	Diethyl Ether 100/a	CH21001	Ozone 10/a
6718501	Dimethyl Formamide 10/b	6724701	Pentane 100/a
6718701	Dimethyl Sulphate 0.005/c	8101551	Perchloroethylene 0.1/a
6728451	Dimethyl Sulphide 1/a	8101501	Perchloroethylene 2/a
6728111	Epichlorohydrin 5/c	6730201	Petroleum Hydrocarbons 100A
8103761	Ethanol 100/a	8101691	Petroleum Hydrocarbons 10A
6728381	Ethyl Benzene 30/a	8101641	Phenol 1/b
6726801	Ethyl Glycol Acetate 50/a	8101521	Phosgene 0.02/a
8101331	Ethylene 0.1/a	8103711	Phosphine 0,1/c
8101351	Ethylene Glycol 10	8101611	Phosphine 0.01/a
6728961	Ethylene Oxide 1/a	8103341	Phosphine 0.1/b in Acetylene
8101491	Fluorine 0.1/a	8101801	Phosphine 1/a
6733081	Formaldehyde 0.2/a	8101621	Phosphine 25/a
8101751	Formaldehyde 2/a	CH21201	Phosphine 50/a
6722701	Formic Acid 1/a	6728461	Phosphoric Acid Ester 0.05/a
8103410	Fumigation-Test-Set	8103531	PID-Pre-filter Tube Humidity
8103681	Hexane 10/a	3702013	ppb-Booster Basic X-act 7000
8103351	Hydrazine 0.01/a	8103741	i-Propanol 50/a
CH31801	Hydrazine 0.25/a	6728651	Pyridine 5/A
8101681	Hydrochloric Acid / Nitric Acid 1/a	8101861	Silicagel Type B/G
8103481	Hydrochloric Acid 0,2/a	6728851	Silicagel Type G
CH29501	Hydrochloric Acid 1/a	8101735	Simultaneous Test-Set I for inorganic fumes
6728181	Hydrochloric Acid 50/a	8101736	Simultaneous Test-Set II for inorganic fumes
8103601	Hydrocyanic Acid 0,5/a	8101770	Simultaneous Test-Set III for organic vapours
8101511	Hydrogen 0.2 %/a	8103180	Simultaneus Test Set
CH30901	Hydrogen 0.5 %/a	8103380	Simultaneus Test Set for Container Fumigation
8103251	Hydrogen Fluoride 0.5/a	8103170	Simultaneus Test Set Indicator Substances
CH30301	Hydrogen Fluoride 1.5/b	6723301	Styrene 10/a
8101041	Hydrogen Peroxide 0,1/a	CH27601	Styrene 50/a
CH28201	Hydrogen Sulphide + Sulphur Dioxide 0.2 %/A	6727101	Sulphur Dioxide 0.1/a
CH28101	Hydrogen Sulphide 0.2 %/A	6728491	Sulphur Dioxide 0.5/a
8101461	Hydrogen Sulphide 0.2/a	CH31701	Sulphur Dioxide 1/a
8101991	Hydrogen Sulphide 0.2/b	CH24201	Sulphur Dioxide 20/a
6728041	Hydrogen Sulphide 0.5/a	8101531	Sulphur Dioxide 50/b
6719001	Hydrogen Sulphide 1/c	6728781	Sulphuric Acid 1/a
8101831	Hydrogen Sulphide 1/d	8101341	Tetrahydrothiophene 1/b
CH29101	Hydrogen Sulphide 100/a	CH25803	Thioether
8101211	Hydrogen Sulphide 2 %/a	8101731	Toluene 100/a

6728821	Hydrogen Sulphide 2/a	8101661	Toluene 5/b
8101961	Hydrogen Sulphide 2/b	8101701	Toluene 50/a
CH29801	Hydrogen Sulphide 5/b	6724501	Toluene Diisocyanate 0.02/A
8103521	Iodine 0.1/a	CH21101	Trichloroethane 50/d
8103281	Mercaptan 0.1/a	6728541	Trichloroethylene 2/a
6728981	Mercaptan 0.5/a	8101881	Trichloroethylene 50/a
8101871	Mercaptan 20/a	6718401	Triethylamine 5/a
CH23101	Mercury Vapour 0.1/b	8101721	Vinyl Chloride 0.5/b
8103801	Methanol 20/a	CH19601	Vinyl Chloride 100/a
8103591	Methylene chloride 20/a	CH23401	Water Vapour 0,1
8103485	MITC 0.1/a	8101321	Water Vapour 0,1/a
8610010	MT Chlorine 50-5000 ppb	8101781	Water Vapour 1/b
8610020	MT Ammonia 100-2.500 ppm	8103031	Water Vapour 3/a
8610030	MT Benzene 0,15-10 ppm	8103061	Water Vapour 20/a-P
8610040	MT Perchlorethylene 1-500 ppm	6728531	Water Vapour 5/a-P

2. Hazards identification

2.0 General information:
Dräger-Tubes™ and MicroTubes are articles which are not subject to classification. The requirements of EC regulations 1907/2006 (REACH) and 1272/2008 (GHS/CLP) do not apply to such products. Hence, the information in this Product Safety Information Sheet is purely voluntary!

2.1 Classification: -

2.2 Particular hazards for man and environment:
These products are non-flammable, granulate filled glass tubes. Improper handling, leaks, and/or damage to the tubes may release weak caustic/corrosive and/or irritant/harmful granulate material in solid form.
The chemicals and preparations in the detector tubes may cause different irritation or injury to the skin, eyes, gastrointestinal tract and may cause irritation to the respiratory tract. If the glass tubes are broken, the sharp edges may cause cuts or scratches.

3. Composition/Information on ingredients

3.1 Chemical characterisation (constituent):
not applicable

3.2 Chemical characterisation (mixtures):
Dräger-Tubes™ and MicroTubes are glass tubes usually containing small amounts of inert inorganic carrier materials which have been impregnated with different chemicals. In the following table such chemicals are listed; for detailed information about the ingredients in the different tubes please see the Dräger-Tubes™-/MicroTubes Handbook.

EINECS / ELINCS-No.	CAS-No.	Designation acc. to the EC Regulations	Content	Unit	GHS-Pictogram	H-Phrases
204-309-3	119-26-6	2,4-Dinitrophenylhydrazine	0-0,1	%	GHS01, GHS07	H228, H302, H319
203-564-8	108-24-7	Acetic acid anhydrid	0-1	w/w per cent	GHS02, GHS05, GHS06	H226, H302, H314, H332
n/a	n/a	Amine compounds	0-3	w/w per cent	GHS06, GHS08, GHS09	H302, H312, H314, H317, H332, H351, H410
-	32458-20-1	Bariumchloroanilat	0-0.1	w/w per cent	GHS06	H302, H332
219-666-0	2494-56-6	Butyrylcholiniodide	0-0.1	w/w per cent	GHS06	H315, H319, H335
237-029-5	10294-42-5	Cerium sulfate	0-0.1	w/w per cent	GHS08	H314, H318, H400, H410

215-607-8 232-043-8 232-140-5	1333-82-0 7784-01-2 7789-00-6	**Chromium(VI) salts** Chromium(VI) Oxide Silver Chromate Potassium Dichromate	<1	w/w per cent	GHS05, GHS08, GHS09	H301, H312, H315, H317, H318, H330, H334, H335, H340, H350, H400, H410
n/a	n/a	Copper salts	0-10	w/w per cent	GHS09	H302, H315, H319, H400, H410
203-473-3	107-21-1	Ethylene glycol	0-0,2	w/w per cent	GHS08	H302
200-01-8	50-00-0	Formaldehyde	0-0.1	w/w per cent	GHS06, GHS08	H301, H311, H314, H317, H331, H341, H350
202-626-1	98-00-0	Furfurol	0-0.1	w/w per cent	GHS02, GHS06, GHS07	H302, H312,H319, H331, H335, H351, H373
n/a	n/a	Gold salts	0-1	w/w per cent	GHS05, GHS09	H302, H315, H319, H335, H410
206-114-9	302-01-2	Hydrazine-Hydrate	0-6	w/w per cent	GHS02, GHS05, GHS09	H226, H301, H311, H314, H317, H331, H350, H400, H410
231-595-7	7647-01-0	Hydrochloric acid	0-0.5	w/w per cent	GHS05, GHS07	H314, H335
231-442-4	7553-56-2	Iodine	0-3	w/w per cent	GHS05, GHS08	H312, H332, H400
234-740-2	12029-98-0	Iodinepentoxide	0-0.01	w/w per cent	GHS08	H272, H314, H318
n/a	n.a	Lead salts	0-0,1	w/w per cent	GHS06, GHS08, GHS09	H302, H332, H373, H410
233-108-3	10034-81-8	Magnesium perchlorate	0-0.1	w/w per cent	GHS08	H272, H315, H319, H335
n/a	n/a	Mercury salts	0-0.1	w/w per cent	GHS06, GHS08, GHS09	H300, H310, H330, H360D H372, H410
202-088-8	91-66-7	N,N-Diethylaniline	0-0.2	w/w per cent	GHS05	H301, H311, H331, H373, H411
204-358-0	119-93-7	o-Tolidine	0-0.5	w/w per cent	GHS05	H302, H350, H411
204-355-4	119-90-4	o-Dianisidine	0-0.1	w/w per cent	GHS05	H302, H350
n/a 231-596-2	13566-03-5 7647-10-1	**Palladium compounds** Palladium (II) Sulfat Palladium (II) Chloride	0-0.2	w/w per cent	GHS05	H314
231-760-3	7722-64-7	Potassium permanganate	0-0.1	w/w per cent	GHS08, GHS05	H272, H302, H400, H410, H361d
231-633-2	7664-38-2	o-Phosphoric acid	0-10	w/w per cent	GHS05	H314
203-809-9	110-86-1	Pyridine	0-5	w/w per cent	GHS02, GHS08	H225, H302, H312, H332
211-027-4	628-13-7	Pyridylpyridiniumchloride	0-0.1	w/w per cent	GHS08	H302, H315, H319, H332, H335
n/a	n/a	Silver salts	0-0.1	w/w per cent	GHS06, GHS09	H301, H302, H312, H410

231-194-7	7446-08-4	**Selenium salts** Selenium dioxide	<1	w/w per cent	GHS06, GHS09	H301, H331, H373, H413
n/a	n/a	Sodium salts	0-1	w/w per cent	GHS02, GHS05, GHS08	H260, H314, H302, H319, H361d
231-639-5	7664-93-9	Sulphuric acid	0-5	w/w per cent	GHS05	H314
215-535-7	1330-20-7	Xylene	0-1	w/w per cent	GHS02, GHS08	H226, H312, H315, H332
n/a	n/a	Zirconium compounds	0-0.0005	w/w per cent	GHS08	H314

* based on the gross weight of the Draeger Tube™ or MicroTube. The information contained in this Product Safety Information Sheet is applicable to the hazardous contents of the Draeger Tube™ or MicroTube.

3.3 Other information:
Dräger-Tubes™ and MicroTubes are closed glass tubes which are filled with several preparation layers. The preparation layers are usually fixed by holding and separating elements within the glass tube. Partially the Dräger-Tubes™ and MicroTubes contain filled glass ampoules also with reactive liquids.
Important ingredients in preparations used for the Dräger-Tubes™ and MicroTubes:
- inorganic acid,
- inorganic salts, and
- organic chemicals/indicators in small quantities and in concentrations below the limit for labelling-requirements in acc. to CLP and the German GefStoffV.

Important ingredients of the ampoules used in the Dräger-Tubes™ and MicroTubes:
- inorganic acids,
- organic solvents.

Dräger-Tubes™ and MicroTubes contain no ozone-depleting chemicals and no volatile organic chemicals (except special ampoules). During the manufacturing process for the Dräger-Tubes™ and MicroTubes (except special calibration procedures) no ozone-depleting chemicals (group I-IV of the Montreal Protocol) were used.

4. First-aid measures

4.1 After inhalation:
If dusts of this product is inhaled, remove person immediately to fresh air. Seek medical attention if symptoms develop or persist.

4.2 After contact with skin:
Wash with plenty of water. Tube contents can be neutralized with lime and water, or rinsed with plenty of water, then treated with polyethylene glycol 400. If irritation persists, get medical advice. Discard any shoes or clothing items that cannot be decontaminated.

4.3 After contact with the eyes:
Immediately flush eyes with plenty of water (for at least 15 minutes), while holding eyelids open. Seek medical advice at once. Danger of corneal clouding.

4.4 After ingestion:
If the material is swallowed, get immediate medical attention or advice. Do not induce vomiting (Danger of perforation!).

4.5 Information for the doctor:
After ingestion there is a danger of the oesophagus and the stomach becoming perforated.

5. Fire-fighting measures

5.1 Suitable extinguishing media:
Dry chemical, carbon dioxide. Adapt extinguishing media to the environment. Materials in the glass tubes are non-flammable. Avoid direct contact of this product with water since this may cause an exothermic reaction.

5.2 Extinguishing media which must not be used for safety reasons:
Not checked

5.3 Special exposure hazards arising from substances or preparation itself, combustion products, resulting gases:

Non-Flammable. Thermal decomposition of the tube contents may produce weak amount of harmful, irritant or toxic gases (sulphur oxides, carbon monoxide, etc.). When using water as an extinguishing media, take care of the resulting slight acidic fire-fighting water.
Contents of the tubes are corrosive to the eyes, skin, gastrointestinal tract and may cause irritation to the respiratory tract. Improper handling, leaks, and/or damage to the tube may release caustic granulate material in solid form.

5.4 Special protective equipment for fire-fighters:
Recommendation: Wear full protective clothing, including helmet, self-contained positive pressure or pressure demand breathing apparatus, protective clothing and face mask.

6. Accidental release measures

6.1 Personal precautions:
Do not inhale released vapour, fumes, or dusts from the spilled material. Do not allow spilled materials to contact eyes or skin, use protective gloves (e.g. PE/PP, Latex, rubber) resistant against acidic materials and safety goggles. Isolate area. Keep unnecessary personnel away. Use dust mask with P2/FFP2 filters.

6.2 Environmental precautions:
Block any potential routes to water systems. Do not discharge into the sewer system. Do not allow to enter drains/surface water/groundwater.

6.3 Methods for cleaning up:
Sweep up dry while avoiding formation of dusts. Do not pick up glass with bare hands. Dilute tube contents with water and baking soda. Shovel material into appropriate container for disposal. Thoroughly wash the area with water after a spill or leak clean-up. Sweep up or scrape broken tubes into container for disposal.

6.4 Additional information:
Follow all Local, State, Federal and Provincial regulations for disposal.

7. Handling and storage

7.1 Handling:

Precautions for safety handling:	Observe the Instructions for Use.
Information for protection against fire and explosion:	These products are non-flammable.

7.2 Storage:

Requirements for storage and containers:	Keep containers tightly closed and dry. Do not store at temperatures exceeding 77°F (25°C). Handling according to the Instructions for Use. Store the product in the original packaging. The expiry date on the packaging must be considered.
Information on storage together with other materials:	Observe VCI-concept for storing chemicals.
Further information on storage conditions:	Contents are corrosive. Avoid contact with water. Open tubes should be stored in the container in a well ventilated area until they are disposed of.
Storage class:	LGK 10-13 (VCI-concept).

7.3 Certain application:
n/a

8. Exposure controls/Personal protection

8.1 Components with exposure limit values:
Several, in relation to the chemicals in the tubes (see Section 2). But with normal handling of the Dräger-Tubes™ and MicroTubes there should be no exposure to contents. However, if exposure does occur, follow the national exposure limits for the relevant chemicals. For detailed information about the ingredients in the different tubes, please see the Dräger-Tubes™ -/ MicroTubes Handbook.

EC, Land	CAS-No.	Description of material	Type	Content	Unit
D	7664-93-9	Sulphuric acid	MAK	0,1 E**	mg/m³
D	n/a	Chromium(VI) compounds	TRK	0,05 E*	mg/m³

D	1333-82-0	Chromium trioxide	EG	Carc. Cat 1 / S	
D	7664-38-2	o-Phosphoric acid	MAK	2	mg/m³
D	7778-50-9	Potassium dichromate	EG	Carc. Cat 1 / Muta. Cat. 2 / S	
D	110-86-1	Pyridine	DFG, EU-classification	16 5	mg/m³ mL/m³
		E = inhalable fraction			
		Carc. Cat 1 = Carcinogen to human body	MAK = German TLV		
		Carc. Cat 2 = Carcinogen to human body is possible.			
		Muta. Cat 2 = Reproductive toxic to human body is possible.			
		S = Hazard of sensitization			

8.2 Exposure controls:

8.2.1 Occupational exposure controls:
General protection and hygiene measures:
With normal handling of the Dräger-Tubes™ and MicroTubes there should be no exposure to contents. However, if exposure does occur, follow the exposure limits.
Use good industrial hygiene practices.

Personal protection:

8.2.1.1 Respiratory protection:
Not necessary when handled according to the Instructions for Use.

8.2.1.2 Hand protection:
With normal handling of the Dräger-Tubes™ and MicroTubes there should be no exposure to contents. In case of accidents use suitable protective gloves made from PE/ PP, Latex, butyl or nitrile rubber. Please observe the glove manufacturers instructions on permeability and rupture times as well as the specific workplace conditions.

8.2.1.3 Eye protection:
Not necessary when handled according to the Instructions for Use.
Recommendation: Wear safety glasses with side shields.

8.2.1.4 Skin protection:
Prophylactic skin protection is recommended. Wash thoroughly after handling. Skin care.

8.2.2 Additional information on plant design:
Handling according to the Instructions for Use.

9. Physical and chemical properties

9.1 General information:

Form:	Glass tubes containing colourless and/or coloured solids.
Colour:	various
Odour:	slightly pungent/odourless

9.2 Important information about the protection of health, safety and the environment: **Method (67/548/EEC):**

Solubility:	n/a
pH-value:	n/a (weak acidic reaction)
Boiling point:	n/a
Melting point:	n/a
Flame point:	n/a
Inflameability:	n/a
Explosion limits:	
lower:	n/a

upper:	n/a
Ignition temperature:	n/a
Vapour pressure:	n/a
Mass density:	n/a
Further information:	n/a

9.3 Other information
n/a

10. Stability and reactivity

General information:
Stable under normal conditions and appropriate commerce.

10.1 Conditions to avoid:
Do not mix other substances with contents of tubes. Avoid contact with water. Stable under normal conditions. Hazardous polymerisation will not occur. Do not store above 25°C (77°F).

10.2 Materials to avoid:
Tubes contents react with bases. Possibility of a slight exothermic reaction.

10.3 Hazardous decomposition products:
Decomposition of granulate in the tubes may produce toxic substances (e.g. sulphur oxides).

Possibility of a dangerous exothermic reaction:	Avoid contact with bases/water, tube contents may react with bases and water in an exothermic reaction.
Dangerous products of decomposition at contact with water:	Acids and solutions of (heavy) metal salts

10.4 Further information:
n/a

11. Toxicological information

11.1 Toxicity tests:
Classification-relevant LD/LC_{50}-values: No toxicity data are available for the contents of the tubes (carrier materials impregnated with different chemicals!).

11.1.1 Specific symptoms in animal studies: No data are available.

11.1.2 Irritant/corrosive effects: Irritant and weak corrosive effects of the contents of the tubes cannot be excluded.

11.1.3 Sensitization: Sensitization effects of the contents of the tubes cannot be excluded.

11.1.4 Subacute and chronical toxicity:

Experiments:	No data are available.
Species:	No data are available.

11.1.5 Carcinogenic, mutagenic and reproductive toxic effects:
No data are available. See Section 11.3

11.1.6 Further information:
For detailed information about the ingredients in the different tubes and their hazards, please see the Dräger-Tubes™-/CMS Handbook and section 2.

11.2 Effects on human body/Experiments made in practice:

after inhalation:
Inhalation of dusts from the tube contents may cause irritation or injury to the respiratory system.
after ingestion:
Product contents may be harmful or fatal if swallowed. This product may produce corrosive damage to the gastrointestinal tract if swallowed.
after eye contact:

Eye contact with contents of the tubes may cause corrosive damage with irritation, and possible eye injury.
after skin contact:
Skin contact with the contents of the tubes may cause slight corrosive damage with irritation.

11.3 Additional toxicological information:
The toxicity of the impregnated carrier material contained in the tubes has not been tested in detail. With respect to the chemicals used for the impregnation these materials should be handled in the same way as the pure chemicals. They may cause sensitization, irritation or injury to the skin, eyes and mucous membrane. Carcinogenic, mutagenic and reproductive toxic effects can not be excluded, because some of the impregnation chemicals in pure form are classified accordingly.

Further information:
If the glass tube is broken, the sharp edges may cause cuts or scratches.

12. Ecological information

12.1 Ecotoxicity:
No ecotoxicity data are available for the preparations/components in the Dräger-Tubes™ and MicroTubes .

12.2 Mobility:
No data are available

12.3 Persistence and degradability:

Biological decompositionability:	No data are available
Behaviour in purification plants:	No data are available

12.4 Bioaccumulative potential:
No data are available

12.5 Other adverse effects:
No data are available

12.6 Additional information:
Dräger-Tubes™ and MicroTubes themselves and also the chemical preparations/components in the tubes shouldn´t be released into water because the chemicals on the carrier material could be dissolved and then contaminate the water. Normally water extracts from the impregnated carrier materials have a low pH-value and contain small amounts of the chemicals used for impregnation. So, it would be expected to produce ecotoxicity upon exposure to aquatic organisms and aquatic systems.
Dräger-Tubes™ and MicroTubes themselves and the chemical preparations/components in the tubes are not expected to accumulate in the food chain.

13. Disposal considerations

13.1 Product (recommendations):
If discarded, wastes may be classified as corrosive waste or reactive waste. Prior to disposal, carefully dilute tube contents with water. Add baking soda to neutralise acidity. Do not allow this material to drain into sewers/water supplies. Waste must be handled in accordance with all federal, state, provincial, and local regulations.
Dräger-Tubes™ and MicroTubes must be disposed of in accordance with local waste disposal regulations. If discarded, wastes may be classified as hazardous waste. Applicable “waste numbers” (federal, state, provincial, and local) for this products or their components have not been checked in detail.

Waste category:	EWL (European waste list): 170204*
Waste designation:	Glass, plastic and wood containing or contaminated with dangerous substances.
Obligation to prove correct disposal:	yes

13.2 Not cleaned packaging material (recommendations):
The disposal of plastic containers and flexible packages is possible by EWL 150102, and fibre board boxes by EWL 150101.

14. Transport information

14.1 Road transport ADR/RID and GGVSE (cross-border/domestic):
UN-No.: ./. Class: ./. Packing group: ./.

Name: ./. Classification code: ./.
Remarks: Dräger-Tubes™ and MicroTubes cited in section 1 are no dangerous goods. These Dräger-Tubes™ are no hazardous material as defined by the transport regulations.

14.2 Marine transport IMDG-Code/GGVSee:

UN-No.	./.	Correct technical name:	./.		
Class:	./.	Sub risk:	Packing group:	./.	
EmS-No.:	./.		MFAG:	./.	
Marine pollutant:	./.				

Remarks: Dräger-Tubes™ and MicroTubes cited in section 1 are no dangerous goods. These Dräger-Tubes™ and MicroTubes are no hazardous material as defined by the transport regulations.

14.3 Air transport ICAO-TI und IATA-DGR:

UN-No.	./.	Proper shipping Name:	./.		
Class	./.	Sub risk:	./.	PG:	./.

Remarks: Dräger-Tubes™ and MicroTubes cited in section 1 are no dangerous goods. These Dräger-Tubes™ and MicroTubes are no hazardous material as defined by the transport regulations.

14.4 Transport/further information:
May be sent by post.

15. Regulatory information

15.1 Labelling according to EC Regulations:
Hazardous symbols and indicators of danger for dangerous substances and preparations: No labelling necessary.

Hazardous components to be indicated on label: contains: n/a

H-Phrases:
n/a
P-Phrases (recommendation):

P102	Keep out of reach of children.
P302+P352	IF ON SKIN: Wash with plenty of water.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P308+P313	IF exposed or concerned: Get medical advice/attention.

15.2 National regulations:
Additional classification acc. to GefStoffV Annex II No. (only if differing from EC classification): n/a
Restrictions of occupation: n/a
Statutory order on hazardous incidents: n/a
Water pollution class: 3 (self-classification)
Information according 1999/13/EC about limitation of emissions of volatile organic compounds (VOC-guideline):
Further regulations, restrictions, and prohibition regulation:
(such as principles of industrial medicine and health and safety regulations)
Instruction Sheet BG-Chemie (Chemical Professional Association):
Other state regulations may apply. Check individual state requirements.

16. Other information

Use of the substance / preparation:
See section 1.2; additional information in the Instructions for Use.

Relevant H-Phrases:

H270	May cause or intensify fire; oxidiser.
H290	May be corrosive to metals
H300	Fatal if swallowed.
H301	Toxic if swallowed.
H302	Harmful if swallowed.
H311	Toxic in contact with skin.
H312	Harmful in contact with skin.

H314	Causes severe skin burns and eye damage.
H315	Causes skin irritation.
H317	May cause an allergic skin reaction.
H318	Causes serious eye damage.
H319	Causes serious eye irritation.
H330	Fatal if inhaled.
H331	Toxic if inhaled.
H332	Harmful if inhaled.
H335	May cause respiratory irritation.
H372	Causes damage to organs through prolonged or repeated exposure.
H373	May cause damage to organs through prolonged or repeated exposure.

H400	Very toxic to aquatic life.
H410	Very toxic to aquatic life with long lasting effects.
H411	Toxic to aquatic life with long lasting effects.

Comments:

n. a.; n/a; ./. :	not applicable
MAC:	Maximum allowable concentration
COD:	Chemical oxygen demand
BOD:	Biochemical oxygen demand
EWL:	European waste list
VOC:	Volatile organic compounds
VCI:	Verband der Chemischen Industrie e.V. (Association of the German chemical industry)
WGK:	German water hazard class

Further information:
The above information represents our current state of experience and describes the product only with respect to safety requirements. The manufacturer makes no representations and assumes no liability for any direct, incidental or consequential damages resulting from its use. It is the responsibility of the customer to test whether the product is suitable for the purpose intended by the customer.
Any questions of warranty and liability for this product are subject to our General Terms and Conditions unless legislation imperatively provides otherwise.

Data sheet issued by:	Global EHS Management
Contact:	Jana Müller, sds@draeger.com

Changes to preceding version: In header and section 1.

Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

* 1 Identification

· **Product identifier**

· **Trade name: Precision Calibration Gas Mixture**
· **Product number:** G-1315
· **Relevant identified uses of the substance or mixture and uses advised against**
Used for calibration of gas measuring devices. Not suitable for human consumption.
· **Product description**
Calibration gas mixture consisting of Carbon Monoxide, Hydrogen Sulfide, Methane, Oxygen and Nitrogen.
· **Application of the substance / the mixture** Pressurized gas, requires appropriate regulator to dispense.

· **Details of the supplier of the safety data sheet**
· **Manufacturer/Supplier:**
Gasco Affiliates, LLC
320 Scarlett Blvd.
Oldsmar, Fl 34677

TELEPHONE NUMBER: (800) 910-0051
FAX NUMBER: (866) 755-8920
E-MAIL: info@gascogas.com
· **Emergency telephone number:**
Inside the US: 1-800-424-9300 (CHEMTREC, 24 hours)
Outside the US: 1-703-527-3887 (CHEMTREC, 24 hours)

* 2 Hazard(s) identification

· **Classification of the substance or mixture**


GHS04 Gas cylinder

Press. Gas H280 Contains gas under pressure; may explode if heated.


GHS08 Health hazard

Repr. 1A H360 May damage fertility or the unborn child.


GHS07

Acute Tox. 4 H332 Harmful if inhaled.

Simple Asphyxiant May displace oxygen and cause rapid suffocation.

· **Label elements**
· **GHS label elements**
The product is classified and labeled according to the Globally Harmonized System (GHS).
· **Hazard pictograms**


GHS04 GHS07 GHS08

(Contd. on page 2)

Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

· **Signal word** Danger

· **Hazard-determining components of labeling:**
Carbon Monoxide
· **Hazard statements**
Contains gas under pressure; may explode if heated.
Harmful if inhaled.
May damage fertility or the unborn child.
May displace oxygen and cause rapid suffocation.
· **Precautionary statements**
Avoid breathing dust/fume/gas/mist/vapors/spray.
Use only outdoors or in a well-ventilated area.
Wear protective gloves/protective clothing/eye protection/face protection.
Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
Call a poison center/doctor if you feel unwell.
IF exposed or concerned: Get medical advice/attention.
Store locked up.
Protect from sunlight. Store in a well-ventilated place.
Dispose of contents/container in accordance with local/regional/national/international regulations.
· **Unknown acute toxicity:**
99.5 percent of the mixture consists of ingredient(s) of unknown toxicity.
· **Classification system:**
· **NFPA ratings (scale 0 - 4)**



Health = 0
Fire = 1
Reactivity = 0

· **HMIS-ratings (scale 0 - 4)**



Health = 0
Fire = 1
Reactivity = 0

· **Hazard(s) not otherwise classified (HNOC):** None known

*

3 Composition/Information on Ingredients

· **Chemical characterization: Mixtures**
· **Description:** Mixture of substances listed below with nonhazardous additions.
· **Dangerous Components:**

CAS: 7727-37-9 RTECS: QW 9700000	Nitrogen Press. Gas, H280; Simple Asphyxiant	75.470 - 91.799%
CAS: 7782-44-7	Oxygen Oxid. Gas 1, H270; Press. Gas, H280	8 - 21%
CAS: 74-82-8 RTECS: PA 1490000	Methane Flam. Gas 1, H220; Press. Gas, H280	0.1 - 3.0%

(Contd. on page 3)

Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

CAS: 630-08-0 RTECS: FG 3500000	Carbon Monoxide Flam. Gas 1, H220; Acute Tox. 3, H331; Repr. 1A, H360; STOT RE 1, H372; Press. Gas, H280	0.0005 - 0.51%
CAS: 7783-06-4	Hydrogen Sulfide Flam. Gas 1, H220; Acute Tox. 2, H330; Aquatic Acute 1, H400; Press. Gas, H280	0.0005 - 0.02%

* 4 First-aid measures

· ***Description of first aid measures***
· ***After inhalation:***
Generally the product does not irritate with inhalation.
Supply fresh air. If required, provide artificial respiration. Consult doctor if symptoms persist.
In case of unconsciousness, place patient securely on side position for transportation.
· ***After skin contact:***
Generally the product does not irritate the skin.
In cases of contact with liquified material, frostbite may occur. Immerse frostbite in cool-warm water and seek medical attention.
· ***After eye contact:***
Not anticipated under normal use.
If irritation occurs thoroughly wash the exposed area and discontinue use. Seek medical attention if any adverse effect occurs.
· ***After swallowing:*** Not a normal route of entry.
· ***Information for doctor:***
· ***Most important symptoms and effects, both acute and delayed:*** No further relevant information available.
· ***Indication of any immediate medical attention and special treatment needed***
No further relevant information available.

* 5 Fire-fighting measures

· ***Extinguishing media***
· ***Suitable extinguishing agents:***
Use fire fighting measures that suit the environment.
Use water spray to cool fire-exposed containers.
· ***Special hazards arising from the substance or mixture***
Closed containers may explode when exposed to extreme heat.
If incinerated, product will release the following toxic fumes: Oxides of Carbon, Nitrogen (NOx) and Sulfur.
· ***Advice for firefighters***
This gas mixture is not flammable; however, containers, when involved in fire, may rupture or burst in the heat of the fire. Firefighters should be aware of the presence of Hydrogen Sulfide in this gas mixture, which can cause significant health effects.
· ***Protective equipment:***
As in any fire, wear self-contained breathing apparatus pressure-demand (NIOSH approved or equivalent), and full protective gear to prevent contact with skin and eyes.

* 6 Accidental release measures

· ***Personal precautions, protective equipment and emergency procedures***
In a confined area, NIOSH approved respiratory protection may be required.
Treat any fumes as toxic.
· ***Environmental precautions:*** Inform authorities in case of gas release.
· ***Methods and material for containment and cleaning up:***
Dispose contaminated material as waste according to section 13.

(Contd. on page 4)

Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

Ensure adequate ventilation.
Dispose of the collected material according to regulations.
· ***Reference to other sections***
See Section 7 for information on safe handling.
See Section 8 for information on personal protection equipment.
See Section 13 for disposal information.

* 7 Handling and storage

· ***Handling:***
· ***Precautions for safe handling***
Ensure good ventilation/exhaustion at the workplace.
Open and handle receptacle with care.
Be aware of any signs of dizziness or fatigue; exposures to fatal concentrations of this gas mixture could occur without any significant warning symptoms due to the potential for oxygen deficiency (simple asphyxiation). Do not attempt to adjust, repain or in any other way modify the cylinders containing this gas mixture. If there is a malfunction or another type of operational problem, contact nearest distributor immediately.
· ***Information about protection against explosions and fires:***
Pressurized container: protect from sunlight and do not expose to temperatures exceeding 50 °C, i.e. electric lights. Do not pierce or burn, even after use.
Keep protective respiratory device available.
Do not cut, grind or weld on container that contains or contained product.
Do not spray on a naked flame or any incandescent material.

· ***Conditions for safe storage, including any incompatibilities***
Store away from strong oxidizing agents, strong bases, phosphorous, organic materials and powdered metals.
· ***Storage:***
· ***Requirements to be met by storerooms and receptacles:***
Store in a cool location.
Cyliners should be firmly secured to prevent falling or being knocked over. Cylinders must be protected from the environment, and preferably kept at room temperature. Cylinders should be stored in dry, well-ventilated areas, away from sources of heat, ignition, and direct sunlight. Protect cylinders against physical damage. Full and empty cylinders should be segregated. Use a "first-in, first-out" inventory system to prevent full containers freom being stored for long periods of time.
· ***Information about storage in one common storage facility:*** Not required.
· ***Further information about storage conditions:*** Store in cool, dry conditions in well sealed receptacles.
· ***Specific end use(s)*** No further relevant information available.

* 8 Exposure controls/personal protection

· ***Additional information about design of technical systems:*** No further data; see section 7.

· ***Control parameters***
All ventilation should be designed in accordance with OSHA standard (29 CFR 1910.94). Use mechanical (general) ventilation for storage areas. Use appropriate ventilation as required to keep Exposure Limits in Air below TLV & PEL limits.

· ***Components with occupational exposure limits:***	
7727-37-9 Nitrogen	
TLV	withdrawn TLV, see App. F; simple asphyxiant
74-82-8 Methane	
TLV	refer to Appendix F, 1000ppm

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Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

630-08-0 Carbon Monoxide	
PEL	Long-term value: 55 mg/m³, 50 ppm
REL	Long-term value: 40 mg/m³, 35 ppm Ceiling limit value: 229 mg/m³, 200 ppm
TLV	Long-term value: 29 mg/m³, 25 ppm BEI
7783-06-4 Hydrogen Sulfide	
PEL	Ceiling limit value: 20; 50* ppm *10-min peak; once per 8-hr shift
REL	Ceiling limit value: 15* mg/m³, 10* ppm *10-min
TLV	Short-term value: 7 mg/m³, 5 ppm Long-term value: 1.4 mg/m³, 1 ppm

· ***Ingredients with biological limit values:***

630-08-0 Carbon Monoxide	
BEI	3.5 % of hemoglobin blood end of shift Carboxyhemoglobin (background, nonspecific) 20 ppm end-exhaled air end of shift Carbon monoxide (background, nonspecific)

· ***Additional information:*** The lists that were valid during the creation of this SDS were used as basis.

· ***Exposure controls***
· ***Personal protective equipment:***
· ***General protective and hygienic measures:***
Keep away from foodstuffs, beverages and feed.
Immediately remove all soiled and contaminated clothing and wash before reuse.
Wash hands before breaks and at the end of work.
Store protective clothing separately.
· ***Breathing equipment:***
Not necessary if room is well-ventilated.
In case of brief exposure or low pollution use respiratory filter device. In case of intensive or longer exposure, use respiratory protective device that is independent of circulating air.
· ***Protection of hands:*** Not required.
· ***Eye protection:*** Not necessary under normal conditions.

9 Physical and chemical properties

· ***Information on basic physical and chemical properties***
· ***General Information***
· ***Appearance:***

Form:	Gaseous
Color:	Clear, colorless
· ***Odor:***	Mild
· ***Odor threshold:***	Not determined.
· ***pH-value:***	Not determined.

(Contd. on page 6)

Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

· **Change in condition**
Melting point/Melting range: Not determined.
Boiling point/Boiling range: -195 °C (-319 °F)

· **Flash point:** Not applicable.

· **Flammability (solid, gaseous):** Not determined.

· **Ignition temperature:**

Decomposition temperature: Not determined.

· **Auto igniting:** Product is not self-igniting.

· **Danger of explosion:** Not determined.

· **Explosion limits:**
Lower: Not determined.
Upper: Not determined.

· **Vapor pressure:** Not determined.

· **Density @ 20 °C (68 °F):** 0.023 g/cm³ (0.192 lbs/gal)
· **Relative density** Not determined.
· **Vapor density** Not determined.
· **Evaporation rate** Not applicable.

· **Solubility in / Miscibility with**
Water: Not miscible or difficult to mix.

· **Partition coefficient (n-octanol/water):** Not determined.

· **Viscosity:**
Dynamic: Not determined.
Kinematic: Not determined.

· **Solvent content:**
Organic solvents: 0.0 %
· **Other information** No further relevant information available.

* 10 Stability and reactivity

· **Reactivity** Stable under normal conditions
· **Chemical stability** Stable under normal conditions.
· **Thermal decomposition / conditions to be avoided:** No decomposition if used according to specifications.
· **Possibility of hazardous reactions** No dangerous reactions known.
· **Conditions to avoid** Heat, flame and ignition sources.
· **Incompatible materials:**
Strong oxidizing agents, strong bases, phosphorous, organic materials and powdered metals.
· **Hazardous decomposition products:** Oxides of Carbon, Nitrogen (NOx) and Sulfur.

* 11 Toxicological information

· **Information on toxicological effects**
· **Acute toxicity:**

· **LD/LC50 values that are relevant for classification:**		
630-08-0 Carbon Monoxide		
Inhalative	LC50/4 h	7520 mg/l (rat)

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Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

7783-06-4 Hydrogen Sulfide		
Inhalative	LC50/4 h	634 mg/l (mouse)
		444 mg/l (rat)
	LC50/96 hours	0.016 mg/l (Pimephales)
74-82-8 Methane		
Inhalative	LC50/4 h	217 mg/l (mouse)

· ***Primary irritant effect:***
· ***on the skin:*** No irritating effect.
· ***on the eye:*** No irritating effect.
· ***Additional toxicological information:***
The product shows the following dangers according to internally approved calculation methods for preparations:

· ***Carcinogenic categories***
· ***IARC (International Agency for Research on Cancer)***
Group 1 - Carcinogenic to humans
Group 2A - Probably carcinogenic to humans
Group 2B - Possibly carcinogenic to humans
Group 3 - Not classifiable as to its carcinogenicity to humans
Group 4 - Probably not carcinogenic to humans

None of the ingredients are listed.

· ***NTP (National Toxicology Program)***

None of the ingredients are listed.

· ***OSHA-Ca (Occupational Safety & Health Administration)***

None of the ingredients are listed.

* 12 Ecological information

· ***Toxicity*** The hazards for the aquatic environment are unknown.
· ***Aquatic toxicity:*** No further relevant information available.
· ***Persistence and degradability*** No further relevant information available.
· ***Behavior in environmental systems:***
· ***Bioaccumulative potential*** No further relevant information available.
· ***Mobility in soil*** No further relevant information available.
· ***Additional ecological information:***
· ***General notes:*** Generally not hazardous for water.
· ***Results of PBT and vPvB assessment***
· ***PBT:*** Not applicable.
· ***vPvB:*** Not applicable.
· ***Other adverse effects*** No further relevant information available.

* 13 Disposal considerations

· ***Waste treatment methods***
· ***Recommendation:***
Release all residual gas pressure in a well ventilated area. Verify the cylinder is completely empty (0 PSIG). Remove or cover any hazard labels. Return empty supplier for recycling.
NOTE: Check with the local waste authority before placing any gas cylinder into a waste container for pickup. GASCO encourages the consumer to return all cylinders.
· ***Waste disposal key:*** The U.S. EPA has not published waste numbers for this product's components.

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Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

· **Uncleaned packagings:**
· **Recommendation:** Return cylinder and unused product to supplier.

* 14 Transport information

· **UN-Number**
· **DOT, ADR, IMDG, IATA** UN1956
· **UN proper shipping name**
· **DOT** Compressed gas, n.o.s.
· **ADR** UN1956 Compressed gas, n.o.s.
· **IMDG, IATA** COMPRESSED GAS, N.O.S.
· **Transport hazard class(es)**

· **DOT**



· **Class** 2.2
· **Label** 2.2

· **ADR**



· **Class** 2.2 1A
· **Label** 2.2

· **IMDG, IATA**



· **Class** 2.2
· **Label** 2.2
· **Packing group** -
· **Environmental hazards:** Not applicable.
· **Special precautions for user** Not applicable.
· **Danger code (Kemler):** 20
· **EMS Number:** F-C,S-V
· **Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code** Not applicable.

· **Transport/Additional information:**

· **DOT**
· **Quantity limitations** On passenger aircraft/rail: 75 kg
On cargo aircraft only: 150 kg

· **ADR**
· **Excepted quantities (EQ)** Code: E1
Maximum net quantity per inner packaging: 30 ml
Maximum net quantity per outer packaging: 1000 ml

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Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

· **UN "Model Regulation":** UN1956, Compressed gas, n.o.s., 2.2

* 15 Regulatory information

· **Safety, health and environmental regulations/legislation specific for the substance or mixture**
· **Sara**
· **Section 355 (extremely hazardous substances):**
7783-06-4 Hydrogen Sulfide
· **Section 313 (Specific toxic chemical listings):**
7783-06-4 Hydrogen Sulfide
· **TSCA (Toxic Substances Control Act):**
All ingredients are listed.
· **California Proposition 65**
· **Chemicals known to cause cancer:**
None of the ingredients are listed.
· **Chemicals known to cause reproductive toxicity for females:**
None of the ingredients are listed.
· **Chemicals known to cause reproductive toxicity for males:**
None of the ingredients are listed.
· **Chemicals known to cause developmental toxicity:**
630-08-0 Carbon Monoxide
· **Carcinogenic categories**
· **EPA (Environmental Protection Agency)**
7783-06-4 Hydrogen Sulfide I
· **TLV (Threshold Limit Value established by ACGIH)**
None of the ingredients are listed.
· **NIOSH-Ca (National Institute for Occupational Safety and Health)**
None of the ingredients are listed.
· **GHS label elements**
The product is classified and labeled according to the Globally Harmonized System (GHS).
· **Hazard pictograms**



GHS04 GHS07 GHS08

· **Signal word** Danger

· **Hazard-determining components of labeling:**
Carbon Monoxide
· **Hazard statements**
Contains gas under pressure; may explode if heated.
Harmful if inhaled.
May damage fertility or the unborn child.
May displace oxygen and cause rapid suffocation.

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Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 Reviewed on 06/11/2015

Trade name: Precision Calibration Gas Mixture

· **Precautionary statements**
Avoid breathing dust/fume/gas/mist/vapors/spray.
Use only outdoors or in a well-ventilated area.
Wear protective gloves/protective clothing/eye protection/face protection.
Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
Call a poison center/doctor if you feel unwell.
IF exposed or concerned: Get medical advice/attention.
Store locked up.
Protect from sunlight. Store in a well-ventilated place.
Dispose of contents/container in accordance with local/regional/national/international regulations.

· **National regulations:**

The product is subject to be classified according with the latest version of the regulations on hazardous substances.

· **State Right to Know**

CAS: 7727-37-9 RTECS: QW 9700000	Nitrogen Press. Gas, H280; Simple Asphyxiant	75.470 - 91.799%
CAS: 7782-44-7	Oxygen Oxid. Gas 1, H270; Press. Gas, H280	8 - 21%
CAS: 74-82-8 RTECS: PA 1490000	Methane Flam. Gas 1, H220; Press. Gas, H280	0.1 - 3.0%
CAS: 630-08-0 RTECS: FG 3500000	Carbon Monoxide Flam. Gas 1, H220; Acute Tox. 3, H331; Repr. 1A, H360; STOT RE 1, H372; Press. Gas, H280	0.0005 - 0.51%
CAS: 7783-06-4	Hydrogen Sulfide Flam. Gas 1, H220; Acute Tox. 2, H330; Aquatic Acute 1, H400; Press. Gas, H280	0.0005 - 0.02%

All ingredients are listed.

· **Chemical safety assessment:** A Chemical Safety Assessment has not been carried out.

* 16 Other Information

· **Relevant phrases**
Gasco Affiliates, LLC, makes no express or implied warranties, guarantees or representations regarding the product or the information herein, including but not limited to any implied warranty or merchantability or fitness for use. Gasco Affiliates, LLC shall not be liable for any personal injury, property or other damages of any nature, whether compensatory, consequential, exemplary, or otherwise, resulting from any publication, use or reliance upon the information herein.

· **Date of preparation / last revision** 06/11/2015 / -

· **Abbreviations and acronyms:**
ADR: The European Agreement concerning the International Carriage of Dangerous Goods by Road
ADN: The European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways
IMDG: International Maritime Code for Dangerous Goods
DOT: US Department of Transportation
IATA: International Air Transport Association
ACGIH: American Conference of Governmental Industrial Hygienists
EINECS: European Inventory of Existing Commercial Chemical Substances
ELINCS: European List of Notified Chemical Substances
CAS: Chemical Abstracts Service (division of the American Chemical Society)
NFPA: National Fire Protection Association (USA)
HMIS: Hazardous Materials Identification System (USA)
LC50: Lethal concentration, 50 percent
LD50: Lethal dose, 50 percent

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Safety Data Sheet (SDS)

OSHA HazCom Standard 29 CFR 1910.1200(g) and GHS Rev 03.

Issue date 06/11/2015 *Reviewed on 06/11/2015*

Trade name: Precision Calibration Gas Mixture

Flam. Gas 1: Flammable gases, Hazard Category 1
Oxid. Gas 1: Oxidising Gases, Hazard Category 1
Press. Gas: Gases under pressure: Compressed gas
Acute Tox. 2: Acute toxicity, Hazard Category 2
Acute Tox. 3: Acute toxicity, Hazard Category 3
Acute Tox. 4: Acute toxicity, Hazard Category 4
Repr. 1A: Reproductive toxicity, Hazard Category 1A
STOT RE 1: Specific target organ toxicity - Repeated exposure, Hazard Category 1
Aquatic Acute 1: Hazardous to the aquatic environment - AcuteHazard, Category 1

**** Data compared to the previous version altered.***

SDS created by MSDS Authoring Services www.msdsauthoring.com +1-877-204-9106

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

1 Identification of the substance/mixture and of the supplier

1.1 Product identifier

Trade Name: Alconox
Synonyms:
Product number: Alconox

1.2 Application of the substance / the mixture : Cleaning material/Detergent

1.3 Details of the supplier of the Safety Data Sheet

Manufacturer
Alconox, Inc.
30 Glenn Street
White Plains, NY 10603
1-914-948-4040

Supplier
Not Applicable

Emergency telephone number:
ChemTel Inc
North America: 1-800-255-3924
International: 01-813-248-0585

2 Hazards identification

2.1 Classification of the substance or mixture:

In compliance with EC regulation No. 1272/2008, 29CFR1910/1200 and GHS Rev. 3 and amendments.

Hazard-determining components of labeling:
Tetrasodium Pyrophosphate
Sodium tripolyphosphate
Sodium Alkylbenzene Sulfonate

2.2 Label elements:

Skin irritation, category 2.
Eye irritation, category 2A.

Hazard pictograms:



Signal word: Warning

Hazard statements:
H315 Causes skin irritation.
H319 Causes serious eye irritation.

Precautionary statements:
P264 Wash skin thoroughly after handling.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P302+P352 If on skin: Wash with soap and water.
P305+P351+P338 If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.
P321 Specific treatment (see supplemental first aid instructions on this label).
P332+P313 If skin irritation occurs: Get medical advice/attention.
P362 Take off contaminated clothing and wash before reuse.
P501 Dispose of contents and container as instructed in Section 13.

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

Additional information: None.

Hazard description

Hazards Not Otherwise Classified (HNOC): None

Information concerning particular hazards for humans and environment:

The product has to be labelled due to the calculation procedure of the "General Classification guideline for preparations of the EU" in the latest valid version.

Classification system:

The classification is according to EC regulation No. 1272/2008, 29CFR1910/1200 and GHS Rev. 3 and amendments, and extended by company and literature data. The classification is in accordance with the latest editions of international substances lists, and is supplemented by information from technical literature and by information provided by the company.

3 Composition/information on ingredients

3.1 Chemical characterization : None

3.2 Description : None

3.3 Hazardous components (percentages by weight)

Identification	Chemical Name	Classification	Wt. %
CAS number: 7758-29-4	Sodium tripolyphosphate	Skin Irrit. 2 ; H315 Eye Irrit. 2; H319	12-28
CAS number: 68081-81-2	Sodium Alkylbenzene Sulfonate	Acute Tox. 4; H303 Skin Irrit. 2 ; H315 Eye Irrit. 2; H319	8-22
CAS number: 7722-88-5	Tetrasodium Pyrophosphate	Skin Irrit. 2 ; H315 Eye Irrit. 2; H319	2-16

3.4 Additional Information : None.

4 First aid measures

4.1 Description of first aid measures

General information: None.

After inhalation:

Maintain an unobstructed airway.
Loosen clothing as necessary and position individual in a comfortable position.

After skin contact:

Wash affected area with soap and water.
Seek medical attention if symptoms develop or persist.

After eye contact:

Rinse/flush exposed eye(s) gently using water for 15-20 minutes.
Remove contact lens(es) if able to do so during rinsing.
Seek medical attention if irritation persists or if concerned.

After swallowing:

Rinse mouth thoroughly.
Seek medical attention if irritation, discomfort, or vomiting persists.

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

4.2 Most important symptoms and effects, both acute and delayed

None

4.3 Indication of any immediate medical attention and special treatment needed:

No additional information.

5 Firefighting measures

5.1 Extinguishing media

Suitable extinguishing agents:

Use appropriate fire suppression agents for adjacent combustible materials or sources of ignition.

For safety reasons unsuitable extinguishing agents : None

5.2 Special hazards arising from the substance or mixture :

Thermal decomposition can lead to release of irritating gases and vapors.

5.3 Advice for firefighters

Protective equipment:

Wear protective eye wear, gloves and clothing.
Refer to Section 8.

5.4 Additional information :

Avoid inhaling gases, fumes, dust, mist, vapor and aerosols.
Avoid contact with skin, eyes and clothing.

6 Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures :

Ensure adequate ventilation.
Ensure air handling systems are operational.

6.2 Environmental precautions :

Should not be released into the environment.
Prevent from reaching drains, sewer or waterway.

6.3 Methods and material for containment and cleaning up :

Wear protective eye wear, gloves and clothing.

6.4 Reference to other sections : None

7 Handling and storage

7.1 Precautions for safe handling :

Avoid breathing mist or vapor.
Do not eat, drink, smoke or use personal products when handling chemical substances.

7.2 Conditions for safe storage, including any incompatibilities :

Store in a cool, well-ventilated area.

7.3 Specific end use(s):

No additional information.

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

8 Exposure controls/personal protection





8.1 Control parameters :

7722-88-5, Tetrasodium Pyrophosphate, OSHA TWA 5 mg/m3.

8.2 Exposure controls

Appropriate engineering controls:

Emergency eye wash fountains and safety showers should be available in the immediate vicinity of use or handling.

Respiratory protection:

Not needed under normal conditions.

Protection of skin:

Select glove material impermeable and resistant to the substance.

Eye protection:

Safety goggles or glasses, or appropriate eye protection.

General hygienic measures:

Wash hands before breaks and at the end of work.
Avoid contact with skin, eyes and clothing.

9 Physical and chemical properties

Appearance (physical state, color):	White and cream colored flakes - powder	**Explosion limit lower:** **Explosion limit upper:**	Not determined or not available. Not determined or not available.
Odor:	Not determined or not available.	**Vapor pressure at 20°C:**	Not determined or not available.
Odor threshold:	Not determined or not available.	**Vapor density:**	Not determined or not available.
pH-value:	9.5 (aqueous solution)	**Relative density:**	Not determined or not available.
Melting/Freezing point:	Not determined or not available.	**Solubllities:**	Not determined or not available.
Bolling point/Boiling range:	Not determined or not available.	**Partition coefficient (n-octanol/water):**	Not determined or not available.
Flash point (closed cup):	Not determined or not available.	**Auto/Self-ignition temperature:**	Not determined or not available.
Evaporation rate:	Not determined or not available.	**Decomposition temperature:**	Not determined or not available.

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

Flammability (solid, gaseous):	Not determined or not available.	**Viscosity**:	a. Kinematic: Not determined or not available. b. Dynamic: Not determined or not available.
Density at 20°C:	Not determined or not available.		

10 Stability and reactivity

10.1 Reactivity : None

10.2 Chemical stability : None

10.3 Possibility hazardous reactions : None

10.4 Conditions to avoid : None

10.5 Incompatible materials : None

10.6 Hazardous decomposition products : None

11 Toxicological information

11.1 Information on toxicological effects :

Acute Toxicity:

Oral:

: LD50 > 5000 mg/kg oral rat - Product .

Chronic Toxicity: No additional information.

Skin corrosion/irritation:

Sodium Alkylbenzene Sulfonate: Causes skin irritation. .

Serious eye damage/irritation:

Sodium Alkylbenzene Sulfonate: Causes serious eye irritation .

Tetrasodium Pyrophosphate: Rabbit - Risk of serious damage to eyes .

Respiratory or skin sensitization: No additional information.

Carcinogenicity: No additional information.

IARC (International Agency for Research on Cancer): None of the ingredients are listed.

NTP (National Toxicology Program): None of the ingredients are listed.

Germ cell mutagenicity: No additional information.

Reproductive toxicity: No additional information.

STOT-single and repeated exposure: No additional information.

Additional toxicological information: No additional information.

12 Ecological information

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

12.1 Toxicity:

Sodium Alkylbenzene Sulfonate: Fish, LC50 1.67 mg/l, 96 hours.
Sodium Alkylbenzene Sulfonate: Aquatic invertebrates, EC50 Daphnia 2.4 mg/l, 48 hours.
Sodium Alkylbenzene Sulfonate: Aquatic Plants, EC50 Algae 29 mg/l, 96 hours.
Tetrasodium Pyrophosphate: Fish, LC50 - other fish - 1,380 mg/l - 96 h.
Tetrasodium Pyrophosphate: Aquatic invertebrates, EC50 - Daphnia magna (Water flea) - 391 mg/l - 48 h.

12.2 Persistence and degradability: No additional information.

12.3 Bioaccumulative potential: No additional information.

12.4 Mobility in soil: No additional information.

General notes: No additional information.

12.5 Results of PBT and vPvB assessment:

PBT: No additional information.

vPvB: No additional information.

12.6 Other adverse effects: No additional information.

13 Disposal considerations

13.1 Waste treatment methods (consult local, regional and national authorities for proper disposal)

Relevant Information:

It is the responsibility of the waste generator to properly characterize all waste materials according to applicable regulatory entities. (US 40CFR262.11).

14 Transport information

14.1 UN Number: None
ADR, ADN, DOT, IMDG, IATA

14.2 UN Proper shipping name: None
ADR, ADN, DOT, IMDG, IATA

14.3 Transport hazard classes:
ADR, ADN, DOT, IMDG, IATA

Class: None
Label: None
LTD. QTY: None

US DOT
Limited Quantity Exception: None

Bulk:
RQ (if applicable): None
Proper shipping Name: None
Hazard Class: None
Packing Group: None
Marine Pollutant (if applicable): No additional information.

Non Bulk:
RQ (if applicable): None
Proper shipping Name: None
Hazard Class: None
Packing Group: None
Marine Pollutant (if applicable): No additional information.

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

	Comments: None	**Comments:** None
14.4	**Packing group:** ADR, ADN, DOT, IMDG, IATA	None
14.5	**Environmental hazards** :	None
14.6	**Special precautions for user:**	None
	Danger code (Kemler):	None
	EMS number:	None
	Segregation groups:	None
14.7	**Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code:** Not applicable.	
14.8	**Transport/Additional information:**	
	Transport category:	None
	Tunnel restriction code:	None
	UN "Model Regulation":	None

15 Regulatory Information

15.1 Safety, health and environmental regulations/legislation specific for the substance or mixture.

North American

SARA

Section 313 (specific toxic chemical listings): None of the ingredients are listed.
Section 302 (extremely hazardous substances): None of the ingredients are listed.

CERCLA (Comprehensive Environmental Response, Clean up and Liability Act) Reportable

Spill Quantity: None of the ingredients are listed.

TSCA (Toxic Substances Control Act):

Inventory: All ingredients are listed.
Rules and Orders: Not applicable.

Proposition 65 (California):

Chemicals known to cause cancer: None of the ingredients are listed.

Chemicals known to cause reproductive toxicity for females: None of the ingredients are listed.

Chemicals known to cause reproductive toxicity for males: None of the ingredients are listed.

Chemicals known to cause developmental toxicity: None of the ingredients are listed.

Canadian

Canadian Domestic Substances List (DSL):
All ingredients are listed.

EU

REACH Article 57 (SVHC): None of the ingredients are listed.

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

Germany MAK: Not classified.

Asia Pacific

Australia

Australian Inventory of Chemical Substances (AICS): All ingredients are listed.

China

Inventory of Existing Chemical Substances in China (IECSC): All ingredients are listed.

Japan

Inventory of Existing and New Chemical Substances (ENCS): All ingredients are listed.

Korea

Existing Chemicals List (ECL): All ingredients are listed.

New Zealand

New Zealand Inventory of Chemicals (NZOIC): All ingredients are listed.

Philippines

Philippine Inventory of Chemicals and Chemical Substances (PICCS): All ingredients are listed.

Taiwan

Taiwan Chemical Substance Inventory (TSCI): All ingredients are listed.

16 Other information

Abbreviations and Acronyms: None

Summary of Phrases

Hazard statements:

H315 Causes skin irritation.
H319 Causes serious eye irritation.

Precautionary statements:

P264 Wash skin thoroughly after handling.
P280 Wear protective gloves/protective clothing/eye protection/face protection.
P302+P352 If on skin: Wash with soap and water.
P305+P351+P338 If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.
P321 Specific treatment (see supplemental first aid instructions on this label).
P332+P313 If skin irritation occurs: Get medical advice/attention.
P362 Take off contaminated clothing and wash before reuse.
P501 Dispose of contents and container as instructed in Section 13.

Manufacturer Statement:

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

NFPA: 1-0-0

Safety Data Sheet

according to 1907/2006/EC (REACH), 1272/2008/EC (CLP), 29CFR1910/1200 and GHS Rev. 3

Effective date: 12.08.2015 **Revision** : 12.10.2015

Trade Name: Alconox

HMIS: 1-0-0

Safety Data Sheet (SDS)

Date Prepared/Revised: 11/30/18 Version no.: 03 Supersedes: (8/13/15)

1.) Identification of the Mixture and of the Company

Product identifier**: Aervoe All Purpose Marking Paint - Aerosol**

Product name:

Non-Fluorescent Colors			Fluorescent Colors		
1380 Black	1381 Red	1382 Yellow	1390 Red	1391 Green	1392 Orange
1383 Blue	1384 Green	1385 Orange	1393 Yellow	1394 Blue	1395 Red-Orange
1387 White			1399 Pink		

Relevant identified uses of the substance: This product is designed to adhere to most surfaces - paved or unpaved.
Uses advised against: . Do not apply additional product until the previous coat is dry. Do not apply if surface is wet. Do not store at temperatures below 32°F (0°C). Do not use on turf surfaces.

CAS No:	**Not Applicable (mixture)**
EC No:	**Not Applicable (mixture)**
Index No:	**Not Applicable (mixture)**
Manufacturer/Supplier:	**Aervoe Industries Incorporated**
Street address/P.O. Box:	**1100 Mark Circle**
Country ID/Postcode/Place	**Gardnerville, Nevada 89410**
Telephone number:	**1-775-782-0100**
e-mail:	**mailbox@aervoe.com**
National contact:	**Aervoe Industries Incorporated**
For Product Information:	**1-800-227-0196**
Emergency telephone number:	**1-800-424-9300 (CHEMTREC – 24 hrs)**

2. Hazards identification

Classifications

Physical Hazards: Aerosol - Category 1
Flam. Gas. 1
Press. Gas
Flam. Liq. 2

Health Hazards:
Car 1B
Muta 1B
Asp Tox. 1
Eye Irrit. - 2
Rep. 2
Skin. Irr. 2
STOT SE3

Environmental Hazards: Aquatic Chronic 2

Date Prepared/Revised: 11/30/18 Version no.: 03 Supersedes: (8/13/15)

Labeling

Signal Word: Danger

Hazard Statements:
H220 – Extremely flammable gas
H222 – Extremely flammable aerosol
H225 – Highly flammable liquid and vapour.
H229 - Pressurized container: may burst if heated
H304 – May be fatal if swallowed and enters airways.
H315 – Causes skin irritation.
H319 – Causes serious eye irritation.
H336 – May cause drowsiness or dizziness.
H340 – May cause genetic defects
H350 – May cause cancer
H361 – Suspected of damaging fertility or the unborn child .
H373 – May cause damage to nervous system through prolonged or repeated exposure(Inhalation)

Precautionary Statements:
P101 - If medical advice is needed, have product container or label at hand
P102 - Keep out of reach of children
P103 - Read label before use
P210 - Keep away from heat/sparks/open flames/hot surfaces - no smoking
P211 - Do not spray on an open flame or other ignition source
P251 - Pressurized container: Do not pierce or burn, even after use
P261 - Avoid breathing dust/fume/gas/mist/vapours/spray
P262 - Do not get in eyes, on skin, or on clothing
P264 - Wash … thoroughly after handling
P280 - Wear protective gloves/eye protection/face protection

P303+P361+P353 - If on skin or hair, remove/takeoff immediately all contaminated clothing. Rinse skin with water/shower.
P410+P412 - Protect from sunlight. Do not expose to temperatures exceeding 50ºC/122ºF
P501 - Dispose of contents/container in accordance with local/regional/national/international regulation

Symbols/Pictograms:



3. Composition / Information on Ingredients

Composition

Chemical	Synonyms	CAS Number	EINECS Number	Weight Percent	Hazard Category	H-Code
Hydrocarbon Propellant	LPG	68476-86-8	270-705-8	10-30%	Press. Gas Flam. Gas 1	H220 H229
Hexane	n-Hexane	110-54-3	203-777-6	5-10%	Flam. Liq. 2 Repr. 2 Asp. Tox. 1 STOT RE 2 * Skin Irrit. 2 STOT SE 3 Aquatic Chronic 2	H225 H361f * H304 H373 ** (nervous system) (inhalation) H315 H336 H411
Aliphatic Petroleum Distillates	Solvent Naphtha	64742-89-8	265-192-2	5-10%	Flam Liq. 2 Skin Irr. 2 Asp. Tox. 1 STOT SE 3 Aquatic Tox. 2	H224 H304 H315 H336 H411
Aliphatic Petroleum Distillates	Solvent Naphtha	64742-88-7	265-191-7	1-5%	Asp. Tox. 1	H304
Aliphatic Petroleum Distillates	Solvent Naphtha	8032-32-4	232-453-7	1-5%	Carc. 1B Muta. 1B Asp. Tox. 1	H350 H340 H304
Non-fluorescent colors also contain:					#N/A	#N/A
Acetone	Propanone	67-64-1	200-662-2	1-5%	Flam. Liq. 2 Eye Irrit. 2 STOT SE 3	H225 H319 H336

Other Product Information

Chemical Identity: Mixture

4.) First Aid Measures

General Advice: If symptoms persist, always call a doctor.

Inhalation First Aid: Remove victim to fresh air and provide oxygen if breathing is difficult. If not breathing, give artificial respiration, preferably

	mouth to mouth. Get medical attention immediately.
Skin Contact First Aid:	Wash with soap and water. Remove contaminated clothing and shoes. Get medical attention immediately. Wash clothing before reuse.
Eye Contact First Aid:	If contact with eyes, immediately flush eyes with plenty of water for at least 15 minutes, while holding eyelids open. Get medical attention immediately.
Ingestion First Aid:	If swallowed, wash out mouth with water provided the person is conscious. Do not induce vomiting. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Most Important Symptoms/Effects:	Exposure may cause slight irritation to the skin, eyes, and respiratory tract. Excessive exposure may cause central nervous system effects.

5. Fire Fighting Measures

Flammable Properties:	Aerosol
Auto Ignition Temperature:	Not Available
Suitable extinguishing media:	Carbon dioxide, dry chemical, water spray.
Unsuitable extinguishing media:	None known
Special hazards arising from the substance or mixture:	None known
Hazardous combustion products:	Carbon dioxide, Carbon monoxide
Fire & Explosion Hazards:	Closed Containers may rupture due to the buildup of pressure from extreme temperatures.
Precautions for fire-fighters:	Use water spray to cool containers exposed to heat or fire to prevent pressure build up. In the event of a fire, wear full protective clothing and NIOSH- approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.

6. Accidental Release Measures

PERSONAL PRECAUTIONARY MEASURES:

1) Follow personal protective equipment recommendations found in section 8.
2) Maintain adequate ventilation.

SPILL CLEAN-UP PROCEDURES:

1.) Evacuate unprotected personnel from the area.
2.) Remove sources of ignition if safe to do so.
3.) Pickup spilled materials using non-sparking tools and place in an appropriate container for disposal.
4.) Contain spill to prevent material from entering sewage or ground water systems.
5.) Always dispose of waste materials in accordance with all EU, National and Local Regulations.

7. Handling and Storage

Handling:

Flammable Aerosol, use in a well ventilated area.
Do not use near sources of ignition.
Do not to eat, drink and smoke while working with this material.
Wash hands after use.

Conditions for safe storage, including any incompatibilities:

Store out of direct sunlight.
Storage Temperature: 32° to 120°F (0° to 49°C).
No known incompatibilities.

8. Exposure Controls / Personal Protection

Appropriate engineering controls:
Ensure adequate ventilation. A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits.
Keep away from sources of ignition.
Take precautionary measures against static discharge.

Personal Protection:
Eye & face protection devices such as safety glasses, safety goggles or face shield are recommended.

Skin protection
Wear the appropriate protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.

Respiratory protection:
Use only in an adequately ventilated area. For unknown vapor concentrations use a positive-pressure, pressure-demand, self-contained breathing apparatus (SCBA).

Hazardous Ingredient	CAS Number	ACGIH TLV (TWA)	ACGIH TLV (STEL)	OSHA PEL (TWA)	OSHA PEL (STEL)
Aliphatic Petroleum Distillates	64742-88-7	N/AV	N/AV	N/AV	N/AV
Aliphatic Petroleum Distillates	64742-89-8	N/AV	N/AV	N/AV	N/AV
Hydrocarbon Propellant	68476-86-8	N/AV	N/AV	N/AV	N/AV
Aliphatic Petroleum Distillates	8032-32-4	200ppm	300ppm	200ppm	N/AV
Hexane	110-54-3	50ppm	N/AV	500ppm	N/AV
Acetone	67-64-1	500ppm	750ppm	1000ppm	N/AV

Date Prepared/Revised: 11/30/18 Version no.: 03 Supersedes: (8/13/15)

***Values are based on the 2014 Guide to Occupational Exposure Values by ACGIH**

9. Information on Basic Physical and Chemical Properties

Appearance: Color varies by product.	Odor: Hydrocarbon Odor
Odor Threshold: N/AV	pH: Not Applicable (solvent Base)
Melting Point: N/AV	Freezing Point: N/AV
Initial Boiling Point: N/AV	Boiling Point Range: N/AV
Flash Point: <0° F (-18° C)	Evaporation Rate: Faster than n-Butyl Acetate
Flammability Solid/Gas: Flammable gas	LEL: 0.9% UEL: 13%
Vapor Pressure: N/AV	Vapor Density: Heavier Than Air
Relative Density: N/AV	Solubility: Negligible
Partition Coefficient: n-octanol/ water: N/AV	Auto-ignition Temperature: N/AV
Decomposition Temperature: N/AV	Viscosity: N/AV
Explosive Properties: N/AV	Oxidizing Properties: N/AV

10. Stability & Reactivity

Possibility of hazardous reactions: Hazardous polymerization will not occur under normal conditions
Chemical stability: Stable under normal conditions
Conditions to avoid: Heat and ignition sources
Incompatible materials: Strong Oxidizing Agents
Hazardous decomposition products: Will not occur

11. Toxicological Information

Reports have associated repeated and prolonged overexposure to solvents with permanent brain and nervous system damage. Repeated overexposure can also damage kidneys, lungs, liver, heart and blood

Routes of exposure: Eyes, skin, ingestion, and/or inhalation

Acute toxicological data: (Acetone) Acute oral LD50: 5800mg/kg(rat)
(Acetone) LC50: 21000 ppm / 8 hr (rat)
(Hexane) LD50: 2870 mg/kg (Rat-Oral)

Eye irritation data: N/AV

Skin irritation/sensitization/absorption data: N/AV

Reproductive toxicity data: N/AV

Mutagenicity data: Muta 1B

Symptoms associated with physical contact:	N/AV
Acute/chronic effects from short/long term exposure:	Irritating to skin. Prolonged/repeated contact may cause defatting of the skin which can lead to dermatitis. Not expected to be a skin sensitizer.
Known reportable carcinogens via the following agencies:	
NTP:	N/AV
IARC:	IARC3:Classification not possible from current data
OSHA:	TLV-A4

* Petroleum distillates may contain chemical carcinogens in limited quantities (< 0.01%). These quantities are determined by the supplier/fraction/purity of the distillate during the manufacturing process. Chemicals that may be present within distillates are listed on California's prop 65 list such as ETHYLBENZENE, BENZENE, and TOLUENE.

12. Ecological Information

Ecotoxicity: **No Data Available**
Persistence and degradability: **No Data Available**
Bioaccumulative potential: **No Data Available**
Mobility in soil: **No Data Available**
Results of PBT and vPvB assessment: **No Data Available**
Other adverse effects: **No Data Available**

13. Disposal Considerations

Waste Disposal: Dispose of material in accordance with EU, national and local requirements. For proper disposal of used material, an assessment must be completed to determine the proper and permissible waste management options permitted under applicable rules, regulations and/or laws governing your location.
Product / Packaging disposal: Dispose of packaging in accordance with federal, state and local requirements, regulations and/or laws governing your location.

14. Transportation Information

US DOT

UN Number	Proper Shipping Name	Hazard Class	Packing Group	Marine Pollutant	Special Provisions
UN1950	Aerosols	2.1	Not Applicable	Not Applicable	Reference 49 CFR 172.101

IMDG

UN	Proper Shipping Name	Hazard	Packing	Marine	Special

Number		Class	Group	Pollutant	Provisions
UN1950	Aerosols	2.1	Not Applicable	Not Applicable	Reference IMDG code part 3

IATA:

UN Number	Proper Shipping Name	Hazard Class	Packing Group	Marine Pollutant	Special Provisions
UN1950	Aerosols, Flammable	2.1	Not Applicable	Not Applicable	Reference IATA Dangerous Goods Regulation

15. Regulatory Information

Workplace classification:
This product is considered hazardous under the OSHA Hazard Communication Standard (29 CFR 1910.1200). The Occupational Safety and Health Administration's interpretation of the product's hazard to workers.
SARA Title 3:
Section 311/312 Categorizations (40 CFR 372): This product is a hazardous chemical under 29 CFR 1910.1200, and is categorized as an immediate and delayed health, and flammability physical hazard. Superfund Amendment and Reauthorization Act (SARA) category. SARA requires reporting any spill of any hazardous substance.
TSCA status: All chemicals in this product are listed, or are exempt from listing, on the TSCA Inventory.
WHMIS: This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the (M)SDS contains all of the information required by the CPR.
PROP 65 (CA): WARNING: Cancer and Reproductive Harm – www.P65Warnings.ca.gov.

16. Other Information

This SDS has been completed in accordance with GHS Rev04 (2011): U.S OSHA, CMA, ANSI, Canadian WHMIS standards, and European Directives.

Date of Preparation/Revision: 11/30/18
Supersedes: (8/13/15)

To the best of our knowledge, the information contained herein is believed to be accurate. However, the above data does not imply any guarantee or warranty of any kind, expressed or implied. The final determination of the suitability of any material is the sole responsibility of the user. All materials made present un-known hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee these are the only hazards existing.

Safety Data Sheet

Material Name: Gasoline All Grades

SDS No. 9950
US GHS

Synonyms: Hess Conventional (Oxygenated and Non-oxygenated) Gasoline; Reformulated Gasoline (RFG); Reformulated Gasoline Blendstock for Oxygenate Blending (RBOB); Unleaded Motor or Automotive Gasoline

* * * Section 1 - Product and Company Identification * * *

Manufacturer Information

Hess Corporation
1 Hess Plaza
Woodbridge, NJ 07095-0961

Phone: 732-750-6000 Corporate EHS
Emergency # 800-424-9300 CHEMTREC
www.hess.com (Environment, Health, Safety Internet Website)

* * * Section 2 - Hazards Identification * * *

GHS Classification:

Flammable Liquid - Category 2
Skin Corrosion/Irritation - Category 2
Germ Cell Mutagenicity - Category 1B
Carcinogenicity - Category 1B
Toxic to Reproduction - Category 1A
Specific Target Organ Toxicity (Single Exposure) - Category 3 (respiratory irritation, narcosis)
Specific Target Organ Toxicity (Repeat Exposure) - Category 1 (liver, kidneys, bladder, blood, bone marrow, nervous system)
Aspiration Hazard - Category 1
Hazardous to the Aquatic Environment – Acute Hazard - Category 3

GHS LABEL ELEMENTS

Symbol(s)



Signal Word

DANGER

Hazard Statements

Highly flammable liquid and vapour.
Causes skin irritation.
May cause genetic defects.
May cause cancer.
May damage fertility or the unborn child.
May cause respiratory irritation.
May cause drowsiness or dizziness.
Causes damage to organs (liver, kidneys, bladder, blood, bone marrow, nervous system) through prolonged or repeated exposure.
May be fatal if swallowed and enters airways.
Harmful to aquatic life.

Precautionary Statements

Prevention

Keep away from heat/sparks/open flames/hot surfaces. No smoking
Keep container tightly closed.
Ground/bond container and receiving equipment.
Use explosion-proof electrical/ventilating/lighting/equipment.
Use only non-sparking tools.
Take precautionary measures against static discharge.
Wear protective gloves/protective clothing/eye protection/face protection.
Wash hands and forearms thoroughly after handling.
Obtain special instructions before use.
Do not handle until all safety precautions have been read and understood.
Do not breathe mist/vapours/spray.
Use only outdoors or in well-ventilated area.
Do not eat, drink or smoke when using this product.
Avoid release to the environment.

Response

In case of fire: Use water spray, fog, dry chemical fire extinguishers or hand held fire extinguisher.
IF ON SKIN (or hair): Wash with plenty of soap and water. Remove/Take off immediately all contaminated clothing and wash before reuse. If skin irritation occurs, get medical advice/attention.
IF exposed or concerned: Get medical advice/attention.
IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a poison center or doctor/physician if you feel unwell.
Get medical advice/attention if you feel unwell.
IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician. Do not induce vomiting.

Storage

Store in a well-ventilated place.
Keep cool. Keep container tightly closed.
Store locked up.

Disposal

Dispose of contents/container in accordance with local/regional/national/international regulations.

* * * Section 3 - Composition / Information on Ingredients * * *

CAS #	Component	Percent
86290-81-5	Gasoline, motor fuel	100
108-88-3	Toluene	1-25
106-97-8	Butane	<10
1330-20-7	Xylenes (o-, m-, p- isomers)	1-15
95-63-6	Benzene, 1,2,4-trimethyl-	<6
64-17-5	Ethyl alcohol	0-10
100-41-4	Ethylbenzene	<3
71-43-2	Benzene	0.1-4.9

110-54-3	Hexane	0.5-4

A complex blend of petroleum-derived normal and branched-chain alkane, cycloalkane, alkene, and aromatic hydrocarbons. May contain antioxidant and multifunctional additives. Non-oxygenated Conventional Gasoline and RBOB do not have oxygenates (Ethanol). Oxygenated Conventional and Reformulated Gasoline will have oxygenates for octane enhancement or as legally required.

* * * Section 4 - First Aid Measures * * *

First Aid: Eyes

In case of contact with eyes, immediately flush with clean, low-pressure water for at least 15 min. Hold eyelids open to ensure adequate flushing. Seek medical attention.

First Aid: Skin

Remove contaminated clothing. Wash contaminated areas thoroughly with soap and water or with waterless hand cleanser. Obtain medical attention if irritation or redness develops.

First Aid: Ingestion

DO NOT INDUCE VOMITING. Do not give liquids. Obtain immediate medical attention. If spontaneous vomiting occurs, lean victim forward to reduce the risk of aspiration. Monitor for breathing difficulties. Small amounts of material which enter the mouth should be rinsed out until the taste is dissipated.

First Aid: Inhalation

Remove person to fresh air. If person is not breathing, provide artificial respiration. If necessary, provide additional oxygen once breathing is restored if trained to do so. Seek medical attention immediately.

* * * Section 5 - Fire Fighting Measures * * *

General Fire Hazards

See Section 9 for Flammability Properties.

Vapors may be ignited rapidly when exposed to heat, spark, open flame or other source of ignition. Flowing product may be ignited by self-generated static electricity. When mixed with air and exposed to an ignition source, flammable vapors can burn in the open or explode in confined spaces. Being heavier than air, vapors may travel long distances to an ignition source and flash back. Runoff to sewer may cause fire or explosion hazard.

Hazardous Combustion Products

Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke). Contact with nitric and sulfuric acids will form nitrocresols that can decompose violently.

Extinguishing Media

SMALL FIRES: Any extinguisher suitable for Class B fires, dry chemical, CO2, water spray, fire fighting foam, or gaseous extinguishing agent.

LARGE FIRES: Water spray, fog or fire fighting foam. Water may be ineffective for fighting the fire, but may be used to cool fire-exposed containers.

Firefighting foam suitable for polar solvents is recommended for fuel with greater than 10% oxygenate concentration.

Unsuitable Extinguishing Media

None

Fire Fighting Equipment/Instructions

Small fires in the incipient (beginning) stage may typically be extinguished using handheld portable fire extinguishers and other fire fighting equipment. Firefighting activities that may result in potential exposure to high heat, smoke or toxic by-products of combustion should require NIOSH/MSHA- approved pressure-demand self-contained breathing apparatus with full facepiece and full protective clothing. Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water. For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied fire fighting foam.

* * * Section 6 - Accidental Release Measures * * *

Recovery and Neutralization

Carefully contain and stop the source of the spill, if safe to do so.

Materials and Methods for Clean-Up

Take up with sand or other oil absorbing materials. Carefully shovel, scoop or sweep up into a waste container for reclamation or disposal. Caution, flammable vapors may accumulate in closed containers.

Emergency Measures

Evacuate nonessential personnel and remove or secure all ignition sources. Consider wind direction; stay upwind and uphill, if possible. Evaluate the direction of product travel, diking, sewers, etc. to confirm spill areas. Spills may infiltrate subsurface soil and groundwater; professional assistance may be necessary to determine the extent of subsurface impact.

Personal Precautions and Protective Equipment

Response and clean-up crews must be properly trained and must utilize proper protective equipment (see Section 8).

Environmental Precautions

Protect bodies of water by diking, absorbents, or absorbent boom, if possible. Do not flush down sewer or drainage systems, unless system is designed and permitted to handle such material. The use of fire fighting foam may be useful in certain situations to reduce vapors. The proper use of water spray may effectively disperse product vapors or the liquid itself, preventing contact with ignition sources or areas/equipment that require protection.

Prevention of Secondary Hazards

None

* * * Section 7 - Handling and Storage * * *

Handling Procedures

USE ONLY AS A MOTOR FUEL.
DO NOT SIPHON BY MOUTH

Handle as a flammable liquid. Keep away from heat, sparks, and open flame! Electrical equipment should be approved for classified area. Bond and ground containers during product transfer to reduce the possibility of static-initiated fire or explosion.

Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil) is loaded into tanks previously containing low flash point products (such as this product) - see API Publication 2003, "Protection Against Ignitions Arising Out Of Static, Lightning and Stray Currents."

Storage Procedures

Keep away from flame, sparks, excessive temperatures and open flame. Use approved vented containers. Keep containers closed and clearly labeled. Empty product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose such containers to sources of ignition.

Store in a well-ventilated area. This storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". Avoid storage near incompatible materials. The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks".

Incompatibilities

Keep away from strong oxidizers.

* * * Section 8 - Exposure Controls / Personal Protection * * *

Component Exposure Limits

Gasoline, motor fuel (86290-81-5)

ACGIH: 300 ppm TWA
500 ppm STEL

Toluene (108-88-3)

ACGIH: 20 ppm TWA
OSHA: 200 ppm TWA; 375 mg/m3 TWA
150 ppm STEL; 560 mg/m3 STEL
NIOSH: 100 ppm TWA; 375 mg/m3 TWA
150 ppm STEL; 560 mg/m3 STEL

Butane (106-97-8)

ACGIH: 1000 ppm TWA (listed under Aliphatic hydrocarbon gases: Alkane C1-4)
OSHA: 800 ppm TWA; 1900 mg/m3 TWA
NIOSH: 800 ppm TWA; 1900 mg/m3 TWA

Xylenes (o-, m-, p- isomers) (1330-20-7)

ACGIH: 100 ppm TWA
150 ppm STEL
OSHA: 100 ppm TWA; 435 mg/m3 TWA
150 ppm STEL; 655 mg/m3 STEL

Benzene, 1,2,4-trimethyl- (95-63-6)

NIOSH: 25 ppm TWA; 125 mg/m3 TWA

Ethyl alcohol (64-17-5)

ACGIH: 1000 ppm STEL
OSHA: 1000 ppm TWA; 1900 mg/m3 TWA
NIOSH: 1000 ppm TWA; 1900 mg/m3 TWA

Ethylbenzene (100-41-4)

ACGIH: 20 ppm TWA
OSHA: 100 ppm TWA; 435 mg/m3 TWA
125 ppm STEL; 545 mg/m3 STEL
NIOSH: 100 ppm TWA; 435 mg/m3 TWA
125 ppm STEL; 545 mg/m3 STEL

Benzene (71-43-2)

ACGIH: 0.5 ppm TWA
2.5 ppm STEL
Skin - potential significant contribution to overall exposure by the cutaneous route
OSHA: 5 ppm STEL (Cancer hazard, Flammable, See 29 CFR 1910.1028, 15 min); 0.5 ppm Action Level; 1 ppm TWA
NIOSH: 0.1 ppm TWA
1 ppm STEL

Hexane (110-54-3)

ACGIH: 50 ppm TWA
Skin - potential significant contribution to overall exposure by the cutaneous route
OSHA: 500 ppm TWA; 1800 mg/m3 TWA
NIOSH: 50 ppm TWA; 180 mg/m3 TWA

Engineering Measures

Use adequate ventilation to keep vapor concentrations of this product below occupational exposure and flammability limits, particularly in confined spaces.

Personal Protective Equipment: Respiratory

A NIOSH/MSHA-approved air-purifying respirator with organic vapor cartridges or canister may be permissible under certain circumstances where airborne concentrations are or may be expected to exceed exposure limits or for odor or irritation. Protection provided by air-purifying respirators is limited.

Use a positive pressure, air-supplied respirator if there is a potential for uncontrolled release, exposure levels are not known, in oxygen-deficient atmospheres, or any other circumstance where an air-purifying respirator may not provide adequate protection.

Personal Protective Equipment: Hands

Gloves constructed of nitrile, neoprene, or PVC are recommended.

PERSONAL PROTECTIVE EQUIPMENT

Personal Protective Equipment: Eyes

Safety glasses or goggles are recommended where there is a possibility of splashing or spraying.

Personal Protective Equipment: Skin and Body

Chemical protective clothing such as of E.I. DuPont TyChem®, Saranex® or equivalent recommended based on degree of exposure. Note: The resistance of specific material may vary from product to product as well as with degree of exposure. Consult manufacturer specifications for further information.

* * * Section 9 - Physical & Chemical Properties * * *

Appearance:	Translucent, straw-colored or light yellow	**Odor:**	Strong, characteristic aromatic hydrocarbon odor. Sweet-ether like
Physical State:	Liquid	**pH:**	ND
Vapor Pressure:	6.4 - 15 RVP @ 100 °F (38 °C) (275-475 mm Hg @ 68 °F (20 °C)	**Vapor Density:**	AP 3-4
Boiling Point:	85-437 °F (39-200 °C)	**Melting Point:**	ND
Solubility (H2O):	Negligible to Slight	**Specific Gravity:**	0.70-0.78
Evaporation Rate:	10-11	**VOC:**	ND
Percent Volatile:	100%	**Octanol/H2O Coeff.:**	ND
Flash Point:	-45 °F (-43 °C)	**Flash Point Method:**	PMCC
Upper Flammability Limit (UFL):	7.6%	**Lower Flammability Limit (LFL):**	1.4%
Burning Rate:	ND	**Auto Ignition:**	>530°F (>280°C)

* * * Section 10 - Chemical Stability & Reactivity Information * * *

Chemical Stability

This is a stable material.

Hazardous Reaction Potential

Will not occur.

Conditions to Avoid

Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources.

Incompatible Products

Keep away from strong oxidizers.

Hazardous Decomposition Products

Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke). Contact with nitric and sulfuric acids will form nitrocresols that can decompose violently.

* * * Section 11 - Toxicological Information * * *

Acute Toxicity

A: General Product Information

Harmful if swallowed.

B: Component Analysis - LD50/LC50

Gasoline, motor fuel (86290-81-5)

Inhalation LC50 Rat >5.2 mg/L 4 h; Oral LD50 Rat 14000 mg/kg; Dermal LD50 Rabbit >2000 mg/kg

Toluene (108-88-3)

Inhalation LC50 Rat 12.5 mg/L 4 h; Inhalation LC50 Rat >26700 ppm 1 h; Oral LD50 Rat 636 mg/kg; Dermal LD50 Rabbit 8390 mg/kg; Dermal LD50 Rat 12124 mg/kg

Butane (106-97-8)

Inhalation LC50 Rat 658 mg/L 4 h

Xylenes (o-, m-, p- isomers) (1330-20-7)
Inhalation LC50 Rat 5000 ppm 4 h; Inhalation LC50 Rat 47635 mg/L 4 h; Oral LD50 Rat 4300 mg/kg; Dermal LD50 Rabbit >1700 mg/kg

Benzene, 1,2,4-trimethyl- (95-63-6)
Inhalation LC50 Rat 18 g/m3 4 h; Oral LD50 Rat 3400 mg/kg; Dermal LD50 Rabbit >3160 mg/kg

Ethyl alcohol (64-17-5)
Oral LD50 Rat 7060 mg/kg; Inhalation LC50 Rat 124.7 mg/L 4 h

Ethylbenzene (100-41-4)
Inhalation LC50 Rat 17.2 mg/L 4 h; Oral LD50 Rat 3500 mg/kg; Dermal LD50 Rabbit 15354 mg/kg

Benzene (71-43-2)
Inhalation LC50 Rat 13050-14380 ppm 4 h; Oral LD50 Rat 1800 mg/kg

Hexane (110-54-3)
Inhalation LC50 Rat 48000 ppm 4 h; Oral LD50 Rat 25 g/kg; Dermal LD50 Rabbit 3000 mg/kg

Potential Health Effects: Skin Corrosion Property/Stimulativeness

Practically non-toxic if absorbed following acute (single) exposure. May cause skin irritation with prolonged or repeated contact. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are repeatedly exposed.

Potential Health Effects: Eye Critical Damage/ Stimulativeness

Moderate irritant. Contact with liquid or vapor may cause irritation.

Potential Health Effects: Ingestion

Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous system (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest, and death may occur.

Potential Health Effects: Inhalation

Excessive exposure may cause irritations to the nose, throat, lungs and respiratory tract. Central nervous system (brain) effects may include headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and death.

WARNING: the burning of any hydrocarbon as a fuel in an area without adequate ventilation may result in hazardous levels of combustion products, including carbon monoxide, and inadequate oxygen levels, which may cause unconsciousness, suffocation, and death.

Respiratory Organs Sensitization/Skin Sensitization

This product is not reported to have any skin sensitization effects.

Generative Cell Mutagenicity

This product may cause genetic defects.

Carcinogenicity

A: General Product Information

May cause cancer.

IARC has determined that gasoline and gasoline exhaust are possibly carcinogenic in humans. Inhalation exposure to completely vaporized unleaded gasoline caused kidney cancers in male rats and liver tumors in female mice. The U.S. EPA has determined that the male kidney tumors are species-specific and are irrelevant for human health risk assessment. The significance of the tumors seen in female mice is not known. Exposure to light hydrocarbons in the same boiling range as this product has been associated in animal studies with effects to the central and peripheral nervous systems, liver, and kidneys. The significance of these animal models to predict similar human response to gasoline is uncertain.

This product contains benzene. Human health studies indicate that prolonged and/or repeated overexposure to benzene may cause damage to the blood-forming system (particularly bone marrow), and serious blood disorders such as aplastic anemia and leukemia. Benzene is listed as a human carcinogen by the NTP, IARC, OSHA and ACGIH.

B: Component Carcinogenicity

Gasoline, motor fuel (86290-81-5)

ACGIH: A3 - Confirmed Animal Carcinogen with Unknown Relevance to Humans

Toluene (108-88-3)

ACGIH: A4 - Not Classifiable as a Human Carcinogen
IARC: Monograph 71 [1999]; Monograph 47 [1989] (Group 3 (not classifiable))

Xylenes (o-, m-, p- isomers) (1330-20-7)

ACGIH: A4 - Not Classifiable as a Human Carcinogen
IARC: Monograph 71 [1999]; Monograph 47 [1989] (Group 3 (not classifiable))

Ethyl alcohol (64-17-5)

ACGIH: A3 - Confirmed Animal Carcinogen with Unknown Relevance to Humans
IARC: Monograph 100E [in preparation] (in alcoholic beverages); Monograph 96 [2010] (in alcoholic beverages) (Group 1 (carcinogenic to humans))

Ethylbenzene (100-41-4)

ACGIH: A3 - Confirmed Animal Carcinogen with Unknown Relevance to Humans
IARC: Monograph 77 [2000] (Group 2B (possibly carcinogenic to humans))

Benzene (71-43-2)

ACGIH: A1 - Confirmed Human Carcinogen
OSHA: 5 ppm STEL (Cancer hazard, Flammable, See 29 CFR 1910.1028, 15 min); 0.5 ppm Action Level; 1 ppm TWA
NIOSH: potential occupational carcinogen
NTP: Known Human Carcinogen (Select Carcinogen)
IARC: Monograph 100F [in preparation]; Supplement 7 [1987]; Monograph 29 [1982] (Group 1 (carcinogenic to humans))

Reproductive Toxicity

This product is suspected of damaging fertility or the unborn child.

Specified Target Organ General Toxicity: Single Exposure

This product may cause drowsiness or dizziness.

Specified Target Organ General Toxicity: Repeated Exposure

This product causes damage to organs through prolonged or repeated exposure.

Aspiration Respiratory Organs Hazard

The major health threat of ingestion occurs from the danger of aspiration (breathing) of liquid drops into the lungs, particularly from vomiting. Aspiration may result in chemical pneumonia (fluid in the lungs), severe lung damage, respiratory failure and even death.

* * * Section 12 - Ecological Information * * *

Ecotoxicity

A: General Product Information

Very toxic to aquatic life with long lasting effects. Keep out of sewers, drainage areas and waterways. Report spills and releases, as applicable, under Federal and State regulations.

B: Component Analysis - Ecotoxicity - Aquatic Toxicity

Gasoline, motor fuel (86290-81-5)

Test & Species		Conditions
96 Hr LC50 Alburnus alburnus	119 mg/L [static]	
96 Hr LC50 Cyprinodon variegatus	82 mg/L [static]	
72 Hr EC50 Pseudokirchneriella subcapitata	56 mg/L	
24 Hr EC50 Daphnia magna	170 mg/L	

Toluene (108-88-3)

Test & Species		Conditions
96 Hr LC50 Pimephales promelas	15.22-19.05 mg/L [flow-through]	1 day old
96 Hr LC50 Pimephales promelas	12.6 mg/L [static]	
96 Hr LC50 Oncorhynchus mykiss	5.89-7.81 mg/L [flow-through]	
96 Hr LC50 Oncorhynchus mykiss	14.1-17.16 mg/L [static]	
96 Hr LC50 Oncorhynchus mykiss	5.8 mg/L [semi-static]	
96 Hr LC50 Lepomis macrochirus	11.0-15.0 mg/L [static]	
96 Hr LC50 Oryzias latipes	54 mg/L [static]	
96 Hr LC50 Poecilia reticulata	28.2 mg/L [semi-static]	
96 Hr LC50 Poecilia reticulata	50.87-70.34 mg/L [static]	
96 Hr EC50 Pseudokirchneriella subcapitata	>433 mg/L	
72 Hr EC50 Pseudokirchneriella subcapitata	12.5 mg/L [static]	
48 Hr EC50 Daphnia magna	5.46 - 9.83 mg/L [Static]	
48 Hr EC50 Daphnia magna	11.5 mg/L	

Xylenes (o-, m-, p- isomers) (1330-20-7)

Test & Species		Conditions
96 Hr LC50 Pimephales promelas	13.4 mg/L [flow-through]	

96 Hr LC50 Oncorhynchus mykiss	2.661-4.093 mg/L [static]
96 Hr LC50 Oncorhynchus mykiss	13.5-17.3 mg/L
96 Hr LC50 Lepomis macrochirus	13.1-16.5 mg/L [flow-through]
96 Hr LC50 Lepomis macrochirus	19 mg/L
96 Hr LC50 Lepomis macrochirus	7.711-9.591 mg/L [static]
96 Hr LC50 Pimephales promelas	23.53-29.97 mg/L [static]
96 Hr LC50 Cyprinus carpio	780 mg/L [semi-static]
96 Hr LC50 Cyprinus carpio	>780 mg/L
96 Hr LC50 Poecilia reticulata	30.26-40.75 mg/L [static]
48 Hr EC50 water flea	3.82 mg/L
48 Hr LC50 Gammarus lacustris	0.6 mg/L

Benzene, 1,2,4-trimethyl- (95-63-6)

Test & Species	Conditions
96 Hr LC50 Pimephales promelas	7.19-8.28 mg/L [flow-through]
48 Hr EC50 Daphnia magna	6.14 mg/L

Ethyl alcohol (64-17-5)

Test & Species	Conditions
96 Hr LC50 Oncorhynchus mykiss	12.0 - 16.0 mL/L [static]
96 Hr LC50 Pimephales promelas	>100 mg/L [static]
96 Hr LC50 Pimephales promelas	13400 - 15100 mg/L [flow-through]
48 Hr LC50 Daphnia magna	9268 - 14221 mg/L
24 Hr EC50 Daphnia magna	10800 mg/L
48 Hr EC50 Daphnia magna	2 mg/L [Static]

Ethylbenzene (100-41-4)

Test & Species	Conditions
96 Hr LC50 Oncorhynchus mykiss	11.0-18.0 mg/L [static]
96 Hr LC50 Oncorhynchus mykiss	4.2 mg/L [semi-static]
96 Hr LC50 Pimephales promelas	7.55-11 mg/L [flow-through]
96 Hr LC50 Lepomis macrochirus	32 mg/L [static]
96 Hr LC50 Pimephales promelas	9.1-15.6 mg/L [static]
96 Hr LC50 Poecilia reticulata	9.6 mg/L [static]
72 Hr EC50 Pseudokirchneriella subcapitata	4.6 mg/L
96 Hr EC50 Pseudokirchneriella subcapitata	>438 mg/L
72 Hr EC50 Pseudokirchneriella subcapitata	2.6 - 11.3 mg/L [static]

96 Hr EC50 Pseudokirchneriella subcapitata	1.7 - 7.6 mg/L [static]
48 Hr EC50 Daphnia magna	1.8 - 2.4 mg/L

Benzene (71-43-2)

Test & Species	Conditions
96 Hr LC50 Pimephales promelas	10.7-14.7 mg/L [flow-through]
96 Hr LC50 Oncorhynchus mykiss	5.3 mg/L [flow-through]
96 Hr LC50 Lepomis macrochirus	22.49 mg/L [static]
96 Hr LC50 Poecilia reticulata	28.6 mg/L [static]
96 Hr LC50 Pimephales promelas	22330-41160 µg/L [static]
96 Hr LC50 Lepomis macrochirus	70000-142000 µg/L [static]
72 Hr EC50 Pseudokirchneriella subcapitata	29 mg/L
48 Hr EC50 Daphnia magna	8.76 - 15.6 mg/L [Static]
48 Hr EC50 Daphnia magna	10 mg/L

Hexane (110-54-3)

Test & Species	Conditions
96 Hr LC50 Pimephales promelas	2.1-2.98 mg/L [flow-through]
24 Hr EC50 Daphnia magna	>1000 mg/L

Persistence/Degradability

No information available.

Bioaccumulation

No information available.

Mobility in Soil

No information available.

* * * Section 13 - Disposal Considerations * * *

Waste Disposal Instructions

See Section 7 for Handling Procedures. See Section 8 for Personal Protective Equipment recommendations.

Disposal of Contaminated Containers or Packaging

Dispose of contents/container in accordance with local/regional/national/international regulations.

* * * Section 14 - Transportation Information * * *

Component Marine Pollutants

This material contains one or more of the following chemicals required by US DOT to be identified as marine pollutants.

Component	CAS #	
Gasoline, motor fuel	86290-81-5	DOT regulated marine pollutant

DOT Information

Shipping Name: Gasoline
UN #: 1203 **Hazard Class:** 3 **Packing Group:** II
Placard:



* * * Section 15 - Regulatory Information * * *

Regulatory Information

A: Component Analysis

This material contains one or more of the following chemicals required to be identified under SARA Section 302 (40 CFR 355 Appendix A), SARA Section 313 (40 CFR 372.65) and/or CERCLA (40 CFR 302.4).

Toluene (108-88-3)
SARA 313: 1.0 % de minimis concentration
CERCLA: 1000 lb final RQ; 454 kg final RQ

Xylenes (o-, m-, p- isomers) (1330-20-7)
SARA 313: 1.0 % de minimis concentration
CERCLA: 100 lb final RQ; 45.4 kg final RQ

Benzene, 1,2,4-trimethyl- (95-63-6)
SARA 313: 1.0 % de minimis concentration

Ethylbenzene (100-41-4)
SARA 313: 0.1 % de minimis concentration
CERCLA: 1000 lb final RQ; 454 kg final RQ

Benzene (71-43-2)
SARA 313: 0.1 % de minimis concentration
CERCLA: 10 lb final RQ (received an adjusted RQ of 10 lbs based on potential carcinogenicity in an August 14, 1989 final rule); 4.54 kg final RQ (received an adjusted RQ of 10 lbs based on potential carcinogenicity in an August 14, 1989 final rule)

Hexane (110-54-3)

SARA 313: 1.0 % de minimis concentration
CERCLA: 5000 lb final RQ; 2270 kg final RQ

SARA Section 311/312 – Hazard Classes

Acute Health	Chronic Health	Fire	Sudden Release of Pressure	Reactive
X	X	X	--	--

Component Marine Pollutants

This material contains one or more of the following chemicals required by US DOT to be identified as marine pollutants.

Component	CAS #	
Gasoline, motor fuel	86290-81-5	DOT regulated marine pollutant

State Regulations

Component Analysis - State

The following components appear on one or more of the following state hazardous substances lists:

Component	**CAS**	**CA**	**MA**	**MN**	**NJ**	**PA**	**RI**
Gasoline, motor fuel	86290-81-5	No	No	No	No	Yes	No
Toluene	108-88-3	Yes	Yes	Yes	Yes	Yes	No
Butane	106-97-8	Yes	Yes	Yes	Yes	Yes	No
Xylenes (o-, m-, p- isomers)	1330-20-7	Yes	Yes	Yes	Yes	Yes	No
Benzene, 1,2,4-trimethyl-	95-63-6	No	Yes	Yes	Yes	Yes	No
Ethyl alcohol	64-17-5	Yes	Yes	Yes	Yes	Yes	No
Ethylbenzene	100-41-4	Yes	Yes	Yes	Yes	Yes	No
Benzene	71-43-2	Yes	Yes	Yes	Yes	Yes	No
Hexane	110-54-3	No	Yes	Yes	Yes	Yes	No

The following statement(s) are provided under the California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65):

WARNING! This product contains a chemical known to the state of California to cause cancer.
WARNING! This product contains a chemical known to the state of California to cause reproductive/developmental effects.

Component Analysis - WHMIS IDL

The following components are identified under the Canadian Hazardous Products Act Ingredient Disclosure List:

Component	CAS #	Minimum Concentration
Toluene	108-88-3	1 %
Butane	106-97-8	1 %
Benzene, 1,2,4-trimethyl-	95-63-6	0.1 %
Ethyl alcohol	64-17-5	0.1 %
Ethylbenzene	100-41-4	0.1 %
Benzene	71-43-2	0.1 %
Hexane	110-54-3	1 %

Additional Regulatory Information

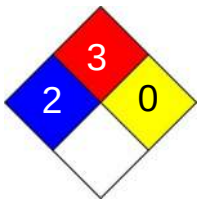
Component Analysis - Inventory

Component	CAS #	TSCA	CAN	EEC
Gasoline, motor fuel	86290-81-5	No	DSL	EINECS
Toluene	108-88-3	Yes	DSL	EINECS
Butane	106-97-8	Yes	DSL	EINECS
Xylenes (o-, m-, p- isomers)	1330-20-7	Yes	DSL	EINECS
Benzene, 1,2,4-trimethyl-	95-63-6	Yes	DSL	EINECS
Ethyl alcohol	64-17-5	Yes	DSL	EINECS
Ethylbenzene	100-41-4	Yes	DSL	EINECS
Benzene	71-43-2	Yes	DSL	EINECS
Hexane	110-54-3	Yes	DSL	EINECS

* * * Section 16 - Other Information * * *

NFPA® Hazard Rating

Health	2
Fire	3
Reactivity	0



HMIS® Hazard Rating

Health	2	Moderate
Fire	3	Serious
Physical	0	Minimal
		*Chronic

Key/Legend

EPA = Environmental Protection Agency; TSCA = Toxic Substance Control Act; ACGIH = American Conference of Governmental Industrial Hygienists; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; OSHA = Occupational Safety and Health Administration., NJTSR = New Jersey Trade Secret Registry.

Literature References

None

Other Information

Information presented herein has been compiled from sources considered to be dependable, and is accurate and reliable to the best of our knowledge and belief, but is not guaranteed to be so. Since conditions of use are beyond our control, we make no warranties, expressed or implied, except those that may be contained in our written contract of sale or acknowledgment.

Vendor assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally, vendor assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material, even if reasonable safety procedures are followed. Furthermore, vendee assumes the risk in their use of the material.

End of Sheet

Nitric Acid, 1.0N (1.0M)

Safety Data Sheet

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Date of issue: 10/31/2013 Revision date: 01/10/2018 Supersedes: 12/19/2016 Version: 1.2

SECTION 1: Identification

1.1. Identification

Product form : Mixtures

Product name : Nitric Acid, 1.0N (1.0M)

Product code : LC17840

1.2. Recommended use and restrictions on use

Use of the substance/mixture : For laboratory and manufacturing use only.

Recommended use : Laboratory chemicals

Restrictions on use : Not for food, drug or household use

1.3. Supplier

LabChem Inc
Jackson's Pointe Commerce Park Building 1000, 1010 Jackson's Pointe Court
Zelienople, PA 16063 - USA
T 412-826-5230 - F 724-473-0647
info@labchem.com - www.labchem.com

1.4. Emergency telephone number

Emergency number : CHEMTREC: 1-800-424-9300 or 011-703-527-3887

SECTION 2: Hazard(s) identification

2.1. Classification of the substance or mixture

GHS-US classification

Corrosive to metals Category 1	H290	May be corrosive to metals
Skin corrosion/irritation Category 1B	H314	Causes severe skin burns and eye damage
Serious eye damage/eye irritation Category 1	H318	Causes serious eye damage

Full text of H statements : see section 16

2.2. GHS Label elements, including precautionary statements

GHS-US labeling

Hazard pictograms (GHS-US) :



GHS05

Signal word (GHS-US) : Danger

Hazard statements (GHS-US) : H290 - May be corrosive to metals
H314 - Causes severe skin burns and eye damage

Precautionary statements (GHS-US) : P234 - Keep only in original container
P260 - Do not breathe mist, vapors, spray
P264 - Wash exposed skin thoroughly after handling
P280 - Wear protective gloves, protective clothing, eye protection, face protection
P301+P330+P331 - IF SWALLOWED: rinse mouth. Do NOT induce vomiting
P303+P361+P353 - IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower
P304+P340 - IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing
P305+P351+P338 - If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a poison center or doctor/physician
P363 - Wash contaminated clothing before reuse
P390 - Absorb spillage to prevent material damage
P405 - Store locked up
P406 - Store in corrosive resistant container with a resistant inner liner
P501 - Dispose of contents/container to comply with local, state and federal regulations

2.3. Other hazards which do not result in classification

Other hazards not contributing to the classification : None.

2.4. Unknown acute toxicity (GHS US)

Not applicable

SECTION 3: Composition/Information on ingredients

3.1. Substances

Not applicable

3.2. Mixtures

Name	Product identifier	%	GHS-US classification
Water	(CAS-No.) 7732-18-5	93.9	Not classified
Nitric Acid, 70% w/w	(CAS-No.) 7697-37-2	6.1	Ox. Liq. 3, H272 Met. Corr. 1, H290 Skin Corr. 1A, H314 Eye Dam. 1, H318

Full text of hazard classes and H-statements : see section 16

SECTION 4: First-aid measures

4.1. Description of first aid measures

First-aid measures general : Never give anything by mouth to an unconscious person. If you feel unwell, seek medical advice (show the label where possible).

First-aid measures after inhalation : Remove victim to fresh air and keep at rest in a position comfortable for breathing. Immediately call a poison center or doctor/physician.

First-aid measures after skin contact : Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower. Immediately call a poison center or doctor/physician.

First-aid measures after eye contact : Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center or doctor/physician.

First-aid measures after ingestion : Rinse mouth. Do NOT induce vomiting. Immediately call a poison center or doctor/physician.

4.2. Most important symptoms and effects (acute and delayed)

Symptoms/effects : Causes severe skin burns and eye damage.

Symptoms/effects after eye contact : Causes serious eye damage.

4.3. Immediate medical attention and special treatment, if necessary

No additional information available

SECTION 5: Fire-fighting measures

5.1. Suitable (and unsuitable) extinguishing media

Suitable extinguishing media : Foam. Dry powder. Carbon dioxide. Water spray. Sand.

Unsuitable extinguishing media : Do not use a heavy water stream.

5.2. Specific hazards arising from the chemical

Reactivity : Thermal decomposition generates : Corrosive vapors.

5.3. Special protective equipment and precautions for fire-fighters

Firefighting instructions : Use water spray or fog for cooling exposed containers. Exercise caution when fighting any chemical fire. Prevent fire-fighting water from entering environment.

Protection during firefighting : Do not enter fire area without proper protective equipment, including respiratory protection.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

6.1.1. For non-emergency personnel

Protective equipment : Protective goggles. Protective clothing. Gloves. Combined gas/dust mask with filter type B/P3.

Emergency procedures : Evacuate unnecessary personnel.

6.1.2. For emergency responders

Protective equipment : Equip cleanup crew with proper protection.

Emergency procedures : Ventilate area.

6.2. Environmental precautions

Prevent entry to sewers and public waters. Notify authorities if liquid enters sewers or public waters.

6.3. Methods and material for containment and cleaning up

Methods for cleaning up : Soak up spills with inert solids, such as clay or diatomaceous earth as soon as possible. Collect spillage. Store away from other materials. Absorb spillage to prevent material damage.

6.4. Reference to other sections

See Heading 8. Exposure controls and personal protection.

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Additional hazards when processed : May be corrosive to metals.

Precautions for safe handling : Wash hands and other exposed areas with mild soap and water before eating, drinking or smoking and when leaving work. Provide good ventilation in process area to prevent formation of vapor. Do not breathe mist, vapors, spray.

Hygiene measures : Wash exposed skin thoroughly after handling. Wash contaminated clothing before reuse.

7.2. Conditions for safe storage, including any incompatibilities

Technical measures : Comply with applicable regulations.

Storage conditions : Keep only in the original container in a cool, well ventilated place away from : incompatible materials. Keep container closed when not in use.

Incompatible products : Strong bases. Halogens. metals. aluminum. Strong reducing agents.

Incompatible materials : Sources of ignition. Direct sunlight.

Packaging materials : Store in a corrosion resistant container with a resistant inner liner.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Nitric Acid, 70% w/w (7697-37-2)		
ACGIH	ACGIH TWA (ppm)	2 ppm (Nitric acid; USA; Time-weighted average exposure limit 8 h; TLV - Adopted Value)
ACGIH	ACGIH STEL (ppm)	4 ppm (Nitric acid; USA; Short time value; TLV - Adopted Value)
OSHA	OSHA PEL (TWA) (mg/m³)	5 mg/m³
OSHA	OSHA PEL (TWA) (ppm)	2 ppm
IDLH	US IDLH (ppm)	25 ppm
NIOSH	NIOSH REL (TWA) (mg/m³)	5 mg/m³
NIOSH	NIOSH REL (TWA) (ppm)	2 ppm
NIOSH	NIOSH REL (STEL) (mg/m³)	10 mg/m³
NIOSH	NIOSH REL (STEL) (ppm)	4 ppm

Water (7732-18-5)
Not applicable

8.2. Appropriate engineering controls

Appropriate engineering controls : Emergency eye wash fountains should be available in the immediate vicinity of any potential exposure. Provide adequate general and local exhaust ventilation.

8.3. Individual protection measures/Personal protective equipment

Personal protective equipment:

Gloves. Protective clothing. Protective goggles. Chemical resistant apron. Gas mask.



Hand protection:

Wear protective gloves

Eye protection:

Chemical goggles or face shield

Skin and body protection:

Wear suitable protective clothing

Respiratory protection:

Wear appropriate mask

Other information:

Do not eat, drink or smoke during use.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state	:	Liquid
Appearance	:	Colorless to pale yellow liquid.
Color	:	Colourless to light yellow
Odor	:	characteristic Pungent
Odor threshold	:	No data available
pH	:	No data available
Melting point	:	No data available
Freezing point	:	No data available
Boiling point	:	No data available
Flash point	:	No data available
Relative evaporation rate (butyl acetate=1)	:	No data available
Flammability (solid, gas)	:	Non flammable.
Vapor pressure	:	No data available
Relative vapor density at 20 °C	:	No data available
Relative density	:	No data available
Specific gravity / density	:	1.03 g/ml
Solubility	:	Soluble in water.
Log Pow	:	No data available
Auto-ignition temperature	:	No data available
Decomposition temperature	:	No data available
Viscosity, kinematic	:	0.99 cSt
Viscosity, dynamic	:	No data available
Explosion limits	:	No data available
Explosive properties	:	No data available
Oxidizing properties	:	No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

Thermal decomposition generates : Corrosive vapors.

10.2. Chemical stability

Not established.

10.3. Possibility of hazardous reactions

Not established.

10.4. Conditions to avoid

Direct sunlight. Extremely high or low temperatures.

10.5. Incompatible materials

Strong reducing agents. Strong bases. metals. aluminum. Ammonia. combustible materials. Halogens.

10.6. Hazardous decomposition products

Nitrogen oxides. Thermal decomposition generates : Corrosive vapors.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Likely routes of exposure : Skin and eye contact; Inhalation

Acute toxicity : Not classified

Water (7732-18-5)	
LD50 oral rat	≥ 90000 mg/kg
ATE US (oral)	90000 mg/kg body weight

Skin corrosion/irritation : Causes severe skin burns and eye damage.

Serious eye damage/irritation : Causes serious eye damage.

Respiratory or skin sensitization : Not classified

Germ cell mutagenicity : Not classified

Carcinogenicity : Not classified

Reproductive toxicity : Not classified

Specific target organ toxicity – single exposure : Not classified

Specific target organ toxicity – repeated exposure : Not classified

Aspiration hazard : Not classified

Potential Adverse human health effects and symptoms : Based on available data, the classification criteria are not met.

Symptoms/effects after eye contact : Causes serious eye damage.

SECTION 12: Ecological information

12.1. Toxicity

Nitric Acid, 70% w/w (7697-37-2)	
EC50 Daphnia 1	180 mg/l (EC50; 48 h)
LC50 fish 2	72 ppm (LC50; 96 h)
Threshold limit algae 1	> 19 mg/l (EC0)

12.2. Persistence and degradability

Nitric Acid, 1.0N (1.0M)	
Persistence and degradability	Not established.

Nitric Acid, 70% w/w (7697-37-2)	
Persistence and degradability	Biodegradability: not applicable. No test data on mobility of the components available.
Biochemical oxygen demand (BOD)	Not applicable
Chemical oxygen demand (COD)	Not applicable
ThOD	Not applicable

Water (7732-18-5)	
Persistence and degradability	Not established.

12.3. Bioaccumulative potential

Nitric Acid, 1.0N (1.0M)	
Bioaccumulative potential	Not established.

Nitric Acid, 70% w/w (7697-37-2)	
BCF fish 1	<= 1 (BCF)
Log Pow	-2.3 (OECD 107: Partition Coefficient (n-octanol/water): Shake Flask Method)
Bioaccumulative potential	Bioaccumulation: not applicable.

Water (7732-18-5)	
Bioaccumulative potential	Not established.

12.4. Mobility in soil

No additional information available

12.5. Other adverse effects

Effect on the global warming : No known effects from this product.

GWPmix comment : No known effects from this product.

Other information : Avoid release to the environment.

SECTION 13: Disposal considerations

13.1. Disposal methods

Waste disposal recommendations : Dispose in a safe manner in accordance with local/national regulations. Dispose of contents/container to comply with local, state and federal regulations.

Ecology - waste materials : Avoid release to the environment.

SECTION 14: Transport information

Department of Transportation (DOT)

In accordance with DOT

Transport document description : UN2031 Nitric acid other than (red fuming, with not more than 20 percent nitric acid), 8, II

UN-No.(DOT) : UN2031

Proper Shipping Name (DOT) : Nitric acid other than
red fuming, with not more than 20 percent nitric acid

Transport hazard class(es) (DOT) : 8 - Class 8 - Corrosive material 49 CFR 173.136

Packing group (DOT) : II - Medium Danger

Hazard labels (DOT) : 8 - Corrosive



DOT Packaging Non Bulk (49 CFR 173.xxx) : 158

DOT Packaging Bulk (49 CFR 173.xxx) : 242

DOT Special Provisions (49 CFR 172.102) : A6 - For combination packaging, if plastic inner packaging are used, they must be packed in tightly closed metal receptacles before packing in outer packaging.
B2 - MC 300, MC 301, MC 302, MC 303, MC 305, and MC 306 and DOT 406 cargo tanks are not authorized.
B47 - Each tank may have a reclosing pressure relief device having a start-to-discharge pressure setting of 310 kPa (45 psig).
B53 - Packaging must be made of either aluminum or steel.
IB2 - Authorized IBCs: Metal (31A, 31B and 31N); Rigid plastics (31H1 and 31H2); Composite (31HZ1). Additional Requirement: Only liquids with a vapor pressure less than or equal to 110 kPa at 50 C (1.1 bar at 122 F), or 130 kPa at 55 C (1.3 bar at 131 F) are authorized.
T8 - 4 178.274(d)(2) Normal..... Prohibited
TP2 - a. The maximum degree of filling must not exceed the degree of filling determined by the following: (image) Where: tr is the maximum mean bulk temperature during transport, tf is the temperature in degrees celsius of the liquid during filling, and a is the mean coefficient of cubical expansion of the liquid between the mean temperature of the liquid during filling (tf) and the maximum mean bulk temperature during transportation (tr) both in degrees celsius. b. For liquids transported under ambient conditions may be calculated using the formula: (image) Where: d15 and d50 are the densities (in units of mass per unit volume) of the liquid at 15 C (59 F) and 50 C (122 F), respectively.
TP12 - This material is considered highly corrosive to steel.

DOT Packaging Exceptions (49 CFR 173.xxx)	:	None
DOT Quantity Limitations Passenger aircraft/rail (49 CFR 173.27)	:	1 L
DOT Quantity Limitations Cargo aircraft only (49 CFR 175.75)	:	30 L
DOT Vessel Stowage Location	:	D - The material must be stowed ‘‘on deck only’’ on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overall vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded.
Other information	:	No supplementary information available.

SECTION 15: Regulatory information

15.1. US Federal regulations

Nitric Acid, 1.0N (1.0M)	
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard

All components of this product are listed, or excluded from listing, on the United States Environmental Protection Agency Toxic Substances Control Act (TSCA) inventory

Chemical(s) subject to the reporting requirements of Section 313 or Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR Part 372.

Nitric Acid, 70% w/w	CAS-No. 7697-37-2	6.1%

Nitric Acid, 70% w/w (7697-37-2)	
RQ (Reportable quantity, section 304 of EPA's List of Lists)	1000 lb
SARA Section 302 Threshold Planning Quantity (TPQ)	1000 lb
SARA Section 311/312 Hazard Classes	Immediate (acute) health hazard

15.2. International regulations

CANADA

No additional information available

EU-Regulations

No additional information available

National regulations

No additional information available

15.3. US State regulations

California Proposition 65 - This product does not contain any substances known to the state of California to cause cancer, developmental and/or reproductive harm

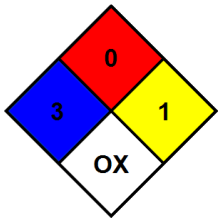
SECTION 16: Other information

Revision date	:	01/10/2018
Other information	:	None.

Full text of H-phrases: see section 16:

H272	May intensify fire; oxidizer
H290	May be corrosive to metals
H314	Causes severe skin burns and eye damage
H318	Causes serious eye damage

NFPA health hazard	:	3 - Materials that, under emergency conditions, can cause serious or permanent injury.
NFPA fire hazard	:	0 - Materials that will not burn under typical dire conditions, including intrinsically noncombustible materials such as concrete, stone, and sand.
NFPA reactivity	:	1 - Materials that in themselves are normally stable but can become unstable at elevated temperatures and pressures.
NFPA specific hazard	:	OX - Materials that posses oxidizing properties.



Hazard Rating

Health	:	3 Serious Hazard - Major injury likely unless prompt action is taken and medical treatment is given
Flammability	:	0 Minimal Hazard - Materials that will not burn
Physical	:	1 Slight Hazard - Materials that are normally stable but can become unstable (self-react) at high temperatures and pressures. Materials may react non-violently with water or undergo hazardous polymerization in the absence of inhibitors.
Personal protection	:	H H - Splash goggles, Gloves, Synthetic apron, Vapor respirator

SDS US LabChem

Information in this SDS is from available published sources and is believed to be accurate. No warranty, express or implied, is made and LabChem Inc assumes no liability resulting from the use of this SDS. The user must determine suitability of this information for his application.

Honeywell

SAFETY DATA SHEET

1. Identification

Product identifier **Eyesaline Eyewash or Sterile Eyesaline**

Other means of identification

Product code 32-ST1050, 32-ST2050, 32-000440, 32-000445, 32-000451, 32-000452, 32-000454, 32-000455, 32-000456, 32-000457, 32-000460, 32-000461, 32-000462, 32-000465, 32-000494, 32-000497, 32-000498

Recommended use Emergency eyewash.

Recommended restrictions None known.

Manufacturer/Importer/Supplier/Distributor information

Company name: Honeywell Safety Products USA, Inc

Address: 825 East Highway 151
Platteville, WI 53818 USA

Telephone: 1-800-873-5242

Contact Person hsptechsupport@honeywell.com

E-mail: msds@chemtrec.com

Emergency phone number: +1-703-741-5500 for USA/Canada

2. Hazard(s) identification

Physical hazards Not classified.

Health hazards Not classified.

OSHA defined hazards Not classified.

Label elements

Hazard symbol None.

Signal word None.

Hazard statement The mixture does not meet the criteria for classification.

Precautionary statement

Prevention Observe good industrial hygiene practices.

Response Wash hands after handling.

Storage Store away from incompatible materials.

Disposal Dispose of waste and residues in accordance with local authority requirements.

Hazard(s) not otherwise classified (HNOC) None known.

Supplemental information

None.

3. Composition/information on ingredients

Mixtures

The manufacturer lists no ingredients as hazardous according to OSHA 29 CFR 1910.1200.

4. First-aid measures

Inhalation If symptomatic, move to fresh air. Get medical attention if symptoms persist.

Skin contact Wash skin with soap and water. Get medical attention promptly if symptoms occur after washing.

Eye contact Remove contact lenses. Get medical attention promptly if symptoms occur after flushing.

Ingestion Seek medical advice.

Most important symptoms/effects, acute and delayed No specific symptoms noted.

Indication of immediate medical attention and special treatment needed	Treat symptomatically.
General information	In the case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).

5. Fire-fighting measures

Suitable extinguishing media	Water. Water fog. Foam. Dry chemical powder. Carbon dioxide (CO2).
Unsuitable extinguishing media	No restrictions known.
Specific hazards arising from the chemical	None.
Special protective equipment and precautions for firefighters	Self-contained breathing apparatus and full protective clothing must be worn in case of fire.
Fire fighting equipment/instructions	None.
General fire hazards	No unusual fire or explosion hazards noted.

6. Accidental release measures

Personal precautions, protective equipment and emergency procedures	For industrial use, wear appropriate personal protective equipment (See Section 8).
Methods and materials for containment and cleaning up	Stop leak if you can do so safely. Absorb spill with appropriate sand, clay or other inert sorbent material, then place in appropriate waste container. Large Spills: Flush area with water. Treat runoff per applicable environmental regulations pertaining to drains, water courses and ground water, diking if required.
Environmental precautions	Treat discharge into drains, water courses or onto the ground according to applicable regulations.

7. Handling and storage

Precautions for safe handling	Observe good industrial hygiene practices. Avoid inhalation of vapors and contact with skin and eyes.
Conditions for safe storage, including any incompatibilities	Keep container closed. Store away from incompatible materials. Do not allow material to freeze. Keep at temperature not exceeding 43°C / 110°F.

8. Exposure controls/personal protection

Occupational exposure limits	No exposure limits noted for ingredient(s).
Biological limit values	No biological exposure limits noted for the ingredient(s).
Exposure guidelines	No exposure standards allocated.
Appropriate engineering controls	Not required.

Individual protection measures, such as personal protective equipment

Eye/face protection	None under normal conditions.
Skin protection	
Hand protection	Chemical resistant gloves are recommended.
Other	None under normal working conditions.
Respiratory protection	Not normally needed.
Thermal hazards	Wear appropriate thermal protective clothing, when necessary.
General hygiene considerations	Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking.

9. Physical and chemical properties

Appearance	Colorless liquid.
Physical state	Liquid.
Form	Liquid.
Color	Colorless.
Odor	No discernable odor.
Odor threshold	Not available.

pH	6.9 - 7.4
Melting point/freezing point	Not available.
Initial boiling point and boiling range	200 °F (93.33 °C)
Flash point	Not available.
Evaporation rate	Not available.
Flammability (solid, gas)	Not available.
Upper/lower flammability or explosive limits	
Flammability limit - lower (%)	Not available.
Flammability limit - upper (%)	Not available.
Explosive limit - lower (%)	Not available.
Explosive limit - upper (%)	Not available.
Vapor pressure	760 mm Hg
Vapor density	Not available.
Relative density	1
Solubility(ies)	
Solubility (water)	Completely soluble in water.
Partition coefficient (n-octanol/water)	Not available.
Auto-ignition temperature	Not available.
Decomposition temperature	Not available.
Viscosity	Not available.

10. Stability and reactivity

Reactivity	Stable at normal conditions.
Chemical stability	Material is stable under normal conditions.
Possibility of hazardous reactions	Hazardous polymerization does not occur.
Conditions to avoid	Contact with incompatible materials. Freezing. Elevated temperatures.
Incompatible materials	None.
Hazardous decomposition products	No hazardous decomposition products are known.

11. Toxicological information

Information on likely routes of exposure

Inhalation	Under normal conditions of intended use, this material is not expected to be an inhalation hazard.
Skin contact	Prolonged or repeated contact may dry skin and cause irritation.
Eye contact	May cause temporary eye irritation.
Ingestion	No harmful effects expected in amounts likely to be ingested by accident.
Symptoms related to the physical, chemical and toxicological characteristics	May cause discomfort if swallowed.

Information on toxicological effects

Acute toxicity	No adverse effects due to eye or skin contact are expected.
Skin corrosion/irritation	Not classified.
Serious eye damage/eye irritation	Not classified.
Respiratory or skin sensitization	
Respiratory sensitization	Not classified.
Skin sensitization	Not a skin sensitizer.
Germ cell mutagenicity	Not classified.

Carcinogenicity Not classified.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not listed.

Reproductive toxicity Not classified.

Specific target organ toxicity - single exposure Not classified.

Specific target organ toxicity - repeated exposure Not classified.

Aspiration hazard Not classified.

Chronic effects Not classified.

12. Ecological information

Ecotoxicity The product is not classified as environmentally hazardous. However, this does not exclude the possibility that large or frequent spills can have a harmful or damaging effect on the environment.

Persistence and degradability No data available.

Bioaccumulative potential The product is not expected to bioaccumulate.

Mobility in soil The product is completely soluble in water.

Other adverse effects No other adverse environmental effects (e.g. ozone depletion, photochemical ozone creation potential, endocrine disruption, global warming potential) are expected from this component.

13. Disposal considerations

Disposal instructions Dispose in accordance with all applicable regulations. Do not allow runoff to sewer, waterway or ground.

Hazardous waste code Waste codes should be assigned by the user based on the application for which the product was used.

Waste from residues / unused products Dispose of in accordance with local regulations.

Contaminated packaging Since emptied containers may retain product residue, follow label warnings even after container is emptied.

14. Transport information

DOT

Not regulated as dangerous goods.

IATA

Not regulated as dangerous goods.

IMDG

Not regulated as dangerous goods.

Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code Not applicable.

15. Regulatory information

US federal regulations This product is not hazardous according to OSHA 29CFR 1910.1200.
One or more components are not listed on TSCA.

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

Not regulated.

OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050)

Not listed.

CERCLA Hazardous Substance List (40 CFR 302.4)

Not listed.

Superfund Amendments and Reauthorization Act of 1986 (SARA)

Hazard categories Immediate Hazard - No
Delayed Hazard - No
Fire Hazard - No
Pressure Hazard - No
Reactivity Hazard - No

SARA 302 Extremely hazardous substance

Not listed.

SARA 311/312 Hazardous chemical No

SARA 313 (TRI reporting)

Not regulated.

Other federal regulations

Clean Air Act (CAA) Section 112 Hazardous Air Pollutants (HAPs) List

Not regulated.

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130)

Not regulated.

Safe Drinking Water Act (SDWA) Not regulated.

US state regulations This product does not contain a chemical known to the State of California to cause cancer, birth defects or other reproductive harm.

US. Massachusetts RTK - Substance List

Not regulated.

US. New Jersey Worker and Community Right-to-Know Act

Not listed.

US. Pennsylvania Worker and Community Right-to-Know Law

Not listed.

US. Rhode Island RTK

Not regulated.

US. California Proposition 65

Not Listed.

International Inventories

Country(s) or region	Inventory name	On inventory (yes/no)*
Australia	Australian Inventory of Chemical Substances (AICS)	Yes
Canada	Domestic Substances List (DSL)	No
Canada	Non-Domestic Substances List (NDSL)	Yes
China	Inventory of Existing Chemical Substances in China (IECSC)	Yes
Europe	European Inventory of Existing Commercial Chemical Substances (EINECS)	Yes
Europe	European List of Notified Chemical Substances (ELINCS)	No
Japan	Inventory of Existing and New Chemical Substances (ENCS)	Yes
Korea	Existing Chemicals List (ECL)	Yes
New Zealand	New Zealand Inventory	Yes
Philippines	Philippine Inventory of Chemicals and Chemical Substances (PICCS)	Yes
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates this product complies with the inventory requirements administered by the governing country(s).
A "No" indicates that one or more components of the product are not listed or exempt from listing on the inventory administered by the governing country(s).

16. Other information, including date of preparation or last revision

Issue date 02-July-2015

Revision date -

Version # 01

Further information The classification for health and environmental hazards is derived by a combination of calculation methods and test data, if available.

NFPA ratings



List of abbreviations

References

ACGIH
EPA: Acquire database
NLM: Hazardous Substances Data Base
US. IARC Monographs on Occupational Exposures to Chemical Agents
National Toxicology Program (NTP) Report on Carcinogens
ACGIH Documentation of the Threshold Limit Values and Biological Exposure Indices
ESIS (European chemical Substances Information System)
HSDB® - Hazardous Substances Data Bank
IARC Monographs. Overall Evaluation of Carcinogenicity

Disclaimer

This information is provided without warranty. The information is believed to be correct. This information should be used to make an independent determination of the methods to safeguard workers and the environment.

MSDS Number: **H3880** * * * * * *Effective Date:* ***01/19/06*** * * * * * *Supercedes:* ***09/24/04***

MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

HYDROCHLORIC ACID, 33 - 40%

1. Product Identification

Synonyms: Muriatic acid; hydrogen chloride, aqueous
CAS No.: 7647-01-0
Molecular Weight: 36.46
Chemical Formula: HCl
Product Codes:
J.T. Baker: 5367, 5537, 5575, 5800, 5814, 5821, 5839, 5861, 5862, 5894, 5962, 5963, 5972, 5994, 6900, 7831, 9529, 9530, 9534, 9535, 9536, 9538, 9539, 9540, 9544, 9548
Mallinckrodt: 2062, 2515, 2612, 2624, 2626, 3861, 5583, 5587, H611, H613, H987, H992, H999, V078, V628

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Hydrogen Chloride	7647-01-0	33 - 40%	Yes
Water	7732-18-5	60 - 67%	No

3. Hazards Identification

Emergency Overview

POISON! DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. INHALATION MAY CAUSE LUNG DAMAGE.

SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 3 - Severe (Poison)
Flammability Rating: 0 - None
Reactivity Rating: 2 - Moderate
Contact Rating: 4 - Extreme (Corrosive)
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Inhalation:
Corrosive! Inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory failure, and death.
Ingestion:
Corrosive! Swallowing hydrochloric acid can cause immediate pain and burns of the mouth, throat, esophagus and gastrointestinal tract. May cause nausea, vomiting, and diarrhea. Swallowing may be fatal.
Skin Contact:
Corrosive! Can cause redness, pain, and severe skin burns. Concentrated solutions cause deep ulcers and discolor skin.
Eye Contact:
Corrosive! Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.
Chronic Exposure:
Long-term exposure to concentrated vapors may cause erosion of teeth. Long term exposures seldom occur due to the corrosive properties of the acid.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders or eye disease may be more susceptible to the effects of this substance.

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4. First Aid Measures

Inhalation:
Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.
Ingestion:
DO NOT INDUCE VOMITING! Give large quantities of water or milk if available. Never

give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.
Eye Contact:
Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.

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5. Fire Fighting Measures

Fire:
Extreme heat or contact with metals can release flammable hydrogen gas.
Explosion:
Not considered to be an explosion hazard.
Fire Extinguishing Media:
If involved in a fire, use water spray. Neutralize with soda ash or slaked lime.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Structural firefighter's protective clothing is ineffective for fires involving hydrochloric acid. Stay away from ends of tanks. Cool tanks with water spray until well after fire is out.

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6. Accidental Release Measures

Ventilate area of leak or spill. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Neutralize with alkaline material (soda ash, lime), then absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker NEUTRASORB® acid neutralizers are recommended for spills of this product.

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7. Handling and Storage

Store in a cool, dry, ventilated storage area with acid resistant floors and good drainage. Protect from physical damage. Keep out of direct sunlight and away from heat, water, and incompatible materials. Do not wash out container and use it for other purposes. When

diluting, the acid should always be added slowly to water and in small amounts. Never use hot water and never add water to the acid. Water added to acid can cause uncontrolled boiling and splashing. When opening metal containers, use non-sparking tools because of the possibility of hydrogen gas being present. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

---

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
For Hydrochloric acid:
- OSHA Permissible Exposure Limit (PEL):
5 ppm (Ceiling)
- ACGIH Threshold Limit Value (TLV):
2 ppm (Ceiling), A4 Not classifiable as a human carcinogen
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, a full facepiece respirator with an acid gas cartridge may be worn up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres.
Skin Protection:
Rubber or neoprene gloves and additional protection including impervious boots, apron, or coveralls, as needed in areas of unusual exposure to prevent skin contact.
Eye Protection:
Use chemical safety goggles and/or a full face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.

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9. Physical and Chemical Properties

Appearance:
Colorless, fuming liquid.
Odor:
Pungent odor of hydrogen chloride.
Solubility:
Infinite in water with slight evolution of heat.
Density:
1.18
pH:

For HCL solutions: 0.1 (1.0 N), 1.1 (0.1 N), 2.02 (0.01 N)
% Volatiles by volume @ 21C (70F):
100
Boiling Point:
53C (127F) Azeotrope (20.2%) boils at 109C (228F)
Melting Point:
-74C (-101F)
Vapor Density (Air=1):
No information found.
Vapor Pressure (mm Hg):
190 @ 25C (77F)
Evaporation Rate (BuAc=1):
No information found.

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10. Stability and Reactivity

Stability:
Stable under ordinary conditions of use and storage. Containers may burst when heated.
Hazardous Decomposition Products:
When heated to decomposition, emits toxic hydrogen chloride fumes and will react with water or steam to produce heat and toxic and corrosive fumes. Thermal oxidative decomposition produces toxic chlorine fumes and explosive hydrogen gas.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
A strong mineral acid, concentrated hydrochloric acid is incompatible with many substances and highly reactive with strong bases, metals, metal oxides, hydroxides, amines, carbonates and other alkaline materials. Incompatible with materials such as cyanides, sulfides, sulfites, and formaldehyde.
Conditions to Avoid:
Heat, direct sunlight.

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11. Toxicological Information

Inhalation rat LC50: 3124 ppm/1H; oral rabbit LD50: 900 mg/kg (Hydrochloric acid concentrated); investigated as a tumorigen, mutagen, reproductive effector.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Hydrogen Chloride (7647-01-0)	No	No	3
Water (7732-18-5)	No	No	None

---

12. Ecological Information

Environmental Fate:
When released into the soil, this material is not expected to biodegrade. When released into the soil, this material may leach into groundwater.
Environmental Toxicity:
This material is expected to be toxic to aquatic life.

---

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

---

14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: HYDROCHLORIC ACID
Hazard Class: 8
UN/NA: UN1789
Packing Group: II
Information reported for product/size: 475LB

International (Water, I.M.O.)

Proper Shipping Name: HYDROCHLORIC ACID
Hazard Class: 8
UN/NA: UN1789
Packing Group: II
Information reported for product/size: 475LB

---

15. Regulatory Information

Risk and Safety Phrases:
Symbol: C
Risk: 34-37
Safety: (1/2-)26-45

```
--------\Chemical Inventory Status - Part 1\---------------------------------
Ingredient                                        TSCA  EC   Japan  Australia
```

Hydrogen Chloride (7647-01-0)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\--------

Ingredient	Korea	--Canada-- DSL	NDSL	Phil.
Hydrogen Chloride (7647-01-0)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Hydrogen Chloride (7647-01-0)	5000	500*	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Hydrogen Chloride (7647-01-0)	5000	No	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: No TSCA 12(b): No CDTA: Yes
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: No (Mixture / Liquid)

Australian Hazchem Code: 2R
Poison Schedule: None allocated.
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

---

16. Other Information

NFPA Ratings: Health: **3** Flammability: **0** Reactivity: **1**
Label Hazard Warning:
POISON! DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. INHALATION MAY CAUSE LUNG DAMAGE.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor or mist.
Use only with adequate ventilation.
Wash thoroughly after handling.
Store in a tightly closed container.
Remove and wash contaminated clothing promptly.
Label First Aid:

In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. In all cases get medical attention immediately.

Product Use:

Laboratory Reagent.

Revision Information:

MSDS Section(s) changed since last revision of document include: 16.

Disclaimer:

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Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

Material Safety Data Sheet

Isobutylene

Section 1. Chemical product and company identification

Product Name : Isobutylene

Supplier : AIRGAS INC., on behalf of its subsidiaries
259 North Radnor-Chester Road
Suite 100
Radnor, PA 19087-5283
1-610-687-5253

Product use : Synthetic/Analytical chemistry.

MSDS# : 001031

Date of Preparation/Revision : **4/3/2007.**

In case of emergency : 1-866-734-3438

Section 2. Hazards identification

Physical state : Gas. (COLORLESS LIQUEFIED COMPRESSED GAS WITH A SWEET GASOLINE-LIKE ODOR)

Emergency overview : Warning!

FLAMMABLE GAS.
CONTENTS UNDER PRESSURE.
VAPOR MAY CAUSE FLASH FIRE.

Keep away from heat, sparks and flame. Do not puncture or incinerate container. Keep container closed. Use only with adequate ventilation.

Contact with rapidly expanding gases can cause frostbite.

Routes of entry : Inhalation

Potential acute health effects

Eyes : No known significant effects or critical hazards.

Skin : No known significant effects or critical hazards.

Inhalation : Acts as a simple asphyxiant.

Ingestion : Ingestion is not a normal route of exposure for gases

Potential chronic health effects : **CARCINOGENIC EFFECTS** Not available.
MUTAGENIC EFFECTS Not available.
TERATOGENIC EFFECTS Not available.

Medical conditions aggravated by overexposure : Acute or chronic respiratory conditions may be aggravated by overexposure to this gas.

See toxicological Information (section 11)

Section 3. Composition, Information on Ingredients

Name	CAS number	% Volume	Exposure limits
Isobutylene	115-11-7	100	**Del Lietuvos Higienos Normos (Lithuania, 12/2001).** TWA: 100 mg/m^3 8 hour(s). Form: All forms

Section 4. First aid measures

No action shall be taken involving any personal risk or without suitable training.If fumes are still suspected to be present, the rescuer should wear an appropriate mask or a self-contained breathing apparatus.It may be dangerous to the person providing aid to give mouth-to-mouth resuscitation.

Eye contact : In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention if irritation occurs.

Skin contact : In case of contact, immediately flush skin with plenty of water. Remove contaminated clothing and shoes. Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention.

Frostbite : Try to warm up the frozen tissues and seek medical attention.

Inhalation : If inhaled, remove to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. Get medical attention.

Ingestion : Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention if symptoms appear.

Section 5. Fire fighting measures

Flammability of the product : Flammable.

Auto-ignition temperature : 465°C (869°F)

Flammable limits : Lower: 1.8% Upper: 9.6%

Products of combustion : These products are carbon oxides (CO, CO_2).

Fire hazards in presence of various substances : Extremely flammable in presence of open flames, sparks and static discharge, of oxidizing materials.

Fire fighting media and instructions : In case of fire, use water spray (fog), foam, dry chemicals, or CO_2.

If involved in fire, shut off flow immediately if it can be done without risk. Apply water from a safe distance to cool container and protect surrounding area.

Extremely flammable. Gas may accumulate in confined areas, travel considerable distance to source of ignition and flash back causing fire or explosion.

Special protective equipment for fire-fighters : Fire fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full facepiece operated in positive pressure mode.

Section 6. Accidental release measures

Personal precautions : Immediately contact emergency personnel. Keep unnecessary personnel away. Use suitable protective equipment (Section 8). Shut off gas supply if this can be done safely. Isolate area until gas has dispersed.

Environmental precautions : Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers.

Section 7. Handling and storage

Handling : Keep container closed. Use only with adequate ventilation. Keep away from heat, sparks and flame. To avoid fire, minimize ignition sources. Use explosion-proof electrical (ventilating, lighting and material handling) equipment. Do not puncture or incinerate container. High pressure gas. Use equipment rated for cylinder pressure. Close valve after each use and when empty. Protect cylinders from physical damage; do not drag, roll, slide, or drop. Use a suitable hand truck for cylinder movement.

Storage : Keep container tightly closed. Keep container in a cool, well-ventilated area. Cylinders should be stored upright, with valve protection cap in place, and firmly secured to prevent falling or being knocked over. Cylinder temperatures should not exceed 52 °C (125 °F).

Section 8. Exposure Controls, Personal Protection

Engineering controls : Use only with adequate ventilation. Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. The engineering controls also need to keep gas, vapor or dust concentrations below any explosive limits. Use explosion-proof ventilation equipment.

Personal protection

Eyes : Safety eyewear complying with an approved standard should be used when a risk assessment indicates this is necessary to avoid exposure to liquid splashes, mists or dusts.

Skin : Personal protective equipment for the body should be selected based on the task being performed and the risks involved and should be approved by a specialist before handling this product.

Respiratory : Use a properly fitted, air-purifying or air-fed respirator complying with an approved standard if a risk assessment indicates this is necessary.Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator.

The applicable standards are (US) 29 CFR 1910.134 and (Canada) Z94.4-93

Hands : Chemical-resistant, impervious gloves or gauntlets complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary.

Personal protection in case of a large spill : A self-contained breathing apparatus should be used to avoid inhalation of the product.

Consult local authorities for acceptable exposure limits.

Section 9. Physical and chemical properties

Molecular weight : 56.12 g/mole

Molecular formula : C4-H8

Boiling/condensation point : -6.89°C (19.6°F)

Melting/freezing point : -139.99°C (-220°F)

Critical temperature : 144.8°C (292.6°F)

Vapor pressure : 24.3 psig

Vapor density : 1.9 (Air = 1)

Specific Volume (ft^3/lb) : 6.68449

Gas Density (lb/ft^3) : 0.1496

Section 10. Stability and reactivity

Stability and reactivity : The product is stable.

Incompatibility with various substances : Extremely reactive or incompatible with oxidizing agents.

Section 11. Toxicological information

Other toxic effects on humans : No specific information is available in our database regarding the other toxic effects of this material for humans.

Specific effects

Carcinogenic effects : No known significant effects or critical hazards.

Mutagenic effects : No known significant effects or critical hazards.

Reproduction toxicity : No known significant effects or critical hazards.

Section 12. Ecological information

Products of degradation : These products are carbon oxides (CO, CO_2) and water.

Toxicity of the products of biodegradation : The product itself and its products of degradation are not toxic.

Environmental fate : Not available.

Environmental hazards : No known significant effects or critical hazards.

Toxicity to the environment : Not available.

Section 13. Disposal considerations

Product removed from the cylinder must be disposed of in accordance with appropriate Federal, State, local regulation.Return cylinders with residual product to Airgas, Inc.Do not dispose of locally.

Section 14. Transport information

Regulatory information	UN number	Proper shipping name	Class	Packing group	Label	Additional information
DOT Classification	UN1055	ISOBUTYLENE SEE ALSO PETROLEUM GASES, LIQUEFIED	2.1	Not applicable (gas).		**Limited quantity** Yes. **Packaging instruction** **Passenger Aircraft** Quantity limitation: Forbidden. **Cargo Aircraft** Quantity limitation: 150 kg **Special provisions** 19, T50
TDG Classification	UN1055	ISOBUTYLENE	2.1	Not applicable (gas).		**Explosive Limit and Limited Quantity Index** 0.125 **ERAP Index** 3000 **Passenger Carrying Ship Index** Forbidden **Passenger Carrying Road or Rail Index** Forbidden **Special provisions** 29
Mexico Classification	UN1055	ISOBUTYLENE SEE ALSO PETROLEUM GASES, LIQUEFIED	2.1	Not applicable (gas).		-

Section 15. Regulatory information

United States

U.S. Federal regulations : TSCA 8(b) inventory: 2-Methylpropene(Isobutylene)

SARA 302/304/311/312 extremely hazardous substances: No products were found.
SARA 302/304 emergency planning and notification: No products were found.
SARA 302/304/311/312 hazardous chemicals: 2-Methylpropene(Isobutylene)
SARA 311/312 MSDS distribution - chemical inventory - hazard identification: 2-Methylpropene(Isobutylene): Fire hazard, Sudden Release of Pressure

Clean Water Act (CWA) 307: No products were found.

Clean Water Act (CWA) 311: No products were found.

Clean air act (CAA) 112 accidental release prevention: 2-Methylpropene(Isobutylene)

Clean air act (CAA) 112 regulated flammable substances: 2-Methylpropene(Isobutylene)

Clean air act (CAA) 112 regulated toxic substances: No products were found.

State regulations : Pennsylvania RTK: 2-Methylpropene(Isobutylene): (generic environmental hazard)
Massachusetts RTK: 2-Methylpropene(Isobutylene)
New Jersey: 2-Methylpropene(Isobutylene)

Canada

WHMIS (Canada) : Class A: Compressed gas.
Class B-1: Flammable gas.

CEPA DSL: 2-Methylpropene(Isobutylene)

Section 16. Other information

United States

Label Requirements : FLAMMABLE GAS.
CONTENTS UNDER PRESSURE.
VAPOR MAY CAUSE FLASH FIRE.

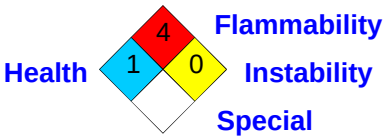
Canada

Label Requirements : Class A: Compressed gas.
Class B-1: Flammable gas.

Hazardous Material Information System (U.S.A.) :



National Fire Protection Association (U.S.A.) :



Notice to reader

To the best of our knowledge, the information contained herein is accurate. However, neither the above named supplier nor any of its subsidiaries assumes any liability whatsoever for the accuracy or completeness of the information contained herein.
Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

LIQUINOX MSDS

Section 1 : MANUFACTURER INFORMATION

Supplier: Same as manufacturer.

Manufacturer: Alconox, Inc.
30 Glenn St.
Suite 309
White Plains, NY 10603.

Manufacturer emergency phone number: 800-255-3924.
813-248-0585 (outside of the United States).

Manufacturer: Alconox, Inc.
30 Glenn St.
Suite 309
White Plains, NY 10603.

Supplier MSDS date: 2005/02/24

D.O.T. Classification: Not regulated.

Section 2 : HAZARDOUS INGREDIENTS

C.A.S.	CONCENTRATION %	Ingredient Name	T.L.V.	LD/50	LC/50
25155-30-0	10-30	SODIUM DODECYLBENZENESULFONATE	NOT AVAILABLE	438 MG/KG RAT ORAL 1330 MG/KG MOUSE ORAL	NOT AVAILABLE

Section 3 : PHYSICAL / CHEMICAL CHARACTERISTICS

Physical state: Liquid.

Appearance & odor: Odourless.
Pale yellow.

Odor threshold (ppm): Not available.

Vapour pressure (mmHg): @ 20°C (68°F).
17

Vapour density (air=1): >1

Volatiles (%)

By volume: Not available.

Evaporation rate (butyl acetate = 1): < 1.

Boiling point (°C):	100 (212F)
Freezing point (°C):	Not available.
pH:	8.5
Specific gravity @ 20 °C:	(water = 1). 1.083
Solubility in water (%):	Complete.
Coefficient of water\oil dist.:	Not available.
VOC:	None

Section 4 : FIRE AND EXPLOSION HAZARD DATA

Flammability:	Not flammable.
Conditions of flammability:	Surrounding fire.
Extinguishing media:	Carbon dioxide, dry chemical, foam. Water Water fog.
Special procedures:	Self-contained breathing apparatus required. Firefighters should wear the usual protective gear. Use water spray to cool fire exposed containers.
Auto-ignition temperature:	Not available.
Flash point (°C), method:	None
Lower flammability limit (% vol):	Not applicable.
Upper flammability limit (% vol):	Not applicable.

Not available.

Sensitivity to mechanical impact:	Not available.
Hazardous combustion products:	Oxides of carbon (COx). Hydrocarbons.
Rate of burning:	Not available.
Explosive power:	Containers may rupture if exposed to heat or fire.

Section 5 : REACTIVITY DATA

Chemical stability:	Product is stable under normal handling and storage conditions.
Conditions of instability:	Extreme temperatures.
Hazardous polymerization:	Will not occur.
Incompatible substances:	Strong acids. Strong oxidizing agents.
Hazardous decomposition products:	See hazardous combustion products.

Section 6 : HEALTH HAZARD DATA

Route of entry:	Skin contact, eye contact, inhalation and ingestion.
Effects of Acute Exposure	
Eye contact:	May cause irritation.
Skin contact:	Prolonged and repeated contact may cause irritation.
Inhalation:	May cause headache and nausea.
Ingestion:	May cause vomiting and diarrhea. May cause gastric distress.
Effects of chronic exposure:	See effects of acute exposure.
LD50 of product, species & route:	> 5000 mg/kg rat oral.
LC50 of product, species & route:	Not available.
Exposure limit of material:	Not available.
Sensitization to product:	Not available.
Carcinogenic effects:	Not listed as a carcinogen.
Reproductive effects:	Not available.
Teratogenicity:	Not available.
Mutagenicity:	Not available.
Synergistic materials:	Not available.
Medical conditions aggravated by exposure:	Not available.
First Aid	
Skin contact:	Remove contaminated clothing. Wash thoroughly with soap and water. Seek medical attention if irritation persists.
Eye contact:	Check for and remove contact lenses. Flush eyes with clear, running water for 15 minutes while holding eyelids open: if irritation persists, consult a physician.
Inhalation:	Remove victim to fresh air. If irritation persists, seek medical attention.
Ingestion:	Do not induce vomiting, seek medical attention. Dilute with two glasses of water. Never give anything by mouth to an unconscious person.

Section 7 : PRECAUTIONS FOR SAFE HANDLING AND USE

Leak / Spill:	Contain the spill. Prevent entry into drains, sewers, and other waterways. Wear appropriate protective equipment. Small amounts may be flushed to sewer with water. Soak up with an absorbent material. Place in appropriate container for disposal. Notify the appropriate authorities as required.
Waste disposal:	In accordance with local and federal regulations.
Handling procedures and equipment:	Protect against physical damage. Avoid breathing vapors/mists. Wear personal protective equipment appropriate to task.

Wash thoroughly after handling.
Keep out of reach of children.
Avoid contact with skin, eyes and clothing.
Avoid extreme temperatures.
Launder contaminated clothing prior to reuse.

Storage requirements: Store away from incompatible materials.
Keep containers closed when not in use.

Section 8 : CONTROL MEASURES

Precautionary Measures

Gloves / Type:



Wear appropriate gloves.

Respiratory / Type: None required under normal use.

Eye / Type:



Safety glasses recommended.

Footwear / Type: Safety shoes per local regulations.

Clothing / Type: As required to prevent skin contact.

Other / Type: Eye wash facility should be in close proximity.
Emergency shower should be in close proximity.

Ventilation requirements: Local exhaust at points of emission.

Safety Data Sheet

SECTION 1: IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Product Name: DURACELL® ALKALINE BATTERIES
Product Identification: Alkaline Manganese Dioxide Cells –
Tradenames: Plus, Ultra, Simply

Product Use: Energy Source
SDS Date of Preparation: November 2, 2009; Updated May 19, 2010

Duracell Designations:

Name/Size	Duracell Designation	Voltage	IEC Designation
Duracell Plus/Simply D	MN1300	1,5	LR20
Duracell Ultra D	MX1300	1,5	LR20
Duracell Plus/Simply C	MN1400	1,5	LR14
Duracell Ultra C	MX1400	1,5	LR14
Duracell Plus/Simply AA	MN1500	1,5	LR6
Duracell Ultra AA	MX1500	1,5	LR6
Duracell Plus/Simply AAA	MN2400	1,5	LR03
Duracell Ultra AAA	MX2400	1,5	LR03
Duracell Plus/Simply 9V	MN1604	9	6LR61
Duracell Ultra 9V	MX1604	9	6LR61
Duracell 4.5V	MN1203	4,5	3LR12
Duracell AAAA	MN2500	1,5	
Duracell MN11	MN11	6	
Duracell MN9100 N	MN9100	1,5	LR1
Duracell 7K67 J	7K67J	6,2	4LR61

Company Identification:

EU Office
Procter & Gamble UK.
The Heights, Brooklands
Weybridge, Surrey
KT13 0XP UK
Telephone: +44-1-93-289-6000

Switzerland Office
Procter& Gamble
Switzerland SARL
Route de Saint-Georges 47
1213 Petit-Lancy, 1, Geneva,
Telephone: +41-58-004-6111

US Office
Duracell, a division of P&G
Berkshire Corporate Park
Bethel, CT 06801 USA
Telephone: 203-796-4000

Emergency Phone Number: INFOTRAC 24-Hour Emergency Response Hotline: 1-352-323-3500 (United States of America)

SECTION 2: HAZARDS IDENTIFICATION

Physical Appearance: Copper top battery.

CAUTION: May explode or leak, and cause burn injury, if recharged, disposed of in fire, mixed with a different battery type, inserted backwards or disassembled. Replace all used batteries at the same time. Do not carry batteries loose in your pocket or purse. Do not remove the battery label.

EU Classification of Preparation: Not classified as a dangerous preparation.

SECTION 3: COMPOSITION/INFORMATION ON INGREDIENTS

Chemical Name	CAS Number	EINECS Number	Amount	Classification
Manganese Dioxide	1313-13-9	215-202-6	35-40 %	Xn, R20/22
Zinc	7440-66-6	231-175-3	10-25 %	N, R50/53
Potassium Hydroxide (35 %)	1310-58-3	215-181-3	5-10 %	C, Xn, R22, R35
Graphite (natural or synthetic)	7782-42-5, 7440-44-0	231-955-3 231-153-3	1-5 %	None

Note: Some Duracell alkaline batteries contain a Duracell Power Check™ battery energy gauge, which is a small conductive strip located underneath the PVC battery label that indicates the amount of charge in the battery. It is composed of minute quantities of conductive materials. Due to the small quantity of materials and their solid form, a health or environmental risk is unlikely.

SECTION 4: FIRST AID MEASURES

General Advice: The chemicals and metals in this product are contained in a sealed can. Exposure to the contents will not occur unless the battery leaks, is exposed to high temperatures or is mechanically, physically, or electrically abused. Damaged battery will release concentrated potassium hydroxide, which is caustic. Anticipated potential leakage of potassium hydroxide is 2 to 20 ml, depending on battery size.

Eye Contact: If battery is leaking and material contacts the eye, flush thoroughly with copious amounts of running water for 30 minutes. Seek immediate medical advice.

Skin Contact: If battery is leaking and material contacts the skin, remove any contaminated clothing and flush exposed skin with copious amounts of running water for at least 15 minutes. If irritation, injury or pain persists, seek medical advice.

Inhaled: If battery is leaking, contents may be irritating to respiratory passages. Move to fresh air. If irritation persists, seek medical advice.

Swallowed: If battery contents are swallowed, do not induce vomiting. If the victim is alert, have them rinse their mouth are the surrounding skin with water for at least 15 minutes. Seek immediate medical attention.

Note: This SDS does not include or address the small button cell batteries which can be ingested.

SECTION 5: FIRE FIGHTING MEASURES

Fire and Explosion Hazards: Batteries may burst and release hazardous decomposition products when exposed to a fire situation.

Extinguishing Media: Use any extinguishing media that is appropriate for the surrounding fire.

Special Fire Fighting Procedures: Firefighters should wear positive pressure self-contained breathing apparatus and full protective clothing. Fight fire from a distance or protected area. Cool fire exposed

batteries to prevent rupture. Use caution when handling fire-exposed containers (containers may rocket or explode in heat of fire).

Hazardous Combustion Products: Thermal degradation may produce hazardous fumes of zinc and manganese; hydrogen gas, caustic vapors of potassium hydroxide and other toxic by-products.

SECTION 6: ACCIDENTAL RELEASE MEASURES

Notify safety personnel of large spills. Caustic potassium hydroxide may be released from leaking or ruptured batteries. Clean-up personnel should wear appropriate protective clothing to avoid eye and skin contact and inhalation of vapors or fumes. Increase ventilation. Carefully collect batteries and place in an appropriate container for disposal.

SECTION 7: HANDLING AND STORAGE

Avoid mechanical or electrical abuse. DO NOT short circuit or install incorrectly. Batteries may explode, pyrolize or vent if disassembled, crushed, recharged or exposed to high temperatures. Install batteries in accordance with equipment instructions. Do not mix battery systems, such as alkaline and zinc carbon, in the same equipment. Replace all batteries in equipment at the same time. Do not carry batteries loose in a pocket or bag. Do not remove battery tester or battery label.

Storage: Store batteries in a dry place at normal room temperature. Do not refrigerate – this will not make them last longer.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

The following occupational exposure limits are provided for informational purposes. No exposure to the battery components should occur during normal consumer use. **Refer to specific country regulations for additional exposure limit information.**

Chemical Name	Exposure Limits
Manganese Dioxide	0,5 mg/m^3 TWA UK WEL 0,5 mg/m^3 TWA (inhalable) DFG MAK 0,2 mg/m^3 VL Belgium 0,2 mg/m^3 TWA Denmark LV
Zinc	None established for zinc metal
Potassium Hydroxide	2 mg/m^3 STEL UK WEL 2 mg/m^3 VCD Belgium 2 mg/m^3 Ceiling Denmark LV
Graphite	4 mg/m^3 TWA UK WEL (respirable dust) 10 mg/m^3 TWA UK WEL (inhalable dust) 1,5 mg/m^3 TWA DFG MAK (respirable dust) 4 mg/m^3 TWA DFG MAK (inhalable dust) 2 mg/m^3 VL Belgium (respirable dust)

Ventilation: No special ventilation is needed for normal use.

Respiratory Protection: None required for normal use.

Skin Protection: None required for normal use. Use neoprene, rubber or latex gloves when handling leaking batteries.

Eye Protection: None required for normal use. Wear safety goggles when handling leaking batteries.

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor: Copper top battery.
Water Solubility: Insoluble

SECTION 10: STABILITY AND REACTIVITY

Stability: This product is stable.

Incompatibility/Conditions to Avoid: Contents are incompatible with strong oxidizing agents. Do not heat, crush, disassemble, short circuit or recharge.

Hazardous Decomposition Products: Thermal decomposition may produce hazardous fumes of zinc and manganese; caustic vapors of potassium hydroxide and other toxic by-products.

Hazardous Polymerization: Will not occur

SECTION 11: TOXICOLOGICAL INFORMATION

Potential Health Effects:

The chemicals and metals in this product are contained in a sealed can. Exposure to the contents will not occur unless the battery leaks, is exposed to high temperatures or is mechanically, physically, or electrically abused. Damaged battery will release concentrated potassium hydroxide, which is caustic. Anticipated potential leakage of potassium hydroxide is 2 to 20 ml, depending on battery size.

Eye Contact: Contact with battery contents may cause severe irritation and burns. Eye damage is possible.

Skin Contact: Contact with battery contents may cause severe irritation and burns.

Inhalation: Inhalation of vapors or fumes released due to heat or a large number of leaking batteries may cause respiratory and eye irritation.

Ingestion: Swallowing is not anticipated due to battery size. Choking may occur if smaller AAA batteries are swallowed. Ingestion of battery contents (from a leaking battery) may cause mouth, throat and intestinal burns and damage.

Acute Toxicity Data:
Manganese Dioxide: LD50 oral rat >3478 mg/kg
Potassium Hydroxide: LD50 oral rat 273 mg/kg

Chronic Effects: The chemicals in this product are contained in a sealed can and exposure does not occur during normal handling and use. No chronic effects would be expected from handling a leaking battery.

Target Organs: Skin, eyes and respiratory system.

Carcinogenicity: None of the components of this product are listed as carcinogens by the EU Directive on the classification and labeling of substances.

SECTION 12: ECOLOGICAL INFORMATION

No ecotoxicity data is available. This product is not expected to present an environmental hazard.

SECTION 13: DISPOSAL INFORMATION

Disposal should be in accordance with national and local regulations. Do not incinerate except for disposal in a controlled incinerator.

Duracell alkaline manganese dioxide batteries are labeled in compliance with EU Battery Directive 2006/66.

SECTION 14: TRANSPORT INFORMATION

Transportation Information – Products covered by this SDS, in their original form, are considered "dry cell" batteries and are not regulated as "DANGEROUS GOODS" for transportation.

For finished packaged product transported by ground (ADR/RID): – not regulated
For finished packaged product transported by sea (IMDG) – not regulated
For finished packaged product transported by air (IATA): – not regulated

SECTION 15: REGULATORY INFORMATION

EU Classification of Preparation: Not classified as a dangerous preparation.

REACH: These products are manufactured articles and not subject to REACH registration requirements.

EU Labeling: None Required
Labeling is not required because batteries are classified as articles under the both REACH and the Dangerous Preparations Directive and as such are exempt from the requirement for labeling.

SECTION 16: OTHER INFORMATION

P&G Hazard Rating: Health: 0 Fire: 0 Reactivity: 0

EU Classes and Risk Phrases for Reference (See Sections 2 and 3)
C Corrosive
N Dangerous for the Environment
Xn Harmful
R20/22 : Harmful by inhalation and if swallowed.
R22 Harmful if swallowed.
R35 Causes severe burns
R50/53 : Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
==========

Data supplied is for use only in connection with occupational safety and health.

DISCLAIMER: This SDS is intended to provide a brief summary of our knowledge and guidance regarding the use of this material. The information contained here has been compiled from sources considered by Procter & Gamble to be dependable and is accurate to the best of the Company's knowledge. It is not meant to be an all-inclusive document on worldwide hazard communication regulations.

This information is offered in good faith. Each user of this material needs to evaluate the conditions of use and design the appropriate protective mechanisms to prevent employee exposures, property damage or release to the environment. Procter & Gamble assumed no responsibility for injury to the recipient or third persons, or for any damage to any property resulting from misuse of the product.

1. IDENTIFICATION

Product Identifier: Diesel Fuel

Synonyms: Diesel Fuel, Motor Vehicle Diesel Fuel, Dyed Diesel, * DieselOne®, * DieselOne® w/Platinum Plus DFX, Low Sulfur Diesel (LSD), Ultra Low Sulfur Diesel (ULSD)

Intended use of the product: Fuel

Contact:
Global Companies LLC
Water Mill Center
800 South St.
Waltham, MA 02454-9161
www.globalp.com

Contact Information: EMERGENCY TELEPHONE NUMBER (24 hrs): CHEMTREC (800) 424-9300
COMPANY CONTACT (business hours): 800-542-0778

2. HAZARD IDENTIFICATION

According to OSHA 29 CFR 1910.1200 HCS

Classification of the Substance or Mixture

Classification (GHS-US):

Flam. Liquid	Category 3	H226
Skin Corrosion/Irritation	Category 2	H315
Aspiration Hazard	Category 1	H304
STOT SE	Category 3	H336
Carcinogenicity	Category 2	H350
Aquatic Chronic	Category 2	H411
Serious Eye Damage/ Irritation	Category 2B	H319

Labeling Elements



Signal Word (GHS-US): **Danger**

Hazard Statements (GHS-US):
H226 – Flammable liquid and vapor.
H315 – Causes Skin irritation.
H304 – May be fatal if swallowed and enters airways.
H336 – May cause drowsiness or dizziness.
H350 – May cause cancer.
H411 – Toxic to aquatic life with long lasting effects.
H319 – May cause eye damage/irritation.

Precautionary Statements (GHS-US):
P210 - Keep away from heat/sparks/open flames/hot surfaces. - No smoking.
P233 - Keep container tightly closed.
P240 – Ground/bond container and receiving equipment.

P241 – Use explosion-proof electrical/ventilating/lighting equipment pursuant to applicable electrical code.
P242 – Use only non-sparking tools.
P243 – Take precautionary measures against static discharge.
P261 – Avoid breathing dust/fume/gas/mist/vapors/spray.
P264 – Wash skin thoroughly after handling.
P271 – Use only outdoors or in a well-ventilated area.
P273 – Avoid release to the environment.
P280 - Wear protective gloves/protective clothing/eye protection/face protection.
P303+361+353 - If on skin (or hair): Take off immediately all contaminated clothing. Rinse with water/shower.
P308+311 - If exposed or concerned: Get medical advice/attention.
P301+310 - If swallowed: Immediately call a poison center/doctor/…
P331 - Do NOT induce vomiting.
P370+P378 – In case of fire use firefighting foam or other appropriate media for Class B fires to extinguish.
P403+235 - Store in a well-ventilated place. Keep cool.
P405 - Store locked up.
P501 – Dispose of contents/container in accordance with local/regional/national/international regulation.

Other information:

NFPA 704
Health: 1
Fire: 2
Reactivity: 0



3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Composition Information
Mixture

Name	Product Identifier (CAS#)	% (w/w)	Classification
Diesel Fuel	68476-34-6	100	Flam Liq. 3, H226; Skin Irrit. 2, H315; Aspiration 1, H304; STOT SE 3, H336; Carc.2. H350; Aquatic chronic 2, H411
Naphthalene	91-20-3	<0.1	Carc. 2, H351; Acute Tox. 4, H302; Aquatic Acute 1, H400; Aquatic Chronic 1, H410

Additional Formulation Information:
Diesel Fuel consists of C9+ hydrocarbons resulting from distillation of crude oil.

Low Sulfur Diesel Fuel typically contains less than 500 ppm of sulfur

Ultra Low Sulfur Diesel Fuel typically contains less than 15 ppm of sulfur

4. FIRST AID MEASURES

Route	Measures
Inhalation	Remove person to fresh air. If person is not breathing, ensure an open airway and provide artificial respiration. If necessary, provide additional oxygen once breathing is restored if trained to do so. Seek medical attention immediately.
Ingestion	Aspiration Hazard: DO NOT INDUCE VOMITING. Do not give liquids. Obtain immediate medical attention. If spontaneous vomiting occurs, lean victim forward to reduce the risk of aspiration. Ingestion may cause gastrointestinal disturbances including irritation, nausea, vomiting, and diarrhea, and central nervous system (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory failure, and death.
Eye Contact	In case of contact with eyes, immediately flush with clean, low-pressure water for at least 15 min. Hold eyelids open to ensure adequate flushing. Seek medical attention. In case of contact lenses, remove immediately.
Skin Contact	Remove contaminated clothing and shoes. Wash contaminated areas thoroughly with soap and water or waterless hand cleanser. Obtain medical attention if irritation or redness develops. Thermal burns require immediate medical attention depending on the severity and of the area of the body burned.

Most Important Symptoms
Contact with eyes and face may cause irritation. Long-term exposure may cause dermatitis (itching, irritation, pain and swelling).

Inhalation may cause irritation and significant or long term exposure could cause respiratory insufficiency and pulmonary edema.

Ingestion may cause aspiration, gastrointestinal disturbance, and CNS effects.

Immediate Medical Attention and Special Treatment
For contact with skin or eyes, immediately wash or flush contaminated eyes with gently flowing water. If possible, irrigate each eye continuously with 0.9% saline (NS). If ingested, rinse mouth. Do NOT induce vomiting, as this may cause chemical pneumonia (fluid in the lungs).

If inhaled, administer oxygen or establish a patent airway if breathing is labored. Suction if necessary. Monitor closely, anticipate seizures. Consider orotracheal or nostracheal intubation of airway control if patient is unconscious or is in severe respiratory distress.

Discard any clothing or shoes contaminated as they may be flammable.

5. FIRE-FIGHTING MEASURES

Extinguishing Media
Foam, carbon dioxide, dry chemical are most suitable

SMALL FIRES: Any extinguisher suitable for Class B fires, dry chemical, C02, water spray, firefighting foam, or Halon. Small fires in the incipient (beginning) stage may typically be extinguished using handheld portable fire extinguishers and other firefighting equipment.

LARGE FIRES: Foam, carbon dioxide, dry chemical. Water may be ineffective for fighting the fire, but may be used to cool fire-exposed containers.

Specific Hazards / Products of Combustion
Moderate fire hazard when exposed to heat or flame with a very low flash point. Product is flammable and easily ignited when exposed to heat, spark, open flame or other source of ignition. Flowing product may be ignited by self-generated static electricity. When mixed with air and exposed to an ignition source, flammable vapors can burn in the open or explode in confined spaces. Being heavier than air, vapors may travel long distances to an ignition source and flash back. Runoff to sewer may cause fire or explosion hazard.

Combustion may produce smoke, carbon monoxide and other products of incomplete combustion.

Special Precautions and Protective Equipment for Firefighters
Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water.

For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied firefighting foam.

Fighting Equipment/Instructions
Firefighting activities that may result in potential exposure to high heat, smoke or toxic by-products of combustion should require NIOSH- approved pressure-demand self-contained breathing apparatus with full face piece and protective clothing.

Refer to Section 9 for fire properties of this chemical including flash point, auto ignition temperature, and explosive limits.

6. ACCIDENTAL RELEASE MEASURES

ACTIVATE FACILITY SPCC, SPILL CONTINGENCY or EMERGENCY PLAN.

Personal Precautions
Due to high vapor density, flammable / toxic vapors may be present in low lying areas, dikes, pits, drains, or trenches. Vapors may accumulate in low lying areas and reach ignitable concentrations. Ventilate the area. Use of non-sparking tools and intrinsically safe equipment is recommended. Potential for flammable atmosphere should be monitored using a combustible gas indicator positioned downwind of the spill area. Refer to Sections 2 and 7 for further hazard warnings and handling instructions.

Use appropriate personal protective equipment to prevent eye/skin contact and absorption. Use NIOSH approved respiratory protection, if warranted, to prevent exposures above permissible limits. Refer to Section 8. Contaminated clothing should not be near sources of ignition.

Emergency Measures
As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions. Consider wind direction. Secure all ignition sources (flame, spark, hot work, hot metal, etc.) from area. Evaluate the direction of product travel, diking sewers, etc. to confirm spill areas. Do not touch or walk-through spilled material. For large spills, isolate initial action distance downwind 1,000 ft. (300 m).

Environmental Precautions
Stop the spill to prevent environmental release if it can be done safely. Product is toxic to aquatic life. Take action to isolate environmental receptors including drains, storm sewers and natural water bodies. Keep on impervious surface if at all possible. Use water sparingly to prevent product from spreading. Foam and absorbents may be used to reduce / prevent airborne release.

Spills may infiltrate subsurface soil and groundwater; professional assistance may be necessary to determine the extent of subsurface impact.

Follow federal, state or local requirements for reporting environmental release where necessary. Refer to Section 15 for further information.

Containment and Clean-Up Methods
Carefully contain and stop the source of the spill, if safe to do so. Protect bodies of water by diking absorbents, or absorbent boom, if possible. Do not flush down sewer or drainage systems, unless system is designed and permitted to handle such material. The use of firefighting foam may be useful in certain situations to reduce vapors. The proper use of water spray may effectively disperse product vapors or the liquid itself, preventing contact with ignition sources or areas/equipment that require protection.

Take up with dry earth, sand or other non-combustible, inert oil absorbing materials. Carefully shovel, scoop or sweep up into a waste container with clean, non-sparking tools for reclamation or disposal. Response and cleanup crews must be properly trained and must utilize proper protective equipment. Refer to Section 8 for appropriate protective equipment.

7. HANDLING AND STORAGE

USE ONLY AS A FUEL.
DO NOT SIPHON BY MOUTH.

Handling Precautions
Handle as a flammable liquid. Keep away from heat, sparks, and open flame. No smoking. Electrical equipment should be approved for classified area. Bond and ground containers during product transfer pursuant to NFPA 70 and API RP 2003 to

reduce the possibility of static-initiated fire or explosion. Follow precautions to prevent static initiated fire.

Use good personal hygiene practices. Use only with protective equipment specified in Section 8. Avoid repeated and/or prolonged skin exposure. Use only outdoors or in well ventilated areas. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves. Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure.

Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil) is loaded into tanks previously containing low flash point products (such as this product) - see API RP 2003, "Protection Against Ignitions Arising Out Of Static, Lightning and Stray Currents."

Storage
Large quantities of diesel fuel are stored in tanks or portable containers at an ambient storage temperature. Separate from incompatible chemicals (Refer to Section 10) by distance or secondary containment. Keep away from flame, sparks, excessive temperatures and open flame. Use approved vented containers that are clearly labeled. Label all secondary containers that this material is transferred into with the chemical name and associated hazard(s). Empty product containers or vessels may contain flammable vapors. Do not pressurize, cut, heat, weld or expose such containers to sources of ignition.

Storage tanks should have a venting system. If stored in small containers, the area should be well ventilated, away from ignition sources and protected from potential damage or vehicular traffic. Post “No Smoking” signs in product storage areas. This storage area should comply with NFPA 30 “Flammable and Combustible Liquid Code” or applicable building code. The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 “Cleaning Mobile Tanks in Flammable and Combustible Liquid Service” and API RP 2015 “Safe Entry and Cleaning of Petroleum Storage Tanks”.

Incompatibles
Keep away from strong oxidizers, ignition sources and heat.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Limits

Component	CAS #	List	Value
Diesel Fuel	68476-34-6	ACGIH TLV-TWA	100 mg/m3*
Naphthalene	91-20-3	ACGIH TLV-TWA OSHA PEL ACGIH STEL	10 ppm 10 ppm 15 ppm

*Critical effects; Skin; A3; CNS impairment.

Engineering Controls
Use adequate ventilation to keep vapor concentrations of this product below occupational exposure and flammability limits, particularly in confined spaces. Intrinsically safe equipment and non-sparking tools shall be used in circumstances where concentrations may exceed lower flammable limits. Grounding and bonding shall be used to prevent accumulation and discharge of static electricity. Emergency shower and eyewash should be provided in proximity to handling areas in the event of exposure to decontaminate.

Personal Protective Equipment

Exposure	Equipment
Eye / Face	Wear appropriate chemical protective glasses or goggles or face shields to prevent skin and eye contact especially caused from splashing.
Skin	Wear appropriate personal protective clothing to prevent skin contact. Gloves constructed of nitrile, neoprene or PVC are recommended when handling this material. Chemical protective clothing such as of E.I. DuPont TyChem®, Saranex® or equivalent recommended based on degree of exposure. Note: The resistance of specific material may vary from product to product as well as with degree of exposure.

Exposure	Equipment
Respiratory	A NIOSH/MSHA-approved air-purifying respirator with organic vapor cartridges or canister may be permissible under certain circumstances where airborne concentrations are or may be expected to exceed exposure limits or for odor or irritation. Protection provided by air-purifying respirators is limited. Refer to OSHA 29 CFR 1910.134, ANSI Z88.2-1992, NIOSH Respirator Decision Logic, and the manufacturer for additional guidance on respiratory protection selection and limitations. Use a positive pressure, air-supplied respirator if there is a potential for uncontrolled release, exposure levels are not known, in oxygen-deficient atmospheres, or any other circumstance where an air-purifying respirator may not provide adequate protection.
Thermal	Product is stored at ambient temperature. No thermal protection is required except for emergency operations involving actual or potential for fire. Use adequate ventilation to keep vapor concentrations of this product below occupational exposure and flammability limits, particularly in confined spaces.

9. PHYSICAL AND CHEMICAL PROPERTIES

Property	Value	
Appearance	Clear or straw-colored liquid. May be dyed red for distribution.	
Odor	Mild characteristic petroleum distillate odor.	
Odor Threshold	<1 ppm	
pH	Not available	
Melting Point	-22 to -0.4 ˚F (-30 to -18 ˚C)	
Boiling Point Range	320 to 690 ˚F (160 to 366 ˚C)	
Flash Point	> 125.6 ˚F (52 ˚C) PMCC	
Evaporation Rate	Slow, varies with conditions	
Flammability	Flammable liquid	
Flammable Limits	0.6 % - 6.5%	
Vapor Pressure	0.009 psia @ 70 ˚F	
Vapor Density	> 1	(air=1)
Specific Gravity	0.83-0.86 @ 60 ˚F (16 ˚C)	(water=1)
Solubility	Insoluble in water; miscible with other petroleum solvents.	
Partition Coefficient (N-octanol/water)	Log Kow range of 3.3 to >.6.0	
Autoignition Temperature	494 ˚F (257 ˚C)	
Decomposition Temperature	When heated it emits acrid smoke and irritating vapors.	
Viscosity	>3 cSt	
Percent Volatiles	100	

10. STABILITY AND REACTIVITY

Stability
This is a stable material that is flammable liquid (OSHA/GHS hazard category 3). Stable during transport.

Reactivity
Material is not self-reacting. Flammable concentrations may be present in air. Compound can react with oxidizing materials.

Possibility of Hazardous Reactions
Hazardous polymerization will not occur.

Incompatibility
Keep away from strong oxidizers such as nitric and sulfuric acids.

Conditions to Avoid
Avoid high temperatures, open flames, sparks, static electricity, welding, smoking and other ignition sources.

Hazardous Decomposition Products
Carbon monoxide, carbon dioxide and non-combusted hydrocarbons (smoke).

11. TOXICOLOGICAL INFORMATION

Acute Toxicity:
Acute Toxicity (Inhalation LC50)
Diesel Fuel (68476-34-6)
LC50 Inhalation Rat >6 mg/l/4h

Acute Toxicity (Dermal LD50)
Diesel Fuel (68476-34-6)
LD50 Dermal Rabbit >5000 mg/kg

Acute Toxicity (Oral LD50)
Diesel Fuel (68476-34-6)
LD50 Oral Rabbit >5000 mg/kg

Skin Corrosion/Irritation: Prolonged and repeated contact may cause skin irritation leading to dermatitis. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are exposed repeatedly.

Serious Eye Damage/Irritation: Causes serious eye irritation.

Respiratory or Skin Sensitization: Not classified

Germ Cell Mutagenicity: Not classified

Teratogenicity: Not available

Carcinogenicity: OSHA: NO, IARC: Group 3, NTP: NO, ACGIH: NOIC:A3, NIOSH: NO

IARC: Group 3 – Not classifiable as to their carcinogenicity to humans

ACGIH: A3 – Confirmed animal carcinogen with unknown relevance to humans.

Studies have shown that similar products produce skin tumors in laboratory animals following repeated applications without washing or removal. The significance of this finding to human exposure has not been determined. Other studies with active skin carcinogens have shown that washing the animal's skin with soap and water between applications reduced tumor formation.

IARC classifies whole diesel fuel exhaust particulates (byproduct of combustion of this material) carcinogenic to humans (Group 1) and NIOSH regards diesel fuel exhaust particulate as a potential occupational carcinogen.

Reproductive Toxicity: Not classified

Specific Target Organ Toxicity (Repeated Exposure): Not classified

Specific Target Organ Toxicity (Single Exposure): Inhalation exposure may cause drowsiness or dizziness by inhalation exposure.

Aspiration Hazard: The major health threat of ingestion occurs from the danger of aspiration (breathing) of liquid drops into the lungs, particularly from vomiting. Aspiration may result in chemical pneumonia (fluid in the lungs), severe lung damage, respiratory failure and even death.

Potential Health Effects: Vapor irritating to skin, eyes, nose, and throat. Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous system (brain) effects similar to alcohol intoxication. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest, and death may occur.

WARNING: The burning of any hydrocarbon as a fuel in an area without adequate ventilation may result in hazardous levels of

combustion products, including carbon monoxide, and inadequate oxygen levels, which may cause unconsciousness, suffocation, and death.

12. ECOLOGICAL INFORMATION

Toxicity:
This material is expected to be toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment.

Data for Component: Diesel Fuel (68476-34-6)

Material is toxic to aquatic organisms based on an acute basis (LC50/EC50 >1 but ≤ 10 mg/L in the most sensitive species tested).

Material is a long-term aquatic hazard based on a chronic basis (LC50/EC50 >1 but ≤ 10 mg/L in the most sensitive species tested).

Persistence and Degradation: This material is not expected to be readily biodegradable.

Bioaccumulative Potential: Not available

Mobility in Soil: Not available

Other Adverse Effects: None known

Other Information: Avoid release to the environment.

13. DISPOSAL CONSIDERATIONS

Consult federal, state and local waste regulations to determine appropriate disposal options. May be considered a hazardous waste if disposed. Direct solid waste (landfill) or incineration at a solid waste facility is not permissible. Do not discharge to sanitary or storm sewer. Personnel handling waste containers should follow precautions provided in this document.

Shipping containers must be DOT authorized packages. Follow licensure and regulations for transport of hazardous material and hazardous waste as applicable.

14. TRANSPORT INFORMATION

US DOT

UN Identification Number	NA 1993 / UN 1202
Proper Shipping Name	Diesel Fuel
Hazard Class and Packing Group	3, PGIII
Shipping Label	Combustible liquid
Placard / Bulk Package	Combustible liquid, 1993
Emergency Response Guidebook Guide Number	128

IATA Information

UN Identification Number	UN 1202
Proper Shipping Name	Combustible-Liquid, N.O.S. (Fuel, Diesel)
Hazard Class and Packing Group	3, PGIII
ICAO Label	3
Packing Instructions Cargo	310
Max Quantity Per Package Cargo	220L
Packing Instructions Passenger	309Y
Max Quantity per Package	60L

ICAO

UN Identification Number	UN 1202
Shipping Name / Description	Combustible-Liquid, N.O.S. (Fuel, Diesel)
Hazard Class and Packing Group	3, PG III
IMDG Label	3

IMDG

UN Identification Number	UN 1202
Shipping Name / Description	Combustible-Liquid, N.O.S. (Fuel, Diesel)
Hazard Class and Packing Group	3, PGIII
IMDG Label	3
EmS Number	F-E-S-E
Marine Pollutant	Yes

15. REGULATORY INFORMATION

U.S. Federal, State, and Local Regulatory Information
Any spill or uncontrolled release of this product, including any substantial threat of release, may be subject to federal, state and/or local reporting requirements. This product and/or its constituents may also be subject to other federal, state, or local regulations; consult those regulations applicable to your facility/operation.

OSHA Hazard Communication Standard
This product is a "Hazardous Chemical" as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

Superfund Amendments and Reauthorization Act of 1986 Title III (Emergency Planning And Community Right-to-Know Act of 1986) Sections 311 and 312

Immediate (Acute) Health Hazard	Yes
Delayed (Chronic) Health Hazard	Yes
Fire Hazard	Yes
Reactive Hazard	No
Sudden Release of Pressure Hazard	No

Clean Water Act (Oil Spills)
Any spill or release of this product to “navigable waters” (Essentially any surface water, including certain wetlands) or adjoining shorelines sufficient to cause a visible sheen or deposit of a sludge or emulsion must be reported immediately to the National Response Center (1-800-424-8802) or, if not practical, the U.S. Coast Guard with follow up to the National Response Center, as required by U.S. Federal Law. Also contact appropriate state and local regulatory agencies as required.

CERCLA Section 103 and SARA Section 304 (Release to the Environment)
The CERCLA definition of hazardous substances contains a “petroleum exclusion” clause which exempts this material. This product does not contain any chemicals subject to the reporting requirements of CERCLA Section 103 or SARA 304.

SARA Section 313- Supplier Notification
This product does not contain any chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act (EPCRA) of 1986 and of 40 CFR 372.

EPA Notification (Oil Spills)
If the there is a discharge of more than 1,000-gallons of oil into or upon navigable waters of the United States, or if it is the second spill event of 42 gallons or more of oil into water within a twelve (12) month period, a written report must be submitted to the Regional Administrator of the EPA within sixty days of the event.

Pennsylvania Right to Know Hazardous Substance list:
The following product components are cited in the Pennsylvania Special Hazardous Substance List, and are present at levels which require reporting.

Component	CAS	Amount
Diesel Fuel	68476-34-6	100%

New Jersey Right to Know Hazardous Substance list:
The following product components are cited in the New Jersey Right to Know Hazardous Substance List, and are present at levels which require reporting.

Component	CAS	Amount
Diesel Fuel	68476-34-6	100%

California Proposition 65 WARNING: This product contains chemicals known to the State of California to cause Cancer or Reproductive Toxicity.

Component	CAS	Amount
Naphthalene	91-20-3	<0.1%

U.S. Toxic Substances Control Act
All components of this product are on the TSCA Inventory or are exempt from TSCA Inventory requirements under 40 CFR 720.30.

CEPA - Domestic Substances List (DSL)
All substances contained in this product are listed on the Canadian Domestic Substances List (DSL) or are not required to be listed.

Canadian Regulatory Information (WHMIS)
Class B3 – Combustible Liquid
Class D2A – Materials causing other toxic effects. (Very Toxic)

16. OTHER INFORMATION

Version	4
Issue Date	May 20, 2016
Prior Issue Date	May 3, 2015

Description of Revisions
Revised to meet Globally Harmonized System for chemical hazard communication requirements pursuant to OSHA regulatory revisions 77 FR 17884, March 26, 2012.

Abbreviations

˚F	Degrees Fahrenheit (temperature)
<	Less than
=	Equal to
>	Greater than
AP	Approximately
C	Centigrade (temperature)
kg	Kilogram
L	Liter
mg	Milligrams
mL	Milliliter
mm^2	Square millimeters
mmHg	Millimeters of mercury (pressure)
N/A	Not applicable
N/D	Not determined
ppm	Parts per million
sec	Second
ug	Micrograms

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
AL	Action Level
ANSI	American National Standards Institute
API	American Petroleum Institute
CAS	Chemical Abstract Service
CERCLA	Comprehensive Emergency Response, Compensation, and Liability Act
DOT	U.S. Department of Transportation
EC50	Ecological concentration 50%
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guideline
GHS	Global Harmonized System
HMIS	Hazardous Materials Information System
IARC	International Agency for Research On Cancer
IATA	International Air Transport Association
IMDG	International Maritime Dangerous Goods
Koc	Soil Organic Carbon
LC50	Lethal concentration 50%
LD50	Lethal dose 50%
MSHA	Mine Safety and Health Administration
NFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NOIC	Notice of Intended Change

NTP	National Toxicology Program
OPA	Oil Pollution Act of 1990
OSHA	U.S. Occupational Safety & Health Administration
PEL	Permissible Exposure Limit (OSHA)
RCRA	Resource Conservation and Recovery Act Reauthorization Act of 1986 Title III
REL	Recommended Exposure Limit (NIOSH)
RVP	Reid Vapor Pressure
SARA	Superfund Amendments and
SCBA	Self Contained Breathing Apparatus
SPCC	Spill Prevention, Control, and Countermeasures
STEL	Short Term Exposure Limit (generally 15 minutes)
TLV	Threshold Limit Value (ACGIH)
TSCA	Toxic Substances Control Act
TWA	Time Weighted Average (8 hr.)
UN	United Nations
UNECE	United Nations Economic Commission for Europe
WEEL	Workplace Environmental Exposure Level (AIHA)
WHMIS	Canadian Workplace Hazardous Materials Information System

Disclaimer of Expressed and Implied Warranties

Information presented herein has been compiled from sources considered to be dependable, and is accurate and reliable to the best of our knowledge and belief, but is not guaranteed to be so. Since conditions of use are beyond our control, we make no warranties, expressed or implied, except those that may be contained in our written contract of sale or acknowledgment.

Vendor assumes no responsibility for injury to vendee or third persons proximately caused by the material if reasonable safety procedures are not adhered to as stipulated in the data sheet. Additionally, vendor assumes no responsibility for injury to vendee or third persons proximately caused by abnormal use of the material, even if reasonable safety procedures are followed. Furthermore, vendee assumes the risk in their use of the material.

** End of Safety Data Sheet **

Section 1: IDENTIFICATION

Product Name: Simple Green® All-Purpose Cleaner
Additional Names:

Manufacturer's Part Number: **Please refer to Section 16*

Recommended Use: Cleaner & Degreaser for water tolerant surfaces.
Restrictions on Use: Do not use on non-rinsable surfaces.

Company: Sunshine Makers, Inc.
15922 Pacific Coast Highway
Huntington Beach, CA 92649 USA
Telephone: 800-228-0709 ● 562-795-6000 *Mon – Fri, 8am – 5pm PST*
Fax: 562-592-3830
Email: info@simplegreen.com
Emergency Phone: Chem-Tel 24-Hour Emergency Service: 800-255-3924

Section 2: HAZARDS IDENTIFICATION

This product has been assessed in accordance to 2012 OSHA Hazard Communication Standards (29 CFR 1910.1200) and has been determined to not be classifiable as hazardous.

OSHA HCS 2012
Label Elements
Signal Word: None **Hazard Symbol(s)/Pictogram(s):** None required

Hazard Statements: None
Precautionary Statements: None
Hazards Not Otherwise Classified (HNOC): None
Other Information: None Known

Section 3: COMPOSITION/INFORMATION ON INGREDIENTS

Ingredient	CAS Number	Percent Range
Water	7732-18-5	> 84.8%*
C9-11 Alcohols Ethoxylated	68439-46-3	< 5%*
Sodium Citrate	68-04-2	< 5%*
Sodium Carbonate	497-19-8	< 1%*
Tetrasodium Glutamate Diacetate	51981-21-6	< 1%*
Citric Acid	77-92-9	< 1%*
Methylchloroisothiazolinone	26172-55-4	< 0.002%*
Methylisothiazolinone	2682-20-4	< 0.001%*
Fragrance	Proprietary Mixture	< 1%*
Liquitint Colorant	Proprietary Mixture	< 1%*

**specific percentages of composition are being withheld as a trade secret*

Section 4: FIRST-AID MEASURES

Inhalation: Not expected to cause respiratory irritation. If adverse effect occurs, move to fresh air.
Skin Contact: Not expected to cause skin irritation. If adverse effect occurs, rinse skin with water.
Eye Contact: Not expected to cause eye irritation. If adverse effect occurs, flush eyes with water.
Ingestion: May cause upset stomach. Drink plenty of water to dilute. See section 11.

Most Important Symptoms/Effects, Acute and Delayed: None known.

Indication of Immediate Medical Attention and Special Treatment Needed, if necessary: Treat symptomatically

Section 5: FIRE-FIGHTING MEASURES

Suitable & Unsuitable Extinguishing Media: Use Dry chemical, CO2, water spray or "alcohol" foam. Avoid high volume jet water.
Specific Hazards Arising from Chemical: In event of fire, fire created carbon oxides may be formed.
Special Protective Actions for Fire-Fighters: Wear positive pressure self-contained breathing apparatus; Wear full protective clothing.

This product is non-flammable. See Section 9 for Physical Properties.

Section 6: ACCIDENTAL RELEASE MEASURES

Personal Precautions, Protective Equipment and Emergency Procedures: *For non-emergency and emergency personnel:* See section 8 – personal protection. Avoid eye contact. Safety goggles suggested.

Environmental Precautions: Do not allow into open waterways and ground water systems.

Methods and Materials for Containment and Clean Up: Dike or soak up with inert absorbent material. See section 13 for disposal considerations.

Section 7: HANDLING AND STORAGE

Precautions for Safe Handling: Ensure adequate ventilation. Keep out of reach of children. Keep away from heat, sparks, open flame and direct sunlight. Do not pierce any part of the container. Do not mix or contaminate with any other chemical. Do not eat, drink or smoke while using this product.

Conditions for Safe Storage including Incompatibilities: Keep container tightly closed. Keep in cool dry area. Avoid prolonged exposure to sunlight. Do not store at temperatures above 109°F (42.7°C). If separation occurs, mix the product for reconstitution.

Section 8: EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Limit Values: No components listed with TWA or STEL values under OSHA or ACGIH.

Appropriate Engineering Controls: Showers, eyewash stations, ventilation systems

Individual Protection Measures / Personal Protective Equipment (PPE)
Eye Contact: Use protective glasses or safety goggles if splashing or spray-back is likely.
Respiratory: Use in well ventilated areas or local exhaust ventilations when cleaning small spaces.
Skin Contact: Use protective gloves (any material) when used for prolonged periods or dermally sensitive.
General Hygiene Considerations: Wash thoroughly after handling and before eating or drinking.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Green Liquid	**Partition Coefficient: n-octanol/water:**	Not determined
Odor:	Added sassafras odor	**Autoignition Temperature:**	Non-flammable
Odor Threshold:	Not determined	**Decomposition Temperature:**	42.7°C (109°F)
pH ASTM D-1293**:**	8.5 – 9.2	**Viscosity:**	Like water
Freezing Point ASTM D-1177**:**	0-3.33°C (32-38°F)	**Specific Gravity** ASTM D-891**:**	1.01 – 1.03
Boiling Point & Range ASTM D-1120**:**	101°C (213.8°F)	**VOCs:**	***Water & fragrance exemption in calculation
Flash Point ASTM D-93**:**	> 212°F	SCAQMD 304-91 / EPA 24:	0 g/L / 0 lb/gal / 0%
Evaporation Rate ASTM D-1901**:**	½ Butyl Acetate @ 25°C	CARB Method 310**:	2.5 g/L / 0.021 lb/gal / 0.25%
Flammability (solid, gas):	Not applicable	SCAQMD Method 313:	Not tested
Upper/Lower Flammability or Explosive Limits:	Not applicable	**VOC Composite Partial Pressure:**	Not determined
Vapor Pressure ASTM D-323**:**	0.60 PSI @77°F, 2.05 PSI @100°F	**Relative Density** ASTM D-4017**:**	8.42 – 8.59 lb/gal
Vapor Density:	Not determined	**Solubility:**	100% in water

Section 10: STABILITY AND REACTIVITY

Reactivity: Non-reactive.
Chemical Stability: Stable under normal conditions 70°F (21°C) and 14.7 psig (760 mmHg).
Possibility of Hazardous Reactions: None known.
Conditions to Avoid: Excessive heat or cold.
Incompatible Materials: Do not mix with oxidizers, acids, bathroom cleaners, or disinfecting agents.
Hazardous Decomposition Products: Normal products of combustion - CO, CO2.

Section 11: TOXICOLOGICAL INFORMATION

Likely Routes of Exposure:
Inhalation - Overexposure may cause headache.
Skin Contact - Not expected to cause irritation, repeated contact may cause dry skin.
Eye Contact - Not expected to cause irritation.
Ingestion - May cause upset stomach.

Symptoms related to the physical, chemical and toxicological characteristics: no symptoms expected under typical use conditions.
Delayed and immediate effects and or chronic effects from short term exposure: no symptoms expected under typical use conditions.
Delayed and immediate effects and or chronic effects from long term exposure: headache, dry skin, or skin irritation may occur.
Interactive effects: Not known.

Numerical Measures of Toxicity

Acute Toxicity:
Oral LD_{50} (rat) > 5 g/kg body weight
Dermal LD_{50} (rabbit) > 5 g/kg body weight
Calculated via OSHA HCS 2012 / Globally Harmonized System of Classification and Labelling of Chemicals

Skin Corrosion/Irritation: Non-irritant per Dermal Irritection® assay modeling. No animal testing performed.
Eye Damage/Irritation: Non/Minimal irritant per Ocular Irritection® assay modeling. No animal testing performed.
Germ Cell Mutagenicity: Mixture does not classify under this category.
Carcinogenicity: Mixture does not classify under this category.
Reproductive Toxicity: Mixture does not classify under this category.
STOT-Single Exposure: Mixture does not classify under this category.
STOT-Repeated Exposure: Mixture does not classify under this category.
Aspiration Hazard: Mixture does not classify under this category.

Section 12: ECOLOGICAL INFORMATION

Ecotoxicity: Volume of ingredients used does not trigger toxicity classifications under the Globally Harmonized System of Classification and Labelling of Chemicals.
Aquatic: Aquatic Toxicity - Low, based on OECD 201, 202, 203 + Microtox: EC_{50} & IC_{50} ≥100 mg/L. Volume of ingredients used does not trigger toxicity classifications under the Globally Harmonized System of Classification and Labelling of Chemicals.
Terrestrial: Not tested on finished formulation.

Persistence and Degradability: Readily Biodegradable per OCED 301D, Closed Bottle Test. Reaches 100% biodegradability within 1 year or less.
Bioaccumulative Potential: No data available.
Mobility in Soil: No data available.
Other Adverse Effects: No data available.

Section 13: DISPOSAL CONSIDERATIONS

Unused or Used Liquid: May be considered hazardous in your area depending on usage and tonnage of disposal – check with local, regional, and or national regulations for appropriate methods of disposal.

Empty Containers: May be offered for recycling.

Never dispose of used degreasing rinsates into lakes, streams, and open bodies of water or storm drains.

Section 14: TRANSPORT INFORMATION

U.N. Number: Not applicable
U.N. Proper Shipping Name: Cleaning Compound, Liquid NOI
Transport Hazard Class(es): Not applicable
Packing Group: Not applicable
Environmental Hazards: Marine Pollutant - NO
Transport in Bulk (according to Annex II of MARPOL 73/78 and IBC Code): Unknown.
Special precautions which user needs to be aware of/comply with, in connection with transport or conveyance either within or outside their premises: None known.

U.S. (DOT) / Canadian TDG: Not Regulated for shipping.
IMO / IDMG: Not classified as Hazardous
ICAO/ IATA: Not classified as Hazardous
ADR/RID: Not classified as Hazardous

Section 15: REGULATORY INFORMATION

All components are listed on: TSCA and DSL Inventory.

SARA Title III: Sections 311/312 Hazard Categories – Not applicable.
Sections 313 Superfunds Amendments and Reauthorizations Act of 1986 – Not applicable.
Sections 302 – Not applicable.

Clean Air Act (CAA): Not applicable
Clean Water Act (CWA): Not applicable

State Right To Know Lists: No ingredients listed
California Proposition 65: No ingredients listed
Texas ESL:

Ethoxylated Alcohol	68439-46-3	60 µg/m³ long term	600 µg/m³ short term
Sodium Citrate	68-04-2	5 µg/m³ long term	50 µg/m³ short term
Sodium Carbonate	497-19-8	5 µg/m³ long term	50 µg/m³ short term
Citric Acid	77-92-9	10 µg/m³ long term	100 µg/m³ short term

This product has been classified as "not classifiable as hazardous" in accordance with Consumer Product Safety Commission (16 CFR Chapter 2), and labelled and packaged accordingly.

Section 16: OTHER INFORMATION

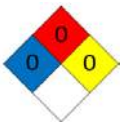
Size	UPC	Size	UPC
2 fl. oz.	043318131035	67.6 fl. oz.	043318130144
4 fl. oz.	043318130014	67.6 fl. oz.	043318000393
16 fl. oz.	043318130021	1 gallon	043318000799
22 fl. oz.	043318130229	1 gallon	043318130052
24 fl. oz.	043318130137	1 gallon	043318004957
32 fl. oz.	043318002557	1 gallon w/ dilution bottle	043318480492
32 fl. oz.	043318130335	140 fl. oz. w/ dilution bottle	043318001468
32 fl. oz.	043318000652	2.5 gallon	043318004889

USA items listed only. Not all items listed. USA items may not be valid for international sale.

Section 16: OTHER INFORMATION - continued

NFPA:

Health – None
Flammability – Non-flammable
Stability – Stable
Special - None



Acronyms

NTP	National Toxicology Program	IARC	International Agency for Research on Cancer
OSHA	Occupational Safety and Health Administration	CPSC	Consumer Product Safety Commission
TSCA	Toxic Substances Control Act	DSL	Domestic Substances List

Prepared / Revised By: Sunshine Makers, Inc., Regulatory Department.
This SDS has been revised in the following sections: Clarification on hazards in section 2, expanded transparency in section 3, revised layout in section 9, 14 & 16, added statement in section 15.

DISCLAIMER: The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Safety Data Sheet

Falcon Signal Horn

Section 1. Identification

Product Identifier	Falcon Signal Horn
Synonyms	FSH1, FSH1V, FSH1BU, FSH, FSHR, FSH39, FSH39R, FSH39BU
Manufacturer Stock Numbers	N/A
Recommended use	Produces Loud Sound - Hand held signaling device.
Uses advised against	This device creates a loud noise and should not be used unnecessarily or near ears. Read all directions and warnings printed on product. Use as directed and keep out of reach of children. Intentional misuse by deliberately concentrating and/or inhaling contents may be fatal.
Manufacturer Contact Address	Falcon Safety Products, Inc. 25 ImClone Drive Branchburg, NJ, 08876 USA

Phone	Emergency Phone	Fax
(908) 707-4900	(800) 498-7192	N/A

Section 2. Hazards Identification

Classification	FLAMMABLE GASES - Category 1 GASES UNDER PRESSURE - Compressed gas
Signal Word	Danger
Pictogram	
Hazard Statements	Contains gas under pressure; may explode if heated Extremely flammable gas
Precautionary Statements Response	Eliminate all ignition sources if safe to do so.

	Leaking gas fire: Do not extinguish, unless leak can be stopped safely.
Prevention	DO NOT SMOKE Keep away from heat. Keep container tightly closed. Pressurized container: Do not pierce or burn, even after use.
Storage	Do not store in enclosed vehicle. Protect from sunlight. Store in a well-ventilated place.
Disposal	N/A
General	Keep out of reach of children
Ingredients of unknown toxicity	0%
Hazards not Otherwise Classified	Contact with liquid may cause frostbite.
	No Data Available

Section 3. Ingredients

CAS	Ingredient Name	Weight %
75-28-5	Propane, 2-methyl-	100 %

Occupational exposure limits, if available, are listed in Section 8.

Section 4. First-Aid Measures

Eye	Immediately flush with plenty of water. After initial flushing, remove any contact lenses and continue flushing for at least 15 minutes. Have eyes examined and tested by medical personnel.
Skin	For liquid contact, warm areas gradually by flushing with lukewarm water. Do not rub affected area, If blistering occurs, apply a sterile dressing. Seek medical attention.
Ingestion	Is not considered a potential route of exposure.
Inhalation	Remove to fresh air. If not breathing, give artificial respiration or give oxygen by trained personnel. Seek immediate medical attention.
General Advice	Never give anything by mouth to an unconscious person. When symptoms persist or in all cases of doubt, seek medical advice.
Inhalation	Harmful if inhaled.

Section 5. Fire Fighting Measures

Suitable Extinguishing Media	Dry Chemical. Foam.
Unsuitable Extinguishing Media	No applicable data available.
Flammable Properties	Flammable by WHMIS/OSHA criteria. Containers may exlode when heated. Vapors are heavier than air and may travel along the ground to some distance source of ignition and flash back.
Firefighters Specific Hazards From Chemical	Contents under pressure. Pressurized container may explode when exposed to heat or flame. Cool containers with floodings quantities of water until well after fire is out.
Protective Equipment for Firefighters	Firefighters should wear full protective clothing including self-contained breathing apparatus.
Hazardous Combustions Products	May include and are not limited to: Oxides of carbon.

Section 6. Accidental Release Measures

Clean-up	Wear a self-contained breathing apparatus and appropriate Personal protection. (See Exposure Controls/Personal Protection section.)
Safeguards (Personnel)	Evacuate personnel to safe areas. Ventilate the area. Refer to protective measures listed in sections 7 and 8.
Methods for Containment	Eliminate all ignition sources (no smoking, flares, sparks, or flames in immediate area). Evacuate all personnel from area. Evaporates quickly forming flammable vapors. Reduce vapors with fog or fine water spray, taking care not to spread liquid with water. Significant spill or leak is unlikely in aerosol containers.

Section 7. Handling and Storage

Handling (Personnel)	Avoid breathing vapors or mist. Avoid contact with skin, eyes and clothing. Provide sufficient air exchange and/or exhaust in work rooms. For personal protection see section 8. Handle in accordance with good industrial hygiene and safety practice.
Storage Temperature	Do not expose to temperatures above 120 degrees F (49 degrees C) as overheating could cause can to burst. DO NOT leave in direct sunlight or enclosed vehicle.
Storage	Keep away from heat and flame. Keep away from sources of ignition. Keep out of reach of children.

Section 8. Exposure Controls/Personal Protection

Occupational Exposure Limits	Ingredient Name	ACGIH TLV	OSHA PEL	STEL
	Propane, 2-methyl-	N/A	N/A	N/A
Personal Protective Equipment	N/A			
Engineering Controls	Use with adequate ventilation. Keep container tightly closed.			
Eye-Face Protection	As required by employer code. If there is a risk of contact with the eyes or face, wear safety glasses with side shields.			
Skin and body protection	As required by employer code. If there is risk of skin contact, wear protective clothing, gloves, etc. Direct contact with liquid can cause frostbite.			
Respiratory Protection	Where exposure guideline levels may be exceeded, use an approved NIOSH respirator.			
General Hygiene Considerations	Handle in accordance with good industrial hygiene and safety practices.			

Section 9. Physical and Chemical Properties

Physical State	Gas
Color	Colorless Gas
Odor	Slight Ethereal
Odor Threshold	No data
Solubility	Negligible
Partition coefficient Water/n-octanol	No data
VOC%	N/A
Viscosity	N/A
Specific Gravity	0.523
Density lbs/Gal	0.59
Pounds per Cubic Foot	N/A
Flash Point	-117°F
FP Method	Open Cup
Ph	N/A
Melting Point	No data
Boiling Point	10.94°F / -11.7°C
Boiling Range	N/A
LEL	1.8
UEL	8.4
Evaporation Rate	>1 (Ethyl Ether=1.0)
Flammability	N/A
Decomposition Temperature	No data
Auto-ignition Temperature	860°F/460°C
Vapor Pressure	300 kPa
Vapor Density	2.006

Additional Information	Gas/vapor heavier than air. May accumulate in confined spaces, particularly at or below ground level.

Section 10. Stability and Reactivity

Stability	Stable under recommended storage conditions.
Conditions to Avoid	Heat, open flames, static discharge, sparks, and other ignition sources. Aerosol containers are unstable at temperatures above 120 degrees F/49 degress C. NO SMOKING
Incompatible Materials	Strong oxidizing agents. Oxygen.
Hazardous Decomposition Products	May include and are not limited to: Oxides of carbon.

Section 11. Toxicological Information

Component Analysis - LC50	Isobutane 658 mh/l/4h rat
Component Analysis - Oral LD50	Isobutane - Not available.
Effects of Acute Exposure	Eye - Vapors may cause mild irritation. Contact with liquid may cause frostbite. Skin - Vapors are not irritating. Contact with liquid may cause frostbite. Inhalation- Excessive intentional inhalation may cause respiratory tract irritation and central nervous system effects (headache, dizziness). May cause asphyxiation in high concentrations. Ingestion - Not a normal route of exposure. Ingestion of liquid may cause frostbite to mucous membranes and central nervous system depression.
Sensitization	Non-hazardous by WHMIS/OSHA criteria.
Local Effects	Repeated or prolonged inhalation may cause toxic effects.
Chronic Effects	Non-hazardous by WHMIS/OSHA Criteria
Carcinogenicity	Non-hazardous by WHMIS/OSHA criteria.
Mutagenicity	Non-hazardous by WHMIS/OSHA Criteria.
Reproductive Effects	Non-hazardous by WHMIS/OSHA Criteria.
Teratogenicity	Non-hazardous by WHMIS/OSHA Criteria.

Section 12. Ecological Information

Toxicity	No classified hazards
Persistence and Degradability	The hydrocarbons in this material are expected to be biodegradable.
Bioaccumulative Potential	Not expected as having the potential to bioaccumulate.
Other Adverse Effects	None anticipated.

Section 13. Disposal

Waste Disposal Method	Comply with applicable Federal, State/Provincial, and Local Regulations. Do not pierce or burn, even after use.
Contaminated Packaging	Not Available

Section 14. Transport Information

UN Number	1075
UN Proper Shipping Name	Petroleum Gases, Liquified
DOT Classification	2.1
Packing Group	N/A
Additional Information	Labeled Flammable Gas

Section 15. Regulatory Information

TSCA	On the inventory, or in compliance with the inventory.
Canada Domestic Substances List (DSL)	This product is listed on the DSL inventory list and complies with the inventory requirements administered by the governing country.
SARA Title III	CERCLA/SARA (Section 302) Extremely Hazardous Substances and TPQs (in pounds): This material does not contain any chemicals subject to the reporting requirements of SARA 302 and 40 CFR 372.
SARA (313) Chemicals	Not listed
California Prop. 65	This product does not contain a chemical known to the State of California to cause cancer, birth defects or other reproductive harm.

Section 16. Other Information

Revision Date	8/11/2016
Disclaimer	Information contained herein was obtained from sources considered technically accurate and reliable. While every effort has been made to ensure full disclosure of product hazards, in some cases data is not available and is so stated. Since conditions of actual product use are beyond control of the supplier, it is assumed that users of this material have been fully trained according to the requirements of all applicable legislation and regulatory instruments. No warranty, expressed or implied, is made and supplier will not be liable for any losses, injuries or consequential damages which may result from the use of or reliance on any information contained in this document.
Prepared By	Falcon Safety Products, Inc. 908-707-4900

Safety Data Sheet

RUST-OLEUM CORPORATION
* Trusted Quality Since 1921 *
www.rustoleum.com

1. Identification

Product Name:	PRO LSPR 6PK 2X MRKNG FLUORSCNT RED ORNG	**Revision Date:**	1/29/2015
Product Identifier:	266590	**Supercedes Date:**	New SDS
Product Use/Class:	Marking Paint/Aerosols		
Supplier:	Rust-Oleum Corporation 11 Hawthorn Parkway Vernon Hills, IL 60061 USA	**Manufacturer:**	Rust-Oleum Corporation 11 Hawthorn Parkway Vernon Hills, IL 60061 USA
Preparer:	Regulatory Department		
Emergency Telephone:	24 Hour Hotline: 847-367-7700		

2. Hazard Identification

EMERGENCY OVERVIEW: Harmful if swallowed. Extremely flammable liquid and vapor. Vapors may cause flash fire or explosion. Contents Under Pressure. Harmful if inhaled. May affect the brain or nervous system causing dizziness, headache or nausea. May cause eye, skin, or respiratory tract irritation. KEEP OUT OF REACH OF CHILDREN. Harmful if inhaled. Causes eye irritation. Use ventilation necessary to keep exposures below recommended exposure limits, if any. Vapor Harmful. Causes Eye, Skin, Nose, and Throat Irritation.

Classification

Symbol(s) of Product



Signal Word
Danger

GHS HAZARD STATEMENTS

Flammable Aerosol, category 1	H222	Extremely flammable aerosol.
Flammable Liquid, category 1	H224	Extremely flammable liquid and vapour.
Acute Toxicity, Oral, category 5	H303	May be harmful if swallowed.
Acute Toxicity, Dermal, category 5	H313	May be harmful in contact with skin.
Skin Irritation, category 2	H315	Causes skin irritation.
Eye Irritation, category 2	H319	Causes serious eye irritation.
Acute Toxicity, Inhalation, category 4	H332	Harmful if inhaled.
STOT, single exposure, category 3, RTI	H335	May cause respiratory irritation.
STOT, single exposure, category 3, NE	H336	May cause drowsiness or dizziness.
Aspiration Hazard, category 2	H305	May be harmful if swallowed and enters airways.
Eye Irritation, category 2B	H320	Causes eye irritation.
Flammable Aerosol, category 1	H280	Contains gas under pressure; may explode if heated

Germ Cell Mutagenicity, category 1B	H340	May cause genetic defects. Classified as mutagenic Category 1 if one ingredient is present at or above 0.1%. Applies to liquids, solids (w/w units) and gases (v/v). The substance may also have its own exposure limit. Routes of exposure are dependent on ingredient form.
Carcinogenicity, category 1A	H350	May cause cancer. Classified as carcinogenic Category 1 on the basis of epidemiological and/or animal data. Mixtures are classified as carcinogenic when at least 1 ingredient has been classified as carcinogenic and is present at 0.1% or above Routes of exposure are dependant on ingredient form.May cause cancer <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
STOT, repeated exposure, category 2	H373	May cause damage to organs <or state all organs affected, if known> through prolonged or repeated exposure <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.

GHS PRECAUTIONARY STATEMENTS

P211	Do not spray on an open flame or other ignition source.
P220	Keep/Store away from clothing/…/combustible materials.
P235	Keep cool.
P251	Pressurized container: Do not pierce or burn, even after use.
P375	Fight fire remotely due to the risk of explosion.
P102	Keep out of reach of children.
P103	Read label before use.
P202	Do not handle until all safety precautions have been read and understood.
P234	Keep only in original container.
P260	Do not breathe dust/fume/gas/mist/vapours/spray.
P261	Avoid breathing dust/fume/gas/mist/vapours/spray.
P262	Do not get in eyes, on skin, or on clothing.
P264	Wash … thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P281	Use personal protective equipment as required.
P285	In case of inadequate ventilation wear respiratory protection.
P312	Call a POISON CENTER or doctor/physician if you feel unwell.
P351	Rinse cautiously with water for several minutes.
P374	Fight fire with normal precautions from a reasonable distance.
P402	Store in a dry place.
P210	Keep away from heat/sparks/open flames/hot surfaces. – No smoking.
P410+P412	Protect from sunlight. Do no expose to temperatures exceeding 50°C/ 122°F.
P240	Ground/bond container and receiving equipment.
P241	Use explosion-proof electrical/ventilating/lighting/…/ equipment.
P242	Use only non-sparking tools.
P243	Take precautionary measures against static discharge.
P303+P361+P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P370+P378	In case of fire: Use … for extinction.
P403+P235	Store in a well-ventilated place. Keep cool.
P501	Dispose of contents/container to …
P321	Specific treatment (see … on this label).
P352	Wash with plenty of soap and water.
P362	Take off contaminated clothing and wash before reuse.
P332+P313	If skin irritation occurs: Get medical advice/attention.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313	If eye irritation persists: Get medical advice/attention.
P304+P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P405	Store locked up.
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P201	Obtain special instructions before use.
P308+P313	IF exposed or concerned: Get medical advice/attention.

P314	Get medical advice/attention if you feel unwell.
P302+P350	IF ON SKIN: Gently wash with plenty of soap and water.

3. Composition/Information On Ingredients

HAZARDOUS SUBSTANCES

Chemical Name	CAS-No.	Wt.% Range	GHS Symbols	GHS Statements
Liquefied Petroleum Gas	68476-86-8	10-25	GHS08	H340-350
Xylene (mixed isomers)	1330-20-7	2.5-10	GHS02-GHS07	H226-312-332-315
Limestone	1317-65-3	2.5-10		
Aliphatic Hydrocarbon	64742-89-8	2.5-10	GHS08	H340-350
Barium Sulfate	7727-43-7	2.5-10		
Hydrotreated Light Distillate	64742-47-8	2.5-10	GHS06	H331
Mineral Spirits	64742-88-7	1.0-2.5	GHS06-GHS08	H331-372
Ethylbenzene	100-41-4	1.0-2.5	GHS02-GHS07	H225-332

The text for GHS Hazard Statements shown above (if any) is given in the "16. Other Information" section.

4. First-aid Measures

FIRST AID - EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes holding eyelids open. Get medical attention. Do NOT allow rubbing of eyes or keeping eyes closed.

FIRST AID - SKIN CONTACT: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists.

FIRST AID - INHALATION: If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately. Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention. Do NOT use mouth-to-mouth resuscitation.

FIRST AID - INGESTION: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention. If swallowed, get medical attention.

5. Fire-fighting Measures

EXTINGUISHING MEDIA: Alcohol Film Forming Foam, Carbon Dioxide, Dry Chemical, Dry Sand, Water Fog

UNUSUAL FIRE AND EXPLOSION HAZARDS: FLASH POINT IS LESS THAN 20°F. EXTREMELY FLAMMABLE LIQUID AND VAPOR!Water spray may be ineffective. Closed containers may explode when exposed to extreme heat. Vapors may form explosive mixtures with air. Vapors can travel to a source of ignition and flash back. Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Perforation of the pressurized container may cause bursting of the can. Closed containers may explode when exposed to extreme heat due to buildup of steam. No unusual fire or explosion hazards noted.

SPECIAL FIREFIGHTING PROCEDURES: Evacuate area and fight fire from a safe distance. Full protective equipment including self-contained breathing apparatus should be used. Water may be used to cool closed containers to prevent pressure buildup and possible autoignition or explosion. Use water spray to keep fire-exposed containers cool. Containers may explode when heated.

6. Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers. Isolate the hazard area and deny entry to unnecessary and unprotected personnel. Ventilate area, isolate spilled material, and remove with inert absorbent. Dispose of contaminated absorbent, container, and unused contents in accordance with local, state, and federal regulations.

7. Handling and Storage

HANDLING: Wash thoroughly after handling. Wash hands before eating. Use only in a well-ventilated area. Follow all MSDS/label precautions even after container is emptied because it may retain product residues. Avoid breathing fumes, vapors, or mist. Remove contaminated clothing and launder before reuse. Use only with adequate ventilation. Avoid contact with eyes, skin and clothing.

STORAGE: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Contents under pressure. Do not store above 120 ° F. Store large quantities in buildings designed and protected for storage of NFPA Class I flammable liquids. Contents under pressure. Do not expose to heat or store above 120 ° F. Product should be stored in tightly sealed containers and protected from heat, moisture, and foreign materials. Store in a dry, well ventilated place. Keep container tightly closed when not in use. Keep away from heat, sparks, flame and sources of ignition. Avoid excess heat.

8. Exposure Controls/Personal Protection

Chemical Name	CAS-No.	Weight % Less Than	ACGIH TLV-TWA	ACGIH TLV-STEL	OSHA PEL-TWA	OSHA PEL-CEILING
Liquefied Petroleum Gas	68476-86-8	25.0	N.E.	N.E.	N.E.	N.E.
Xylene (mixed isomers)	1330-20-7	10.0	100 ppm	150 ppm	100 ppm	N.E.
Limestone	1317-65-3	10.0	15 mg/m3 (Total Dust, OSHA)	N.E.	5 mg/m3 (Respirable Dust)	N.E.
Aliphatic Hydrocarbon	64742-89-8	10.0	350 ppm	N.E.	500 ppm	N.E.
Barium Sulfate	7727-43-7	5.0	5 mg/m3 (Inhlalable fraction w/o asbestos and <1% cryst.silica)	N.E.	15 mg/m3 [Total Dust]	N.E.
Hydrotreated Light Distillate	64742-47-8	5.0	100 ppm	N.E.	500 ppm	N.E.
Mineral Spirits	64742-88-7	5.0	100 ppm	N.E.	100 ppm	N.E.
Ethylbenzene	100-41-4	5.0	20 ppm	125 ppm	100 ppm	N.E.

PERSONAL PROTECTION

ENGINEERING CONTROLS: Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits. Use explosion-proof ventilation equipment. Prevent build-up of vapors by opening all doors and windows to achieve cross-ventilation. Provide general dilution of local exhaust ventilation in volume and pattern to keep TLV of hazardous ingredients below acceptable limits.

RESPIRATORY PROTECTION: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

SKIN PROTECTION: Use impervious gloves to prevent skin contact and absorption of this material through the skin. Nitrile or Neoprene gloves may afford adequate skin protection. Use gloves to prevent prolonged skin contact.

EYE PROTECTION: Use safety eyewear designed to protect against splash of liquids.

OTHER PROTECTIVE EQUIPMENT: Refer to safety supervisor or industrial hygienist for further information regarding personal protective equipment and its application. Refer to safety supervisor or industrial hygienist for further guidance regarding types of personal protective equipment and their applications.

HYGIENIC PRACTICES: Wash thoroughly with soap and water before eating, drinking or smoking. Remove contaminated clothing immediately and launder before reuse.

9. Physical and Chemical Properties

Appearance:	Aerosolized Mist	**Physical State:**	Liquid
Odor:	Solvent Like	**Odor Threshold:**	N.E.
Relative Density:	0.859	**pH:**	N.A.
Freeze Point, °C:	N.D.	**Viscosity:**	N.D.
Solubility in Water:	Slight	**Partition Coefficient, n-octanol/ water:**	No Information
Decompostion Temp., °C:	No Information		
Boiling Range, °C:	-34 - 415	**Explosive Limits, vol%:**	0.9 - 12.6
Flammability:	Does not Support Combustion	**Flash Point, °C:**	-105
Evaporation Rate:	Faster than Ether	**Auto-ignition Temp., °C:**	No Information
Vapor Density:	Heavier than Air	**Vapor Pressure:**	N.D.

(See "Other information" Section for abbreviation legend)

10. Stability and Reactivity

CONDITIONS TO AVOID: Avoid temperatures above 120 ° F. Avoid all possible sources of ignition. Avoid contact with strong acid and strong bases.

INCOMPATIBILITY: Incompatible with strong oxidizing agents, strong acids and strong alkalies.

HAZARDOUS DECOMPOSITION: By open flame, carbon monoxide and carbon dioxide. When heated to decomposition, it emits acrid smoke and irritating fumes. Contains solvents which may form carbon monoxide, carbon dioxide, and formaldehyde.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

STABILITY: This product is stable under normal storage conditions.

11. Toxicological information

EFFECTS OF OVEREXPOSURE - EYE CONTACT: Causes Serious Eye Irritation

EFFECTS OF OVEREXPOSURE - SKIN CONTACT: Substance may cause slight skin irritation. Prolonged or repeated contact may cause skin irritation. May cause skin irritation. Allergic reactions are possible.

EFFECTS OF OVEREXPOSURE - INHALATION: Harmful if inhaled. High gas, vapor, mist or dust concentrations may be harmful if inhaled. Avoid breathing fumes, spray, vapors, or mist. High vapor concentrations are irritating to the eyes, nose, throat and lungs. Prolonged or excessive inhalation may cause respiratory tract irritation.

EFFECTS OF OVEREXPOSURE - INGESTION: Aspiration hazard if swallowed; can enter lungs and cause damage. Harmful if swallowed.

EFFECTS OF OVEREXPOSURE - CHRONIC HAZARDS: IARC lists Ethylbenzene as a possible human carcinogen (group 2B). Overexposure to xylene in laboratory animals has been associated with liver abnormalities, kidney, lung, spleen, eye and blood damage as well as reproductive disorders. Effects in humans, due to chronic overexposure, have included liver, cardiac abnormalities and nervous system damage. May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headaches, paralysis, and blurred vision) and/or damage.

PRIMARY ROUTE(S) OF ENTRY: Eye Contact, Ingestion, Inhalation, Skin Absorption, Skin Contact

ACUTE TOXICITY VALUES

The acute effects of this product have not been tested. Data on individual components are tabulated below:

CAS-No.	Chemical Name	Oral LD50	Dermal LD50	Vapor LC50
1330-20-7	Xylene (mixed isomers)	4300 mg/kg Rat	N.I.	47635 mg/L Rat
64742-89-8	Aliphatic Hydrocarbon	N.I.	3000 mg/kg Rabbit	N.I.
64742-47-8	Hydrotreated Light Distillate	>5000 mg/kg Rat	>2000 mg/kg Rabbit	>5.2 mg/L Rat
64742-88-7	Mineral Spirits	>5000 mg/kg Rat	3000 mg/kg Rabbit	>5.28 mg/L Rat
100-41-4	Ethylbenzene	3500 mg/kg Rat	15354 mg/kg Rabbit	17.2 mg/L Rat

N.I. - No Information

12. Ecological Information

ECOLOGICAL INFORMATION: Product is a mixture of listed components. Product is a mixture of listed components.

13. Disposal Information

DISPOSAL INFORMATION: Dispose of material in accordance to local, state, and federal regulations and ordinances. Do not allow to enter waterways, wastewater, soil, storm drains or sewer systems.

14. Transport Information

	Domestic (USDOT)	International (IMDG)	Air (IATA)	TDG (Canada)
UN Number:	N.A.	1950	1950	N.A.
Proper Shipping Name:	Paint Products in Limited Quantities	Aerosols	Aerosols	Paint Products in Limited Quantities
Hazard Class:	N.A.	2.1	2.1	N.A.
Packing Group:	N.A.	N.A.	N.A.	N.A.
Limited Quantity:	Yes	Yes	Yes	Yes

15. Regulatory Information

U.S. Federal Regulations:

CERCLA - SARA Hazard Category

This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

Fire Hazard, Pressure Hazard, Acute Health Hazard, Chronic Health Hazard

Sara Section 313:

This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

Chemical Name	CAS-No.
Xylene (mixed isomers)	1330-20-7
Ethylbenzene	100-41-4

Toxic Substances Control Act:

This product contains the following chemical substances subject to the reporting requirements of TSCA 12(b) if exported from the United States:

Chemical Name	CAS-No.
Acetaldehyde	75-07-0

CALIFORNIA PROPOSITION 65:

WARNING: This product contains a substance known to the State of California to cause cancer.

Chemical Name	CAS-No.
Ethylbenzene	100-41-4
Pigment Orange 13	3520-72-7
Crystalline Silica / Quartz	14808-60-7
Formaldehyde	50-00-0
Benzene	71-43-2
Lead Compounds	7439-92-1
Cadmium Compounds	7440-43-9
1,4-Dioxane	123-91-1
Acetaldehyde	75-07-0
Ethylene Oxide	75-21-8

CALIFORNIA PROPOSITION 65 REPRODUCTIVE TOXINS

WARNING: This product contains a substance known to the State of California to cause birth defects or other reproductive harm.

Chemical Name	CAS-No.
Toluene	108-88-3
Benzene	71-43-2
Cadmium Compounds	7440-43-9
Lead Compounds	7439-92-1
Ethylene Oxide	75-21-8

International Regulations:

CANADIAN WHMIS:

This SDS has been prepared in compliance with Controlled Product Regulations except for the use of the 16 headings.

16. Other Information

HMIS RATINGS

Health:	2*	**Flammability:**	4	**Physical Hazard:**	0	**Personal Protection:**	X

CANADIAN WHMIS CLASS: AB5 D2A

NFPA RATINGS

Health:	2	**Flammability:**	4	**Instability**	0

VOLATILE ORGANIC COMPOUNDS, g/L: 559

MSDS REVISION DATE: 1/29/2015

REASON FOR REVISION: No Information

Legend: N.A. - Not Applicable, N.E. - Not Established, N.D. - Not Determined

Text for GHS Hazard Statements shown in Section 3 describing each ingredient:

H225	Highly flammable liquid and vapor.
H226	Flammable liquid and vapor.
H312	Harmful in contact with skin.
H315	Causes skin irritation.
H331	Toxic if inhaled.
H332	Harmful if inhaled.
H340	May cause genetic defects <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
H350	May cause cancer <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
H372	Causes damage to organs <or state all organs affected, if known> through prolonged or repeated exposure <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.

Icons for GHS Pictograms shown in Section 3 describing each ingredient:

GHS02



GHS06



GHS07



GHS08



Rust-Oleum Corporation believes, to the best of its knowledge, information and belief, the information contained herein to be accurate and reliable as of the date of this safety data sheet. However, because the conditions of handling, use, and storage of these materials are beyond our control, we assume no responsibility or liability for personal injury or property damage incurred by the use of these materials. Rust-Oleum Corporation makes no warranty, expressed or implied, regarding the accuracy or reliability of the data or results obtained from their use. All materials may present unknown hazards and should be used with caution. The information and recommendations in this material safety data sheet are offered for the users' consideration and examination. It is the responsibility of the user to determine the final suitability of this information and to comply with all applicable international, federal, state, and local laws and regulations.

Safety Data Sheet

RUST-OLEUM CORPORATION
* Trusted Quality Since 1921 *
www.rustoleum.com

1. Identification

Product Name: PRO LSPR 6PK MARK SAFETY RED

Revision Date: 4/30/2015

Product Identifier: 2564838

Supercedes Date: New SDS

Product Use/Class: Topcoat/ Aerosol

Supplier:
Rust-Oleum Corporation
11 Hawthorn Parkway
Vernon Hills, IL 60061
USA

Manufacturer:
Rust-Oleum Corporation
11 Hawthorn Parkway
Vernon Hills, IL 60061
USA

Preparer: Regulatory Department

Emergency Telephone: 24 Hour Hotline: 847-367-7700

2. Hazard Identification

EMERGENCY OVERVIEW: Extremely flammable liquid and vapor. Vapors may cause flash fire or explosion. Harmful if inhaled. May affect the brain or nervous system causing dizziness, headache or nausea. Contents Under Pressure. May cause eye, skin, or respiratory tract irritation. KEEP OUT OF REACH OF CHILDREN. Harmful if inhaled. Harmful if swallowed. Causes eye irritation. Use ventilation necessary to keep exposures below recommended exposure limits, if any. Vapor Harmful. Causes Eye, Skin, Nose, and Throat Irritation.

Classification

Symbol(s) of Product



Signal Word
Danger

Possible Hazards
74% of the mixture consists of ingredient(s) of unknown acute toxicity

GHS HAZARD STATEMENTS

Flammable Aerosol, category 1	H222	Extremely flammable aerosol.
Flammable Liquid, category 1	H224	Extremely flammable liquid and vapor.
Acute Toxicity, Oral, category 5	H303	May be harmful if swallowed.
Acute Toxicity, Dermal, category 5	H313	May be harmful in contact with skin.
Skin Irritation, category 2	H315	Causes skin irritation.
Eye Irritation, category 2	H319	Causes serious eye irritation.
Acute Toxicity, Inhalation, category 4	H332	Harmful if inhaled.
STOT, single exposure, category 3, RTI	H335	May cause respiratory irritation.
STOT, single exposure, category 3, NE	H336	May cause drowsiness or dizziness.
Aspiration Hazard, category 2	H305	May be harmful if swallowed and enters airways.
Eye Irritation, category 2B	H320	Causes eye irritation.
Flammable Aerosol, category 1	H280	Contains gas under pressure; may explode if heated.

Germ Cell Mutagenicity, category 1B	H340	May cause genetic defects. Classified as mutagenic Category 1 if one ingredient is present at or above 0.1%. Applies to liquids, solids (w/w units) and gases (v/v). The substance may also have its own exposure limit. Routes of exposure are dependent on ingredient form.
Carcinogenicity, category 1B	H350	May cause cancer. Classified as carcinogenic Category 1 on the basis of epidemiological and/or animal data. Mixtures are classified as carcinogenic when at least 1 ingredient has been classified as carcinogenic and is present at 0.1% or above Routes of exposure are dependant on ingredient form.

GHS PRECAUTIONARY STATEMENTS

P211	Do not spray on an open flame or other ignition source.
P220	Keep/Store away from clothing/…/combustible materials.
P235	Keep cool.
P251	Pressurized container: Do not pierce or burn, even after use.
P375	Fight fire remotely due to the risk of explosion.
P102	Keep out of reach of children.
P103	Read label before use.
P202	Do not handle until all safety precautions have been read and understood.
P234	Keep only in original container.
P260	Do not breathe dust/fume/gas/mist/vapors/spray.
P261	Avoid breathing dust/fume/gas/mist/vapors/spray.
P262	Do not get in eyes, on skin, or on clothing.
P264	Wash … thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P281	Use personal protective equipment as required.
P285	In case of inadequate ventilation wear respiratory protection.
P312	Call a POISON CENTER or doctor/physician if you feel unwell.
P351	Rinse cautiously with water for several minutes.
P374	Fight fire with normal precautions from a reasonable distance.
P402	Store in a dry place.
P210	Keep away from heat/sparks/open flames/hot surfaces. – No smoking.
P410+P412	Protect from sunlight. Do not expose to temperatures exceeding 50°C / 122°F.
P240	Ground/bond container and receiving equipment.
P241	Use explosion-proof electrical/ventilating/lighting/…/ equipment.
P242	Use only non-sparking tools.
P243	Take precautionary measures against static discharge.
P303+P361+P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P370+P378	In case of fire: Use … for extinction.
P403+P235	Store in a well-ventilated place. Keep cool.
P501	Dispose of contents/container to …
P321	Specific treatment (see … on this label).
P352	Wash with plenty of soap and water.
P362	Take off contaminated clothing and wash before reuse.
P332+P313	If skin irritation occurs: Get medical advice/attention.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P337+P313	If eye irritation persists: Get medical advice/attention.
P304+P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P405	Store locked up.
P403+P233	Store in a well-ventilated place. Keep container tightly closed.
P201	Obtain special instructions before use.
P308+P313	IF exposed or concerned: Get medical advice/attention.
P302+P350	IF ON SKIN: Gently wash with plenty of soap and water.

3. Composition/Information On Ingredients

HAZARDOUS SUBSTANCES

Chemical Name	CAS-No.	Wt.% Range	GHS Symbols	GHS Statements
Acetone	67-64-1	25-50	GHS02-GHS07	H225-336-319
Propane	74-98-6	10-25		
Aliphatic Hydrocarbon	64742-89-8	10-25	GHS08	H340-350
n-Butane	106-97-8	2.5-10		
Limestone	1317-65-3	2.5-10		
Xylene (mixed isomers)	1330-20-7	2.5-10	GHS02-GHS07	H226-312-332-315
Hydrous Magnesium Silicate	14807-96-6	2.5-10		
Naphtha, Petroleum, Hydrotreated Light	64742-49-0	2.5-10	GHS08	H340-350
Titanium Dioxide	13463-67-7	1.0-2.5		
Iron Oxide	1309-37-1	1.0-2.5		
Ethylbenzene	100-41-4	1.0-2.5	GHS02-GHS07	H225-332

The text for GHS Hazard Statements shown above (if any) is given in the "16. Other Information" section.

4. First-aid Measures

FIRST AID - EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes holding eyelids open. Get medical attention. Do NOT allow rubbing of eyes or keeping eyes closed.

FIRST AID - SKIN CONTACT: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists.

FIRST AID - INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention. Do NOT use mouth-to-mouth resuscitation. If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately.

FIRST AID - INGESTION: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention. If swallowed, get medical attention.

5. Fire-fighting Measures

EXTINGUISHING MEDIA: Alcohol Film Forming Foam, Carbon Dioxide, Dry Chemical, Dry Sand, Water Fog

UNUSUAL FIRE AND EXPLOSION HAZARDS: FLASH POINT IS LESS THAN 20°F. EXTREMELY FLAMMABLE LIQUID AND VAPOR!Water spray may be ineffective. Closed containers may explode when exposed to extreme heat due to buildup of steam. Closed containers may explode when exposed to extreme heat. Vapors may form explosive mixtures with air. Vapors can travel to a source of ignition and flash back. Isolate from heat, electrical equipment, sparks and open flame. Perforation of the pressurized container may cause bursting of the can. No unusual fire or explosion hazards noted. Keep containers tightly closed.

SPECIAL FIREFIGHTING PROCEDURES: Full protective equipment including self-contained breathing apparatus should be used. Evacuate area and fight fire from a safe distance. Water may be used to cool closed containers to prevent pressure buildup and possible autoignition or explosion. Use water spray to keep fire-exposed containers cool. Containers may explode when heated.

6. Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Isolate the hazard area and deny entry to unnecessary and unprotected personnel. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers. Ventilate area, isolate spilled material, and remove with inert absorbent. Dispose of contaminated absorbent, container, and unused contents in accordance with local, state, and federal regulations.

7. Handling and Storage

HANDLING: Wash thoroughly after handling. Wash hands before eating. Remove contaminated clothing and launder before reuse. Use only with adequate ventilation. Follow all MSDS/label precautions even after container is emptied because it may retain product residues. Avoid breathing fumes, vapors, or mist. Avoid contact with eyes, skin and clothing.

STORAGE: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Contents under pressure. Do not store above 120 ° F. Store large quantities in buildings designed and protected for storage of NFPA Class I flammable liquids. Product should be stored in tightly sealed containers and protected from heat, moisture, and foreign materials. Store in a dry, well ventilated place. Keep container tightly closed when not in use. Keep away from heat, sparks, flame and sources of ignition. Avoid excess heat.

8. Exposure Controls/Personal Protection

Chemical Name	CAS-No.	Weight % Less Than	ACGIH TLV-TWA	ACGIH TLV-STEL	OSHA PEL-TWA	OSHA PEL-CEILING
Acetone	67-64-1	30.0	500 ppm	750 ppm	1000 ppm	N.E.
Propane	74-98-6	20.0	1000 ppm	N.E.	1000 ppm	N.E.
Aliphatic Hydrocarbon	64742-89-8	15.0	350 ppm	N.E.	500 ppm	N.E.
n-Butane	106-97-8	10.0	1000 ppm	1000 ppm	N.E.	N.E.
Limestone	1317-65-3	10.0	15 mg/m3 (Total Dust, OSHA)	N.E.	5 mg/m3 (Respirable Dust)	N.E.
Xylene (mixed isomers)	1330-20-7	10.0	100 ppm	150 ppm	100 ppm	N.E.
Hydrous Magnesium Silicate	14807-96-6	5.0	2 mg/m3 (Respirable Dust)	N.E.	20 mppcf (Mineral Dust <1% Quartz)	N.E.
Naphtha, Petroleum, Hydrotreated Light	64742-49-0	5.0	200 mg/m3	N.E.	N.E.	N.E.
Titanium Dioxide	13463-67-7	5.0	10 mg/m3 (Total Dust)	N.E.	15 mg/m3 [Total Dust]	N.E.
Iron Oxide	1309-37-1	5.0	5 mg/m3 (Respirable Dust, OSHA)	N.E.	15 mg/m3 (Total Dust)	N.E.
Ethylbenzene	100-41-4	5.0	20 ppm	125 ppm	100 ppm	N.E.

PERSONAL PROTECTION

ENGINEERING CONTROLS: Use explosion-proof ventilation equipment. Provide general dilution of local exhaust ventilation in volume and pattern to keep TLV of hazardous ingredients below acceptable limits. Prevent build-up of vapors by opening all doors and windows to achieve cross-ventilation. Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits.

RESPIRATORY PROTECTION: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

SKIN PROTECTION: Use gloves to prevent prolonged skin contact. Nitrile or Neoprene gloves may afford adequate skin protection.

EYE PROTECTION: Use safety eyewear designed to protect against splash of liquids.

OTHER PROTECTIVE EQUIPMENT: Refer to safety supervisor or industrial hygienist for further guidance regarding types of personal protective equipment and their applications.

HYGIENIC PRACTICES: Wash thoroughly with soap and water before eating, drinking or smoking. Remove contaminated clothing immediately and launder before reuse.

9. Physical and Chemical Properties

Appearance:	Aerosolized Mist	**Physical State:**	Liquid
Odor:	Solvent Like	**Odor Threshold:**	N.E.
Relative Density:	0.808	**pH:**	N.A.
Freeze Point, °C:	N.D.	**Viscosity:**	N.D.
Solubility in Water:	Slight	**Partition Coefficient, n-octanol/ water:**	No Information
Decompostion Temp., °C:	No Information		
Boiling Range, °C:	-11 - 999	**Explosive Limits, vol%:**	0.7 - 13.0
Flammability:	Does not Support Combustion	**Flash Point, °C:**	>93
Evaporation Rate:	Faster than Ether	**Auto-ignition Temp., °C:**	No Information
Vapor Density:	Heavier than Air	**Vapor Pressure:**	N.D.

(See "Other information" Section for abbreviation legend)

10. Stability and Reactivity

CONDITIONS TO AVOID: Avoid temperatures above 120 ° F. Avoid contact with strong acid and strong bases. Avoid all possible sources of ignition.

INCOMPATIBILITY: Incompatible with strong oxidizing agents, strong acids and strong alkalies.

HAZARDOUS DECOMPOSITION: By open flame, carbon monoxide and carbon dioxide. When heated to decomposition, it emits acrid smoke and irritating fumes. Contains solvents which may form carbon monoxide, carbon dioxide, and formaldehyde.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

STABILITY: This product is stable under normal storage conditions.

11. Toxicological information

EFFECTS OF OVEREXPOSURE - EYE CONTACT: Causes Serious Eye Irritation

EFFECTS OF OVEREXPOSURE - SKIN CONTACT: May cause skin irritation. Allergic reactions are possible.

EFFECTS OF OVEREXPOSURE - INHALATION: High gas, vapor, mist or dust concentrations may be harmful if inhaled. High vapor concentrations are irritating to the eyes, nose, throat and lungs. Harmful if inhaled. Avoid breathing fumes, spray, vapors, or mist. Prolonged or excessive inhalation may cause respiratory tract irritation.

EFFECTS OF OVEREXPOSURE - INGESTION: Harmful if swallowed.

EFFECTS OF OVEREXPOSURE - CHRONIC HAZARDS: IARC lists Ethylbenzene as a possible human carcinogen (group 2B). Overexposure to xylene in laboratory animals has been associated with liver abnormalities, kidney, lung, spleen, eye and blood damage as well as reproductive disorders. Effects in humans, due to chronic overexposure, have included liver, cardiac abnormalities and nervous system damage. Contains Titanium Dioxide. Titanium Dioxide is listed as a Group 2B-"Possibly carcinogenic to humans" by IARC. No significant exposure to Titanium Dioxide is thought to occur during the use of products in which Titanium Dioxide is bound to other materials, such as in paints during brush application or drying. Risk of overexposure depends on duration and level of exposure to dust from repeated sanding of surfaces or spray mist and the actual concentration of Titanium Dioxide in the formula. (Ref: IARC Monograph, Vol. 93, 2010)May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headaches, paralysis, and blurred vision) and/or damage.

PRIMARY ROUTE(S) OF ENTRY: Eye Contact, Ingestion, Inhalation, Skin Absorption, Skin Contact

ACUTE TOXICITY VALUES

The acute effects of this product have not been tested. Data on individual components are tabulated below:

CAS-No.	Chemical Name	Oral LD50	Dermal LD50	Vapor LC50
74-98-6	Propane	N.I.	N.I.	658 mg/L Rat
64742-89-8	Aliphatic Hydrocarbon	N.I.	3000 mg/kg Rabbit	N.I.
1330-20-7	Xylene (mixed isomers)	4300 mg/kg Rat	N.I.	47635 mg/L Rat
64742-49-0	Naphtha, Petroleum, Hydrotreated Light	>5000 mg/kg Rat	>3160 mg/kg Rabbit	N.I.
13463-67-7	Titanium Dioxide	>10000 mg/kg Rat	N.I.	N.I.
1309-37-1	Iron Oxide	>10000 mg/kg Rat	N.I.	N.I.
100-41-4	Ethylbenzene	3500 mg/kg Rat	15354 mg/kg Rabbit	17.2 mg/L Rat

N.I. - No Information

12. Ecological Information

ECOLOGICAL INFORMATION: Product is a mixture of listed components.

13. Disposal Information

DISPOSAL INFORMATION: Dispose of material in accordance to local, state, and federal regulations and ordinances. Do not allow to enter waterways, wastewater, soil, storm drains or sewer systems.

14. Transport Information

	Domestic (USDOT)	International (IMDG)	Air (IATA)	TDG (Canada)
UN Number:	N.A.	1950	1950	N.A.
Proper Shipping Name:	Paint Products in Limited Quantities	Aerosols	Aerosols	Paint Products in Limited Quantities
Hazard Class:	N.A.	2.1	2.1	N.A.
Packing Group:	N.A.	N.A.	N.A.	N.A.
Limited Quantity:	Yes	Yes	Yes	Yes

15. Regulatory Information

U.S. Federal Regulations:

CERCLA - SARA Hazard Category

This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

Fire Hazard, Pressure Hazard, Acute Health Hazard, Chronic Health Hazard

Sara Section 313:

This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

Chemical Name	CAS-No.
Xylene (mixed isomers)	1330-20-7
Ethylbenzene	100-41-4

Toxic Substances Control Act:

This product contains the following chemical substances subject to the reporting requirements of TSCA 12(b) if exported from the United States:

No TSCA 12(b) components exist in this product.

CALIFORNIA PROPOSITION 65:

Chemical Name	CAS-No.
Titanium Dioxide	13463-67-7
Ethylbenzene	100-41-4

CALIFORNIA PROPOSITION 65 REPRODUCTIVE TOXINS

No Proposition 65 Reproductive Toxins exist in this product.

International Regulations:

CANADIAN WHMIS:

This SDS has been prepared in compliance with Controlled Product Regulations except for the use of the 16 headings.

16. Other Information

HMIS RATINGS

Health:	2*	**Flammability:**	4	**Physical Hazard:**	0	**Personal Protection:**	X

CANADIAN WHMIS CLASS: AB5 D2A

NFPA RATINGS

Health:	2	**Flammability:**	4	**Instability**	0

VOLATILE ORGANIC COMPOUNDS, g/L: 536

MSDS REVISION DATE: 4/30/2015

REASON FOR REVISION: No Information

Legend: N.A. - Not Applicable, N.E. - Not Established, N.D. - Not Determined

Text for GHS Hazard Statements shown in Section 3 describing each ingredient:

H225	Highly flammable liquid and vapor.
H226	Flammable liquid and vapor.
H312	Harmful in contact with skin.
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H332	Harmful if inhaled.
H336	May cause drowsiness or dizziness.
H340	May cause genetic defects <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.
H350	May cause cancer <state route of exposure if it is conclusively proven that no other routes of exposure cause the hazard>.

Icons for GHS Pictograms shown in Section 3 describing each ingredient:

GHS02



GHS07



GHS08



Rust-Oleum Corporation believes, to the best of its knowledge, information and belief, the information contained herein to be accurate and reliable as of the date of this safety data sheet. However, because the conditions of handling, use, and storage of these materials are beyond our control, we assume no responsibility or liability for personal injury or property damage incurred by the use of these materials. Rust-Oleum Corporation makes no warranty, expressed or implied, regarding the accuracy or reliability of the data or results obtained from their use. All materials may present unknown hazards and should be used with caution. The information and recommendations in this material safety data sheet are offered for the users' consideration and examination. It is the responsibility of the user to determine the final suitability of this information and to comply with all applicable international, federal, state, and local laws and regulations.

Safety Data Sheet

RUST-OLEUM CORPORATION
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1. Identification

Product Name: PRO LSPR 6PK 2X WB MRKNG HIGH VIS YELLOW

Revision Date: 10/11/2017

Product Identifier: 266577

Supercedes Date: 5/18/2017

Product Use/Class: Marking Paint/Aerosols

Supplier: Rust-Oleum Corporation
11 Hawthorn Parkway
Vernon Hills, IL 60061
USA

Manufacturer: Rust-Oleum Corporation
11 Hawthorn Parkway
Vernon Hills, IL 60061
USA

Preparer: Regulatory Department

Emergency Telephone: 24 Hour Hotline: 847-367-7700

2. Hazard Identification

Classification

Symbol(s) of Product



Signal Word
Danger

Possible Hazards
28% of the mixture consists of ingredient(s) of unknown acute toxicity.

GHS HAZARD STATEMENTS

Flammable Aerosol, category 1	H222	Extremely flammable aerosol.
Compressed Gas	H280	Contains gas under pressure; may explode if heated.
Carcinogenicity, category 2	H351	Suspected of causing cancer.

GHS LABEL PRECAUTIONARY STATEMENTS

P210	Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.
P211	Do not spray on an open flame or other ignition source.
P251	Do not pierce or burn, even after use.

P410+P412	Protect from sunlight. Do not expose to temperatures exceeding 50°C / 122°F.
P410+P403	Protect from sunlight. Store in a well-ventilated place.
P201	Obtain special instructions before use.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P308+P313	IF exposed or concerned: Get medical advice/attention.
P405	Store locked up.
P501	Dispose of contents/container in accordance with local, regional and national regulations.

3. Composition / Information On Ingredients

HAZARDOUS SUBSTANCES

Chemical Name	CAS-No.	Wt.% Range	GHS Symbols	GHS Statements
Propane	74-98-6	10-25	GHS04	H280
Naphtha, Petroleum, Hydrotreated Light	64742-49-0	2.5-10	GHS08	H304
n-Butane	106-97-8	2.5-10	GHS04	H280
n-Butyl Acetate	123-86-4	2.5-10	GHS02-GHS07	H226-336
Titanium Dioxide	13463-67-7	2.5-10	Not Available	Not Available
Xylenes (o-, m-, p- isomers)	1330-20-7	2.5-10	GHS02-GHS07	H226-315-319-332
Talc (Hydrous Magnesium Silicate)	14807-96-6	2.5-10	Not Available	Not Available
Ethylbenzene	100-41-4	0.1-1.0	GHS02-GHS07-GHS08	H225-304-332-351-373
Crystalline Silica / Quartz	14808-60-7	0.1-1.0	Not Available	Not Available

4. First-Aid Measures

FIRST AID - EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes holding eyelids open. Get medical attention. Do NOT allow rubbing of eyes or keeping eyes closed.

FIRST AID - SKIN CONTACT: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists.

FIRST AID - INHALATION: If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately. Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention. Do NOT use mouth-to-mouth resuscitation.

FIRST AID - INGESTION: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention. If swallowed, get medical attention.

5. Fire-Fighting Measures

EXTINGUISHING MEDIA: Alcohol Film Forming Foam, Carbon Dioxide, Dry Chemical, Dry Sand, Water Fog

UNUSUAL FIRE AND EXPLOSION HAZARDS: FLASH POINT IS LESS THAN 20°F. EXTREMELY FLAMMABLE LIQUID AND VAPOR!Water spray may be ineffective. Closed containers may explode when exposed to extreme heat. Vapors may form explosive mixtures with air. Vapors can travel to a source of ignition and flash back. Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Perforation of the pressurized container may cause bursting of the can. Closed containers may explode when exposed to extreme heat due to buildup of steam. No unusual fire or explosion hazards noted.

SPECIAL FIREFIGHTING PROCEDURES: Evacuate area and fight fire from a safe distance. Full protective equipment including self-contained breathing apparatus should be used. Water may be used to cool closed containers to prevent pressure buildup and possible autoignition or explosion. Use water spray to keep fire-exposed containers cool. Containers may explode when heated.

6. Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers. Isolate the hazard area and deny entry to unnecessary and unprotected personnel. Ventilate area, isolate spilled material, and remove with inert absorbent. Dispose of contaminated absorbent, container, and unused contents in accordance with local, state, and federal regulations.

7. Handling and Storage

HANDLING: Wash thoroughly after handling. Wash hands before eating. Use only in a well-ventilated area. Follow all MSDS/label precautions even after container is emptied because it may retain product residues. Avoid breathing fumes, vapors, or mist. Remove contaminated clothing and launder before reuse. Use only with adequate ventilation. Avoid contact with eyes, skin and clothing.

STORAGE: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Contents under pressure. Do not store above 120 ° F. Store large quantities in buildings designed and protected for storage of flammable aerosols. Contents under pressure. Do not expose to heat or store above 120 ° F. Product should be stored in tightly sealed containers and protected from heat, moisture, and foreign materials. Store in a dry, well ventilated place. Keep container tightly closed when not in use. Keep away from heat, sparks, flame and sources of ignition. Avoid excess heat.

8. Exposure Controls / Personal Protection

Chemical Name	CAS-No.	Weight % Less Than	ACGIH TLV-TWA	ACGIH TLV-STEL	OSHA PEL-TWA	OSHA PEL-CEILING
Propane	74-98-6	20.0	N.E.	N.E.	1000 ppm	N.E.
Naphtha, Petroleum, Hydrotreated Light	64742-49-0	10.0	N.E.	N.E.	N.E.	N.E.
n-Butane	106-97-8	10.0	N.E.	1000 ppm	N.E.	N.E.
n-Butyl Acetate	123-86-4	10.0	50 ppm	150 ppm	150 ppm	N.E.
Titanium Dioxide	13463-67-7	5.0	10 mg/m3	N.E.	15 mg/m3	N.E.
Xylenes (o-, m-, p- isomers)	1330-20-7	5.0	100 ppm	150 ppm	100 ppm	N.E.
Talc (Hydrous Magnesium Silicate)	14807-96-6	5.0	2 mg/m3	N.E.	N.E.	N.E.
Ethylbenzene	100-41-4	1.0	20 ppm	N.E.	100 ppm	N.E.
Crystalline Silica / Quartz	14808-60-7	1.0	0.025 mg/m3	N.E.	50 µg/m3	N.E.

PERSONAL PROTECTION

ENGINEERING CONTROLS: Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits. Use explosion-proof ventilation equipment. Prevent build-up of vapors by opening all doors and windows to achieve cross-ventilation. Provide general dilution of local exhaust ventilation in volume and pattern to keep TLV of hazardous ingredients below acceptable limits.

RESPIRATORY PROTECTION: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

SKIN PROTECTION: Use impervious gloves to prevent skin contact and absorption of this material through the skin. Nitrile or Neoprene gloves may afford adequate skin protection. Use gloves to prevent prolonged skin contact.

EYE PROTECTION: Use safety eyewear designed to protect against splash of liquids.

OTHER PROTECTIVE EQUIPMENT: Refer to safety supervisor or industrial hygienist for further information regarding personal protective equipment and its application. Refer to safety supervisor or industrial hygienist for further guidance regarding types of personal protective equipment and their applications.

HYGIENIC PRACTICES: Wash thoroughly with soap and water before eating, drinking or smoking. Remove contaminated clothing immediately and launder before reuse.

9. Physical and Chemical Properties

Appearance:	Aerosolized Mist	**Physical State:**	Liquid
Odor:	Solvent Like	**Odor Threshold:**	N.E.
Relative Density:	0.853	**pH:**	N.A.
Freeze Point, °C:	N.D.	**Viscosity:**	N.D.
Solubility in Water:	Slight	**Partition Coefficient, n-octanol/ water:**	N.D.
Decompostion Temp., °C:	N.D.		
Boiling Range, °C:	-37 - 537	**Explosive Limits, vol%:**	0.9 - 12.6
Flammability:	Supports Combustion	**Flash Point, °C:**	-96
Evaporation Rate:	Faster than Ether	**Auto-ignition Temp., °C:**	N.D.
Vapor Density:	Heavier than Air	**Vapor Pressure:**	N.D.

(See "Other information" Section for abbreviation legend)

10. Stability and Reactivity

CONDITIONS TO AVOID: Avoid temperatures above 120°F (49°C). Avoid all possible sources of ignition.

INCOMPATIBILITY: Incompatible with strong oxidizing agents, strong acids and strong alkalies.

HAZARDOUS DECOMPOSITION: By open flame, carbon monoxide and carbon dioxide. When heated to decomposition, it emits acrid smoke and irritating fumes. Contains solvents which may form carbon monoxide, carbon dioxide, and formaldehyde.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

STABILITY: This product is stable under normal storage conditions.

11. Toxicological Information

EFFECTS OF OVEREXPOSURE - EYE CONTACT: Causes Serious Eye Irritation

EFFECTS OF OVEREXPOSURE - SKIN CONTACT: Substance may cause slight skin irritation. Prolonged or repeated contact may cause skin irritation. May cause skin irritation. Allergic reactions are possible.

EFFECTS OF OVEREXPOSURE - INHALATION: Harmful if inhaled. High gas, vapor, mist or dust concentrations may be harmful if inhaled. Avoid breathing fumes, spray, vapors, or mist. High vapor concentrations are irritating to the eyes, nose, throat and lungs. Prolonged or excessive inhalation may cause respiratory tract irritation.

EFFECTS OF OVEREXPOSURE - INGESTION: Aspiration hazard if swallowed; can enter lungs and cause damage. Harmful if swallowed.

EFFECTS OF OVEREXPOSURE - CHRONIC HAZARDS: Overexposure to xylene in laboratory animals has been associated with liver abnormalities, kidney, lung, spleen, eye and blood damage as well as reproductive disorders. Effects in humans, due to chronic overexposure, have included liver, cardiac abnormalities and nervous system damage. IARC lists Ethylbenzene as a possible human carcinogen (group 2B). Contains Titanium Dioxide. Titanium Dioxide is listed as a Group 2B-"Possibly carcinogenic to humans" by IARC. No significant exposure to Titanium Dioxide is thought to occur during the use of products in which Titanium Dioxide is bound to other materials, such as in paints during brush application or drying. Risk of overexposure depends on duration and level of exposure to dust from repeated sanding of surfaces or spray mist and the actual concentration of Titanium Dioxide in the formula. (Ref: IARC Monograph, Vol. 93, 2010)May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headaches, paralysis, and blurred vision) and/or damage.

PRIMARY ROUTE(S) OF ENTRY: Eye Contact, Ingestion, Skin Absorption, Skin Contact

ACUTE TOXICITY VALUES

The acute effects of this product have not been tested. Data on individual components are tabulated below:

CAS-No.	Chemical Name	Oral LD50	Dermal LD50	Vapor LC50
74-98-6	Propane	N.I.	N.I.	658 mg/L Rat
64742-49-0	Naphtha, Petroleum, Hydrotreated Light	>5000 mg/kg Rat	>3160 mg/kg Rabbit	>4951 mg/L Rat
106-97-8	n-Butane	N.I.	N.I.	658 mg/L Rat
123-86-4	n-Butyl Acetate	10768 mg/kg Rat	>17600 mg/kg Rabbit	> 21 mg/L Rat
13463-67-7	Titanium Dioxide	>10000 mg/kg Rat	2500 mg/kg	N.I.
1330-20-7	Xylenes (o-, m-, p- isomers)	3500 mg/kg Rat	>4350 mg/kg Rabbit	29.08 mg/L Rat
14807-96-6	Talc (Hydrous Magnesium Silicate)	6000	N.I.	30
100-41-4	Ethylbenzene	3500 mg/kg Rat	15400 mg/kg Rabbit	17.4 mg/L Rat
14808-60-7	Crystalline Silica / Quartz	5500 mg/kg Rat	5500	100 mg/L

N.I. - No Information

12. Ecological Information

ECOLOGICAL INFORMATION: Product is a mixture of listed components. Product is a mixture of listed components.

13. Disposal Information

DISPOSAL INFORMATION: Dispose of material in accordance to local, state, and federal regulations and ordinances. Do not allow to enter waterways, wastewater, soil, storm drains or sewer systems.

14. Transport Information

	Domestic (USDOT)	International (IMDG)	Air (IATA)	TDG (Canada)
UN Number:	N.A.	1950	1950	N.A.
Proper Shipping Name:	Paint Products in Limited Quantities	Aerosols	Aerosols	Paint Products in Limited Quantities
Hazard Class:	N.A.	2.1	2.1	N.A.
Packing Group:	N.A.	N.A.	N.A.	N.A.
Limited Quantity:	Yes	Yes	Yes	Yes

15. Regulatory Information

U.S. Federal Regulations:

CERCLA - SARA Hazard Category

This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

No Information

Sara Section 313:

This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

Chemical Name	CAS-No.
Xylenes (o-, m-, p- isomers)	1330-20-7
Ethylbenzene	100-41-4

Toxic Substances Control Act:

This product contains the following chemical substances subject to the reporting requirements of TSCA 12(b) if exported from the United States:

Chemical Name	CAS-No.
Castor oil, sulfated, sodium salt	68187-76-8

No TSCA 12(b) components exist in this product.

16. Other Information

HMIS RATINGS

Health:	2*	**Flammability:**	4	**Physical Hazard:**	0	**Personal Protection:**	X

NFPA RATINGS

Health:	2	**Flammability:**	4	**Instability**	0

VOLATILE ORGANIC COMPOUNDS, g/L: 567

SDS REVISION DATE: 10/11/2017

REASON FOR REVISION: Product Composition Changed
Substance and/or Product Properties Changed in Section(s):
15 - Regulatory Information
Statement(s) Changed

Legend: N.A. - Not Applicable, N.E. - Not Established, N.D. - Not Determined

Rust-Oleum Corporation believes, to the best of its knowledge, information and belief, the information contained herein to be accurate and reliable as of the date of this safety data sheet. However, because the conditions of handling, use, and storage of these materials are beyond our control, we assume no responsibility or liability for personal injury or property damage incurred by the use of these materials. Rust-Oleum Corporation makes no warranty, expressed or implied, regarding the accuracy or reliability of the data or results obtained from their use. All materials may present unknown hazards and should be used with caution. The information and recommendations in this material safety data sheet are offered for the users' consideration and examination. It is the responsibility of the user to determine the final suitability of this information and to comply with all applicable international, federal, state, and local laws and regulations.

Safety Data Sheet

RUST-OLEUM CORPORATION
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1. Identification

Product Name: ICWB LSPR 12PK WHITE MARKING

Revision Date: 8/17/2018

Product Identifier: 203039

Supercedes Date: 8/17/2018

Recommended Use: Marking Paint

Supplier:
Rust-Oleum Corporation
11 Hawthorn Parkway
Vernon Hills, IL 60061
USA

Rust-Oleum Canada (ROCA)
200 Confederation Parkway
Concord, ON L4K 4T8
Canada
Emergency Phone: 800-387-3625

Manufacturer:
Rust-Oleum Corporation
11 Hawthorn Parkway
Vernon Hills, IL 60061
USA

Preparer: Regulatory Department

Emergency Telephone: 24 Hour Hotline: 847-367-7700

2. Hazard Identification

Classification

Symbol(s) of Product



Signal Word
Danger

Possible Hazards
35% of the mixture consists of ingredient(s) of unknown acute toxicity.

GHS HAZARD STATEMENTS

Flammable Aerosol, category 1	H222	Extremely flammable aerosol.
Compressed Gas	H280	Contains gas under pressure; may explode if heated.
Carcinogenicity, category 2	H351	Suspected of causing cancer.
STOT, repeated exposure, category 2	H373	May cause damage to organs through prolonged or repeated exposure.

GHS LABEL PRECAUTIONARY STATEMENTS

P210	Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. No smoking.

P211	Do not spray on an open flame or other ignition source.
P251	Do not pierce or burn, even after use.
P410+P412	Protect from sunlight. Do not expose to temperatures exceeding 50°C / 122°F.
P410+P403	Protect from sunlight. Store in a well-ventilated place.
P201	Obtain special instructions before use.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P308+P313	IF exposed or concerned: Get medical advice/attention.
P405	Store locked up.
P501	Dispose of contents/container in accordance with local, regional and national regulations.
P260	Do not breathe dust/fume/gas/mist/vapors/spray.
P314	Get medical advice/attention if you feel unwell.

3. Composition / Information On Ingredients

HAZARDOUS SUBSTANCES

Chemical Name	CAS-No.	Wt.%	GHS Symbols	GHS Statements
Propane	74-98-6	17	GHS04	H280
Titanium Dioxide	13463-67-7	8.7	Not Available	Not Available
n-Butane	106-97-8	8.0	GHS04	H280
Naphtha, Petroleum, Hydrotreated Light	64742-49-0	6.7	GHS08	H304
Xylenes (o-, m-, p- isomers)	1330-20-7	5.0	GHS02-GHS07	H226-315-319-332
Hydrous Magnesium Silicate	14807-96-6	2.1	Not Available	Not Available
n-Butyl Acetate	123-86-4	1.7	GHS02-GHS07	H226-336
Ethylbenzene	100-41-4	1.2	GHS02-GHS07-GHS08	H225-304-332-351-373

4. First-Aid Measures

FIRST AID - EYE CONTACT: Immediately flush eyes with plenty of water for at least 15 minutes holding eyelids open. Get medical attention. Do NOT allow rubbing of eyes or keeping eyes closed.

FIRST AID - SKIN CONTACT: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists.

FIRST AID - INHALATION: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get immediate medical attention. Do NOT use mouth-to-mouth resuscitation. If you experience difficulty in breathing, leave the area to obtain fresh air. If continued difficulty is experienced, get medical assistance immediately.

FIRST AID - INGESTION: Aspiration hazard: Do not induce vomiting or give anything by mouth because this material can enter the lungs and cause severe lung damage. Get immediate medical attention. If swallowed, get medical attention.

5. Fire-Fighting Measures

EXTINGUISHING MEDIA: Alcohol Film Forming Foam, Carbon Dioxide, Dry Chemical, Dry Sand, Water Fog

UNUSUAL FIRE AND EXPLOSION HAZARDS: FLASH POINT IS LESS THAN 20°F. EXTREMELY FLAMMABLE LIQUID AND VAPOR!Water spray may be ineffective. Closed containers may explode when exposed to extreme heat due to buildup of steam. Closed containers may explode when exposed to extreme heat. Vapors may form explosive mixtures with air. Vapors can travel to a source of ignition and flash back. Isolate from heat, electrical equipment, sparks and open flame. Perforation of the pressurized container may cause bursting of the can. No unusual fire or explosion hazards noted. Keep containers tightly closed.

SPECIAL FIREFIGHTING PROCEDURES: Full protective equipment including self-contained breathing apparatus should be used. Evacuate area and fight fire from a safe distance. Water may be used to cool closed containers to prevent pressure buildup and possible autoignition or explosion. Use water spray to keep fire-exposed containers cool. Containers may explode when heated.

Special Fire and Explosion Hazard (Combustible Dust): No Information

6. Accidental Release Measures

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: Contain spilled liquid with sand or earth. DO NOT use combustible materials such as sawdust. Isolate the hazard area and deny entry to unnecessary and unprotected personnel. Remove all sources of ignition, ventilate area and remove with inert absorbent and non-sparking tools. Dispose of according to local, state (provincial) and federal regulations. Do not incinerate closed containers. Ventilate area, isolate spilled material, and remove with inert absorbent. Dispose of contaminated absorbent, container, and unused contents in accordance with local, state, and federal regulations.

7. Handling and Storage

HANDLING: Wash thoroughly after handling. Wash hands before eating. Remove contaminated clothing and launder before reuse. Use only with adequate ventilation. Follow all SDS and label precautions even after container is emptied because it may retain product residues. Avoid breathing fumes, vapors, or mist. Avoid contact with eyes, skin and clothing.

STORAGE: Keep containers tightly closed. Isolate from heat, electrical equipment, sparks and open flame. Contents under pressure. Do not store above 120 ° F. Store large quantities in buildings designed and protected for storage of flammable aerosols. Product should be stored in tightly sealed containers and protected from heat, moisture, and foreign materials. Store in a dry, well ventilated place. Keep container tightly closed when not in use. Keep away from heat, sparks, flame and sources of ignition. Avoid excess heat.

Advice on Safe Handling of Combustible Dust: No Information

8. Exposure Controls / Personal Protection

Chemical Name	CAS-No.	Weight % Less Than	ACGIH TLV-TWA	ACGIH TLV-STEL	OSHA PEL-TWA	OSHA PEL-CEILING
Propane	74-98-6	20.0	N.E.	N.E.	1000 ppm	N.E.
Titanium Dioxide	13463-67-7	10.0	10 mg/m3	N.E.	15 mg/m3	N.E.
n-Butane	106-97-8	10.0	N.E.	1000 ppm	N.E.	N.E.
Naphtha, Petroleum, Hydrotreated Light	64742-49-0	10.0	N.E.	N.E.	N.E.	N.E.
Xylenes (o-, m-, p- isomers)	1330-20-7	10.0	100 ppm	150 ppm	100 ppm	N.E.
Hydrous Magnesium Silicate	14807-96-6	5.0	2 mg/m3	N.E.	N.E.	N.E.
n-Butyl Acetate	123-86-4	5.0	50 ppm	150 ppm	150 ppm	N.E.
Ethylbenzene	100-41-4	5.0	20 ppm	N.E.	100 ppm	N.E.

PERSONAL PROTECTION

ENGINEERING CONTROLS: Use explosion-proof ventilation equipment. Provide general dilution of local exhaust ventilation in volume and pattern to keep TLV of hazardous ingredients below acceptable limits. Prevent build-up of vapors by opening all doors and windows to achieve cross-ventilation. Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits.

RESPIRATORY PROTECTION: A respiratory protection program that meets OSHA 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. A NIOSH/MSHA approved air purifying respirator with organic vapor cartridge or canister may be permissible under certain circumstances where airborne concentrations are expected to exceed exposure limits.

SKIN PROTECTION: Use gloves to prevent prolonged skin contact. Nitrile or Neoprene gloves may afford adequate skin protection.

EYE PROTECTION: Use safety eyewear designed to protect against splash of liquids.

OTHER PROTECTIVE EQUIPMENT: Refer to safety supervisor or industrial hygienist for further guidance regarding types of personal protective equipment and their applications.

HYGIENIC PRACTICES: Wash thoroughly with soap and water before eating, drinking or smoking. Remove contaminated clothing immediately and launder before reuse.

Engineering Measures for Combustible Dust: No Information

9. Physical and Chemical Properties

Appearance:	Aerosolized Mist	**Physical State:**	Liquid
Odor:	Solvent Like	**Odor Threshold:**	N.E.
Relative Density:	0.883	**pH:**	N.D.
Freeze Point, °C:	N.D.	**Viscosity:**	N.D.
Solubility in Water:	Miscible	**Partition Coefficient, n-octanol/ water:**	N.D.
Decompostion Temp., °C:	N.D.		
Boiling Range, °C:	-37 - 537	**Explosive Limits, vol%:**	0.9 - 12.6
Flammability:	Supports Combustion	**Flash Point, °C:**	-96
Evaporation Rate:	Faster than Ether	**Auto-ignition Temp., °C:**	N.D.
Vapor Density:	Heavier than Air	**Vapor Pressure:**	N.D.

(See "Other information" Section for abbreviation legend)

10. Stability and Reactivity

CONDITIONS TO AVOID: Avoid temperatures above 120°F (49°C). Avoid all possible sources of ignition.

INCOMPATIBILITY: Incompatible with strong oxidizing agents, strong acids and strong alkalies.

HAZARDOUS DECOMPOSITION: By open flame, carbon monoxide and carbon dioxide. When heated to decomposition, it emits acrid smoke and irritating fumes. Contains solvents which may form carbon monoxide, carbon dioxide, and formaldehyde.

HAZARDOUS POLYMERIZATION: Will not occur under normal conditions.

STABILITY: This product is stable under normal storage conditions.

11. Toxicological Information

EFFECTS OF OVEREXPOSURE - EYE CONTACT: Causes Serious Eye Irritation

EFFECTS OF OVEREXPOSURE - SKIN CONTACT: May cause skin irritation. Allergic reactions are possible.

EFFECTS OF OVEREXPOSURE - INHALATION: High gas, vapor, mist or dust concentrations may be harmful if inhaled. High vapor concentrations are irritating to the eyes, nose, throat and lungs. Harmful if inhaled. Avoid breathing fumes, spray, vapors, or mist. Prolonged or excessive inhalation may cause respiratory tract irritation.

EFFECTS OF OVEREXPOSURE - INGESTION: Harmful if swallowed.

EFFECTS OF OVEREXPOSURE - CHRONIC HAZARDS: Overexposure to xylene in laboratory animals has been associated with liver abnormalities, kidney, lung, spleen, eye and blood damage as well as reproductive disorders. Effects in humans, due to chronic overexposure, have included liver, cardiac abnormalities and nervous system damage. IARC lists Ethylbenzene as a possible human carcinogen (group 2B). Contains Titanium Dioxide. Titanium Dioxide is listed as a Group 2B-"Possibly carcinogenic to humans" by IARC. No significant exposure to Titanium Dioxide is thought to occur during the use of products in which Titanium Dioxide is bound to other materials, such as in paints during brush application or drying. Risk of overexposure depends on duration and level of exposure to dust from repeated sanding of surfaces or spray mist and the actual concentration of Titanium Dioxide in the formula. (Ref: IARC Monograph, Vol. 93, 2010)May cause central nervous system disorder (e.g., narcosis involving a loss of coordination, weakness, fatigue, mental confusion, and blurred vision) and/or damage. Reports have associated repeated and prolonged occupational overexposure to solvents with permanent brain and nervous system damage. High concentrations may lead to central nervous system effects (drowsiness, dizziness, nausea, headaches, paralysis, and blurred vision) and/or damage.

PRIMARY ROUTE(S) OF ENTRY: Eye Contact, Ingestion, Inhalation, Skin Absorption, Skin Contact

ACUTE TOXICITY VALUES

The acute effects of this product have not been tested. Data on individual components are tabulated below:

CAS-No.	Chemical Name	Oral LD50	Dermal LD50	Vapor LC50
13463-67-7	Titanium Dioxide	>10000 mg/kg Rat	2500 mg/kg	N.E.
106-97-8	n-Butane	N.E.	N.E.	658 mg/L Rat
64742-49-0	Naphtha, Petroleum, Hydrotreated Light	>5000 mg/kg Rat	>3160 mg/kg Rabbit	>4951 mg/L Rat
1330-20-7	Xylenes (o-, m-, p- isomers)	3500 mg/kg Rat	>4350 mg/kg Rabbit	29.08 mg/L Rat
14807-96-6	Hydrous Magnesium Silicate	6000	N.E.	30
123-86-4	n-Butyl Acetate	10768 mg/kg Rat	>17600 mg/kg Rabbit	> 21 mg/L Rat
100-41-4	Ethylbenzene	3500 mg/kg Rat	15400 mg/kg Rabbit	17.4 mg/L Rat

N.E. - Not Established

12. Ecological Information

ECOLOGICAL INFORMATION: Product is a mixture of listed components.

13. Disposal Information

DISPOSAL INFORMATION: Do not incinerate closed containers. This product as supplied is a USEPA defined ignitable hazardous waste. Dispose of unusable product as a hazardous waste (D001) in accordance with local, state, and federal regulation.

14. Transport Information

	Domestic (USDOT)	International (IMDG)	Air (IATA)	TDG (Canada)
UN Number:	N.A.	1950	1950	N.A.
Proper Shipping Name:	Paint Products in Limited Quantities	Aerosols	Aerosols	Paint Products in Limited Quantities
Hazard Class:	N.A.	2.1	2.1	N.A.
Packing Group:	N.A.	N.A.	N.A.	N.A.
Limited Quantity:	Yes	Yes	Yes	Yes

15. Regulatory Information

U.S. Federal Regulations:

CERCLA - SARA Hazard Category

This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

Gas under pressure, Carcinogenicity, Specific target organ toxicity (single or repeated exposure)

Sara Section 313:

This product contains the following substances subject to the reporting requirements of Section 313 of Title III of the Superfund Amendment and Reauthorization Act of 1986 and 40 CFR part 372:

Chemical Name	CAS-No.
Xylenes (o-, m-, p- isomers)	1330-20-7
Ethylbenzene	100-41-4

Toxic Substances Control Act:

This product contains the following chemical substances subject to the reporting requirements of TSCA 12(b) if exported from the United States:

Chemical Name	CAS-No.
Castor oil, sulfated, sodium salt	68187-76-8

16. Other Information

HMIS RATINGS

Health:	2*	**Flammability:**	4	**Physical Hazard:**	0	**Personal Protection:**	X

NFPA RATINGS

Health:	2	**Flammability:**	4	**Instability**	0

Volatile Organic Compounds 532 g/L

SDS REVISION DATE: 8/17/2018

REASON FOR REVISION:

Legend: N.A. - Not Applicable, N.E. - Not Established, N.D. - Not Determined

The manufacturer believes, to the best of its knowledge, information and belief, the information contained herein to be accurate and reliable as of the date of this safety data sheet. However, because the conditions of handling, use, and storage of these materials are beyond our control, we assume no responsibility or liability for personal injury or property damage incurred by the use of these materials. The manufacturer makes no warranty, expressed or implied, regarding the accuracy or reliability of the data or results obtained from their use. All materials may present unknown hazards and should be used with caution. The information and recommendations in this material safety data sheet are offered for the users' consideration and examination. It is the responsibility of the user to determine the final suitability of this information and to comply with all applicable international, federal, state, and local laws and regulations.

APPENDIX F
Jobsite Safety Inspection Checklist

Job Safety Inspection Checklist
Health & Safety

LANGAN

Document #: HSE-HASP-JSIC-FRM-01	Version #: 01

Date: _____ **Inspected By:** _____

Location: _____ **Project #:** _____

Check one of the following: **A:** Acceptable **NA**: Not Applicable **D**: Deficiency

	A	NA	D	Remarks
1. HASP available on site for inspection?				
2. Health & Safety Compliance agreement (in HASP) appropriately signed by Langan employees and subcontractors?				
3. Hospital route map with directions posted on site?				
4. Emergency Notification List posted on site?				
5. First Aid kit available and properly stocked?				
6. Personnel trained in CPR/First Aid on site?				
7. SDSs readily available, and all workers knowledgeable about the specific chemicals and compounds to which they may be exposed?				
8. Appropriate PPE being worn by Langan employees and subcontractors?				
9. Project site safe practices ("Standing Orders") posted?				
10. Project staff have 40-hr./8-hr./Supervisor HAZWOPER training?				
11. Project staff medically cleared to work in hazardous waste sites and fit-tested to wear respirators, if needed?				
12. Respiratory protection readily available?				
13. Health & Safety Incident Report forms available?				
14. Air monitoring instruments calibrated daily and results recorded on the Daily Instrument Calibration check sheet?				
15. Air monitoring readings recorded on the air monitoring data sheet/field log book?				
16. Subcontract workers have received 40-hr./8-hr./Spvsr. HAZWOPER training, as appropriate?				
17. Subcontract workers medically cleared to work on site, and fit-tested for respirator wear?				
18. Subcontract workers have respirators readily available?				
19. Markouts of underground utilities done prior to initiating any subsurface activities?				

20. Decontamination procedures being followed as outlined in HASP?				
21. Are tools in good condition and properly used?				
22. Drilling performed in areas free from underground objects including utilities?				
23. Adequate size/type fire extinguisher supplied?				
24. Equipment at least 20 feet from overhead powerlines?				
25. Evidence that drilling operator is responsible for the safety of his rig.				
26. Trench sides shored, layed back, or boxed?				
27. Underground utilities located and authorities contacted before digging?				
28. Ladders in trench (25-foot spacing)?				
29. Excavated material placed more than 2 feet away from excavation edge?				
30. Public protected from exposure to open excavation?				
31. People entering the excavation regarding it as a permit-required confined space and following appropriate procedures?				
32. Confined space entry permit is completed and posted?				
33. All persons knowledgable about the conditions and characteristics of the confined space?				
34. All persons engaged in confined space operations have been trained in safe entry and rescue (non-entry)?				
35. Full body harnesses, lifelines, and hoisting apparatus available for rescue needs?				
36. Attendant and/or supervisor certified in basic first aid and CPR?				
37. Confined space atmosphere checked before entry and continuously while the work is going on?				
38. Results of confined space atmosphere testing recorded?				
39. Evidence of coordination with off-site rescue services to perform entry rescue, if needed?				
40. Are extension cords rated for this work being used and are they properly maintained?				
41. Are GFCIs provided and being used?				

Unsafe Acts:

Notes:

APPENDIX G
Job Safety Analysis (JSA)

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: Travel
JSA Number: 250079922

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions.

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☐ Safety Boots	☐ Long Sleeves	☐ Safety Vest (Class 2)	☐ Hard Hat	☐ Hearing Protection
☐ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☐ Nitrile Gloves	☐ PVC Gloves
☐ Task Specific Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☒ Traffic Cones or Signs	☐ Life Vest/Jacket	☐ Impact Gloves
☒ Other: Seat belt fastened, Journy Management Plan (JMP)				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Vehicle Inspection prior to departing to Site	1. Slip, Trip, Fall 2. Hitting Obstructions, unseen objects 3. Vehicle start: Rotating parts, belts, dashboard light indicators 4. Opening and closing Vehicle doors	1. Maintain three points of contact. Do not carry anything when entering vehicle. Loade equipment/bags/gear into vehicle first 2. Perform a 360º vehicle walk around to identify any hazards/objects in vehicle vicinity. Identify safest way to depart. Inspect vehicle for any damage that occurred on vehicle while not in motion. 3. Listen to engine when starting vehcile, make sure radio is off to listen to engine/belts. Note if any dashboard indicator lights indicate a vehicular issue 4. Check to make sure fingers, other body parts, or equipment are not between door/tailgate and frame before closing 5. Fill out Vehicle Inspection Form
2. Driving Vehicle	1. Backing up 2. Driving 3. Wildlife	1. Use a spotter to back up if available. Only back up if first forward motion is not a possibility. If backing up, honk horn prior to backing up 2. Drive defensive and abide by all laws and Life-Saving Rules. Let aggressive drivers pass, do not respond to hostile drivers/road rage, pass with caution. 3. No alcohol or drugs while driving. 4. No use of hands free devices or using cell phones. 5. Follow JMP 6. Watch for wildlife signs. Reduce speed when wildlife is nearby. Avoid swerving into stationary items or oncoming traffic.
3. Weather	1. Inclement Weather	1. Check for inclement weather prior to travel. Have appropriate wiper fluid, anitfreeze, salt, sand etc. as needed. Take alternate route if necessary

JSA Title: Travel
JSA Number: 270075501

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
4. Parking	1. Parking Vehicle	1. Park so when departing on next trip the first motion is forward. Use a spotter if one is available.
5. All actvities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear task specific gloves 3. Wear Langan approved safety boots 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Life Saving Rules	Applicable to the task	
Additional Items identified while in the field.		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN	Job Safety Analysis (JSA) Health and Safety
JSA Title: Direct-Push Soil Borings **JSA Number:** JSA004-01 **A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.**	 S – Stop, what has changed? T – Think about the task E – Evaluate potential hazards P – Plan safe approach S - Start task / Stop & regroup

PERSONAL PROTECTIVE EQUIPMENT REQUIRED:				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☒ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☒ Other: Half-face respirator, dust cartridges, PID (if applicable)				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Move equipment to work site	1. Back strain when lifting equipment 2. Slips/ Trips/ Falls while moving equipment 3. Traffic (if applicable) 4. Pinched fingers or running over toes during geoprobe set-up 5. Overturn drilling rig while transporting to loading dock on flat-bed tow truck	1. Use proper lifting technique (use legs for bending and lifting and not the back)/ Use wheeled transport for heavy equipment / Get assistance when handling loads greater than 50 lbs. / Minimize distance to vehicle 2. Use proper lifting technique (use legs for bending and lifting and not the back) / Use wheeled transport for heavy equipment / Get assistance when handling loads greater than 50 lbs. / Minimize distance to vehicle / Have unobstructed path to vehicle or collection point / Do not lift/walk with boxes that are heavy/difficult to lift 3. Wear high visibility safety vests or clothing / Exercise caution 4. Wear proper PPE (cut-resistant gloves) / Stay alert, be aware of geoprobe rig at all times 5. Drill rig should be parked in center of flat-bed tow truck / Emergency brake shall be used at all times during transport on the flat-bed truck/ All unnecessary personnel should stay away from the flat-bed truck during moving activities
2. Calibration of monitoring equipment	1. Skin or eye contact with calibration chemicals 2. Pinch fingers in monitoring equipment	1. Wear proper PPE (safety glasses/ goggles) 2. Wear proper PPE (leather gloves)
3. Set-up geoprobe rig	1. Geoprobe rig movement	1. All field personnel should stay clear of the geoprobe rig while moving / Use a spotter when backing up the geoprobe
4. Advance geoprobe rods below ground surface to desired depth	1. Underground utilities 2. High noise levels	1. Clean all subsurface soil borings to a minimum of 5 feet below grade 2. Wear proper PPE (hearing protection)
5. Remove and open acetate liner	1. Pinched fingers while removing macrocore 2. Cuts/lacerations when cutting acetate liner open	1. Wear proper PPE (nitrile gloves, cut-resistant or leather gloves 2. Wear proper PPE (cut-resistant or leather gloves)

JSA Title: Direct-Push Soil Borings
JSA Number: JSA004-01

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
	3. Exposure to hazardous vapors	3. Do not place face over acetate liner when opening / Monitor hazardous vapors in air with PID / Upgrade PPE as necessary based on levels contained in the Health and Safety Plan
5. Remove and open acetate liner (cont'd)	4. Skin contact with contaminated soil	4. Wear proper PPE (nitrile gloves)
6. Sample Collections a) Monitor parameters b) Prepare sample containers and labels	1. Contact with potentially contaminated soil 2. Lacerations from broken sample bottles 3. Back strain while transporting full coolers 4. Internal exposure to contaminants and metals through inhalation of dust 5. Slips/ Trips/ Falls	1. Use monitoring devices / Wear proper PPE (safety glasses, nitrile gloves) 2. Do not over-tighten bottle caps / Handle bottles safely to prevent breakage 3. Use proper lifting techniques / Do not lift heavy loads without assistance 4. Avoid creating dust / If necessary, wear a half mask respirator with applicable dust cartridge / Inspect respirator for damage and cleanliness prior to use / Clean respirator after each use and store in a clean, secure location 5. Be alert / Follow good housekeeping procedures
7. Remove excess soil from acetate liner and place in 55-gallon drum (IF NOT PERFORMED BY LANGAN, REMOVE!)	1. Cuts/lacerations from acetate liner 2. Pinched fingers/hand while opening/closing drum 3. Skin contact with contaminated soil 4. Soil debris in eyes	1. Wear proper PPE (cut-resistant or leather gloves) 2. Wear proper PPE (cut-resistant or leather gloves) 3. Wear proper PPE (nitrile gloves) 4. Wear proper PPE (safety glasses)
8. Transport drums to central staging location (IF NOT PERFORMED BY LANGAN, REMOVE!)	1. Back, arm or shoulder strain from moving drums 2. Pinch fingers/hand in drum cart when moving drums 3. Pinch fingers/hand when operating lift-gate on vehicle 4. Contact with potentially contaminated groundwater when moving improperly sealed drums 5. Slips when moving drums 6. Drop drum on feet/toes	1. Use drum cart for moving drums / Use proper lifting techniques / Do not lift heavy loads without assistance 2. Wear proper PPE (cut-resistant or leather gloves) 3. Wear proper PPE (cut-resistant or leather gloves) 4. Wear proper PPE (nitrile gloves underneath work gloves) 5. Follow good housekeeping procedures / Ensure route to move drum and storage space is free from obstructions 6. Wear proper PPE (safety shoes) / Work in a safe manner to prevent dropped drum
9. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection

JSA Title: Direct-Push Soil Borings
JSA Number: JSA004-01

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
9. All activities (cont'd)	8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Drilling**
JSA Number: **JSA014-01**

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.



S – ***Stop,*** *what has changed?*
T – ***Think*** *about the task*
E – ***Evaluate*** *potential hazards*
P – ***Plan*** *safe approach*
S - ***Start*** *task /* ***Stop*** *& regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☒ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☒ Other: NomeX (as needed)				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Transport equipment to work area	1. Back Strain 2. Slips/ Trips/ Falls 3. Traffic 4. Cuts/abrasions from equipment 5. Contusions from dropped equipment	1. Use proper lifting techniuqes / Use wheeled transport 2. Minimize distance to work area / Have unobstructed path to work area / Follow good housekeeping procedures 3. Wear proper PPE (high visibility vest or clothing) 4. Wear proper PPE (leather gloves, long sleeves) 5. Wear proper PPE (safety shoes)
2. Set-up HSA/SPT rig	1. Slips/ Trips/ Falls 2. Pinch Hazards 3. High noise levels 4. Clothing entanglement 5. Electrocution/falling equipment and debris from raising HSA/SPT rig mast 6. Carbon monoxide poisoning 7. HSA/SPT rig roll-over 8. HSA/SPT rig movement	1. Be aware of potential trip hazards / Follow good housekeeping procedures / Mark significant below-grade hazards (i.e. holes, trenches) with safety cones or spray paint 2. Wear proper PPE (leather gloves) 3. Wear proper PPE (hearing protection) 4. Wear proper attire for HSA/SPT rig (no loose clothing, strings, etc.) 5. Wear proper PPE (hard hats) / Be aware of locations at all times / Look up, down and around before raising mast / Check HSA/SPT drill rig mast for loose objects/debris before rasining 6. Stand upwind of rig engine 7. Do not move rig with mast raisied / Set stabilizers prior to raising mast / Inspect work area / If area appears unstable, the boring locations should be moved. 8. All field personnel should stay clear of rig while moving / Use a spotter when backing up the rig
3. Advance HSA/SPT rods, augers and casing below ground surface	1. Strain wrist/bruise palm 2. Pinched fingers 3. Back strain	1. Wear proper PPE (leather gloves) / Use proper technique for preparing rods / Use second person, if necessary 2. Wear proper PPE (leather gloves)

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
4. Advance HSA/SPT rods, augers and casing below ground surface (cont'd)	4. Clothing entanglement 5. Carbon monoxide poisoning 6. Bruised/Broken toes/feet 7. High noise levels	3. Use proper lifting techniques / Obtain assistance if needed 4. Wear proper attire for HSA/SPT rig (no loose clothing, strings, etc.) 5. Stand upwind of the rig 6. Wear proper PPE (safety shoes) 7. Wear proper PPE (hearing protection)
5. Remove and open split spoon	1. Pinched fingers 2. Cuts/lacerations 3. Skin contact with contaminated soil and groundwater	1. Wear proper PPE (nitrile and leather gloves) 2. Wear proper PPE (leather gloves) 3. Wear proper PPE (nitrile gloves, safety glasses)
6. Repeat steps 3 and 4 until desired depth is reached	1. See steps 3 and 4	1. See steps 3 and 4
7. Remove HSA/SPT rods, augers and casing and place in storage rack	1. Clothing entanglement 2. Back strain 3. Pinched fingers 4. Carbon monoxide poisoning 5. High noise levels	1. Wear proper attire for HSA/SPT rig (no loose clothing, strings, etc.) 2. Use proper lifting techniques / Obtain assistance if needed 3. Wear proper PPE (leather gloves) 4. Stand upwind of rig engine 5. Wear proper PPE (hearing protection)
8. Tremie-grout borehole with a cement-bentonite grout mixture	1. Splash cement/bentonite grout on face/eyes 2. Back strain 3. Pinched fingers	1. Wear proper PPE (safety glasses) 2. Use proper lifting techniques / Obtain assistance if needed 3. Wear proper PPE (nitrile gloves, leather gloves)
9. Decontaminate equipment	1. Contact with potentially impacted material 2. Contact with sharp pieces of equipment	1. Wear proper PPE (safety glasses, nitrile gloves) 2. Wear proper PPE (leather gloves)
10. Patch soil boring location to return to pre-existing conditions (i.e. concrete, asphalt, grass)	1. Cuts/lacerations 2. Splashed concrete on face/eyes 3. Hammer fingers/hands when patching asphalt	1. Wear proper PPE (leather gloves) / Use scissors for cutting 2. Use proper PPE (safety glasses) 3. Be aware of hands/fingers during hammering / Wear proper PPE (leather gloves)
11. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
		dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN	Job Safety Analysis (JSA) Health and Safety
JSA Title: Environmental Sampling **JSA Number:** JSA021-01 **A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.**	 **S** – ***Stop,*** *what has changed?* **T** – ***Think*** *about the task* **E** – ***Evaluate*** *potential hazards* **P** – ***Plan*** *safe approach* **S** - ***Start*** *task / **Stop** & regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☐ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☐ Leather Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☒ Fire Resistant Clothing	☐ Rubber Boots
☒ Insect/Animal Repellent	☒ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☒ Other: Tyvek Sleeves				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Drive to sample location	1. Rough/Off Road terrain	1. Pay attention to road conditions such as road erosion, unprotected embankments, and soft road conditions.
2. Sample Collection (Walking)	1. Slip/Trips/Falls 2. Back strains 3. Wildlife (Insects, Stray animals, rodents) 4. Poisonous vegetation	1. Minimize distance to sample area/ Plan route and check surface prior to carrying heavy equipment/ Locate safest access point/ Follow good housekeeping procedures/ Mark significant below grade hazards (holes, trenches) with spray paint or cones/ Wear foot protection with ankle support and gripping soles. 2. Use proper lifting techniques/ Use wheeled transport/ Obtain assistance where and when needed/ Consider load weight when evaluating what is safe and unsafe to carry. 3. Be aware of surroundings for the presence of wildlife/ Do not approach stray animals/ Carry and use animal repellant when needed/ Use bug spray when needed. 4. Keep skin covered/ Identify and avoid poisonous vegetation/ Clean areas after contact with suspected vegetation.
3. Sample Collection (Water)	1. Drowning Hazards 2. Chemical burns (when adding acid preservative to sample) 3. Back Strains 4. Ergonomic issues 5. Slip/Trips/Falls	1. Use buddy system/ Wear flotation vest if water is deeper than 2 feet or swift moving/ Select working area with stable footing/ Do not attempt to cross or stand in swift moving water. 2. Wear proper PPE (Nitrile gloves, Tyvek Sleeves) 3. Use proper lifting techniques/ Use wheeled transport/ Obtain assistance where and when needed/ Consider load weight when evaluating what is safe or unsafe to carry. 4. When possible avoid bending over for long periods of time/ Use a small

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
		stool for sitting or knee pad for kneeling. 5. Minimize distance to sample area/ Plan route and check surface prior to carrying heavy equipment/ Locate safest access point/ Follow good housekeeping procedures/ Mark significant below grade hazards (holes, trenches) with spray paint or cones/ Wear foot protection with ankle support and gripping soles/ Avoid standing water or slippery terrain.
4. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: Equipment Transportation and Set-up
JSA Number: JSA012-01

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.



S – ***Stop,*** *what has changed?*
T – ***Think*** *about the task*
E – ***Evaluate*** *potential hazards*
P – ***Plan*** *safe approach*
S - ***Start*** *task /* ***Stop*** *& regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☐ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☐ Other:				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Transport equipment to work area	1. Back Strain 2. Slips/ Trips/ Falls 3. Traffic 4. Cuts/abrasions from equipment 5. Contusions from dropped equipment	1. Use proper lifting techniuqes / Use wheeled transport 2. Minimize distance to work area / Have unobstructed path to work area / Follow good housekeeping procedures 3. Wear proper PPE (high visibility vest or clothing) 4. Wear proper PPE (leather gloves, long sleeves) 5. Wear proper PPE (safety shoes)
2. Moving equipment to its planned location	1. Pinch Hazard 2. Slips/ Trips/ Falls	1. Wear proper PPE (leather gloves) 2. Be aware of potential trip hazards / Practice good housekeeping procedures / Mark significant below-grade hazards (i.e. holes, trenches) with safety cones or spray paint
3. Equipment Set-up	1. Pinch Hazard 2. Cuts/abrasions to knuckles/hands 3. Back Strain	1. Wear proper PPE (leather gloves) 2. Wear proper PPE (leather gloves) 3. Use proper lifting techniques / Use wheeled transport
4. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area

JSA Title: Equipment Transportation and Set-Up
JSA Number: JSA012-01

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
4. All activities (cont'd)	10. Eye Injuries	6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Electric Resistivity (ER) Imaging and Marine Magnetometer (MAG) Surveys**

JSA Number:

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions.

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☐ Hard Hat	☐ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☐ Nitrile Gloves	☐ PVC Gloves
☐ Leather Gloves	☒ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☒ Life Vest/Jacket	
☐ Other:				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Marine Magnetic Survey	1. Muscles strains from weight of Deep Cycle battery 2. Eletrical Shock from battery	1. Use proper lifting techniques when picking up battery; lift with the knees 2. Place plastic protectors over the leads until use during the survey; watch hand placement when protectors are removed; immediately replace plastic protectors when the battery is not being used
2. Electric Resistivity Survey	1. Electrical shock from battery 2. Muscles straings from setting and picking up ER cables	1. Place plastic protectors over the leads until use during the survey; watch hand placement when protectors are removed; immediately replace plastic protectors when the battery is not being used 2. Use proper lifting techniques when picking up battery; lift with the knees
3. Boat hazards	1. Over board	1. Don personal flotation device; be aware of surroundings, edges of the boat, and trip hazards; if fallen overboard, remain calm and tread water until boat has returned to your location
4. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear proper PPE (Langan approved safety shoes) 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection

JSA Title: ER and Mag Surveys
JSA Number:

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
		8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Field Sampling**
JSA Number: **JSA022-01**

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.



S – ***Stop,*** *what has changed?*
T – ***Think*** *about the task*
E – ***Evaluate*** *potential hazards*
P – ***Plan*** *safe approach*
S - ***Start*** *task /* ***Stop*** *& regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☐ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☒ Traffic Cones/Signs	☐ Life Vest/Jacket	
☐ Other:				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1.	1. Back Strains 2. Slip/Trips/Falls 3. Cuts/Abrasions from equipment 4. Contusions from dropped equipment	1. Use proper lifting techniques/Use wheeled transport 2. Minimize distance to work area/Unobstructed path to work area/follow good housekeeping procedures. Mark slip/trip/fall hazards with orange safety cones. 3. Wear proper PPE (leather gloves, long sleeves). 4. Wear proper PPE (Langan approved safety shoes).
2. Initial Site Arrival-Site Assessment	1. Traffic	1. Situational awareness (be alert of your surroundings). Secure area from through traffic.
3. Surface Water Sampling	1. Contaminated media. Skin/eye contact with biological agents and/or chemicals.	1. Wear appropriate PPE (Safety glasses, appropriate gloves). Review (M)SDS for all chemicals being.
4. Sampling from bridges	1. Struck by vehicles	1. Wear appropriate PPE (Safety Vest). Use buddy system and orange safety cones.
5. Icing of Samples/ Transporting coolers/equipment from work area.	1. Back Strains 2. Slips/Trips/Falls 3. Cuts/Abrasions from equipment 4. Pinch/Crushing Hazards.	1. Drain coolers of water. Use proper lifting techniques. Use wheeled transport. 2. Have unobstructed path from work area. Aware of surroundings. 3. Wear proper PPE (Leather gloves, long sleeves) 4. Wear proper PPE (Leather gloves, long sleeves)
6. Site Departure	1. Contaminated PPE/Vehicle	1. Contaminated PPE should be disposed of on-site. Remove boots and soiled clothing for secure storage in trunk. Wash hands promptly.
7. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
	4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: General Construction Activities
JSA Number: JSA010-01

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.



S – ***Stop,*** *what has changed?*
T – ***Think*** *about the task*
E – ***Evaluate*** *potential hazards*
P – ***Plan*** *safe approach*
S - ***Start*** *task /* ***Stop*** *& regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☒ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☒ Traffic Cones/Signs	☐ Life Vest/Jacket	
☐ Other:				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Transport equipment to work area	1. Back Strain 2. Slips/ Trips/ Falls 3. Traffic 4. Cuts/abrasions from equipment 5. Contusions from dropped equipment	1. Use proper lifting techniuqes / Use wheeled transport 2. Minimize distance to work area / Have unobstructed path to work area / Follow good housekeeping procedures 3. Wear proper PPE (high visibility vest or clothing) 4. Wear proper PPE (leather gloves, long sleeves) 5. Wear proper PPE (safety shoes)
2. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid

JSA Title: General Construction Activities
JSA Number: JSA010-01

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
		dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		

Print Name	Sign Name	Date
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Groundwater Sampling**
JSA Number: **JSA008-01**

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.



S – ***Stop,*** *what has changed?*
T – ***Think*** *about the task*
E – ***Evaluate*** *potential hazards*
P – ***Plan*** *safe approach*
S - ***Start*** *task /* ***Stop*** *& regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☐ Cut Resist. Gloves	☒ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☒ Other: Tyvek sleeves, Dermal Protection, PID				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Transport equipment to work area	1. Back Strain 2. Slips/ Trips/ Falls 3. Traffic 4. Cuts/abrasions from equipment 5. Contusions from dropped equipment	1. Use proper lifting techniuqes / Use wheeled transport 2. Minimize distance to work area / Have unobstructed path to work area / Follow good housekeeping procedures 3. Wear proper PPE (high visibility vest or clothing) 4. Wear proper PPE (leather gloves, long sleeves) 5. Wear proper PPE (safety shoes)
2. Remove well cover	1. Scrape knuckles/hand 2. Strain wrist/bruise plam 3. Pinch fingers or hand	1. Wear proper PPE (leather gloves) 2. Using a hammer, tap the end of the wrench to loosen grip of bolts 3. Wear proper PPE (leather gloves)
3. Remove well cap and lock	1. Well can pops from pressure 2. Exposure to hazardous substances through inhalation or dermal exposure 3. Scrape knuckles/hand 4. Strain write/bruise palm	1. Remove cap slowly to relieve pressure / Do not place face over well when opening / Wear proper PPE (safety glasses) 2. Use direct air monitoring/reading instrument (i.e. PID) / Be familiar with and follow actions prescribed in the HASP / Wear proper PPE (nitrile gloves) 3. Wear proper PPE (leather gloves) 4. Using hammer, tap the end of the wrench to loosen grip
4. Measure head-space vapor levels	1. Exposure to hazardous substances through inhalation	1. Do not place face over well when collecting measurement
5. Remove deciated tubing (if necessary)	1. Exposure to hazardous substances through inhalation or dermal exposure 2. Tubing swings around after removal	1. Wear proper PPE (nitrile gloves, Tyvek sleeves) 2. Wear proper PPE (safety glasses)
6. Set-up plastic sheeting for work site around the well	1. Lacerations when cutting plastic sheeting	1. Use scissors to cut plastic sheeting / Cut motions should always be away from body and body parts

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
7. Measure depth to water	1. Exposure to hazardous substances through inhalation or dermal exposure 2. Pinch fingers or hand in water level instrument	1. Wear proper PPE (nitrile gloves) 2. Wear proper PPE (leather gloves)
8. Calibrate monitoring equipment	1. Skin or eye contact with calibration chemicals 2. Pinch fingers or hand in monitoring equipment	1. Wear proper PPE (safety glasses, nitrile gloves) 2. Wear proper PPE (leather gloves) / Avoid pinch points
9. Install sampling pump in well	1. Hand injuries during installation of pump 2. Lacerations when cutting tubing 3. Back strain during installation of pump 4. Physical hazards associated with manual lifting of heavy equipment 5. Back strain from starting generator 6. Burns from hot exhaust from generator 7. Electrical shock from improper use of generator and pump 8. Contaminated water spray from loose connections	1. Wear proper PPE (leather gloves, nitrile gloves) 2. Use safey tubing cutter 3. Use proper lifting techniques 4. Use proper lifting techniques / Use wheeled transport for heavy equipment 5. Use arm when starting generator / Do not over-strain if generator does not start 6. Do not touch generator near exhaust / Use proper handle to carry / Allow generator to cool down before moving 7. Properly plug in pump to generator / Do not allow the pump or generator to contact water / Check for breaks in the cord 8. Check all tubing connections to ensure they are tight and secure
10. Purge water	1. Contact with potentially contamined groundwater 2. Back strain from lifting buckets of water 3. Tripping potential on sample discharge lines and pump electric line	1. Wear proper PPE (safety glasses, nitrile gloves) 2. Use proper lifting techniques / Use wheeled transport 3. Organize discharge of electric line to keep out of way as much as possible / Mark potential tripping hazards with caution tape or safety cones
11. Sample water collection	1. Contact with potentially contaminated groundwater through dermal exposure 2. Contact with and burns from acid used for sample preservation 3. Tripping potential on sample discharge lines and pump electric line 4. Lacerations from broken sample bottles 5. Back strain when transporting coolers full of collected samples 6. Slips/ Trips/ Falls	1. Wear proper PPE (safety glasses, nitrile gloves) 2. Wear proper PPE (safety glasses, nitrile gloves) / Ensure sample bottle lids are secure before use and after sample collection 3. Organize line to keep out of the way as much as possible / Mark potential tripping hazards with caution tape or safety cones 4. Do not over-tighten bottle caps / Handle bottles safely to prevent breakage / Wrap glass bottles in bubble wrap, if possible 5. Use proper lifting techniques / Use wheeled transport / Seek assistance if coolers weight exceeds 50lbs. / Minimize distance to vehicle 6. Have unobstructed path to vehicle or collection point / Follow good housekeeping procedures / Do not lift/walk with coolers that are too heavy/difficult to lift
12. Remove pump and pack up equipment	1. Back strain when removing pump or lifting heavy equipment	1. Use proper lifting technique / Use wheeled transport for heavy equipment
13. Replace well cap and lock	1. Scrape fingers/hand 2. Strain wrist/bruise palm	1. Wear proper PPE (leather gloves) 2. Using hammer, tap the end of the well cap to tighten grip
14. Replace well cover	1. Scrape knuckles/hand 2. Strain write/bruise palm 3. Pinch fingers or hand	1. Wear proper PPE (leather gloves) 2. Using hammer, tap the end of the wrench to tighten the grip of the bolts 3. Wear proper PPE (leather gloves)
15. Transport drums to disposal staging location	1. Back, arm or shoulder strain from moving drums 2. Pinch hazard 3. Contact with potentially contaminated groundwater when moving improperly sealed	1. Use drum cart for moving drums / Use proper lifting techniques / Obtain assistance, if needed 2. Wear proper PPE (leather gloves) 3. Wear proper PPE (nitrile gloves under leather gloves) / Properly seal drum to prevent leak

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
	drums 4. Slips/ Trips/ Falls when moving drum 5. Drop drum on feet/toes	4. Ensure route to move drum to storage space is dry and free from obstructions 5. Wear proper PPE (safety shoes)
16. Place used PPE in designated dispoal drum	1. Pressure build-up inside drum 2. Pinch hazard	1. Remove cap from bung hole in drum to relieve pressure 2. Wear proper PPE (leather gloves)
17. Decontaminate equipment	1. Splashing water/soap from decontamination 2. Contact with potentially contaminated groundwater through dermal exposure 3. Electrical shock from broken electric cords	1. Wear proper PPE (safety glasses) 2. Wear proper PPE (safety glasses, dermal protection) 3. Properly plug in pump to generator / Do not allow the pump or generator to contact water / Check for breaks in the cord
18. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

JSA Title: Groundwater Sampling
JSA Number: JSA008-01

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION

Print Name	Sign Name	Date
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Logging Soil / Soil Sampling**

JSA Number:

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions.

PERSONAL PROTECTIVE EQUIPMENT REQUIRED:				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☒ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☒ Traffic Cones/Signs	☐ Life Vest/Jacket	
☒ Other: H2S meter, Half-face respirator, dust meter, PID (if applicable)				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Unpack equipment	1. Slips/ Trips/ Falls 2. Physical hazards including strains and hand injury	1. Be aware of hazards in area/ Place safety cones in areas of potential slips/trips/falls 2. Use proper lifting techniques / Do not lift heavy loads without assitance / Avoid putting hands near pinch points / Wear proper PPE (leather gloves)
2. Calibration of monitoring equipment	1. Skin or eye contact with calibration chemicals 2. Pinch fingers in monitoring equipment	1. Wear proper PPE (safety glasses/ goggles) 2. Wear proper PPE (leather gloves/ cut resistant gloves)
3. Mobilizing Geoprobe/rig to sample location	1.Contact with overhead lines 2.Contact with underground utilities	1. Stay clear (10 ft min.) of all overhead lines 2. Perform one call a minimum of 3 business days prior to breaking ground 3. Consult all onsite as-built figures 4. Use geophysics if necessary
4. Advancing Geoprobe	1. Physical hazards 2. Pinch points	1. Ensure geoprobe will not break ground on top of an underground utility 2. Stay clear of geoprobe.
5. Sample collections a) Monitor parameters b) Prepare sample containers and labels c) Collect soil sample d) Securely cap containers, label and store in sample cooler until shipping e) Deliver cooler to lab or courier to lab	1. Contact with potentially contaminated soil 2. Lacerations from broken sample bottles 3. Back strain with transporting coolers 4. Internal exposure to contaminants through inhalation of dust 5. Slips/ Trips/ Falls	1. Use monitoring devices / Wear proper PPE (safety glasses, nitrile gloves) 2. Log soil in cores in half-foot increments (0.5 ft) into field book. 3. For headspace readings, place 0.5 ft of soil increments into labeled zip-lock bags. After sufficient time for volatilization (10-15 mings), insert the PID probe into the bag and record the maximum headspace recording. Sample collection should not come from headspace readings. *If sampling for VOCs, the Terracore or Encore must be collected from the undisturbed sample core. 4. Do not over-tighten bottles caps / Handle bottles safety to prevent breakage 5. Use proper lifting techniques / Do not lift heavy loads without assistance 6. Avoid creating dust / If necessary, wear a half-face respirator with applicable dust cartridges / Inspect respirator for damage and cleanliness prior to use / Clean respirator after each use and store in a clean, secure location 7. Be alert / Follow good housekeeping procedures

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
		8. Follow COC standard procedures
6. Decontamination of equipment	1. Splashing water/soap from decontamination 2. Contact with potentially contaminated soil	1. Wear proper PPE (safety glasses, gloves) 2. Wear proper PPE (safety glasses, gloves)
7. All activities 6. All activities (cont'd)	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Monitoring Well Development**
JSA Number: **JSA026-01**

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions. Prior to the start of any work "TAKE 5" and conduct a Last Minute Risk Assessment.



S – ***Stop,*** *what has changed?*
T – ***Think*** *about the task*
E – ***Evaluate*** *potential hazards*
P – ***Plan*** *safe approach*
S - ***Start*** *task /* ***Stop*** *& regroup*

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☐ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☒ Face Shield	☒ Nitrile Gloves	☐ PVC Gloves
☒ Leather Gloves	☒ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☒ Other: Tyvek Sleeves				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Transport equipment to work area	1. Back Strains 2. Slips/Trips/Falls 3. Traffic 4. Cuts/Abrasions/Contusions from equipment	1. Use proper lifting techniques/ Use wheeled transport/ use buddy system when lifting equipment. 2. Minimize distance from work area/ unobstructed path to collection points and vehicle/ Follow good housekeeping procedures. 3. Wear high-visibility vest or clothing/Exercise caution/ Use traffic cones or signage if needed. 4. Wear proper PPE (leather gloves, long sleeves, Langan approved safety shoes).
2. Measure depth of water	1. Exposure to hazardous substances 2. Pinched fingers	1. Wear proper PPE (Nitrile gloves, Safety glasses/Face shield). 2. Wear proper PPE (cut-resistant gloves).
3. Install Tremie pipe in the monitoring well and connect to water source.	1. Hand injuries during installation (pinched fingers/hands). 2. Back strain from holding Tremie pipe. 3. High pressure water spray.	1. Wear proper PPE (Nitrile gloves/cut-resistant gloves). 2. Use proper lifting techniques/ Use two personnel when lowering pump greater than 80 feet. 3. Ensure all hose connections are tight and secure/ Use proper PPE (face shield and safety glasses).
4. Install pump in to well a. Connect pump to sample tubing. b. Lower pump to desired depth in well. c. Connect sample tubing to flow cell d. Connect pump to power source	1. Hand injuries during pump installation and sample tubing cutting. 2. Back strain 3. Electric shock 4. Exhaust gases from generator 5. Burns from hot equipment	1. Wear proper PPE when installing pump and cutting sample tubing (Nitrile and cut-resistant gloves)/ Use tubing cutter. 2. Proper lifting techniques/ Two personnel when installing pump at depths greater than 80 feet/ Use buddy when lifting heavy loads (pump, generator)/Use wheeled transport. 3. Ensure equipment is (LO/TO: locked out/tagged out) prior to preforming any electrical connections/ Inspect wires for frays or cuts/Ensure generator is properly grounded prior to starting.

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
(generator) e. Turn on power source (generator)		4. Position generator so that exhaust is flowing away from work area. 5. Do not touch exhaust or any hot part of generator/ Allow equipment time to cool down prior to carrying/ Use proper PPE (long sleeves, leather gloves)
5. Develop monitoring well a. Jet water into well using Tremie pipe b. Turn pump on and adjust to desired flow rate. c. Surge pump up and down well to remove sediment from screen d. Containerize all purge water from well.	1. Hand injuries 2. Face injuries 3. Contaminated spray from water	1. Wear proper PPE (cut-resistant gloves and nitrile gloves). 2. Wear proper PPE (face shield and safety glasses)/do not stand over well opening. 3. Wear proper PPE (Face shield and safety goggles)/Tyvek over garments/ Ensure all connections are secure and tight/ Tubing outlet is contained in an overflow container.
6. Drum staging area.	1. Back, Arm, and shoulder strain. 2. Pinch points 3. Cross contamination 4. Slip/Trips/Falls	1. Use proper lifting techniques/ Use drum carts when moving drums/ use buddy system for moving of drums if needed/Move drums shortest distance needed. 2. Keep fingers and feet away from pinch points/ Use proper PPE (cut-resistant gloves, Langan approved safety shoes) 3. Use proper PPE (Nitrile gloves, Tyvek sleeves) 4. Ensure pathway is clear prior to moving equipment/ Mark all hazards/ Use additional person as a spotter if needed.
7. Equipment pack-up	1. Back Strains 2. Slips/Trips/Falls 3. Traffic 4. Cuts/Abrasions/Contusions from equipment.	1. Use proper lifting techniques/ Use wheeled transport/ use buddy system when lifting equipment. 2. Minimize distance from work area/ Unobstructed path to collection points and vehicle/ Follow good housekeeping procedures. 3. Wear high-visibility vest or clothing/Exercise caution/ Use traffic cones or signage if needed. 4. Wear proper PPE (leather gloves, long sleeves, Langan approved safety shoes).
8. All activities	1. Slips/ Trips/ Falls 2. Hand injuries, cuts or lacerations during manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress/ Cold Stress 10. Eye Injuries	1. Be aware of potential trip hazards / Follow good housekeeping procedures/ Mark significant hazards 2. Inspect for jagged/sharp edges, and rough or slippery surfaces / Keep fingers away from pinch points / Wipe off greasy, wet, slippery or dirty objects before handling / Wear leather/ cut-resistant gloves 3. Wear Langan approved safety shoes 4. Use proper lifting techniques / Consider load location, task repetition, and load weigh when evaluating what is safe or unsafe to lift / Obtain assistance when possible 5. Wear high visibility clothing & vest / Use cones or signs to designate work area 6. Be aware of surroundings at all times, including the presence of wildlife/ Do not approach stray dogs / Carry/use dog/animal repellant / Use bug spray when needed 7. Wear hearing protection 8. Wear hard hat / Avoid areas were overhead hazards exist. 9. Wear proper attire for weather conditions (sunscreen or protective clothing

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
		in sunlight, layers for cold weather) / Drink plenty of fluids to avoid dehydration / Takes breaks as necessary to avoid heat/cold stress 10. Wear safety glasses.
Additional items.		
Additional Items identified while in the field. (Delete row if not needed.)		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: **Oversight**

JSA Number: **JSA001-01**

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions.

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☐ Nitrile Gloves	☐ PVC Gloves
☒ Task Specific Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☐ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	☐ Snake Chaps
☐ Other:				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Daily Tailgate Safety Meeting	1. None	1. All employees assigned to this task will attend a daily tailgate safety meeting, which will include the pertinent JSA's, Standard Operating Procedures (SOPs), types of potential hazards, and actual hazards present and controls for those hazards.
2. Overall Hazards	1. Slip, Trip, Fall Hazard	1a. All personnel should be constantly watching for trip hazards, such as uneven terrain, holes, ditches, gravel patches, stretched wires or ropes or other materials in their path. 1b. Proper housekeeping of materials during sampling events. 1c. Mark significant below-grade hazards (i.e. holes, trenches) with safety cones or spray paint 1d. Wear proper footwear for terrain and scope of work (steel-toe boots). 1e. Rainy, snowy, or icy conditions will warrant a more cautious work attitude. Employees should change work speed and style to fit the weather conditions.
	2. Weather – cold or heat stress	2. Wear proper attire for weather conditions (sunscreen or protection clothing in sunlight, layers for cold weather); drink plenty of fluids to avoid dehydration; take breaks as necessary to avoid heat/cold stress.
	3. Hand injuries during manual/equipment handling	3a. Workers should inspect materials for jagged or sharp edges, and rough or slippery surfaces. 3b. Workers should keep fingers away from pinch and shear points, especially when setting down materials. 3c. Workers should wipe off greasy, wet, slippery or dirty objects before attempting to handle them. 3d. Leather gloves or equivalent should be worn to prevent injury. 3e. Workers should never carry an open blade (box cutters) 4. Carefully connect equipment and other items which may cause a pinch

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
	4. Pinch fingers or hand 5. Foot injuries 6. Back injuries 7. Broken Sample Jars	point. 5. Steel-toed boots should be used for protection of the feet 6a. All three main factors in manual lifting (load location, task repetition, and load weight) must be considered when evaluating what is safe or unsafe to lift; obtain assistance when possible. 6b. All manual lifting of heavy or bulky objects shall be carefully planned to avoid injuries or damage to equipment. 7a. Never reach into containers containing sample jars, visually verify there is no broken glass. 7b. Once verified that there are no shards obtain bottle with a pair of work gloves (leather or heavy-weight work gloves).
3. Walking around site	1. Uneven terrain 2. Active equipment 3. Working at heights	1a. Pay attention to work area. Step cautiously. 1b. Watch for puddled water and muddy areas. 2. When working around active machinery, always make eye-contact, verbal, or physical hand gestures to the operator, and communicate where you will be moving to. Utilize radios if necessary. 2a. Never enter pinch point while machinery is active (engine on) 2b. Request machinery has its engine off and all parts of the equipment are on the ground (e.g. excavator bucket) when work is not in progress. 2c. When turning around blind corner orally notify workers of your movement. 2d. Establish hand signals to speak with operators and/or confirm radio communication is established, and checked, with all team members. 3. Verify platform has the strength or structural integrity to support individual weight. 3a. If work area is more than 6 feet above ground, ensure guardrail system is in place and secure or fall restraints have been installed. 3b. Be aware of signage and possible debris that could compromise footing.
4. Working near road	1. Passing cars and trucks	1a. Wear reflective vest. Minimize time in this area. 1b. Stay away from roadway or active area where vehicles are passing. 1c. Watch for vehicle traffic. 1d. Ensure mobilizing equipment has a spotter.
Additional items.		

JSA Title: Oversight
JSA Number: JSA001-01

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION

Print Name	Sign Name	Date
Prepared by:		
Reviewed by:		

LANGAN

Job Safety Analysis (JSA)
Health and Safety

JSA Title: VEFR / Dual-Phase Extraction

JSA Number:

A Job Safety Analysis (JSA) must identify all job steps required to complete the task, the potential hazards employees could be exposed to while performing the job step and the preventative/corrective actions required to reduce/mitigate the identified potential hazards. Employees must certify that they have either prepared the JSA or have reviewed the JSA and are aware of the potential hazards associated with this task and will follow the provided preventive/corrective actions.

PERSONAL PROTECTIVE EQUIPMENT (Required or to be worn as needed):				
☒ Safety Shoes	☒ Long Sleeves	☒ Safety Vest (Class 2)	☒ Hard Hat	☒ Hearing Protection
☒ Safety Glasses	☐ Safety Goggles	☐ Face Shield	☐ Nitrile Gloves	☐ PVC Gloves
☒ Task Specific Gloves	☐ Cut Resist. Gloves	☐ Fall Protection	☒ Fire Resistant Clothing	☐ Rubber Boots
☐ Insect/Animal Repellent	☐ Ivy Blocker/Cleaner	☐ Traffic Cones/Signs	☐ Life Vest/Jacket	
☐ Other:				

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
1. Setup area; stage equipment	1. Traffic / Struck-by 2. Trips from hoses/gear 3. Weather exposure	1. Confirm proper permits are acquired prior to beginning work. Walk area to confirm area is competent and safe to set up equipment, confirm egress is clear. Use spotter while positioning vehicles. Set up exclusion zone if needed (cones / caution tape) 2. Practice good housekeeping. Manage good hose runs. Inspect all hosing before use 3. Wear weather appropriate PPE
2. Assemble manifold and connect to wells	1. Fume inhalation 2. Pinch points 3. Static discharge, flammability	1. Identify wind direction and upwind / crosswind. Open valves slowly, verify check valves 2. Wear proper PPE 3. Use intrinsically safe equipment and proper grounding
3. Connect manifold assembly to vacuum truck / knockout pot	1. Hose whip / coupling failure 2. Vacuum collapse 3. Noise	1. Appropriate vacuum-rated hose / couplings. Use whip checks. Keep out of line of fire 2. Confirm equipment (knockout pot, manifold assembly and hoses) are appropriately rated for vacuum before use 3. Wear hearing protection. Confirm knockpot drain is secured / contained.
4. Exhaust routing through GAC (potential more than 1 GAC)	1. Fume exposure 2. Drum tip-over 3. Backpressure to truck	1. Note wind direction, update and communicate muster point locations and cross-wind direction as wind changes 2. Stage drums upright on stable ground. Cap ports when not in use 3. Confirm exhaust direction, monitor pre / inter / post GAC for exhaust breakthrough
5. Operate, Monitor, Shutdown	1. LEL exceedance / fire risk 2. Liquid slugging / spill 3. Stored energy	1. Monitor LEL / PID. Suspend if action level are approached. Maintain ignition control. If fire / LEL alarm goes off, stop work, evacuate upwind and contact Project Management and Site Contacts 2. Isolate wells then truck, depressurize, cap / plug lines
6. All Activities	1. Slips / Trips / Falls 2. Hand Injuries, cuts or lacerations during	1. Be aware of potential trip hazards. Follow good houcekeeping procedures. Mark significant hazards

JSA Title: Wellhead Gas Leak Testing
JSA Number:

JOB STEPS	POTENTIAL HAZARDS	PREVENTATIVE / CORRECTIVE ACTION
	manual handling of materials 3. Foot injuries 4. Back injuries 5. Traffic 6. Wildlife: Stray dogs, Mice/rats, Vectors (i.e. mosquitoes, bees, etc.) 7. High Noise levels 8. Overhead hazards 9. Heat Stress / Cold Stress 10. Eye Injuries	2. Inspect for jagged/sharp edges, and rough or slippery surfaces. Keep fingers away from pinch points. Wipe off greasy, wet, slippery or dirty objects before handling. Wear task specific gloves (i.e. Impact gloves, cut resistant gloves) 3. Wear Langan approved safety boots 4. Use proper lifting techniques. Consider load location, task repetition, and load weight when evaluating what is safe or unsafe to lift. Obtain assistance when possible. 5. Wear high visibility clothing / vest. Use cones or signs to designate work area. 6. Be aware of surroundings at all times, including the presence of wildlife. Do not approach stray dogs. Carry/use dog/animal repellant. Use bug spray as needed. 7. Wear hearing protection. 8. Wear hard hat. Avoid areas where overhead hazards exist. Follow life saving rules at all times. 9. Wear proper attire for weather conditions (sunscreen or protective clothing in sunlight, layers for cold weaterh. Drink plenty of fluids to avoid dehydration. Take breaks as necessary to avoid hea/cold stress. 10. Wear approved savey glasses.
Additional items.		

Print Name	**Sign Name**	**Date**
Prepared by:		
Reviewed by:		

APPENDIX H
Tailgate Safety Briefing Form

Tailgate Safety Briefing Form Health & Safety	LANGAN
Document #: HSE-HASP-TSB-FRM-01	Version #: 01

Date:_____ Time: _____

Leader:_____ Location:_____

Work Task:

_____

SAFETY TOPICS (*provide some detail of discussion points*)

Chemical Exposure Hazards and Control:_____

_____

Physical Hazards and Control: _____

Air Monitoring: _____

PPE: _____

Communications:_____

Safe Work Practices: _____

_____

Emergency Response: _____

Hospital/Medical Center Location: _____

Phone Nos.: _____

Other: _____

FOR FOLLOW-UP (the issues, responsibilities, due dates, etc.**)**

_____

_____

_____

ATTENDEES

PRINT NAME	COMPANY	SIGNATURE

APPENDIX I
VEFR Minimum Technical Requirements

ATTACHMENT A
VEFR MINIMUM TECHNICAL REQUIREMENTS
Vacuum Truck for Pure-Phase Hydrocarbon Service
Use: Plant-contracted subcontractor

1. Codes & Service

- Truck, tank, and vacuum system shall be **suitable for pure-phase hydrocarbon service** (flammable liquids). All vacuum truck operations in hydrocarbon service shall include **proper bonding and grounding** of the truck, hoses, and any connected equipment to mitigate static charge accumulation and reduce the risk of ignition. Subcontractor shall provide and use suitable grounding/bonding cables and clamps in accordance with industry practices and applicable NFPA guidance (e.g., NFPA 30 and NFPA 77) whenever loading, unloading, or transferring flammable liquids or vapors.
- Comply with, at minimum:
    - **NFPA 30** – Flammable and Combustible Liquids Code
    - **NFPA 385** – Tank Vehicles for Flammable and Combustible Liquids
    - **49 CFR** (DOT hazardous materials / tank vehicle requirements, as applicable)
    - **OSHA 29 CFR 1910** (including noise and PPE)
    - Applicable **federal, state, local, and plant** safety and environmental requirements

2. Vacuum System

- **Vacuum Pump / Blower:**
    - Liquid ring, rotary vane, or equivalent design suitable for hydrocarbon vapors.
    - Capable of **28–29 in Hg** vacuum at the tank (near full vacuum).
    - Vacuum **adjustable down to < 10 in Hg** via variable speed and/or relief / throttling valves.
- **Performance:**
    - Minimum **1000 CFM at 15 in Hg**, or subcontractor to state guaranteed CFM vs. vacuum.
- **Instrumentation:**
    - Vacuum gauge (in Hg) at primary operator panel (rear gauge preferred but optional).

3. Tank

- **Capacity:** Nominal **3000-gallon** debris/product tank.
- **Construction:**
    - Carbon steel with compatible lining or stainless steel; suitable for pure hydrocarbons.
    - Designed for **full vacuum (≥ 29 in Hg)**; subcontractor to state MAWP for any positive pressure operation.
- **Access:**
    - At least one top manway.
    - Rear door (if provided) gasketed and vacuum-tight, hydraulic actuation preferred.

4. Level Indication (No Depressurization)

- External **sight tube or sight glass** to indicate liquid level **while tank is under vacuum**.
- Sight tube to include:
    - Top and bottom **isolation valves**
    - Materials rated for hydrocarbon service and full operating pressure/vacuum
    - **Mechanical protection** (guard/cage)
    - Volume or % full markings where practicable

- Electronic level indication (e.g., radar/ultrasonic) is acceptable as supplemental, but a physical visual indication is required.

5. Piping, Connections & Hoses

- **Suction Connections:**
  - Truck suction / tank inlet equipped with **2" camlock** fittings (male/female as needed).
- **Hose:**
  - Minimum **200 ft of 2" full-vacuum-rated hose**
  - Hose compatible with pure hydrocarbons; **2" camlock** each end.
  - On-truck means for storage/handling of hoses.

6. Exhaust & Vapor Management

- **Baseline Requirement:**
  - Vacuum pump exhaust routed through a **silencer/muffler**.
  - Exhaust hard-piped to a **valved manifold** allowing discharge either:
    1. To atmosphere via an appropriate stack, or
    2. To **user-supplied vapor-phase carbon drums** via camlock connection (2" unless otherwise proposed).
- **Catalytic Oxidizer (Optional):**
  - **Not required** by plant.
  - If provided by subcontractor:
    - Shall be sized and suitable for hydrocarbon VOC service.
    - Installed and operated per vendor recommendations and applicable air regulations.
    - Manifold arrangement shall permit **bypass** of catalytic oxidizer when not needed.

7. Controls & Safety

- **Gauges:**
  - Vacuum gauge (in Hg) at operator panel.
  - Tank pressure/vacuum gauge (in Hg and psi if positive pressure is used).
- **Emergency Stops:**
  - Minimum one E-stop at main operator panel; rear E-stop preferred.
- **Protection/Interlocks:**
  - Over-pressure / vacuum relief per applicable code and vendor practices.
  - Interlocks / alarms as needed to prevent unsafe operation (e.g., overfill, over-pressure).

ATTACHMENT B
SUBMITTALS CHECKLIST – VACUUM TRUCK (SUBCONTRACTOR)
Subcontractor shall provide the following documents with bid and/or prior to mobilization, as indicated.

1. Equipment & Performance Data

- Data sheet for **vacuum pump / blower**, including:
  - Type, model, materials of construction
  - Rated CFM vs. vacuum curve (performance curve)
- Data sheet for **3000-gallon tank**, including:
  - Material of construction, internal lining (if any)
  - Design pressure and vacuum ratings (MAWP / external design)
  - Confirmation of suitability for pure hydrocarbon service
- Data sheets for **hoses and fittings**:
  - Hose construction, vacuum rating, temperature rating, chemical compatibility
  - Camlock details (size, material)
- Data sheets for **silencer/muffler** and exhaust manifold arrangement.
- If provided: data sheet(s) for **catalytic oxidizer** and any **carbon vapor treatment** equipment.

2. Compliance & Safety Documentation

- Written statement confirming compliance with:
  - NFPA 30
  - NFPA 385
  - Applicable portions of 49 CFR for transport (if transporting on public roads)
  - OSHA 29 CFR 1910 (including noise and PPE requirements)
  - Applicable environmental regulations for hydrocarbon vapors
- Evidence of tank vehicle approvals / certifications as required for flammable liquid service.
- Noise / sound level documentation: manufacturer's data or representative **field measurements** at typical operating conditions.

3. Instrumentation & Controls

- Description of **vacuum and tank pressure/vacuum gauges** (locations, ranges, units).
- Description of **level indication system**:
  - Type of sight tube / gauge, materials, rating
  - Isolation valves and protection details
  - Any electronic level instrumentation (if provided)
- Description of **control layout** and **emergency stops** (locations and functions).
- Description of **interlocks, alarms, and relief devices** (vacuum/pressure relief, overfill protection, etc.).

4. Operating & Safety Procedures

- Operating manual or **standard operating procedures** for the vacuum truck in hydrocarbon service.
- Specific procedures for:
  - Connecting and using **2" camlock suction hoses**
  - Managing **vacuum pump exhaust** to atmosphere vs. carbon drums
  - Use and bypass of **catalytic oxidizer** (if installed)
- Safety procedures addressing:
  - Fire and explosion risk in hydrocarbon service
  - Static control and bonding/grounding practices (if applicable)
  - PPE requirements and noise exposure controls
  - Spill response and emergency shutdown steps

5. Proof of Experience & Insurance

- List of similar **hydrocarbon vacuum projects** completed in the past 3–5 years.
- Certifications / training for operators (e.g., HAZWOPER, confined space, etc., per plant requirements).
- Current insurance certificates meeting plant contract requirements.

APPENDIX J
Safe Work Certificate

LANGAN	Safe Work Certificate Policy Health & Safety
Effective: October 2, 2023	*Reviewed/Approved: May 24, 2023*

1. Purpose

This document presents Langan's Safe Work Certificate (SWC) Policy. This policy requires a Safe Work Certificate be developed, documented and adhered to by Langan employees while conducting fieldwork as part of a Langan project.

2. Applicability

This policy applies to Langan employees and Subcontractors working on a Langan project when fieldwork is performed as part of the scope of work for a project.

3. Definitions

3.1. Close-Out Meeting

Meeting conducted by the Site Safety Officer at the end of the day or after fieldwork is completed. Close-Out meeting must be documented and include all employees, subcontractors and visitors under Langan control. Close-Out Meeting includes a discussion on health and safety incidents, near-misses observed, stop work interventions, behavior-based safety observations and last minute risk assessments conducted.

3.2. Fieldwork

Work done on-site by Langan employees and Langan subcontractors.

3.3. High Risk Activity

Activities identified by Langan as having an increased potential for incident or injury to an employee, worker or visitor under Langan control. Langan Project Managers must review a high risk activity with Site Safety Officer prior to conducting fieldwork. The review should include the high risk activity, potential hazards, control measures and personal protective equipment required to mitigate the hazard.

3.4. Safe Work Certificate

A Safe Work Certificate (SWC) is a certificate completed daily by Langan employees prior to conducting fieldwork. The SWC contains work tasks employees are scheduled to complete as part of fieldwork and the potential task specific and site specific hazards. The SWC provides information on control measures and personal protective equipment to mitigate hazards.

3.5. Site Specific Hazards

Site specific hazards include known or anticipated potential health and safety hazards at a specific work site, which are normally associated with expected site conditions and the type of fieldwork to be executed. Site specific hazards include, but are not limited to, noise, traffic, slips, trips, and falls, heat stress, cold stress, and poisonous plants.

3.6. Subcontractor

Any firm or person who has been contracted by Langan to provide services and that is not an employee of Langan.

3.7. Tailgate Safety Meeting

Site Safety Officer is a Langan employee who is responsible for conducting a tailgate safety meeting prior to starting fieldwork. Tailgate safety meeting shall be documented and include all employees, subcontractors and visitors under Langan control. Meeting will include discussion on high risk tasks and site work tasks including the associated potential hazards, control measures and personal protective equipment required.

3.8. Task Specific Hazards

Task specific hazards include known or anticipated potential hazards associated with conducting a specific work task. Task specific hazards include, but are not limited to, chemical exposure, elevated work, noise, slips, trips, and falls, manual lifting and underground utilities.

4. Roles & Responsibilities

4.1. Employees

Langan employees shall adhere to the SWC process as described in this policy. This includes attending Tailgate Safety Meetings and Close-Out Meetings, developing SWCs and adhering to the information provided in the SWC.

4.2. Project Managers

Langan Project Managers will ensure a SWC is developed daily when fieldwork is being conducted in association with a Langan project. The SWC must be developed by Langan Project Manager or by a Langan employee under the direction of the Langan Project Manager. Langan Project Managers are responsible for assigning a Langan employee to be the Site Safety Officer and discussing High Risk Activities with Langan employees prior to starting field work.

4.3. Senior Project Management

Langan Senior Project Management will assist in ensuring employees adhere to the SWC policy. This includes reviewing SWCs for fieldwork associated with projects and routinely auditing adherence to the SWC policy on their projects.

4.4. Site Safety Officer

A Site Safety Officer (SSO) will be assigned by the Langan Project Manager for any Langan project requiring fieldwork. The SSO is a Langan employee responsible for completing the SWC in the field, which includes conducting a tailgate safety meeting, signing in/out all employees, subcontractors and visitors under Langan control.

5. Safe Work Certificate Procedure

5.1. Safe Work Certificate

A Safe Work Certificate (SWC) must be completed prior to the start of fieldwork. The SWC must be submitted at the end of the work day or after completion of site fieldwork, whichever occurs first. The Site Safety Officer is responsible for completing the Safe Work Certificate Process.

5.2. Safe Work Certificate Process

The following procedures must be completed and documented.

1. *Development of SWC* - The Project Manager, or a Langan employee under the direction of the Project Manager, will develop the SWC for use in the field. This includes:
    a) Providing project specific information;
    b) Identifying a high risk activity (if applicable);
    c) Selecting a Site Safety Officer;
    d) Identifying site work tasks and site specific hazards; and,
    e) Providing emergency contact information.
2. *High Risk Activity* - If a high risk activity is identified, the Project Manager, or the Langan employee under the direction of the Project Manager, must discuss this with the Site Safety Officer. The review must include:
    a) The high risk activity;
    b) Hazards associated with the high risk activity; and,
    c) Control measures and personal protective equipment required to mitigate hazards.
3. *Tailgate Safety Meeting* - Prior to starting fieldwork, the Site Safety Officer will conduct a Tailgate Safety Meeting which will include:
    a) Identification of Langan employees, subcontractors or visitors under Langan control.
    b) Review of site work tasks to be completed;
    c) Hazards associated with identified site and work tasks; and,
    d) Control and personal protective equipment measures required to mitigate identified hazards.
4. *Close-Out Meeting* - After completion of field work or at the end of the day, the Site Safety Officer will conduct a Close-Out Meeting which will include:
    a) Review of site work tasks completed;
    b) Near-misses observed;
    c) Stop Work interventions;
    d) Behavior based safety observations; and.
    e) Last minute risk assessments.

6. Documentation

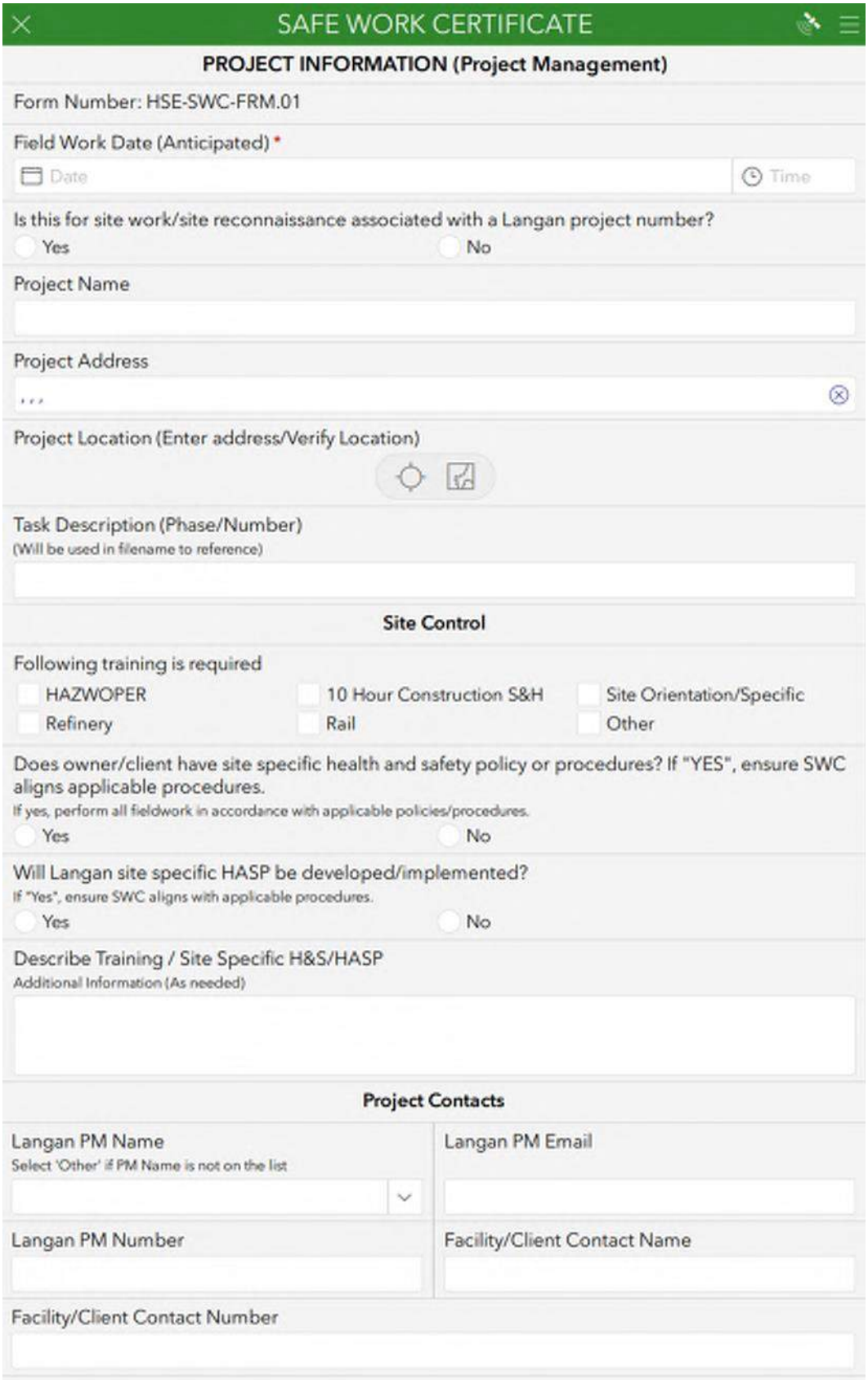
Prior to the start of fieldwork, a Safe Work Certificate must be prepared and reviewed in accordance with the process above. After completion of fieldwork, the completed SWC and any related documents will be saved in the project folder.

7. Training

Employees responsible for coordinating and conducting field work must be trained on this policy prior to commencing the employee's initial field assignment. Documentation of training will be maintained by the Corporate Health & Safety Department.

SAFE WORK CERTIFICATE OVERVIEW

PART 1 OF 8



SAFE WORK CERTIFICATE

PROJECT INFORMATION (Project Management)

Form Number: HSE-SWC-FRM.01

Field Work Date (Anticipated) *

Date | Time

Is this for site work/site reconnaissance associated with a Langan project number?

Yes | No

Project Name

Project Address

Project Location (Enter address/Verify Location)

Task Description (Phase/Number)

(Will be used in filename to reference)

Site Control

Following training is required

HAZWOPER | 10 Hour Construction S&H | Site Orientation/Specific

Refinery | Rail | Other

Does owner/client have site specific health and safety policy or procedures? If "YES", ensure SWC aligns applicable procedures.

If yes, perform all fieldwork in accordance with applicable policies/procedures.

Yes | No

Will Langan site specific HASP be developed/implemented?

If "Yes", ensure SWC aligns with applicable procedures.

Yes | No

Describe Training / Site Specific H&S/HASP

Additional Information (As needed)

Project Contacts

Langan PM Name

Select 'Other' if PM Name is not on the list

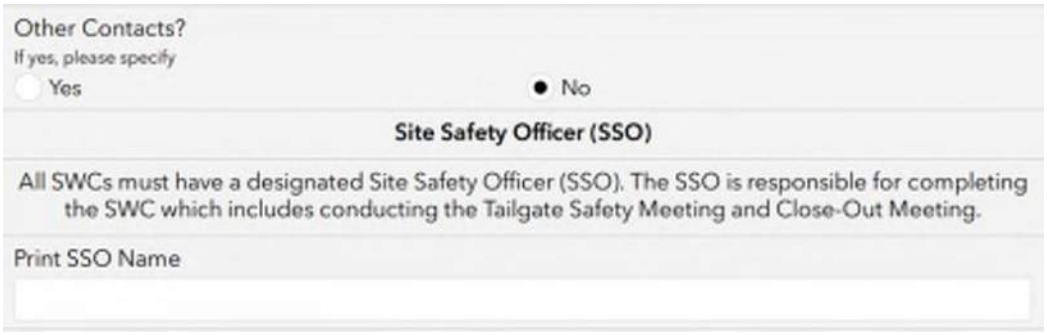
Langan PM Email

Langan PM Number

Facility/Client Contact Name

Facility/Client Contact Number

SAFE WORK CERTIFICATE OVERVIEW


Other Contacts?

If yes, please specify

○ Yes ● No

Site Safety Officer (SSO)

All SWCs must have a designated Site Safety Officer (SSO). The SSO is responsible for completing the SWC which includes conducting the Tailgate Safety Meeting and Close-Out Meeting.

Print SSO Name

SAFE WORK CERTIFICATE OVERVIEW

PART 2 OF 8



SAFE WORK CERTIFICATE

HIGH RISK ACTIVITY (Project Management)

Any "High Risk Activity" associated with field work must be identified. A "High Risk Activity" is an activity identified by Langan as having an increased potential for incident or injury to an employee, worker or visitor under Langan control.

Project management must review the high risk activity with Site Safety Officer prior to conducting fieldwork. This review should include the high risk activity, associated hazards, control measures and PPE measures to protect employees. (Project managers must document this review on Page 5)

Are any High Risk Activities being conducted by Langan or subcontractors? (See list below)

Yes No

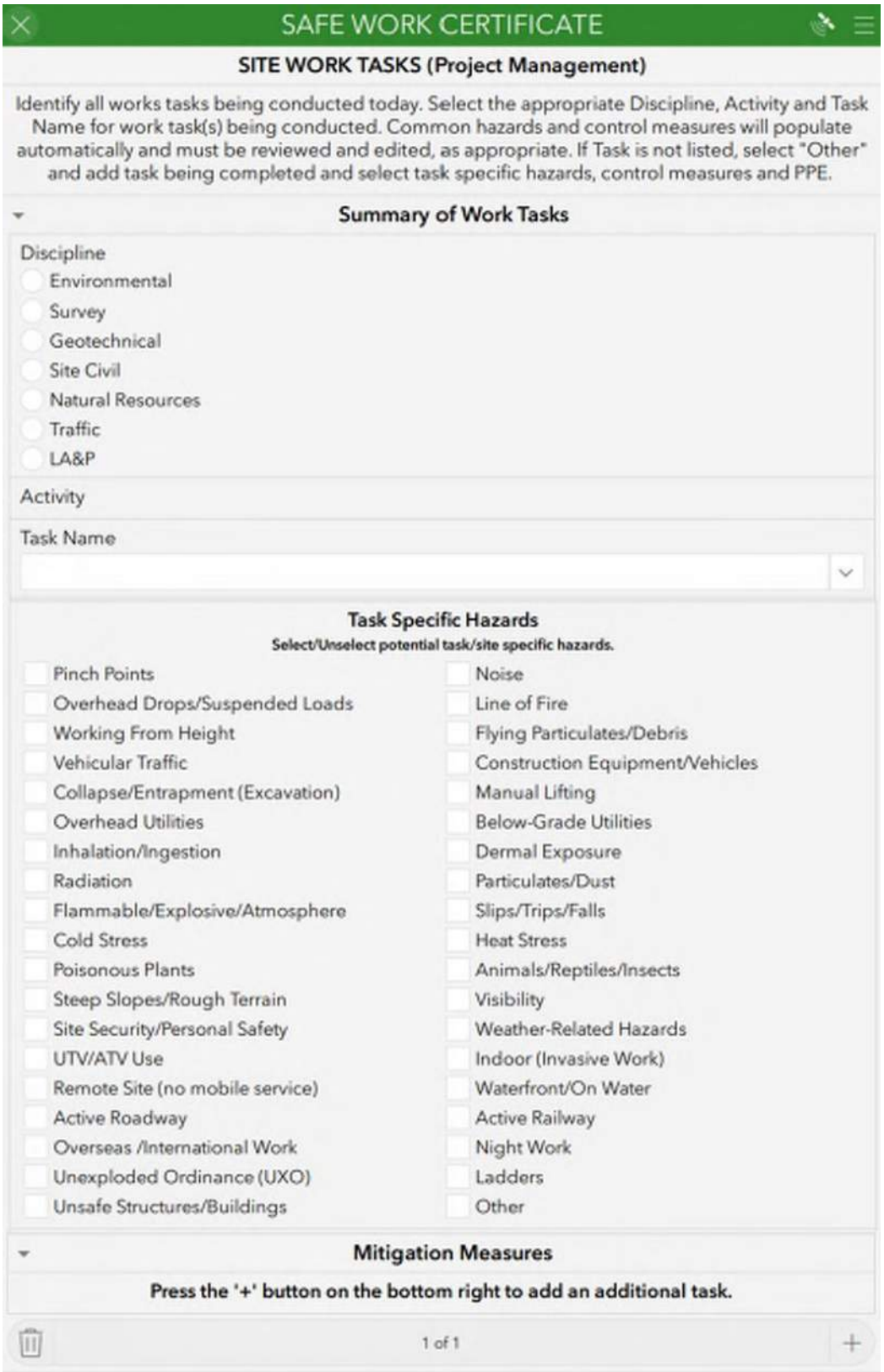
List of High Risk Activities

(For Reference)

- Energized System/LOTO
- Working From Heights
- Confined Space
- Welding/Hot Work
- Hoisting/Lifting
- Radioactive/NORM
- Active Construction/Industrial or SIMOPS
- Ground Disturbance / Underground Utility Clearance
- Excavations (Depth > 5 ft)

SAFE WORK CERTIFICATE OVERVIEW

PART 3 OF 8



SAFE WORK CERTIFICATE

SITE WORK TASKS (Project Management)

Identify all works tasks being conducted today. Select the appropriate Discipline, Activity and Task Name for work task(s) being conducted. Common hazards and control measures will populate automatically and must be reviewed and edited, as appropriate. If Task is not listed, select "Other" and add task being completed and select task specific hazards, control measures and PPE.

Summary of Work Tasks

Discipline

- Environmental
- Survey
- Geotechnical
- Site Civil
- Natural Resources
- Traffic
- LA&P

Activity

Task Name

Task Specific Hazards

Select/Unselect potential task/site specific hazards.

- Pinch Points
- Overhead Drops/Suspended Loads
- Working From Height
- Vehicular Traffic
- Collapse/Entrapment (Excavation)
- Overhead Utilities
- Inhalation/Ingestion
- Radiation
- Flammable/Explosive/Atmosphere
- Cold Stress
- Poisonous Plants
- Steep Slopes/Rough Terrain
- Site Security/Personal Safety
- UTV/ATV Use
- Remote Site (no mobile service)
- Active Roadway
- Overseas /International Work
- Unexploded Ordinance (UXO)
- Unsafe Structures/Buildings
- Noise
- Line of Fire
- Flying Particulates/Debris
- Construction Equipment/Vehicles
- Manual Lifting
- Below-Grade Utilities
- Dermal Exposure
- Particulates/Dust
- Slips/Trips/Falls
- Heat Stress
- Animals/Reptiles/Insects
- Visibility
- Weather-Related Hazards
- Indoor (Invasive Work)
- Waterfront/On Water
- Active Railway
- Night Work
- Ladders
- Other

Mitigation Measures

Press the '+' button on the bottom right to add an additional task.

1 of 1

SAFE WORK CERTIFICATE OVERVIEW

PART 4 OF 8



SAFE WORK CERTIFICATE

EMERGENCY CONTACT INFORMATION (Project Management)

Emergency Numbers

Site Emergency No.	Ambulance/Fire/Police
911 /	911 /
Langan Incident/Injury Hotline 973.560.4699	WorkCare 888.449.7787

Additional Emergency Contacts

Additional contacts can be entered on PROJECT INFORMATION (Page 1) under Project Contacts.

Contact Name	Contact Number

Incident/Injury Reporting

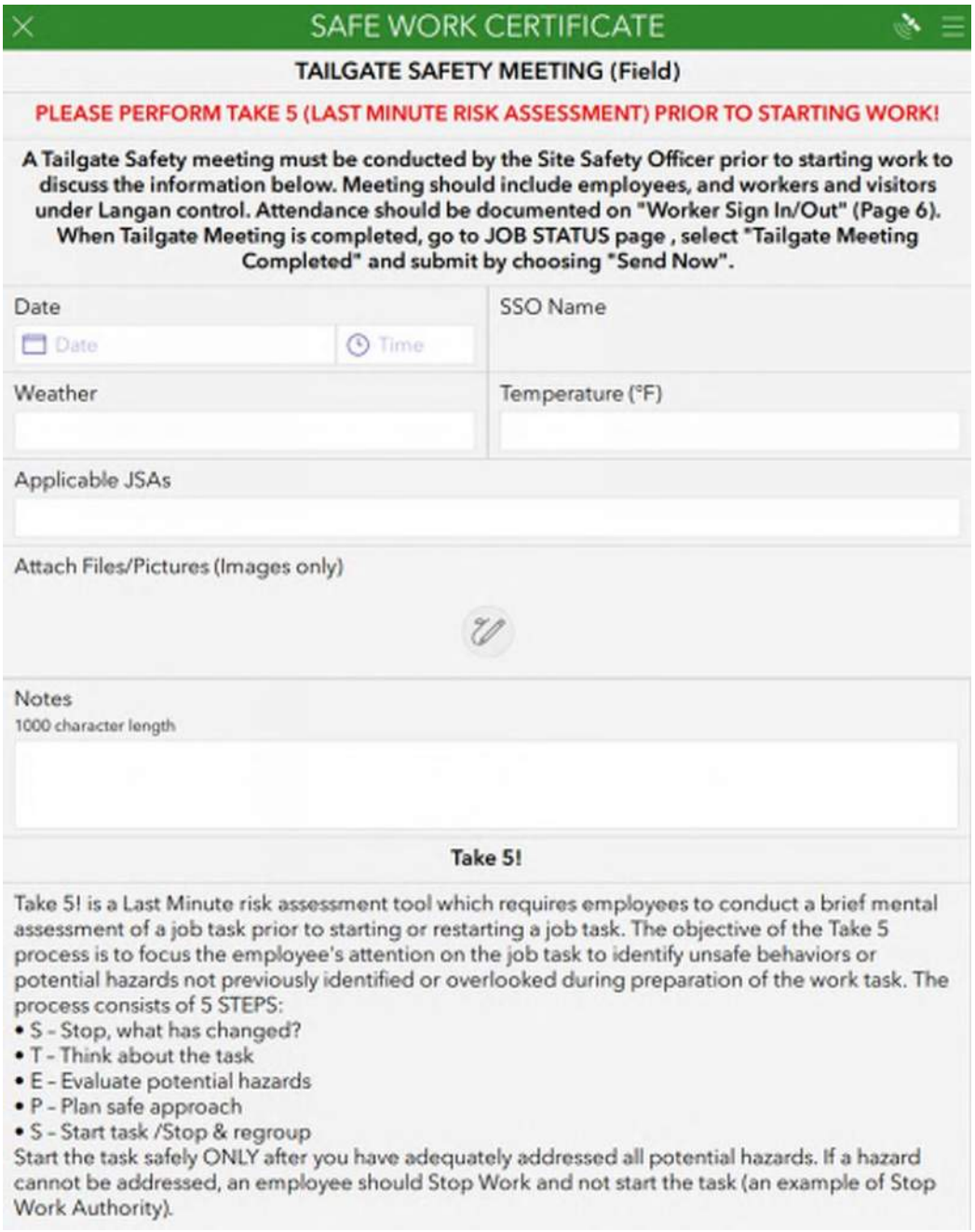
- Seek immediate medical attention, if necessary.
- Notify supervisor and/or project manager.
- Contact Work Care
- Supervisor/Project Manager report to Langan Incident/Injury Hotline
- Supervisor/Project Manager notifies client in accordance with contractual requirements.

Motor Vehicle Incident

- Seek immediate medical attention, if necessary.
- Notify supervisor and/or project manager.
- Report to Langan Incident/Injury Hotline.

SAFE WORK CERTIFICATE OVERVIEW

PART 5 OF 8



SAFE WORK CERTIFICATE

TAILGATE SAFETY MEETING (Field)

PLEASE PERFORM TAKE 5 (LAST MINUTE RISK ASSESSMENT) PRIOR TO STARTING WORK!

A Tailgate Safety meeting must be conducted by the Site Safety Officer prior to starting work to discuss the information below. Meeting should include employees, and workers and visitors under Langan control. Attendance should be documented on "Worker Sign In/Out" (Page 6). When Tailgate Meeting is completed, go to JOB STATUS page , select "Tailgate Meeting Completed" and submit by choosing "Send Now".

Date

Date Time

SSO Name

Weather

Temperature (°F)

Applicable JSAs

Attach Files/Pictures (Images only)

Notes

1000 character length

Take 5!

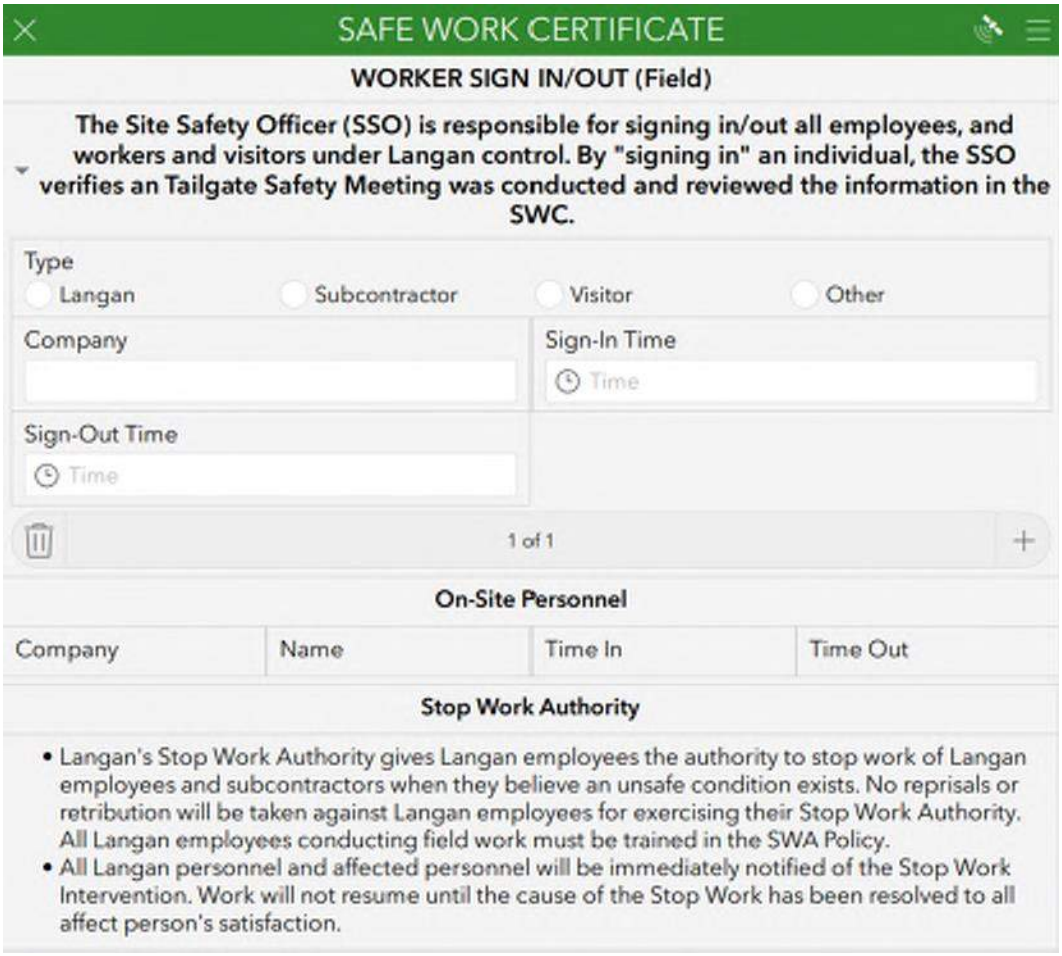
Take 5! is a Last Minute risk assessment tool which requires employees to conduct a brief mental assessment of a job task prior to starting or restarting a job task. The objective of the Take 5 process is to focus the employee's attention on the job task to identify unsafe behaviors or potential hazards not previously identified or overlooked during preparation of the work task. The process consists of 5 STEPS:

- S - Stop, what has changed?
- T - Think about the task
- E - Evaluate potential hazards
- P - Plan safe approach
- S - Start task /Stop & regroup

Start the task safely ONLY after you have adequately addressed all potential hazards. If a hazard cannot be addressed, an employee should Stop Work and not start the task (an example of Stop Work Authority).

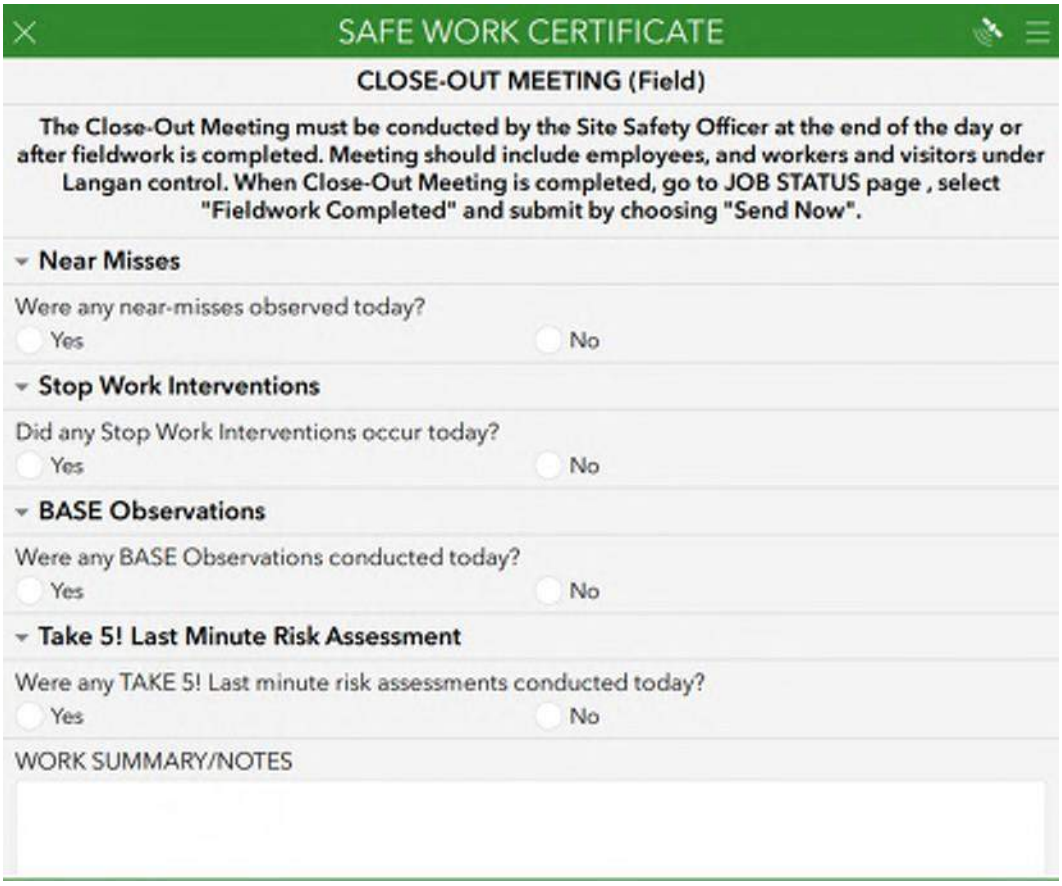
SAFE WORK CERTIFICATE OVERVIEW

PART 6 OF 8



SAFE WORK CERTIFICATE OVERVIEW

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SAFE WORK CERTIFICATE OVERVIEW

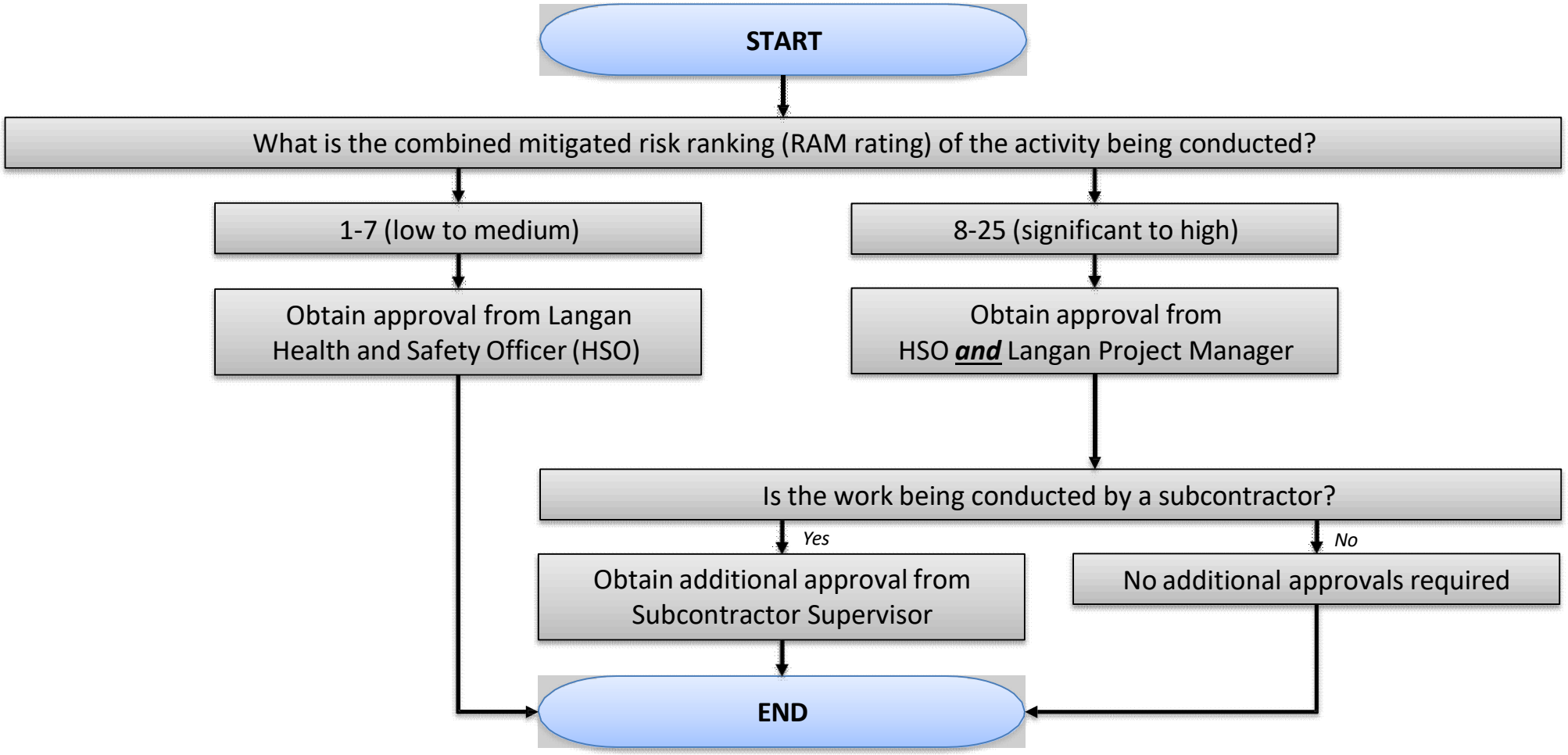
PART 8 OF 8



LANGAN

Safe Work Certificate Approval Flow Chart

Who Approves a Safe Work Certificate?



Confined Space Entry Permit

LANGAN

Document #: HSE-PRCS-ATT-FRM.01 | Version #: 01

A permit-required confined space has one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere; contains material that has the potential to engulf an entrant; has walls that converge inward or floors that slope downward and taper into a smaller area which could trap or asphyxiate an entrant; or contains any other recognized safety or health hazard, such as unguarded machinery, exposed live wires, or heat stress.

This Permit Required Confined Space Entry Permit will be completed by the Entry Supervisor and reviewed with Attendant(s) and Entrants prior to entry into a permit required confined space.

All copies of the permit will remain at the jobsite until job is completed.

Space to be Entered:

Purpose of Entry:

Date and duration of permit:

Authorized Entrants Name	**Sign in**	**Sign out**
Attendant Name	**Sign in**	**Sign out**

Entry Supervisor Name & Signature

Hazards of Space to be Entered:

Measures used to Isolate the Permit Space, Eliminate and/or Control any Hazards before Entry *(i.e. purging, flushing, ventilating and/or lock-out/tag-out):*

REQUIREMENTS COMPLETED	**DATE**	**TIME**
Lock Out/Tag Out/De-energize/Verify	_____	_____
Line (s) Blocked/Capped/Blinded	_____	_____
Purge/Flush/Vent	_____	_____
Ventilation (mechanical/natural)	_____	_____

AIR MONITORING

(continuously monitor confined space atmosphere)

Substance Monitored	**Permissible Limits**	**Monitoring Results** *(Initial results and every 2 hours after)*						
Time								
Oxygen %	19.5-23.5%							
Explosive (LEL)	< 10%							

Toxic 1: H2S	<10 PPM							
Toxic 2:								
Toxic 3:								
Toxic 4:								

Remarks:

Air Tester Name	ID#	Instrument(s) Used	Model # or Type	Serial # or Unit

Communication procedures:

Rescue procedures:

Emergency Contact Numbers:

Ambulance: _____ Fire: _____ Rescue Team: _____ Other: _____

Equipment:	N/A	Yes	No
Direct reading gas monitor-tested:	❑	❑	❑
Safety harnesses and lifelines for entry and standby persons:	❑	❑	❑
Rescue equipment	❑	❑	❑
Hoisting equipment:	❑	❑	❑
Communications equipment:	❑	❑	❑
Personal Protective Equipment (PPE):	❑	❑	❑
All electric equipment listed: Class I, Division I, Group D and non-sparking tools	❑	❑	❑

Other: *(Any other permits issued authorizing work in the permit space: hot work, or any other additional permit)*

Written instruction and safety procedures have been received and are understood. Entry cannot be approved if any squares are marked in the "No" column. This permit not valid unless all appropriate items are completed.

Permit prepared by: _____
Entry Supervisor

Safe Work System
EXCAVATION / TRENCHING PERMIT

Permit # _____

OSHA 1926.650(b) Scope and application. This subpart applies to all open excavations made in the earth's surface. Excavations are defined to include trenches. "Excavation" means any man-made cut, cavity, trench, or depression in an earth surface, formed by earth removal.

- ❑ **Site Address** _____ **Cost Center**_____
- ❑ **Contractor Company** _____ **Work Order/PO #** _____
- ❑ **Name of the authorized Permit Holder** _____ Phone _____
- ❑ **Name of Permit Issuer** _____ Phone_____
- ❑ **The soils have been identified and a suitable excavation plan was designed by a competent person and communicated** **YES ____ NO ____**
- ❑ **The stability of adjoining structures that may potentially be endangered by excavation have been evaluated by a competent person and the plan communicated** **YES ____ NO ____**
- ❑ **Is the operator and equipment certified for the work to be performed** **YES ____ NO ____**
- ❑ **The on site means to contact emergency services are operable** **YES ____ NO ____**
- ❑ **The location of utilities** (such as sewer, telephone, natural gas, fuel, electric, water) **or any other underground installations have been determined prior to opening the excavation** **YES ____ NO ____**
- ❑ **The primary means of access/egress are located per OSHA standards** **YES ____ NO ____**
- ❑ **List the means to be used as a warning system for mobile equipment operating near the edge of excavations** (Such as barricades, hand or mechanical signals, or stop logs) _____
- ❑ **List the other hazards of the Excavation Work being performed** _____

_____

(Such as falling loads/tools/equipment, electrical, exhaust, combustibles, contaminated soil, mechanical defects, design defects, nearby vent stacks, hydrocarbon liquid or vapor, fuel delivery, omission of protective features, extreme temperature, extreme noise, high pressures, structures, weather, other)

- ❑ **List the measures used to eliminate, or control other hazards before work** _____

_____

(Such as barricades, rigging performed by a competent person, stable surface, outriggers set as needed, lockout/tagout/verification of energy sources, correct extinguishers nearby, housekeeping, flag men, work stoppage during fuel delivery, other)

- ❑ **Equipment/Materials are staged at least 2 feet from the edge of excavations** **YES ____ NO ____**
- ❑ **The excavation has been inspected daily, and as needed by a competent person for evidence of standing water, possible cave-ins, failure of protective systems, hazardous atmospheres, or other hazardous conditions** **YES ____ NO____**
- ❑ **A hot work permit is required and issued** (such as for use of equipment using combustible engines) **YES ____ NO ____**
- ❑ **Guardrails are provided for walkways 6 feet or more above lower levels** **YES ____ NO____**
- ❑ **Identify the system in place to protect employees from cave-ins for excavations greater than 5 feet or where the soil has potential for cave in** _____
- ❑ **List the safety equipment to be provided by contractor** (such as extinguishers, PPE, protective equipment/clothing, face and eye protection, communications equipment, alarm systems, 0ther): _____
- ❑ **All components of the excavation equipment and tools have been inspected and tested by a competent person and are adequate for use** **YES ____ NO ____**

(Such as wire rope or straps, evidence of any heat or damage, guards cover moving parts and exhaust, air / hydraulic deterioration or leakage, other)

- ❑ **Any other information necessary, in order to ensure employee safety** _____
- ❑ **Atmospheric conditions are safe for excavation:** (if a well designed hazard assessment has been conducted to identify any underground piping or electrical, then a periodic gas check will be ok) **YES____ NO ____**

Initial Readings:

Oxygen 19.5% - 23.5%	Combustible Gas <10% LEL	Toxic Gas - Type and Levels (CO-35PPM/H2S-10PPM/Other)

Authorized Tester Name _____ Date _____ Time _____

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

Gas Tester Make/Model:	Instrument Serial Number: Calibration Date:
PERMIT VALIDATION	
This Permit is valid from am/pm TO am/pm on / / . (Note: Permit must not exceed 1 day)	
I ensure this permit has been filled out completely and in accordance with all applicable OSHA requirements to provide a safe workplace. I will take action to control hazardous conditions associated with this work.	
Permit Acceptance (print name): Permit Holder Signature: Date: Time:	Permit Authorization (Print Name): Permit Issuer Signature: Date: Time:
PERMIT CLOSE OUT	
All work has been completed in accordance with this Permit and the site has been left in a safe and satisfactory condition.	
Permit Holder Signature: Date: Time:	Permit Issuer Signature: Date: Time:

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

Safe Work System
HOT WORK PERMIT

Permit # _____

OSHA 1926.352(a,b,c) When practical, objects to be welded, cut, or heated shall be moved to a designated safe location or, if the objects to be welded, cut, or heated cannot be readily moved, all movable fire hazards in the vicinity shall be taken to a safe place, or otherwise protected. If the object to be welded, cut, or heated cannot be moved and if all the fire hazards cannot be removed, positive means shall be taken to confine the heat, sparks, and slag, and to protect the immovable fire hazards from them. No welding, cutting, or heating shall be done where the application of flammable paints, or the presence of other flammable compounds, or heavy dust concentrations creates a hazard.

- ❑ **Site Address** _____ **Cost Center**_____
- ❑ **Contractor Company** _____ **Work Order/PO #** _____
- ❑ **Name of the authorized Permit Holder** _____ Phone_____
- ❑ **Name of Permit Issuer** _____ Phone _____
- ❑ **Name of fire watch, if applicable** _____
- ❑ **The purpose and exact location of the Hot Work** _____
- ❑ **List the type of Hot Work being performed** _____
(Such as welding, cutting, drilling, grinding, sandblasting, concrete sawing, other)
- ❑ **List the hazards of the Hot Work being performed** _____
_____
(Such as electrical, atmospheric, combustible, chemical, mechanical, radiation, design defects, nearby vent stacks, hydrocarbon liquid or vapor, fuel delivery, omission of protective features, extreme temperature, extreme noise, high pressures, structures, other)
- ❑ **List the measures used to isolate the space and to eliminate, or control hazards before work**
_____
(Such as barricades, purging, blocking, inerting, ventilating, spark containment, correct extinguishers nearby, intrinsically safe tools, ventilation, bonding, grounding, fire watch, work stoppage during fuel delivery, other)
- ❑ **Sources of energy in the area of Hot Work are locked and tagged out YES _____ NO _____**
- ❑ **The means to contact emergency services are operable YES _____ NO _____**
- ❑ **List the safety equipment to be provided by contractor** (such as PPE, protective equipment/clothing, face and eye protection, spark and direct ray protective screens, testing equipment, communications equipment, alarm systems, and rescue equipment)**:**
_____
- ❑ **All components of the tools have been inspected and are adequate for use YES _____ NO _____**
- ❑ **Any other information necessary, in order to ensure employee safety** _____

The acceptable Hot Work conditions:

Test conditions in the permit space to determine if acceptable conditions exist before work is authorized to begin. Conditions shall be continuously monitored in the areas where authorized work is performed. Record at least every 30 minutes:

Initial Readings:

Oxygen 19.5% - 23.5%	Combustible Gas 0% LEL	Toxic Gas - Type and Levels CO-35PPM/H2S-10PPM/Other)

Authorized Tester Name _____ Date _____ Time _____

Continuous (alarmed) atmosphere Monitoring: (Record at least every 30 minutes)	Test	PEL	Initials	Time:	Time:	Time:	Time:	Time:
	Oxygen	19.5%-23.5%		Value:	Value:	Value:	Value:	Value:
	LEL	0%		Value:	Value:	Value:	Value:	Value:
	Other			Value:	Value:	Value:	Value:	Value:

Gas Tester Make/Model:	Instrument Serial Number:	Calibration Date:

PERMIT VALIDATION

This Permit is valid from am/pm TO am/pm on / / (Note: Permit must not exceed 1 day)

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

I ensure this permit has been filled out completely and in accordance with all applicable OSHA requirements to provide a safe workplace. I will take action to control hazardous conditions associated with this work.	
Permit Acceptance (print name): Permit Holder Signature: Date: Time:	Permit Authorization (Print Name): Permit Issuer Signature: Date: Time:

PERMIT CLOSE OUT

All work has been completed in accordance with this Permit and the site has been left in a safe and satisfactory condition.	
Permit Holder Signature: Date: Time:	Permit Issuer Signature: Date: Time:

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

Safe Work System
HOISTING / RIGGING PERMIT

Permit #_____

OSHA 1926.550 – "Hoist" (or hoisting) means all crane or derrick functions such as lowering, lifting, swinging, booming in and out or up and down, or suspending a personnel platform. The employer shall comply with the manufacturer's specifications and limitations applicable to the operation of all hoists and elevators. Where manufacturer's specifications are not available, the limitations assigned to the equipment shall be based on the determinations of a professional engineer competent in the field and such determinations will be appropriately documented and recorded.

- ❑ **Site Address** _____ **Cost Center**_____
- ❑ **Contractor Company** _____ **Work Order/PO #** _____
- ❑ **Name of authorized Permit Holder** _____ Phone:_____
- ❑ **Name of Permit Issuer** _____ Phone:_____
- ❑ **The purpose and exact location of the Hoisting/Rigging Work** _____
- ❑ **A Lift Plan was completed by a competent person and communicated YES _____ NO _____**
- ❑ **Is the operator certified for the equipment YES _____ NO _____**
- ❑ **The rated load capacities, recommended operating speeds, special hazard warnings, or instruction, is conspicuously posted on all equipment and visible to the operator while at the control station YES _____ NO _____**
- ❑ **Equipment is rated for work to be performed YES _____ NO _____**
- ❑ **A diagram of directional hand signals to crane and derrick operators is posted and reviewed before work begins. YES _____ NO _____**
- ❑ **Verification was made that electric lines or other overhead risks in the vicinity of Hoisting/Rigging operations have been de-energized prior to work YES _____ NO _____**
- ❑ **List the hazards of the Hoisting /Rigging Work being performed** _____

_____

(Such as electrical, exhaust, combustible, chemical, mechanical defects, obstructions, design defects, nearby vent stacks, hydrocarbon liquid or vapor, fuel delivery, omission of protective features, extreme temperature, extreme noise, high pressures, structures, weather, other)

- ❑ **List the measures used to isolate the space and to eliminate, or control hazards before work**

_____

(Such as barricading accessible areas within the swing radius, attachments rated for the load, hooks/hoist/chains and end connections checked for signs of wear/twist/cracks/distorted links/excessive stretch, rigging performed by a competent person, stable surface of operation, outriggers set, proper cribbing, tag lines, lockout/tagout/verification of energy sources, spark containment, correct extinguishers nearby, grounding, housekeeping, flag men, work stoppage during fuel delivery, other)

- ❑ **The on site means to contact emergency services are operable YES _____ NO _____**
- ❑ **List the safety equipment to be provided by contactor** (such as extinguishers, PPE, protective equipment/clothing, face and eye protection, communications equipment, alarm systems, other)**:** _____

_____

- ❑ **All components of the Hoisting/Rigging equipment and tools have been inspected by a competent person and adequate for use YES _____ NO _____**

(Such as wire rope or strap condition, evidence of any heat or damage, guards covering moving parts and exhaust where contact is possible, air or hydraulic systems inspected for deterioration or leakage in lines, tanks, valves, drain pumps, other)

- ❑ **Any other information necessary, in order to ensure employee safety** _____

PERMIT VALIDATION	
This Permit is valid from am/pm TO am/pm on / /	**(Note: Permit must not exceed 1 day)**
I ensure this permit has been filled out completely and in accordance with all applicable OSHA requirements to provide a safe workplace. I will take action to control hazardous conditions associated with this work.	
Permit Acceptance (print name): **Permit Holder Signature:**	**Permit Authorization (Print Name):** **Permit Issuer Signature:**

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

Date: Time:	Date: Time:

PERMIT CLOSE OUT

All work has been completed in accordance with this Permit and the site has been left in a safe and satisfactory condition.

Permit Holder Signature: Date: Time:	Permit Issuer Signature: Date: Time:

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

LANGAN	Health & Safety Procedures LOCKOUT/TAGOUT PERMIT	HSP 023-2 Issue Date: March 2016

Equipment/System to be Isolated: _____

Building: _____ **Floor:** _____ **Column:** _____

Other Location: _____

Purpose of Isolation: _____

Type of Isolation: _____

Authorized Employee: _____ **Date:** _____

Special Instructions: _____

Lockout/Tagout Performed: _____

Tag No.	Device ID	Bldg/Floor/Col.	Installed By	Removed By

Verification System is Safe for Specified Work to Start

Authorized Employee: _____ Date: _____ Time: _____

Accountability **Accepts Protection**

Requesting Authority: _____ Date: _____ Time: _____

Accountability **Release Protection**

Requesting Authority: _____ Date: _____ Time: _____

Lockout/Tagout Removal Authorization

Requesting Authority: _____ Date: _____ Time: _____

Safe Work System

WORK AT HEIGHTS PERMIT

Permit # _____

OSHA 1926.500, 501 This section sets forth requirements for employers to provide fall protection systems. All fall protection required by this section shall conform to the criteria set forth in 1926.502 of this subpart. The employer shall determine if the walking/working surfaces on which its employees are to work have the strength and structural integrity to support employees safely. Employees shall be allowed to work on those surfaces only when the surfaces have the requisite strength and structural integrity. "Unprotected sides and edges." Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 feet (1.8 m) or more above a lower level shall be protected from falling by the use of guardrail systems, safety net systems, or personal fall arrest systems.

- ❑ **Site Address** _____**Cost Center**_____
- ❑ **Contractor Company** _____**Work Order/PO #** _____
- ❑ **The date and the duration of the Working at Height permit** _____
- ❑ **Name of authorized Permit Holder** _____Phone:_____
- ❑ **Name of Permit Issuer** _____Phone:_____
- ❑ **Name of designated safety monitor** _____
(The safety monitor shall be competent to recognize fall hazards)
- ❑ **The purpose and location of the work at height** _____
- ❑ **List the type of activities being performed** _____
- ❑ **List the hazards of the Work being performed** _____
_____
(Such as electrical equipment and overhead lines, combustible, chemical, weather, mechanical design defects, tripping, falling objects, open holes, omission of protective features, extreme temperature, extreme noise, high pressures, structures, other)
- ❑ **List the inspected and fit for purpose measures to eliminate, or control hazards**
_____
(Such as guardrail, safety net, personal fall arrest system, fencing, barricade, lifelines, toe boards, edge and pathway warning lines, lockout/tagout/verification of energy sources, other)
- ❑ **The on site means to contact emergency services are operable YES _____ NO _____**
- ❑ **List the safety equipment to be provided by contractor** _____
_____
(such as PPE, protective clothing, head face and eye protection, communications equipment, alarm systems, other)
- ❑ **Verify all ladders, scaffolding and other means to access work at heights is of proper load, design and constructed per standards, placed on dry stable ground, of proper height, and secured. YES _____ NO _____**
- ❑ **List how vehicle and foot traffic is to be controlled** _____
- ❑ **Any other information necessary, in order to ensure employee safety** _____

PERMIT VALIDATION	
This Permit is valid from am/pm TO am/pm on / / . (Note: Permit must not exceed 1 day)	
I ensure this permit has been filled out completely and in accordance with all applicable OSHA requirements to provide a safe workplace. I will take action to control hazardous conditions associated with this work.	
Permit Acceptance (print name): **Permit Holder Signature:** **Date: Time:**	**Permit Authorization (Print Name):** **Permit Issuer Signature:** **Date: Time:**
PERMIT CLOSE OUT	

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

All work has been completed in accordance with this Permit and the site has been left in a safe and satisfactory condition.	
Permit Holder Signature: Date: Time:	Permit Issuer Signature: Date: Time:

Contractor is solely responsible for the understanding, training and execution of OSHA regulations relative to this activity. Permit forms must be retained for a minimum of two years.

LANGAN	**Health & Safety Procedures** **SIMOPS**	

SIMOPS Coordinator: _____
Description of Work Tasks for Each Party: _____
Locations of Work Parties for Each Party: _____
Competent Supervisor for Each Party[1]: _____

CLASSIFICATION

Operations are classified as:

- ☐ Prohibited (no SIMOPS activities will occur, requires additional planning),
- ☐ Controlled (SIMOPS activities can occur under controlled circumstances), or
- ☐ Acceptable (SIMOPS activities will not directly interfere with each work scope).

A change in the classification of SIMOPS activities during the day must be approved by the SIMOPS Coordinator
Description of SIMOPS Classification change: _____

Approved By: _____
SIMOPS Coordinator

CHECK LIST

☐ Yes	☐ No	If activities are classified as Prohibited or Controlled are proper controls (i.e. signs, barricades, and/or permit boards) in place?
☐ Yes	☐ No	Verify that communication systems between work parties are in place and functioning
☐ Yes	☐ No	Have JSA's been updated to include SIMOPs risks?

AUTHORIZATION

As the SIMOPS Coordinator I authorize that all work activities have been communicated to the work parties and any necessary controls have been implemented to minimize or eliminate simultaneous operations.

Signature: _____ Date:_____ Time: _____

[1] Individual responsible for management of SIMOPS activities
within the work area and will be available in the work area to manage SIMOPS activities. If the Competent Supervisor must leave the work party, the party will be notified and a temporary supervisor will be assigned.

LANGAN

HANDOVER HANDBACK CUSTODY TRANSFER FORM

FROM:

TO:

Is this a SIMOPS worksite? ☐ Yes ☐ No

Facility or Site Description_____

EMERGENCY CONTACTS

Facility/Site Contact _____ Phone _____ Cell _____

On Site Rep Contact _____ Phone _____ Cell _____

SITE CONSIDERATIONS

	Y	N	N/A		Y	N	N/A
Site free of garbage_____	☐	☐	☐	Signage required_____	☐	☐	☐
Site free of Hydrocarbons on ground____	☐	☐	☐	Sufficient distance from powerlines onsite for			
Pits free of Hydrocarbons_____	☐	☐	☐	operation_____	☐	☐	☐
Note environmental considerations of location				Buried pipelines/flowlines including sewer_____	☐	☐	☐
like wildlife, birds, etc._____	☐	☐	☐	Note and mark other buried structures_____	☐	☐	☐
Site drainage satisfactory_____	☐	☐	☐	Landowner concerns_____	☐	☐	☐
Site security (fence, barrier)_____	☐	☐	☐	Other (note in comments)_____	☐	☐	☐

Comments_____

FACILITY / EQUIPMENT HANDED OVER

Hand over complete site/facility? ☐ Yes ☐ No

Comments _____

Hand over partial site/facility? ☐ Yes ☐ No

Comments _____

LOTO in place? ☐ Yes ☐ No Comments_____

Current Piping & Instrumentation Diagram (P&ID)? ☐ Yes ☐ No

Comments_____

ADDITIONAL INFORMATION

Is there a reference map (including site controls for traffic/security) for the site/facility? If yes, provide as attachment_____ ☐ Yes ☐ No ☐ N/A

Is there a utility map for the site/facility? If yes, provide as attachment_____ ☐ Yes ☐ No ☐ N/A

LANGAN **HANDOVER HANDBACK CUSTODY TRANSFER FORM**

TURNED OVER BY (Outgoing)		RECEIVED BY (Incoming)	
On Site Rep. Print	Date	On Site Rep. Print	Date
Sign	Title	Sign	Title
On Site Rep. Print	Date	On Site Rep. Print	Date
Sign	Title	Sign	Title

OUTGOING – NOTIFICATION OF CHANGE

Description of changes made to the site or facility during duration of hand over: _____

APPENDIX K
Lifting and Hoisting

Lifting and Hoisting

Lifting and Hoisting (L&H) operations are inherently hazardous. Key requirements for L&H activities are summarized below.

Mandatory Requirements for Langan Onsite Representative:

1. Verify that all persons involved in L&H operations are trained and competent per their role
2. Communicate and verify the following:
    - The “Ten Questions for a Safe Lift” are addressed in a pre-lift Toolbox Talk for all lifts
    - Applicable lift planning requirements are met for all L&H operations classified as routine, critical, or complex
    - Uncertified home made lifting accessories are prohibited
    - The design requirements and physical condition of lifting appliances, accessories and equipment are appropriate for intended lifting operations
    - The site Lifting Accessory Register is maintained, including forklift attachments
    - Lifting Accessories are marked to show the name or trademark of manufacturer, safe working load, proof test date, and an identification number that can be traced back to the Lifting Accessory Register
    - Lifting Accessories are properly stored
    - That no personnel walk under suspended loads
    - Personnel exclusions zones shall be properly barricaded and access controlled
    - Taglines are used when required
    - Dedicated man-riding winches are labeled and are only used for man riding. Secondary fall protection must be used when man riding
    - Man-riding is considered a “Critical” Lift and requires:
        - Rescue from Height Plan
        - Safe Work Permit
        - JSA

Lifting and hoisting safety

Lifting and hoisting operations are among the major causes of fatalities and serious incidents in global exploration and production (E&P) activities.

IOGP wants to reduce the number and severity of lifting incidents among member companies. We are doing this by highlighting the essential principles of safe lifting and encouraging their strict application.

Despite the vast number of regulations, standards and guidelines that apply to lifting, incidents continue to occur. To address this, we are developing a recommended practice (RP) document, based on current experience and good practice for preventing fatalities and serious incidents.

Although it is not intended to be a comprehensive and technical set of lifting procedures, the RP will provide a source of extensive additional information in the form of appendices and a list of references – all of which have been recommended as being examples of good practice for particular aspects of lifting and hoisting.

Key principles



Key principles

Eight key areas that control lifting and hoisting safety

Planning

- A lift plan is required for every lift. If the lift deviates from the plan, make safe and stop the job.
- Hazard identification and risk assessment are an integral part of planning a lift.
- An assessment of the lift and determination of the lift method, equipment and number of people require

Control

- One person in the lift team is designated as the person in charge of the lifting operation (referred to as P
- The PIC reviews the lift plan and ensure that the required controls are in place and the lift is carried out fo
- The PIC ensures that the lift team has tested and understood visual or radio communications prior to the
- All personnel involved in the lifting operation shall have their individual responsibilities clearly allocated.
- All people shall be kept clear of overhead loads and areas of potential impact.
- Manual load handling shall not be used to stop a swinging load and shall only be performed below shou

Competence

- All persons involved in planning/performing lifting and maintaining lifting equipment shall be trained and
- Refresher training and periodic assessment is necessary to assure competence.

Equipment

- Equipment shall be fit for its intended purpose and operating conditions and shall be designed to a recog
- Equipment shall be fitted with appropriate safety devices.
- Any safety devices installed on lifting equipment shall be operational and not over-ridden.

Inspection, Maintenance and Certification

- Equipment integrity shall be maintained, supported by an equipment register.
- Lifting devices and equipment shall undergo detailed/thorough examination by a competent person at le
  used to lift people.
- All lifting devices and equipment shall be visually examined before use.

Load Integrity and Stability

- Load shall not exceed dynamic and/or static capacities of the lifting equipment.
- The integrity and stability of loads shall be verified before lifting.

Lifting of Personnel

- Lifting of personnel shall be avoided unless the risk has been demonstrated as being as low as is reasona
- Lifting of personnel shall be according to a specific personnel lift plan for that lift.
- Lifted personnel shall be properly secured with lanyards unless written procedures and risk assessment re

Management Systems

- Lifting operations will be conducted in accordance with a documented Management System.

About IOGP

The International Association of Oil & Gas Producers (IOGP) is the voice of the global upstream oil and gas industry.

Our Members operate around the globe, producing 40% of the world's oil and gas.

Together, we identify and share knowledge and good practices to improve the industry in areas such as health, safety, the environment and efficiency.

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LANGAN

Permit Attachment
10 Questions for a Safe Lift

Location: _____ Date: _____

Number of people involved: _____

Description of Job: _____

✓	10 Questions for a Safe Lift
	1. Is everyone involved in the lift aware of, and do they fully understand, the lifting and hoisting procedures applicable to the lift?
	2. Has everyone attended the Daily Tailgate Meeting?
	3. Has a pre-use inspection of the Lifting Equipment been carried out and are the Lifting Accessories tagged or marked with Safe Working Load, a unique ID number, and a valid certification date? Have these been documented?
	4. Are all safety devices working?
	5. Does everyone know who the Person in Charge of the lift is?
	6. Is everyone confident and aware of their task?
	7. Has the lift type been identified and are the proper work authorizations in place (e.g. WCC, Lift Plan, JSA)?
	8. Does everyone know the environmental limits (e.g. maximum permissible wind speed) for the lift?
	9. Is the lift area controlled and is everyone clear of danger if the load falls or swings?
	10. Are signaling methods and communication agreed upon and clear?

	Name	**Signature**
Person in Charge of Lift:	_____	_____
Participants:	_____	_____
	_____	_____
	_____	_____
	_____	_____

Example: Complex Lift Plan

Lift plan Category	Non-Routine Complex			
Lift Description				
References	Lift Plan no.		JSA	

Lift plan number is Date + sequential number of lift plans for that day. (example 01-15-2011-1)

Asset Location			
Date and Time			
Person in Charge of Lift		Position on location	
Supervisor walkthrough	☐Yes ☐ Not Required	Supervisor Name	
Communications	☐ Radio ☐ Hand Signals		

Lift Information Crane #1				
Weight of load:		lbs	Boom Length:	
Allowance for extra weight:(liquid, snow, sludge, ect)		lbs	Boom Angle:	
Weight of rigging:		lbs	Capacity from Load Chart:	
Weight of Block/Ball:		lbs	% of Capacity:	
Weight of attachment:		lbs	Weather Conditions:	
Total weight to be lifted:		lbs	Max Radius to be used:	

Lift Information Crane #2				
Weight of load:		lbs	Boom Length:	
Allowance for extra weight:(liquid, snow, sludge, ect)		lbs	Boom Angle:	
Weight of rigging:		lbs	Capacity from Load Chart:	
Weight of Block/Ball:		lbs	% of Capacity:	
Weight of attachment:		lbs	Weather Conditions:	
Total weight to be lifted:		lbs	Max Radius to be used:	

EXAMPLE

Total weight to be lifted: 10,000 lbs
Divided by: /
Capacity from load chart: 15,500 lbs
X 100 = % of capacity: 64.5 %

Extra safety measures to be considered *(tick as applicable and detail in 'step-by-step'). List is NOT INCLUSIVE.*

.

- ☐ Lifts of expensive items,
  - ☐ Get Subject Matter Expert (SME) or designee input.
  - ☐ All special lifting devices reviewed by Authorized Person.
  - ☐ All special lifting devices certified and inspected per OPS0055.
  - ☐ Consider increasing safety factors of lifting accessories.
- ☐ Lifts near overhead electrical power lines as defined by applicable regulations.
  - ☐ Ensure allowed by local operating procedures
  - ☐ Reference local regulation documentation and attach to this lift plan.
  - ☐ Post extra watch person as needed
  - ☐ De-energize if possible
- ☐ Lifts with "special non-standard rigging such multiple sheave blocks or multiple spreader bars.
  - ☐ Get SME or designee input.
  - ☐ All lifting devices certified and inspected
- ☐ Lifts to upend or lay down (turn vertically 90 degrees) and object with a crane.
  - ☐ Get SME or designee input.
- ☐ Lifts from uncertified lifting points
  - ☐ Get SME or designee input.
  - ☐ Perform Nondestructive Evaluation (NDE) and Inspection per Engineers instructions
  - ☐ Use rigging accessories that are certified and inspected
- ☐ Temporary Crane installations
  - ☐ Get SME or designee input.
  - ☐ Crane operators certified and assessed
  - ☐ NDE performed per Engineers instruction
  - ☐ Inspections and load test performed per API RP 2D
  - ☐ Load test pull points per Engineers instruction
- ☐ Tandem lifts involving two cranes
  - ☐ Get SME or designee input.
  - ☐ Both crane operators are assessed and experienced in tandem lifts.
  - ☐ Designated Signal Person is competent and experienced in tandem lifting with cranes.
- ☐ Lifts using both blocks of one crane
  - ☐ Get SME or designee input.
  - ☐ Both falls must be capable of carrying the full load.
  - ☐ Rigging certified and inspected
- ☐ Temporary hoist foundation
  - ☐ Get SME or designee input.
  - ☐ Tie down performed per Engineers instruction.
  - ☐ NDE performed per Engineers instruction

Example:	Complex Lift Plan

Lifting equipment and accessories to be used *(specify type, safe working load, and configuration)*

Sketches (may be part of Safe Work Plan and attached if applicable)
Sketch detailing the rigging-up of the lifting equipment and lifting accessories *(optional)*

Debrief and learning points *(did the lift go as planned or are changes to the lift plan required?)*

Lifting Focal Point	Print name(s)	Signature(s)	Date
Site Safety Officer	Print name(s)	Signature(s)	Date
Appliance Operator	Print name(s)	Signature(s)	Date
Designated Signal Person	Print name(s)	Signature(s)	Date

Example: Critical Lift Plan

Lift plan Category	Non-Routine Critical (SIMPLE)			
Lift Description				
References	Lift Plan no.		JSA no.	

Lift plan number is Date + sequential number of lift plans for that day. (ex. 01-15-2011-1)

Asset Location			
Date and Time			
Person in Charge of Lift Name (PIC/Lift Focal Point)		Position on location	
Supervisor walkthrough	☐ Yes ☐ Not Required	Supervisor Name	
Communications	☐ Radio ☐ Hand Signals		

Lift Information				
Weight of load:		lbs	Boom Length:	
Allowance for extra weight:(liquid, snow, sludge, ect)		lbs	Boom Angle:	
Weight of rigging:		lbs	Capacity from Load Chart:	
Weight of Block/Ball:		lbs	% of Capacity:	
Weight of attachment:		lbs	Weather Conditions:	
Total weight to be lifted:		lbs	Max Radius to be used:	

EXAMPLE
Total weight to be lifted: 10,000 lbs Divided by: / Capacity from load chart: 15,500 lbs X 100 = % of capacity: 64.5 %

Extra safety measures to be considered *(tick as applicable and detail in 'step-by-step'). List is NOT INCLUSIVE.*

- ☐ Lifts over or within 6' of active or energized hydrocarbon containing equipment.
  - ☐ Is there another route to avoid going over or within the equipment.
  - ☐ If the load bumped the equipment is there any instrumentation or valves whose breakage would cause damage or release.
  - ☐ Performed extra thorough pre-use inspection on all equipment associated with this lift.
  - ☐ Instituted 10:1 safety factor on rigging equipment.
- ☐ Personnel Transfer (Offshore)
  - ☐ Training requirements met
  - ☐ Pre-use inspection performed by Competent Person.
  - ☐ PIC informed that transfer is taking place.
  - ☐ Adequate landing area on vessel.
  - ☐ **Additional checks in next section.
- ☐ Normal Man-riding operations (between monkey board and rig floor).
  - ☐ Pre-start checklist filled out.
  - ☐ All safety devices operational
- ☐ Man-riding "Above Monkeyboard or below Rig Floor.
  - ☐ Pre-start checklist filled out.
  - ☐ All safety devices operational
  - ☐ ADDITIONAL MANAGEMENT APROVAL OBTAINED
- ☐ Lifts that expose a synthetic sling to dynamic shock or snatch conditions.
  - ☐ Document reason for no practical alternative to wire rope slings.
  - ☐ Is within the 12-month manufacture requirement.
  - ☐ The working load limit is double the weight of the item to be lifted.
- ☐ Lifts outside of the designated lifting areas (Offshore)
  - ☐ Document reason for lift to be landed outside of designated lifting area
  - ☐ Landing area surveyed and all potential hazards identified
  - ☐ May be combined with energized hydrocarbon equipment documentation requirements.
  - ☐ Extra riggers added as needed to assist in handling
- ☐ Blind lifts
  - ☐ Follow blind lifting procedures
  - ☐ Operator and Designated Signal Person (DSP) survey area for potential hang points and other hazards.
- ☐ Lifts with awkward shapes, unbalanced weight, unknown/difficult to estimate weight, center of gravity (COG), or a chance of being stuck.
  - ☐ Load indicator used to verify weight not to exceed capacity of lifting appliance.
  - ☐ Auxiliary devices introduced to free stuck object
  - ☐ If unable to easily determine the COG move to complex lift.
- ☐ Personnel lifts with the intent of performing work from a work basket or Aerial Platform.
  - ☐ Follow work basket procedures
  - ☐ Extra attention to body parts outside of work basket during work operation.
  - ☐ All body parts tools and equipment inside work basket during raising, lowering or traveling.
  - ☐ Operator will not perform any other functions or operations during the period of personnel lifting operations.
- ☐ Lifts using more than one lifting appliance, including handing off loads and tailing pipe to a rig. (Offshore)
  - ☐ Is load rigged to prevent slippage during hand off
  - ☐ Is each Appliance capable of handling the load on its own
  - ☐ Care for side loading of sheaves, blocks, trolleys etc…
- ☐ Lifts into or out of confined spaces or shafts, like hull columns. (Offshore)
  - ☐ Extra care for blind lifting communications exercised.
  - ☐ Extra riggers in place in strategic areas.
  - ☐ Additional person in cab to help watch load indicator.
- ☐ Lifts requiring bypass of safety devices.
  - ☐ ADDITIONAL MANAGEMENT APROVAL OBTAINED
  - ☐ Competent person to perform adjustment or bypassing
  - ☐ additional personnel added to monitor
  - ☐ Keep DSP in visual sight of the operator if at all possible

Example: Critical Lift Plan

Lifting of personnel		
☐ Prevention of person(s) becoming stuck/trapped ☐ Prevention of person(s) falling/being crushed ☐ Communications between passengers/operator ☐ Suitability of equipment and accessories	☐ Environmental hazards ☐ Correct PPE/harnesses/etc. ☐ Trained/competent personnel ☐ Certification/pre-use checks	☐ Vessel-/site-specific procedures ☐ Equipment secured in transporter ☐ Efficient means of rescue ☐ Limiting conditions of use

Lifting equipment and accessories to be used *(specify type, safe working load and configuration)*

Sketches
Sketch detailing the rigging-up of the lifting equipment and lifting accessories *(optional)*

Debrief and learning points *(did the lift go as planned or are changes to the lift plan required?)*

Lifting Focal Point	Print name(s)	Signature(s)	Date
Site Safety Officer	Print name(s)	Signature(s)	Date
Appliance Operator	Print name(s)	Signature(s)	Date
Designated Signal Person	Print name(s)	Signature(s)	Date

APPENDIX L
Lock-Out/Tag-Out

LOTO Tutorial: Printer Friendly Version

Note: This page includes the entire LOTO Tutorial. To print full screen pages of the OSHA website, left and right margins need to be set at a maximum of 0.25". On the browser, click File, then Page Setup. Change the settings for left and right margins to 0" (your browser may reset these values to a higher number, which is the minimum setting it will allow; this is acceptable). Select OK. Exit Page Setup and print from the browser print icon or from the File menu.

To print certain sections only, highlight the area you wish to print. Select File, then Print. From the print window, choose Selection, then Print.

Control of Hazardous Energy (Lockout/Tagout)
29 CFR 1910.147

Overview

Workers performing service or maintenance on machinery and equipment are exposed to injuries from the unexpected energization, startup of the machinery or equipment, or release of stored energy in the equipment.

The Lockout/Tagout standard requires the adoption and implementation of practices and procedures to shut down equipment, isolate it from its energy source(s), and prevent the release of potentially hazardous energy while maintenance and servicing activities are being performed. It contains minimum performance requirements, and definitive criteria for establishing an effective program for the control of hazardous energy. However, employers have the flexibility to develop lockout/tagout programs that are suitable for their respective facilities.

This tutorial summarizes for you the key components of the standard in a "plain English" format. This tutorial is intended only to guide OSHA staff in understanding aspects of the Lockout/Tagout standard, not to substitute for compliance with the plain terms of the standard. Nothing in this tutorial is intended to diminish or otherwise affect OSHA's authority to enforce the requirements of section 1910.147 of the Act, nor is it intended to create any legally enforceable right or benefit in any person.

Scope and Application

Who does this standard apply to?

- General Industry workers performing servicing and maintenance on machines and equipment and who are exposed to the unexpected energization, startup, or release of hazardous energy.

What activities or operations are covered?

- Any source of mechanical, hydraulic, pneumatic, chemical, thermal, or other energy.
- Constructing, installing, setting up, adjusting, inspecting, modifying, maintaining and/or servicing machines or equipment, including lubrication, cleaning or unjamming of machines or equipment, and making adjustments or tool changes, where employees could be exposed to the unexpected energization or startup of the equipment or release of hazardous energy.
- Servicing and maintenance activities performed during normal production operations if:
  - An employee is required to remove or bypass machine guards or other safety devices, or
  - An employee is required to place any part of his or her body into a point of operation or into an area on a machine or piece of equipment where work is performed, or into the danger zone associated with the machine's operation.

Who does this standard not apply to?

- General Industry workers performing servicing and maintenance on machines or equipment who are NOT exposed to the unexpected energization or startup of the machines or equipment, or the release of hazardous energy.

What activities and operations are not covered?

- Servicing and maintenance of equipment performed during normal production operations if:
  - the safeguarding provisions of Subpart O, and other applicable general industry standards are effective in preventing worker exposure to hazards created by the unexpected energization or startup of machines or equipment, or the release of energy.
- Minor tool changes and adjustments, and other minor servicing activities that take place during normal production operations which are routine, repetitive, and integral to the use of that production equipment, as long as workers are effectively protected

by alternative measures which provide effective machine safeguarding protection (See Subpart O).

- Construction, agriculture, and maritime workers
- Installations under the exclusive control of electric utilities for power generation, transmission, and distribution.
- Exposure to electrical hazards from work on, near, or with conductors or equipment in electric utilization installations.
- Oil and gas well drilling and servicing.
- Work on cord and plug connected electrical equipment, if:
  - The equipment is unplugged from the energy source and the authorized employee has exclusive control of the plug.
- Hot tap operations that involve transmission and distribution systems for gas, steam, water, or petroleum products on pressurized pipelines, if:
  - Continuity of service is essential, shutdown of the system is impractical, documented procedures are followed, and employees are effectively protected by special equipment.

Purpose

What is the purpose of the standard?

- To prevent the unexpected energization or startup of machines and equipment, or release of stored energy, in order to prevent workplace injuries during service and maintenance operations.

How is this accomplished?

- Employers must establish an energy control program, consisting of energy control procedures, employee training, and periodic inspections to ensure that before service and maintenance is performed, machines and equipment that could unexpectedly startup, become energized, or release stored energy, are isolated from their energy source(s) and rendered safe.

Definitions

What definitions are useful to understand how the lockout tagout standard will be applied?

- Authorized employee: An employee who locks or tags machines or equipment in order to perform servicing or maintenance.
- Affected employee: An employee who is required to use machines or equipment on which servicing is performed under the Lockout/Tagout standard or who performs other job responsibilities in an area where such servicing is performed.
- Other employees: All employees who are or may be in an area where energy control procedures may be utilized.
- Capable of being locked out: An energy-isolating device is considered capable of being locked out if it:
  - Is designed with a hasp or other means of attachment to which a lock can be affixed.
  - Has a locking mechanism built into it.
  - Can be locked without dismantling, rebuilding, or replacing the energy-isolating device or permanently altering its energy control capability.
- Energized: Machines and equipment are energized when they are connected to an energy source or they contain residual or stored energy.
- Energy-isolating device: A mechanical device that physically prevents the transmission or release or energy, including but not limited to the following: A manually operated electrical circuit breaker; a disconnect switch; a manually operated switch by which the conductors of a circuit can be disconnected from all ungrounded supply conductors and, in addition, no pole can be operated independently; a line valve; a block; and any similar device used to block or isolate energy. Push buttons, selector switches and other control circuit type devices are not energy isolating devices.
- Energy source: Any source of electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy.
- Lockout: The placement of a lockout device on an energy-isolating device, in accordance with an established procedure, ensuring that the energy-isolating device and the equipment being controlled cannot be operated until the lockout device is removed.
- Lockout device: Any device that uses positive means, such as a lock, blank flanges and bolted slip blinds, to hold an energy-isolating device in a safe position, thereby preventing the energizing of machinery or equipment.
- Normal production operations: Utilization of a machine or equipment to perform its intended production function.
- Servicing and/or maintenance: Workplace activities such as constructing, installing, setting up, adjusting, inspecting, modifying, maintaining and/or servicing machines or equipment, including lubrication, cleaning or unjamming of machines or equipment, and making adjustments or tool changes, where employees could be exposed to the unexpected energization or startup of the equipment or release of hazardous energy.
- Tagout: The placement of a tagout device on an energy-isolating device, in accordance with an established procedure, to indicate that the energy-isolating device and the equipment being controlled may not be operated until the tagout device is removed.
- Tagout device: Any prominent warning device, such as a tag and a means of attachment, that can be securely fastened to an energy-isolating device to indicate that the machine or equipment to which it is attached may not be operated until the tagout device is removed.

Energy Control Program

What are the core components of the energy control program?

- Energy control procedures that detail and document the specific information that an authorized employee must know to accomplish lockout/tagout, namely, the scope, purpose, authorization rules and techniques to be utilized for the control of hazardous energy.
- Periodic inspections of the energy control procedures to ensure that the procedures and the requirements of the standard are being followed.

Employee training and retraining, along with additional training under a tagout system, to ensure that the purpose and function of the energy control programs are understood by the employer.

What is the intent of the energy control program?

- To ensure that before any employee services equipment where the potential exists for unexpected energization or start-up of equipment or the release of stored energy, the machine or equipment is isolated from the energy source and rendered inoperative.

Does the employer have the flexibility to develop his/her own program?

Yes. Employers are expected to develop programs and procedures, training and inspections, that meet the needs of their particular workplace and the particular types of machines and equipment they use and service as long as they meet the requirements of the standard.

Energy Control Procedures - Documentation

What is the employer's obligation in establishing energy control procedures?

Employers must:

- Develop, document and use specific procedures to control potentially hazardous energy when employees are servicing equipment or machinery.

Under what limited situations is documentation of the procedures not required?

- The machine or equipment has no potential for stored or residual energy, or for reaccumulation of stored energy after shut down, which could endanger employees.
- The machine or equipment has a single energy source that can be readily identified and isolated and the isolation and locking out of that energy source will completely deenergize and deactivate the machine or equipment.
- The machine or equipment is isolated from that energy source and locked out during servicing or maintenance.
- A single lockout device will achieve a locked-out condition.
- The lockout device is under the exclusive control of the authorized employee performing the servicing or maintenance.
- The servicing or maintenance does not create hazards for other employees.
- The employer has had no incidents involving the unexpected activation or reenergization of machines or equipment during servicing or maintenance.

Energy Control Procedures - Required Content

What specific elements must be documented in the employer's energy control procedures?

- The procedures must outline the scope, purpose, authorization, rules and techniques that the employer will use to control hazardous energy.
- The procedures must state the means to be used to enforce compliance.

At a minimum, the procedures must include:

- A specific statement of the intended use of the procedure.
- Specific procedural steps for shutting down, isolating, blocking, and securing machines or equipment to control hazardous energy.
- Specific procedural steps for the placement, removal, and transfer of lockout devices or tagout devices, and a description of who has responsibility for them.
- Specific requirements for testing a machine or piece of equipment to determine and verify the effectiveness of lockout devices, tagout devices, and other energy control measures.

Periodic Inspection

What is the intent of the requirement for the employer to conduct periodic inspections?

To ensure that the energy control procedures continue to be implemented properly, that the employees are familiar with their responsibilities, and that any deviations or procedural inadequacies that are observed are corrected.

How often must the inspection take place?

At least annually.

Who performs the periodic inspection?

An authorized employee not involved in the energy control procedure being inspected.

What does the periodic inspection entail?

- The employer must identify any deficiencies or deviations and correct them.
- Where lockout is used, the inspector must review each authorized employee's responsibilities under the procedure with that employee (group meetings are acceptable).
- Where tagout is used, the inspector must review both the authorized and affected employee's responsibilities with those employees for the energy control procedure being inspected, and the additional training responsibilities of 1910.147(c)(7)(ii).
- The employer must certify that the periodic inspections have been performed.

What must the certification identify?

- Identify machine on which the procedure was utilized.
- Date of inspection.
- Identify the employees included in inspection.
- Identify person who performed the inspection.

Employee Training and Communication

Why must employees affected by this standard be trained?

- So that they understand the purpose and function of the energy control program.
- So that employees acquire the knowledge and skills necessary for the safe application, usage and removal of the energy controls.

The standard requires different levels of training for the three categories of employees; what are the differences in the training required for the three categories?

- Authorized employees must receive training on the recognition of applicable hazardous energy sources, the type and magnitude of the energy available in the workplace, and the methods and means necessary for energy isolation and control.
- Affected employees must receive training on the purpose and use of the energy control procedure.
- Other employees (those whose work activities are or may be in an area where energy control procedures may be utilized) must be instructed about the procedure and about the prohibition relating to attempts to restart or reenergize machines or equipment that are locked out or tagged out.

Additional Training

What additional training is required when tagout systems are used?

Employers must train employees in the following limitations of tags:

- Tags are essentially warning devices affixed to energy isolating devices and do not provide the physical restraint on those devices that is provided by a lock.
- When a tag is attached to an energy isolating means, it is not to be removed without authorization and it is never to be bypassed, ignored, or otherwise defeated.
- Tags must be legible and understandable by all employees.
- Tags and their means of attachment must be made of materials which will withstand the environmental conditions encountered in the workplace.

- Tags may evoke a false sense of security and their meaning needs to be understood as part of the overall energy control program.
- Tags must be securely attached to energy isolating devices so that they cannot be inadvertently or accidentally detached during use.

Employee Retraining

Who must be retrained?

All affected and authorized employees must be retrained under certain conditions listed below.

Is training required annually?

No.

What triggers the retraining requirements?

- A change in job assignments.
- A change in machines, equipment, or processes that present a new hazard.
- A change in the energy control procedures.
- Periodic inspections reveal that there are deviations in the energy control procedure.
- The employer believes that there are deviations from, or inadequacies in, the employee's knowledge or use of the energy control procedures.

What is the object of the retraining?

- To introduce new or revised control methods and procedures as necessary.
- To reestablish employee proficiency.

Does training require certification?

Yes. Employer must certify that training or retraining took place and that the employee is kept up to date.

What information must appear on the certificate?

- Each employee's name.
- The dates of training and /or retraining.

Lockout/Tagout

If an energy isolating device is not capable of being locked out, can the employer use a tagout system?

Yes, when the energy isolating devices are not lockable, tagout may be used, provided the employer complies with the provisions of the standard which require additional training and more rigorous periodic inspections.

If an energy isolating device is capable of being locked out, must the employer use a lock out system?

Yes. Unless the employer can show that the tagout system provides full employee protection, as described in paragraph (c)(3) of the standard.

New or Modified Equipment

What is the date after which all new machines and equipment, or all machines and equipment that undergo major repair, renovations or modification, must be equipped with energy-isolating devices capable of accepting a lockout device?

January 2, 1990.

Full Employee Protection

What are the requirements for the use of tagout devices when lockout devices are capable of being used?

- The tags are attached where the lockout devices would be.
- The employer demonstrates that the tagout will provide protection at least as effective as locks and will assure full employee protection.

How does an employer demonstrate that the protection achieved using the tagout program is equivalent to the level of safety obtained by using a lockout program?

The employer must comply with all tagout-related provisions and also use additional safety measures that provide a level of safety equivalent to that obtained by using lockout. This might include removing and isolating a circuit element, blocking a controlling switch, opening an extra disconnecting device, or removing a valve handle to reduce the potential for any inadvertent energization while the tags are attached.

Materials and Hardware

What protective materials and hardware must be provided by the employer for isolating, securing or blocking machines or equipment from energy sources?

- Locks, tags, chains, wedges, key blocks, adapter pins, self-locking fasteners, or other hardware.

What are the requirements for the lockout and tagout devices?

- Must be durable, so that they are capable of withstanding the environment to which they are exposed for the maximum period of time that exposure is expected.
- Must be singularly identified.
- Must be the only devices used for controlling energy.
- Must not be used for other purposes.
- Must be standardized with in the facility in at least one of the following criteria: color, shape, or size. Additionally, tagout devices must be standardized as to print and format.
- Must be identifiable, in that it indicates the identity of the employee applying the devices.

In addition to the above, what other hardware requirements are specific to lockout?

- Must be substantial enough to prevent removal without the use of excessive force or unusual techniques such as with the use of bolt cutters or other metal cutting tools.

In addition to the above, what other hardware requirements are specific to tagout?

- Must be constructed and printed so that exposure to weather conditions or wet and damp locations will not cause the tag to deteriorate or the message on the tag to become illegible.
- Must not deteriorate when used in corrosive environments such as areas where acid and alkali chemicals are handled and stored.
- Must be standardized in print and format.
- Must be substantial to prevent inadvertent or accidental removal.
- Must have an attachment means of a non-reusable type, attachable by hand, self-locking, and non-releasable with a minimum unlocking strength of no less than 50 pounds and having the general design and basic characteristics of being at least equivalent to a one-piece all-environment-tolerant nylon cable tie.
- Must warn against hazardous conditions if the machine or equipment is energized.
- Must include a legend such as: Do Not Start, Do Not Open, Do Not Close, Do Not Energize, Do Not Operate.

Application of Energy Control

To safely apply energy control to machines or equipment (using either lockout or tagout devices), authorized employees must perform certain procedures, in a specific order. What are the sequential procedures?

- Preparation for shutdown: Before an authorized or affected employee turns off a machine or equipment, the authorized employee must have knowledge of the type and magnitude of the energy, the hazards of the energy to be controlled, and the method or means to control the energy.
- Machine or equipment shutdown: The machine or equipment must be turned off or shut down using the procedures established for it to avoid any additional or increased hazards to employees as a result of the machine or equipment stoppage.
- Machine or equipment isolation: All energy-isolating devices that are needed to control the machine's energy source must be located. These devices must then be used to isolate the machine or equipment from its energy source.
- Lockout or tagout device application: Lockout or tagout devices must be affixed to each energy-isolating device by authorized employees. Lockout devices where used, must be affixed in a manner that will hold the energy isolating devices in a "safe" or "off" position. Where tagout devices are used, it must be affixed in a manner that will clearly indicate that the operation or movement of energy isolating devices from the "safe" or "off" position is prohibited. If the tag can not be affixed directly to the energy isolating device, the tag must be located as close as safely possible to the device, in a position that will be immediately obvious to anyone attempting to operate the device
- Stored energy: After the energy-isolating device has been locked out or tagged out, all potentially hazardous stored or residual energy must be relieved, disconnected, restrained, or otherwise rendered safe.
- Verification of isolation: Before any work begins on machines or equipment that have been locked out or tagged out, an authorized employee must verify that the machine or equipment has been properly isolated and deenergized.

Release from Lockout/Tagout

The Lockout/Tagout standard includes requirements for releasing machines or equipment that have been locked out or tagged out prior to restoring energy to the equipment and using it. Before lockout or tagout devices are removed, and energy restored, what procedures must the authorized employee follow?

- Machine/equipment inspection: The work area must be inspected to ensure that nonessential items (e.g., tools, spare parts) have been removed and that all of the machine or equipment components are operationally intact.

- Positioning of employees: The work area must be checked to ensure that all employees have been safely positioned or have cleared the area. In addition, all affected employees must be notified that the lockout or tagout devices have been removed before the equipment is started.
- Lockout or tagout device removal: Each lockout or tagout device must be removed from the energy-isolating device by the employee who applied the device.

What is the unique circumstance that allows an employee other than the one who applied the lockout/tagout device to remove the device?

When the authorized employee who applied the lockout or tagout device is not available to remove it, that device may be removed under the direction of the employer, provided that specific procedures and training for such removal have been developed, documented, and incorporated into the employer's energy control program.

What steps must the employer take if an employee, other than the one who applied the lockout/tagout device, removes the device?

- The employer must verify that the authorized employee who applied the device is not at the facility.
- The employer must make all reasonable efforts to contact the authorized employee to inform him/her that his/her lockout or tagout device has been removed.
- The employer must ensure that the authorized employees knows that the lockout device has been removed before he/she resumes work at the facility.

Testing of Machines

When may lockout or tagout devices be removed temporarily?

In some circumstances, employees need to temporarily restore energy to a machine or piece of equipment during servicing or maintenance to test and /or reposition the machine or piece of equipment. Lockout or tagout devices may be removed temporarily in order to perform these tasks.

What sequence of action must occur in the temporary removal of the lockout/tagout devices?

1. The machine or equipment must be cleared of tools and materials.
2. Employees must be removed from the machine or equipment area.
3. All lockout or tagout devices may then be removed.
4. Authorized employees may then proceed to energize and test or position the equipment or machinery.
5. Following testing or positioning, all systems must be deenergized and energy control measures reapplied to continue the servicing and /or maintenance.

Outside Personnel (Contractors)

What are the obligations of the outside contractor and the on-site employer?

- Whenever contractors and other outside servicing personnel perform tasks covered by the Lockout/Tagout standard, they must adhere to all the standard's requirements.
- The contractor or outside employer and the on-site employer must inform each other of their respective energy control program responsibilities.
- The on-site employer must ensure that his/her employees understand and comply with the restrictions and prohibitions of the outside employer's energy control program.

Group Lockout/Tagout Requirements

Can servicing or maintenance be performed by a crew, department, or other group under this standard?

Yes. If they have been properly trained and the energy control program is followed.

What procedures must be followed that will offer group employees the same protection that the standard provides to individual employees?

- A group lockout/tagout must afford each employee a level of protection equivalent to that provided by the implementation of a personal lockout or tagout device.
- Primary responsibility for a set number of employees working under the protection of a group lockout or tagout device must be vested in a single authorized employee.
- The single authorized employee must determine the exposure status of individual group members.
- If there will be more than one crew, department, or group involved in the activity, a single authorized employee must be designated to coordinate affected workforces and to ensure continuity of protection.
- Each authorized employee must affix a personal lockout or tagout device to the machine or equipment when work begins and remove it when work is completed.

Shift & Personnel Changes

How is the continuity of lockout or tagout protection maintained during shift or personnel changes?

- Employers must ensure the continuity of employee protection by providing for the orderly transfer of lockout or tagout device protection between off-going and incoming employees. This will help to minimize exposure to hazards from the unexpected energization or start-up of the machine or equipment or the release of stored energy.

(The Appendix to 1910.147 offers non-mandatory guidelines to help employers and employees in complying with the requirements of this section, as well as to provide other helpful information.)

APPENDIX M
Heat Illness Protection Plan

MIPC
Heat Illness Prevention Plan

Per Pennsylvania Workplace Heat Protection Standards Act (HB1580), the employer shall establish, implement, and maintain, an effective heat illness prevention plan. The plan shall be in writing in both English and the language understood by the majority of the employees and shall be made available at the worksite to employees and to representatives of the Division upon request. The Heat Illness Prevention Plan may be included as part of the employer's Illness and Injury Prevention Program. Heat Illness Prevention is currently addressed in the Site HASP. This appendix has been developed to supplement the HASP.

This Heat Illness Prevention Plan contains the minimum requirements for heat illness prevention at the above-referenced site. It should be noted that additional training is provided in conjunction with this plan. This plan contains four main sections:

(1) Procedures for the provision of water and access to shade.

(2) The high heat procedures referred to in subsection (e).

(3) Emergency Response Procedures in accordance with subsection (f).

(4) Acclimatization methods and procedures in accordance with subsection (g).

Section (1): Procedures for the provision of water and access to shade.

Provision of water: Employees shall have access to potable drinking water meeting the requirements, as applicable, including but not limited to the requirements that it be fresh, pure, suitably cool, and provided to employees free of charge. The water shall be located as close as practicable to the areas where employees are working. Where drinking water is not plumbed or otherwise continuously supplied, it shall be provided in sufficient quantity at the beginning of the work shift to provide one quart per employee per hour for drinking for the entire shift. Employers may begin the shift with smaller quantities of water if they have effective procedures for replenishment during the shift as needed to allow employees to drink one quart or more per hour. The frequent drinking of water shall be encouraged.

Water is provided at the site at the project office (Muster Point 1 in the Site ERP), and in individual bottle form, free to all site workers and employees. Further, it is encouraged for all crews working remotely from the project office to bring a supplied cooler with drinking water to their work location.

(d) Access to shade.

(1) Shade shall be present when the temperature exceeds 80 degrees Fahrenheit. When the outdoor temperature in the work area exceeds 80 degrees Fahrenheit, the employer shall have and maintain one or more areas with shade at all times while employees are present that are either open to the air or provided with ventilation or

cooling. The amount of shade present shall be at least enough to accommodate the number of employees on recovery or rest periods, so that they can sit in a normal posture fully in the shade without having to be in physical contact with each other. The shade shall be located as close as practicable to the areas where employees are working. Subject to the same specifications, the amount of shade present during meal periods shall be at least enough to accommodate the number of employees on the meal period who remain onsite.

(2) Shade shall be available when the temperature exceeds 80 degrees Fahrenheit. When the outdoor temperature in the work area does exceed 80 degrees Fahrenheit employers shall either provide shade or provide timely access to shade upon an employee's request.

(3) Employees shall be allowed and encouraged to take a preventative cool-down rest in the shade when they feel the need to do so to protect themselves from overheating.  *Such access to shade shall be permitted at all times. An individual employee who takes a preventative cool-down rest (A) shall be monitored and asked if he or she is experiencing symptoms of heat illness; (B) shall be encouraged to remain in the shade; and (C) shall not be ordered back to work until any signs or symptoms of heat illness have abated, but in no event less than 5 minutes in addition to the time needed to access the shade.*

(4) If an employee exhibits signs or reports symptoms of heat illness while taking a preventative cool-down rest or during a preventative cool-down rest period, the employer shall provide appropriate first aid or emergency response.

Air conditioning is available at the site at the project office and in field vehicles. In addition, Langan or their subcontractor may also provide outdoor shaded areas. Langan and their subcontractors are trained in heat illness prevention and identification, and are mandated to follow the heat illness prevention procedures within the site HASP. Site workers are encouraged to take rest breaks within the project office or other shaded areas when needed.

Section (2): The high heat procedures referred to in subsection (e).

Langan shall implement high-heat procedures when the temperature equals or exceeds 95 degrees Fahrenheit. These procedures shall include the following to the extent practicable:

(1) Ensuring that effective communication by voice, observation, or electronic means is maintained so that employees at the work site can contact a supervisor when necessary. An electronic device, such as a cell phone or text messaging device, may be used for this purpose only if reception in the area is reliable.

(2) Observing employees for alertness and signs or symptoms of heat illness. Langan shall ensure effective employee observation/monitoring by implementing one or more of the following:

(A) Supervisor or designee observation of 20 or fewer employees, or

(B) Mandatory buddy system, or

(C) Regular communication with lone workers via two-way radios, or

(D) Other effective means of observation.

(3) Designating one or more employees on each worksite as authorized to call for emergency medical services, and allowing other employees to call for emergency services when no designated employee is available. Langan employees are trained in the use of "Stop Work Authority", which everyone on the site has the right to use. In the event of an emergency, the site's Emergency Response Plan will be followed.

(4) Reminding employees throughout the work shift to drink water.

(5) Pre-shift meetings before beginning work to review the high heat procedures, encourage employees to drink plenty of water, and remind employees of their right to take a cool-down rest when necessary.

Section (3): Emergency Response Procedures in accordance with subsection (f).

Langan, as part of the Site Specific HASP and ERP, shall implement effective emergency response procedures including:

(1) Ensuring that effective communication by voice, observation, or electronic means is maintained so that employees at the work site can contact a supervisor or emergency medical services when necessary. An electronic device, such as a cell phone or text messaging device, may be used for this purpose only if reception in the area is reliable. If an electronic device will not furnish reliable communication in the work area, Langan will ensure a means of summoning emergency medical services.

(2) Responding to signs and symptoms of possible heat illness, including but not limited to first aid measures and how emergency medical services will be provided. These topics are addressed in the Site HASP, and reinforced with supplemental temporal training.

(A) If a supervisor observes, or any employee reports, any signs or symptoms of heat illness in any employee, the supervisor shall take immediate action commensurate with the severity of the illness.

(B) If the signs or symptoms are indicators of severe heat illness (such as, but not limited to, decreased level of consciousness, staggering, vomiting, disorientation, irrational behavior or convulsions), the employer must implement emergency response procedures.

(C) An employee exhibiting signs or symptoms of heat illness shall be monitored and shall not be left alone or sent home without being offered onsite first aid and/or being provided with emergency medical services in accordance with the employer's procedures.

3) Contacting emergency medical services and, if necessary, transporting employees to a place where they can be reached by an emergency medical provider. This is addressed in the site-specific HASP and ERP.

(4) Ensuring that, in the event of an emergency, clear and precise directions to the work site can and will be provided as needed to emergency responders. This is outlined in the Site ERP.

Section (4): Acclimatization methods and procedures

(g) Acclimatization.

(1) All employees shall be closely observed by a supervisor or designee during a heat wave. For purposes of this section only, "heat wave" means any day in which the predicted high temperature for the day will be at least 85 degrees Fahrenheit and at least ten degrees Fahrenheit higher than the average high daily temperature in the preceding five days.

(2) An employee who has been newly assigned to a high heat area shall be closely observed by a supervisor or designee for the first 14 days of the employee's employment.

The Langan SSE (Short Service Employee) program assigns a mentor to any new worker to the site. The mentor will closely monitor the new employee, especially during heat waves.

All Langan and site employees have stop work authority, and have been trained in the use of last-minute risk assessment procedures. Employees will reinforce the symptoms and treatment methods of heat illnesses through periodic meetings and safety stand-downs. The attached pages can be used for discussion.

Employee Acknowledgment Sheet

I have read and understand this site-specific Heat Illness Prevention Plan, its relationship to the project HASP, and my roles and responsibilities as a site worker.

Print Name	Signature	Date

Employee Acknowledgment Sheet

I have read and understand this site-specific Heat Illness Prevention Plan, its relationship to the project HASP, and my roles and responsibilities as a site worker.

Print Name	Signature	Date

ATTACHMENT 1

HEAT ILLNESS SYMPTOMS AND PREVENTION

HEAT STRESS CONTROL

Heat stress is recognized as one of the most common health effects caused by working in high heat conditions and especially when working in personal protective clothing. It can pose as great a danger to worker health as chemical exposure. This procedure has been developed to establish guidelines for the implementation and operation of a heat stress prevention, evaluation, and response program.

Scope

This procedure applies to all Langan activity where personnel may be exposed to heat stress factors (hot environment, high work demands, and protective clothing requirements).

Definitions

Acclimation - Acclimation is the process of the body becoming accustomed to extremes in temperature.

Administrative Controls - Methods of controlling employee exposure by job rotation, work assignment, time periods away from the hazard, or training in specific work practices designed to reduce the exposure.

ACGIH TLV - Heat Stress Threshold Limit Values (TLVs) are intended to protect workers from the severest effects of heat stress and heat injury and to describe exposures to hot working conditions under which it is believed that nearly all workers can be repeatedly exposed without adverse health effects. The TLV objective is to prevent the deep body core temperature from exceeding 38°C (100.4^{o}F).

Engineering Controls - Methods of controlling employee exposures by modifying the source or reducing the quantity of contaminants released into the work environment.

Wet-Bulb Globe Temperature (WBGT) - This is the simplest and most suitable technique to measure the environmental factors associated with heat stress. The value is calculated by using equations shown in Attachment B.

Work-Rest Regimen - This is a ratio of time spent working versus time spent resting. The ratio applies to one hour periods. For example, a work-rest regiment of 75% work, 25% rest corresponds to 45 minutes work, 15 minutes rest each hour. See Attachment A.

Responsibilities

Site Personnel - All site personnel must be alert to signs and symptoms of heat stress in themselves and in those working with them. Personnel must also be aware of the emergency corrective actions to be taken in response to the symptoms of heat stress.

Health and Safety Officer (HSO) - The HSO is responsible for establishing and enforcing the necessary engineering, administrative, and

personal protection controls as appropriate to control heat stress.

Procedures

Acclimation to heat involves a series of physiological and psychological adjustments that occur in an individual during his/her first week of exposure to hot environmental conditions. The work - rest regimen in this procedure is valid for acclimated workers who are physically fit as determined through medical monitoring procedures.

Recognition of Heat Stress

Hot weather can cause physical discomfort, loss of efficiency, and personal injury. Wearing personal protective equipment (PPE) puts a worker at a higher potential risk of developing heat stress since protective clothing decreases natural body ventilation. Overprotection must be avoided. Regular monitoring and preventive measures are essential to the health and safety of personnel conducting fieldwork.

Early symptoms of heat stress may include fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement. If not recognized or treated, heat stress may become fatal.

Heat stress comes in different forms, which are listed below in order of increasing severity.

1. Heat Rash caused by continuous exposure to hot and humid air, and aggravation of the skin by chafing clothes. In addition to being a nuisance, this decreases the ability to tolerate heat.

2. Heat Cramps caused by profuse perspiration in conjunction with inadequate fluid intake and chemical replacement (especially salts). Signs of heat cramp include muscle spasms and pain in the extremities and abdomen.

3. Heat Exhaustion caused by stress on various organs to meet increased demands for body cooling. Signs include shallow breathing; pale, cool, moist skin; profuse sweating; dizziness; and/or fatigue.

4. Heat Stroke is the most severe form of heat stress. Heat stroke is considered an Immediately Dangerous to Life or Health (IDLH) condition and as such must be treated as an emergency. Any person suffering from heat stroke must be cooled down immediately and brought to a hospital. Decontamination procedures should not be implemented. Signs of heat stroke include red, hot, dry skin; no perspiration; nausea; dizziness and confusion; strong, rapid pulse; and/or coma.

It is important to note that individuals vary in their susceptibility and their reactions to heat related conditions. Factors that may predispose someone to a heat condition include:

- Lack of physical fitness;
- Lack of acclimation;
- Age;
- Dehydration;
- Obesity;
- Alcohol and drug use;
- Infection;
- Sunburn;
- Diarrhea;
- Chronic disease: and
- Use of medication

First-Aid / Medical Treatment

First-aid and medical treatments recommended as corrective actions for people suffering from different forms of heat stress are outlined below.

1. Heat Rash - Apply mild drying lotions and utilize cool, dry sleeping quarters to allow skin to dry between heat exposures.

2. Heat Cramps – To relieve heat cramps, which may take several hours, follow these steps:
   a. Rest in a cool place,
   b. Drink lightly salted cool water of a commercial sports drink
   c. Massage cramped muscles.

3. Heat Exhaustion – To treat heat exhaustion, follow these steps:
   a. Move the victim immediately out of the heat to a cool place
   b. Give cool liquids (lightly salted water of sports drink)
   c. Raise the victim's legs
   d. Remove excess clothing
   e. Sponge with cool water and fan the victim
   f. If no improvement is seen within 30 minutes, seek medical attention.

4. Heat Stroke - A medical emergency that must be treated rapidly**!** Every minute delayed increases the likelihood of serious complications or death.
   a. Move the victim immediately out of the heat to a cool place,
   b. Remove clothing down to the victim's underwear,
   c. Keep the victim's head and shoulders slightly elevated
   d. Seek immediate medical attention, even if the victim seems to be recovering,
   e. Cool the victim quickly and by any means possible, such as:
      (1) Spray the victim with water then fan him/her,
      (2) Place ice bags wrapped in towels against the large veins in the groin, armpits, and sides of the neck.

Heat Stress Prevention

Following the measures outlined below will help prevent or reduce heat stress:

1. Drinking water shall be made available and all personnel shall be encouraged to take frequent small drinks, (i.e. one cup every 15-20 minutes, about 150 ml or 1/4 pint), even though they may not be thirsty. The water shall be kept reasonably cool (55-60°F) and shall be placed outside the contaminated areas. Personnel shall also be encouraged to maintain a healthy lifestyle, ideal bodyweight, and electrolyte balance. Commercially available products such as Gatorade or Exceed may be used for electrolyte replacement.

2. Cooling devices may be used to aid natural body ventilation; however, these devices add weight and, therefore, their use should be balanced against worker efficiency.

3. Long cotton underwear should be worn. It acts as a wick to help absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing.

4. Air conditioned shelter or shaded areas should be provided to protect personnel during rest periods.

5. Mobile showers and/or hose-down facilities should be provided to reduce body temperature and cool protective clothing.

6. Physically demanding work should be conducted in the early morning, late afternoon or evening, normally the cooler times of the day.

7. A rotating shift schedule should be implemented.

8. Additional personnel should be added to work teams to reduce exposure time for each member of the team

9. Workers should be permitted the freedom to interrupt work when they feel extreme heat discomfort slowdowns.

10. Good hygienic standards must be maintained by frequent change of clothing and daily showering. Clothing should be permitted to dry during rest periods.

11. All personnel shall be instructed in hot weather procedures. The training program shall include, as a minimum, instruction in:

12. Proper cooling procedures and appropriate first-aid treatment;
13. Proper clothing practices;
14. Proper eating and drinking habits;
15. Recognition of signs and symptoms of heat stress
16. Safe work practices.

Work-Rest Regimen

A work-rest regimen will be established for field work where personnel may be exposed to environments exceeding 80 degrees Fahrenheit for Level D work, and environments exceeding 70 degrees Fahrenheit for Levels C and B work. The American Conference of Governmental Industrial Hygienists' Screening Criteria for Heat Stress Exposure (Attachment A) shall be used as a guideline.

If any heat stress symptoms are identified by the site personnel, the HSO shall be notified immediately and all work activity shall cease until the situation is corrected.

Biological Monitoring

In order to evaluate the effectiveness of the work-rest regimen, employees shall monitor their heart rates.

Heart rate (HR) should be measured by taking the pulse for 30 seconds at the beginning of each rest period. The HR should not exceed 110 beats/ min. If the HR is higher, the next work period should be shortened by 33 percent, while the length of rest period stays the
same. If the pulse rate is still greater than 110 beats/min. at the beginning of the next rest period, the following work cycle should again be shortened by 33 percent. The length of the initial work period will be determined by the HSO.

References

America Conference of Governmental Industrial Hygienists (ACGIH), *Threshold Limit Values and Biological Exposure Indices*

Attachments

ATTACHMENT A	Screening Criteria for Heat Stress Exposure
ATTACHMENT B	Wet Bulb Globe Temperature Index
ATTACHMENT C	Manual Measurement of WBGT Factors

ATTACHMENT A
SCREEING CRITERIA for HEAT STRESS EXPOSURE
(values are given in ºF WBGT)

WORK LOAD

Work-Rest Regimen	Light	Moderate	Heavy
Continuous Work	86	80	77
75% Work - 25% Rest, Each Hour	87	82	78
50% Work - 50% Rest, Each Hour	89	85	82
25% Work - 75% Rest, Each Hour	90	88	86

Source: America Conference of Governmental Industrial Hygienists (ACGIH), *Threshold Limit Values and Biological Exposure Indices*

ATTACHMENT B
WET BULB GLOBE TEMPERATURE INDEX

A baseline work-rest regimen is selected using the WBGT procedure. The period of work will be adjusted based on the biological monitoring.

The WBGT in conjunction with the work load required to perform each task is used to determine work-rest regimen. **Light** work examples include such tasks as sitting or standing to control machines or performing light hand or arm work. **Moderate** work includes walking about in coated coveralls and respirators doing moderate lifting and pushing. **Heavy** work corresponds to pick and shovel-type work or the use of full body protective clothing. *It must be assumed that any activity involving this type of clothing will be considered heavy work.*

In order to determine the WBGT the following equations are used:

- Outdoors with solar load: WBGT = 0.7 WB + 0.2 GT + 0.1 DB

- Indoors or outdoors with no solar load: WBGT = 0.7 WB + 0.3 GT

WB = Natural Wet-Bulb Temperature DB = Dry-Bulb Temperature
GT = Globe Thermometer Temperature

The factors involved in the above equations can be measured using a direct reading instrument or manually measuring each factor.

- An example of a direct-reading heat stress monitor is the Reuter-Stokes Widget No. RSS-214 heat stress monitor.

    - Assessment of individual factors requires the following equipment:

        - Dry-bulb thermometer
        - Natural wet-bulb thermometer
        - Globe thermometer
        - Stand

ATTACHMENT C
MANUAL MEASUREMENT of WBGT FACTORS

The range of the dry and the natural wet-bulb thermometers shall be -5°C to 50°C with an accuracy of 0.5°

A. The dry-bulb thermometer must be shielded from the sun and the other radiant surfaces of the environment without restricting the airflow around the bulb. The wick of the natural wet-bulb thermometer shall be kept wet with distilled water for at least ½ hour before the temperature reading is made. It is not enough to immerse the other end of the wick into a reservoir of distilled water and wait until the whole wick becomes wet by capillary action. The wick shall be wetted by direct application of water from a syringe ½ hour before each reading. The wick shall extend over the bulb of the thermometer, covering the stem about one additional bulb length. The wick should always be clean and new wicks shall be washed before using.

A globe thermometer, consisting of a 15 cm (6-inch) diameter hollow copper sphere painted on the outside with a matted black finish, or equivalent, shall be used. The bulb or sensor of a thermometer (range -5°C to 100 C with an accuracy of 0.5°C) must be fixed in the center of the sphere. The globe thermometer shall be exposed at least 25 minutes before it is read.

A stand shall be used to suspend the three thermometers so that they do not restrict free airflow around the bulbs.

It is permissible to use any other type of temperature sensor that gives identical reading as that of a mercury thermometer under the same conditions.

The thermometers must be so placed that the readings are representative of the condition where the men work and rest, respectively. All readings shall be recorded on the site log.

In many cases WBGT is the simplest and most suitable technique to measure heat. However, this system is only valid for light summer clothing. When special personal protective clothing is required for performing a particular job the worker's heat tolerance is reduced and the permissible heat exposure limits are not applicable, since this clothing is heavier, impedes sweat evaporation and/or has higher insulation value.

ATTACHMENT 2

LANGAN HEAT ILLNESS DISCUSSION GUIDANCE

LANGAN

Tailgate Safety Meeting
Health and Safety

Heat Stress

(Employees should present and discuss the information provided to conduct a brief training on the topic.)

Exposure to hot and humid environments can put workers at risk for illnesses such as heat cramps, heat rash, heat stroke and heat exhaustion. Heat stroke is the most serious heat related illness. It is important to recognize when workers are experiencing symptoms of heat exhaustion and heat stroke and administering proper first aid. The following information should be read and understood to protect employees working in hot environments.

Heat Exhaustion

The symptoms of heat exhaustion include:

- Headache, Dizziness, Fainting, Weakness, Irritability, Confusion, Thirst, Nausea and Vomiting

The following First Aid measures should be administered if symptoms of heat exhaustion are present:

- Move to cool area and shaded area, Provide plenty of water, Apply cool water to the body, and obtain medical assistance if needed.

Heat Stroke

The symptoms of heat stroke include:

- Confusion, Loss of consciousness, Collapse, Seizures and Lack of sweating

The following First Aid measures should be administered if symptoms of heat stroke are present:

- Get medical assistance, Move worker to a cool, shaded area, Remove excess clothing, and apply cool water to the worker's body.

What are the causes of heat-related illnesses?

- High temperature and humidity
- Direct sun exposure
- Low or no water intake
- Heavy physical labor
- Personnel protective equipment and clothing
- No recent expose to hot weather



Prevention

To prevent heat related illness, the following precautions should be taken while working in environments with high temperatures and humidity:

- Understand symptoms of heat related illness;
- Monitor your physical condition and that of co-workers;
- Wear light-colored, loose fitting, breathable clothing;
- Schedule heavy work during coolest part of day;
- Take regularly scheduled breaks;
- Block out direct sunlight and other heat sources;
- Drink water frequently (before you become thirsty); and
- Be aware personal protective equipment may increase potential for heat related illness

ATTACHMENT 3

HEAT ILLNESS PRESENTATION

Heat Illness Prevention

2015

University of California
Agriculture and Natural Resources

Heat Illness



- Natural bodily systems fail to cool the body
- Very high body temperatures can be lethal

Heat-related illnesses include:

- Heat rash - skin irritation from excessive sweating
- Heat cramps - muscle pains or spasms
- Heat exhaustion - can precede heatstroke
- Heatstroke - a life-threatening illness

Heat Illness – Heat Rash

Signs and symptoms:

- Clusters of red bumps on skin
- Often appears on neck, upper chest, folds of skin
- Common problem in hot work environments

What to do:

- Try to work in a cooler, less humid environment when possible
- Keep the affected area dry



Heat Illness – Heat Cramps



Signs and symptoms:

- Muscle spasms
- Pain
- Usually in abdomen, arms, or legs
- Can be a first sign of worsening heat-related illness

What to do:

- Have worker rest in shady, cool area
- Drink water or other cool beverages
- Wait a few hours before allowing returning to strenuous work
- Seek medical attention if cramps don't go away

Heat Illness – Heat Exhaustion



Signs and symptoms:

- Heavy sweating
- Weakness
- Cold, pale, and clammy skin
- Fast, weak pulse
- Nausea or vomiting
- Headache, dizziness, lightheadedness

What to do:

- Move to a cooler location
- Lie down and loosen clothing
- Apply cool, wet cloths to as much of the body as possible
- Sip water
- Seek medical attention immediately for prolonged vomiting

Heat Illness – Heat Stroke



Signs and Symptoms:

- Very high body temperature (above 103˚ F)
- Hot, red, dry or moist skin
- Rapid and strong pulse
- Possible fainting, confusion, or seizures

What to do:

- **Call 911 immediately — this is a medical emergency.**

While waiting for emergency services:

- Move the person to a cooler environment. Do **NOT** give fluids.
- Reduce the person's body temperature with cool cloths or even a bath.

Heat Illness Standard – Title 8, Section 3395

- Applies to outdoor worksites
- Must have a written plan (can be part of IIPP)
- Triggered by temperature at worksite
- Employee and Supervisor training is specified
- High heat procedures (temperature > 95F)
- Emergency response procedures
- Acclimatization procedures

Heat Illness Standard – Changes to Regulation

The Occupational Safety & Health Standards Board (OSHSB) approved amendments to the heat illness regulation. The new regulations went into effect on **May 1, 2015**, in time for this year's growing season and warmer weather.

see CalOSHA websites for updates
https://www.dir.ca.gov/dosh/heatillnessinfo.html
https://www.dir.ca.gov/oshsb/Heat_illness_prevention.html

Heat Illness Standard - Water



- One quart per person, per hour (2 gallons for an 8-hr shift)
- Must be *"fresh, pure, suitably cool… free of charge"* (potable water, not ice cold)
- As close as practicable to worksite (if not plumbed or supplied at site)
- Educate workers and actively encourage them to drink small amounts of water often (up to 4 cups/hour)

Heat Illness Standard - Shade

- Shade = blockage of direct sunlight
- *Required to be available at 80F (formerly required at 85F)*
- Must accommodate *"the number of employees" on rest or recovery break*
- Access to shade must be permitted at all times
  - Must be made available upon request if <80F
  - If unsafe or not feasible, define alternative procedures



Heat Illness Standard – Cool-down Rest Periods



- Must be allowed and encouraged
- Employees shall be monitored for symptoms and signs of heat illness (observation and inquiry is sufficient)
- If symptoms or signs occur:
  - *First aid or emergency response is required (based on level of heat-related illness)*
  - *Workers must not be ordered back to work, sent home, or left alone until symptoms have abated*

Heat Illness Standard - High Heat Procedures



- Triggered at 95F (unchanged in regulation)
- *Pre-shift meeting to review high heat procedures*
- *Observation of employees for signs and symptoms*
- *Mandatory 10 minutes cool-down recovery time for each two hour period of continuous work*
- *Employees must be authorized and able to call for emergency service (or designate one employee onsite)*

Heat Illness Standard – Emergency Response



- *Ensure effective communication with employees*
- *First aid procedures*
- *Emergency medical services (how and when are they provided?)*
- *“Clear and precise” directions to the worksite*
- *Employees must be able to call for emergency service*

Heat Illness Standard – Acclimatization

- *Include concept/definition and specific procedures in training and written plan*
- *Applies to new employees, heatwave events, and employees returning to work after extended absence from heat*
- *New employees must be observed for first 14 days*
- *All employees observed during heat wave events (≥80F AND 10 degrees higher than average of previous 5 days)*
- *Procedure: define gradual increase in work hours over multi-day period or define alternative work arrangements*

Heat Illness Standard - Training



- Employer responsibilities and worker's rights
- Signs and symptoms of heat illness
- Personal/environmental risk factors and acclimatization
- First aid and emergency response for various levels of heat illness
- High heat procedures (pre-shift meeting required)
- Emergency response procedures

Heat Illness Standard – Written Plan

- *Heat Illness Prevention Plan (English/Spanish)*
- *Must be available at worksite upon request*
  - Procedures for complying with standard (water, shade, training
  - High heat procedures
  - Emergency response procedures
  - Acclimatization procedures
- Updated template available from EHS by May 1



Heat Illness Standard – Helpful Resources

UC-ANR resources:

http://ucanr.edu/heatillness

CalOSHA Heat Illness prevention website:

https://www.dir.ca.gov/dosh/heatillnessinfo.html

Text of changes (took effect May 1, 2015):

https://www.dir.ca.gov/oshsb/documents/Heat_illness_prevention_txtbrdconsider.pdf

Heat Illness Standard – Helpful Resources

Federal government resources

OSHA picture-based pamphlet:

https://www.osha.gov/SLTC/heatillness/3422_factsheet_en.pdf

OSHA Heat Illness prevention website:

https://www.osha.gov/SLTC/heatstress/prevention.html

CDC Heat Stress website:

http://www.cdc.gov/niosh/topics/heatstress/

APPENDIX N
Cold Stress

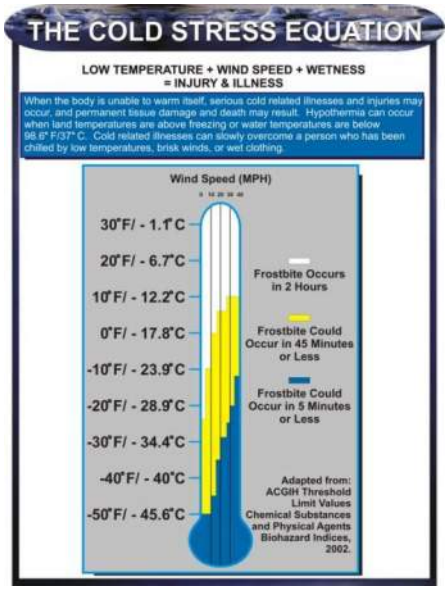
LANGAN

Tailgate Safety Meeting
Health and Safety

Cold Stress

(Employees should present and discuss the information provided to conduct a brief training on the topic.)

Serious cold-related illnesses and injuries occur when the body is unable to warm itself. Trench foot, Hypothermia and Frost Bite are all serious illnesses that can occur in cold, wet environments. Review the following information to learn about the workers most at risk, the symptoms of cold-induced illnesses and how to protect yourself and other coworkers when working in cold environments.



<u>Workers most at risk:</u>

- Employees that have predisposing health conditions such as cardiovascular disease, diabetes and high blood pressure.
- Employees taking certain medications.
- Employees in poor physical condition, older in age or have a poor diet.

<u>How to protect yourself:</u>

- Recognize environmental and workplace conditions that could potentially lead to cold-induced illnesses and injuries.
- Be aware of the warning signs and symptoms of cold-induced illnesses and injuries (listed below).
- Wear the proper clothing: Gloves, hard hat liners, water-proof clothing if you're in a wet environment, wear many layers but breathable materials.
- Work in pairs and take frequent breaks.
- Drink warm beverages- avoid caffeine. Eat warm, high-caloric foods, such as pasta.

<u>Cold-induced Injuries and Illnesses:</u>

- <u>Trent foot</u> (immersion foot) is caused by having your feet immersed in cold water temperatures above freezing for long periods of time. Symptoms of trench foot include tingling, itching or burning sensation and blisters may form.
- <u>Hypothermia</u> is when the body temperature drops to below 95°F. Symptoms of hypothermia include fatigue, drowsiness, uncontrollable shivering, clumsy movements, slurred speech and irritable, irrational or confused behavior.
- <u>Frost Bite</u> is when the skin becomes hard and numb- it typically affects the fingers, hands, toes, feet, ears and nose. The skin can become a pale, waxy-white color and it causes a freezing in the deep layers of the skin and tissue.

<u>What to do in cases of emergency:</u>

- Call for emergency help – dial 9-1-1.
- Move the individual to a dry, warm area and remove any wet or tight fit clothing.
- Do <u>not</u> rub the affected areas when frost bite is present!

- In cases of hypothermia, have the individual move their arms and legs to create heat.

APPENDIX O
Behavior Based Observation Form

LANGAN

Field Observation Form
Behavior Awareness, Safety Engagement Program

Date/Time: _____ **Project #:** Only if requested _____

Observer: ☐ Employee ☐ Other **Observer Name:** _____

Observee: ☐ Employee ☐ Other **Discipline Observed:** _____

Activity Observed: _____

Was near miss observed? ☐ YES ☐ NO ***(If "Yes", complete Near-Miss Report form)***

PREVENTION	**SAFE**	**AT-RISK**	**NA**
HASP/SSA			
- Completed	☐	☐	☐
- Reviewed	☐	☐	☐
Job Safety Analysis			
- Completed	☐	☐	☐
- Reviewed	☐	☐	☐
Safety Data Sheet	☐	☐	☐
Stop Work Authority	☐	☐	☐
Hazard Communication	☐	☐	☐
TAKE 5	☐	☐	☐

ENVIRONMENT	**SAFE**	**AT-RISK**	**NA**
Slip, Trip, Fall Hazards	☐	☐	☐
Chemical Use	☐	☐	☐
Housekeeping	☐	☐	☐
Weather, Heat/Cold	☐	☐	☐
Work Zone Setup	☐	☐	☐

TOOLS/EQUIPMENT	**SAFE**	**AT-RISK**	**NA**
Correct Tool	☐	☐	☐
Condition	☐	☐	☐
Proper Use/Storage	☐	☐	☐

PPE IN USE	**SAFE**	**AT-RISK**	**NA**
Head	☐	☐	☐
Eye	☐	☐	☐
Feet	☐	☐	☐
Skin	☐	☐	☐
High Visibility Clothing	☐	☐	☐
Hand	☐	☐	☐
Hearing	☐	☐	☐
Other *(Note in Comments)*	☐	☐	☐

BODY POSITIONING	**SAFE**	**AT-RISK**	**NA**
Pushing, Pulling	☐	☐	☐
Posture	☐	☐	☐
Hand Placement	☐	☐	☐
Lifting, Bending	☐	☐	☐
Reaching, Twisting	☐	☐	☐

SITUATIONAL	**SAFE**	**AT-RISK**	**NA**
Eyes on Task, Path	☐	☐	☐
Struck By Potential	☐	☐	☐
Pinch Point	☐	☐	☐
Energy/Utility Control	☐	☐	☐
Security	☐	☐	☐

Corrective Actions: _____

_____

_____

Actions to Encourage Safe Behaviors: _____

_____

_____

Comments: _____

_____

_____

Langan's goal is to be SAFE! - (Stay Accident-Free Everyday!)

APPENDIX P
Driver Safety

LANGAN

Memorandum

2700 Kelly Road, Suite 200 Warrington, PA 18976 T: 215.491.6500 F: 215.491.6501
Mailing Address: P.O. Box 1569 Doylestown, PA 18901

To: All Employees

From: Rory Johnston; Tony Moffa

Date: February 2019

Re: **The Use of Hand-Held Cellular Phones and Wireless Communication Devices While Driving**

Employees' job responsibilities may require occasional or regular driving and the use of cellular phones or other wireless communication devices. While driving and utilizing modern technology, employees must remember that safety comes first.

The use of hand-held cellular phones and other hand-held wireless communication devices while operating a Company owned, leased or rented vehicle, or any other vehicle, while engaged in the scope of employment, is prohibited. The occasional use of a hands-free device is permitted, provided such use is permissible under applicable state law. However, employees may not compose, read or send text messages or e-mail, or access the Internet on a wireless communication device while driving. The use of hand-held and other wireless communication devices, including GPS systems, are only permissible if programming and interaction with the device is done while the vehicle is stopped.

In emergency situations where a Langan driver has determined it's unsafe or impractical to stop the vehicle or the utilization of a hands-free device is not available, the Langan driver may briefly utilize a hand-held cellular phone while driving where not prohibited by law. Emergency situations include reporting: a medical emergency, a serious traffic accident or crime, security situation or when the driver's or passenger's personal safety is at risk.

Wireless communication devices include, but are not limited to, cellular phones (including smart phones), personal digital assistants, GPS systems, Blackberries, iPhones and other portable electronic computing devices capable of transmitting or receiving data.

Employees must comply with this policy in addition to all applicable federal and state laws, and local rules and regulations regarding the use of cellular phones and wireless communication devices while driving.

Journey Management Plan

Langan's Journey Management Plan identifies practices for safely operating motor vehicles used by Langan employees while traveling on Company business. It is the intent that the identified practices within this plan will minimize the number and frequency of travel-related incidents and improve safety performance when traveling by motor vehicle. This program applies to employees who must drive a Company or personal vehicle on Company business. A copy of the Journey Management Plan will be provided to and shall be reviewed by applicable employees before they drive on Company business.

1.0 General Requirements

Vehicle travel should be conducted only when necessary for the achievement of business and when safer travel options have been excluded. Teleconference and video conference should be explored to replace travel, but if travel is necessary, air, train and bus should be considered, if practical as they are a safer means of travel. Driving trips should be planned and scheduled to allow for completion of several tasks to reduce the need for future travel.

2.0 Safe Driving Practices

The following safe practices should be followed by employees when driving.

- Adhere to Langan's policy regarding use of cell phones and wireless communication devices.
- Do not drive if under the influence of alcohol, illegal drugs or medications that would impair the ability to drive safely.
- Restrict driving to daylight whenever possible.
- If night driving is required, use common sense by reducing speed and taking extra caution.
- Check the weather forecast in areas to be traveled and avoid driving under adverse conditions, whenever possible.
- Make sure the vehicle that will be driven is appropriate for the terrain and weather conditions.
- Make sure company vehicles are equipped with a roadside emergency kit.
- When traveling to an unfamiliar location, review printed copies of driving directions before departing. A GPS may be used in a safe manner for directions; however, printed copies of driving directions should be obtained and brought as backup.
- Notify management or other designated individuals not traveling with you of travel plans. Travel-plan information should include destination, departure time, estimated arrival time, estimated return date and time, travel route, and your phone number, if applicable.
- Carry a reliable method of communication such as a cellphone in case of emergency.
- Reduce the potential for fatigue by taking breaks, resting before the trip, and rotating drivers if another licensed driver is present.
- If having trouble staying awake, pull off the road to a safe location and exit the vehicle for fresh air or take a power nap, if appropriate, prior to resuming driving.
- If traveling late at night or when experiencing drowsiness, consider securing a hotel room for the evening and continue traveling in the morning.
- Obey all posted driving speed limits.
- All occupants must wear seatbelts.
- Avoid distractions during driving.

3.0 Written Journey Management Plan

A written Journey Management Plan must be completed by an employee and reviewed and approved by management prior to vehicle travel during the following conditions:

- Driving time to the destination will exceed 4.5 hours,
- Travel distance to the destination will exceed 250 miles, or
- A destination is determined by Langan management to be a high-risk area.

High-risk areas are those designated as hazardous or dangerous because of location, time of day, weather, road conditions, road quality, or surroundings. High-risk areas include, but are not limited to, those that are remote, difficult to access, have dangerous surroundings, or are visited outside of normal working hours.

Employees must complete the Company's Journey Management Plan document and forward it to their managers for review and approval. Managers are responsible for reviewing the plan with the employees and determining whether the proposed travel plan is acceptable. The employee must carry a copy of the written Journey Management Plan while traveling. Management or other designated individuals who are not traveling with the employee must also maintain a copy the Journey Management Plan.

Driving Training Health & Safety	LANGAN
Document #: HSE-DTU-FRM-01	Version #: 01

Employee:_____ Date: _____

Office Location/Address: _____

Driver License Verified:
Yes ☐ No ☐ State & License # _____

Prior Driving Experience (Types of vehicles):
Automobile (car) ☐ Automobile (Pick-up Truck) ☐
ATV ☐ UTV ☐ Other: _____

Online Training Provided for the Following:
Automobile (car) ☐ Automobile (Pick-up Truck) ☐
ATV ☐ UTV ☐

Hands-On Training Provided for the Following (Training is to include Operation, Safety & Maintenance):
Automobile (car) ☐ Automobile (Pick-up Truck) ☐
ATV ☐ UTV ☐
Unpaved/Off-Road: Mud ☐ Rough Terrain ☐ Inclines/Slopes ☐
Inclement Weather: Rain ☐ Snow ☐

Comments:

_____

_____

Type of Vehicles Authorized to Operate:
Automobile (car) ☐ Automobile (Pick-up Truck) ☐
ATV ☐ UTV ☐
None ☐

Comments:

_____

_____

Employee acknowledgement:
Employee Signature: _____ Date: _____

Training Conducted By: _____ Date: _____

LANGAN **VEHICLE INSPECTION CHECKLIST** revised 2016

Make / Model / Plate #			**Inspectors Name:**
Mileage:			**Date:**
ITEM INSPECTED	**CHECK IF SATISFACTORY**		**COMMENTS**
VEHICLE REGISTRATION			
INSURANCE INFORMATION			
TIRES (TREAD DEPTH, INFLATION)			
SPARE TIRE			
SHOCKS			
EXHAUST SYSTEM			
ENGINE			
STEERING			
HORN			
MIRRORS			
FIRST AID KIT			
FIRE EXTINGUISHERS			
BRAKES			
PARKING BRAKE			
WINDSHIELD			
WINDSHIELD WIPERS & WASHERS			
LIGHTS (LOW, HIGH, TAIL, BRAKE, BACK-UP, INSTRUMENT)			
TURN SIGNALS			
BODY CONDITION			
BACK UP ALARM			
SAFETY RESTRAINTS			
FLUIDS (OIL, BRAKE, WASHER, POWER STEERING, TRANSMISSION, COOLANT)	*Oil:*		
	Brake:		
	Power Steering:		
	Transmission:		
	Coolant:		
Notes:			

APPENDIX Q
Short Service Employee

Short Service Employee Program

Langan's Short Service Employee (SSE) Program provides mentoring to newly hired employees to increase their safety awareness and reduce the potential for work-related incidents and injuries. The program allows a new employee a transition period to become familiar with new surroundings and to learn efficient, safe work practices. Short Service Employees and their managers are required to adhere to the requirements of this program.

A Short Service Employee is defined as any new Langan employee. For the purposes of this program, a new employee will be considered an SSE as follows:

- A new employee new to the industry will be considered an SSE for six months.
- A new employee with experience in the industry will be considered an SSE for three months. (The employee's immediate supervisor will determine whether the newly hired employee has sufficient experience.)

An employee will be considered an SSE during the timeframe indicated above and until the immediate supervisor is satisfied that the SSE has demonstrated competency and compliance with Langan's health, safety and environmental policies, procedures and work practices. The SSE's immediate supervisor is responsible for determining when an employee is no longer an SSE and can be removed from the program. Exceptions to this program must be directed to the Corporate H&S Manager and client principal in charge.

1.0 Mentors

An SSE will be assigned a mentor to provide guidance in developing and understanding safe and proper work practices. Mentors will be employees with the following qualifications: experience and knowledge in the work tasks being conducted; demonstrated history of safe work, and policy-procedural knowledge; and effective communication skills. Mentors can only be assigned one SSE at a time and must remain on site with the SSE at all times. Mentors will be assigned by the SSE's immediate supervisor.

The mentor in the SSE Program has the following responsibilities:

- Instructing the SSE on proper and safe practices to follow when conducting work tasks,
- Monitoring the SSE for compliance with company health, safety and environmental policies, procedures and work practices,
- Prohibiting the SSE from conducting work tasks for which they do not have adequate experience or training,
- Being a positive role model in regard to work ethic and safety, and
- Providing the SSE's immediate supervisor with updates on the SSE's behavior and performance including both positive and negative observations.

2.0 Work/Field Crews

Langan project managers must notify the owner/client when an SSE will be working at the site as part of a field crew. Notifications should include the number of SSEs to be on site and the method used to identify SSE personnel. Work and field crews with SSEs must adhere to the following requirements:

- A single person work and field crew cannot consist solely of the SSE,
- Work and field crews consisting of less than five employees may only contain one SSE,
- Work and field crews with five or more employees shall not exceed 20% SSEs,
- Under no circumstances can SSEs work alone, and,
- An SSE will be identified by an SSE sticker on the employee's hard hat or by an owner- or client-specific identifier, if applicable.

3.0 Subcontractors

Subcontractors must have SSE programs in place meeting the requirements of Langan's SSE Program, at a minimum. Subcontractors whose programs do not meet Langan's SSE Program will be required to adhere to Langan's SSE Program.

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Short Service Employee (SSE) Notification Form

Company Name: _____ Request Date: _____

SSE Name: _____ Date of Employment: _____

Current Job Title: _____ Exp. In Present Position: ____Yrs ____Mos

Years of Oilfield Exp.: _____ Types of Oilfield Exp.: _____

Has this employee received appropriate and required trainings to perform this job? ☐ Yes ☐ No

List of Safety Training Provided to SSE	List of Specialty/Job Training Provided to SSE

Signature of SSE being submitted *(optional):* _____

SSE Mentor Information

Mentor Name: _____ Date of Employment: _____ Years of Oilfield Exp. _____

Current Job Title: _____ Exp. In Present Position: ____Yrs ____Mos

Signature of SSE Mentor being submitted *(optional):* _____

Notes: _____

SSE Review and Approval

Project Manager Approval:

SSE's Direct Supervisor Approval:

(If different from above) Print Name Job Title Signature Date

Removal from SSE Program*

Project Manager Approval:

Corporate H&S Manager: *(or designee)*

Print Name Job Title Signature Date

Justification for Early Removal from SSE Program

*Attach documentation of SSE training including dates, trainings, mentors, and instruction topics at a minimum

Short Service Employee (SSE) Weekly Tracking Form				Week/ Period: _____ to _____			LANGAN
Employee: _____		Site: _____		Assigned Mentors: _____			
	Date:_____	Date:_____	Date:_____	Date:_____	Date:_____	Date:_____	Date:_____
Tasks Performed:							
Trainings: (Site-specific, External, etc)							
Daily Log: Mentor/ Review							
Weekly Review Comments:							

APPENDIX R
Medical Data Sheet

VOLUNTARY MEDICAL DATA SHEET

Project: MIPC

Name _____ Phone Number _____

Address _____

_____

Age _____ Height _____ Weight _____

Emergency Contact: _____

Relation: _____

Phone Number: _____

Current Medications _____

_____

_____

Drug Allergies: _____

_____

_____

Medical Restrictions or Conditions _____

_____

_____

Contact Lenses: (circle one) Y N

COVID-19 Vaccination Status: (circle one) VACCINATED NOT VACCINATED

Name of Primary Care Doctor; _____

Phone Number: _____

OTHER INFORMATION: _____

_____

_____

_____

_____

APPENDIX S
Management of Change

1.1. Purpose

The purpose of this document is to establish Langan's Management of Change (MOC) policy. The MOC is a best practice intended to ensure that safety, health and environmental risks are reviewed and addressed when there are personnel, physical and procedural changes. This policy will provide the process to review these changes, and steps and approvals required prior to implementation.

1.2. Applicability

The MOC policy applies to any personnel, physical and procedural changes done by Langan that may create a safety, health or environmental risk.

1.3. Definitions

The following definitions apply to this policy.

1.3.1. Personnel Change

Personnel Change includes any changes to a job site's employee staffing plan or an employee's job responsibilities. Employee rotations and shift changes and "replacement-in-kind" are exempt from this definition and do not require a MOC.

1.3.2. Procedural Change

Procedural Change includes any changes to established standard operating procedures, developed site-specific procedures to complete work tasks, emergency response procedures, or management approval processes.

1.3.3. Physical Change

Physical Change includes all changes to equipment, whether temporary or permanent. Physical Changes included:

- Alterations to equipment design;
- Equipment changes, including addition of new equipment or modifications
- Introduction/Use of new or different products/chemicals;
- Generation of new waste or by-products;
- By-passing of equipment normally in service; and
- Modifications to instrumentation or control systems.

Physical changes considered "replacement-in-kind" are exempt from this definition and do not require a MOC.

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1.3.4. Replacement-in-kind

Personnel Change - Replacement-in-kind is the substitution of one employee for another employee with similar qualifications, training and experience required for the task at hand.

Physical Change - Replacement-in-kind is the exchange or replacement of an equipment component or piece, with another component or piece with similar specifications or performance characteristics.

1.4. Management of Change Procedure

When there are personnel, physical and procedural change that is applicable to this MOC policy, the below procedures must be followed:

- Notification
- MOC Form Completion
- Evaluation Team
- Authorizer
- Notification of affected employees
- Implementation

1.4.1. Notification

The Langan employee who identified or became aware of the personnel, physical and procedural change that may be subject to the MOC shall immediately notify the Langan Manager, or designee, overseeing the project. The Langan Manager, or designee, is responsible for determining if the change requires an MOC.

1.4.2. MOC Form Completion

The Langan employee who identified or became aware of the personnel, physical and procedural change shall complete the MOC Authorization Form (HS1701) with the assistance of the Langan Manager overseeing the project, or their designee.

The Langan Manager, or their designee, is required to identify Langan personnel to fill the role of MOC Coordinator. The MOC Coordinator is responsible for being the lead on completing the MOC process. This includes interaction with the Evaluation Team, development of implementation timeline and review with the identified Authorizer for approval or denial. The MOC Coordinator is responsible for ensuring the MOC Form (HS1701) is forwarded to the Evaluation Team and the Authorizer.

1.4.3. Evaluation Team

The Evaluation Team consists of Langan employees assigned by the MOC Coordinator. The Evaluation Team is responsible for:

- Reviewing the completed MOC Form (HS1701).
- Evaluating the proposed change.
- Ensuring potential HSE impacts are mitigated or controlled;
- Discussing the MOC with MOC Coordinator.
- Indicating on MOC Form (HS1701) if proposed change is approved or denied.

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- Providing relevant comments, if needed.
- Signing name and date.
- Forwarding completed form to MOC Coordinator.

1.4.4. Authorizer

The Authorizer must be the Principal-In-Charge of the project. If there is more than one Authorizer the other Authorizer must be a Langan employee at the level of Project Personnel or above. The Authorizer is responsible for:

- Reviewing the completed MOC Form (HS1701) after the Evaluation Team has completed their review.
- Discussing MOC with Evaluation Team and MOC Coordinator.
- Indicating on MOC Form (HS1701) if change is approved or denied.
- Providing relevant comments, if needed.
- Signing name and date.
- Forwarding authorized form to MOC Coordinator and H&S Department.

1.4.5. Notification of affected employees/contractors

The MOC Coordinator is responsible for notifying all employees, subcontractors and contractors that may be affected by the approved MOC. This notification will include the proposed change and any measures taken to mitigate identified HSE impacts.

1.4.6. Implementation

The MOC Coordinator is responsible for implementing the change identified on the MOC in accordance with the implementation timeline on the MOC Form (HS1701). Any changes to the implementation timeline must be re-evaluated to determine if the MOC must be redone.

1.5. Training

Employees subject to Langan's MOC will be trained on the contents and their responsibilities. Employees trained on the MOC will be informed or trained on any changes or revisions.

1.6. Recordkeeping

Copies of completed MOC Form (HS1701) are to be maintained under the project files and a copy sent the Langan's H&S Department. These copies will be maintained for a minimum of five years.

1.7. Disciplinary

A violation of the MOC may result in disciplinary action up to and including termination of employment.

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Management of Change Authorization Form

Completed By: _____ Date: _____

Project Name: _____ Project #: _____

Management of Change
Type of Change*:** ☐ ***Personnel ☐ ***Procedural*** ☐ ***Physical***
Description of / Reason for change: _____
HS&E Impacts: _____

(Langan Manager, or designee, must complete below sections and assign roles of MOC Coordinator, Evaluation Team, Reviewers and Authorizer Approvals)

MOC Coordinator		
Print Name	*Signature*	*Date*
Evaluation Team: ☐ *Approved* ☐ *Denied*		
Print Name	*Signature*	*Date*
Implementation Timeline		
Authorizer *(Principal In Charge)* ☐ *Approved* ☐ *Denied*		
Print Name	Signature	Date
Comments		

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APPENDIX T
Subcontractor Health and Safety Documents and Procedures

AWT ENVIRONMENTAL SERVICES, INC.

One Contractor. Many Solutions.

Site Specific Health and Safety Plan (HASP)

Prepared for:

LANGAN

PROJECT NAME	SITE LOCATION
MIPC Chelsea Tank Farm Facility	920 Cherry Road Aston, PA 19014
PREPARED BY	**TITLE**
Jose “Junior” Hernandez-Aponte, CHST **December 11, 2025**	AWT Health and Safety Manager
Revised on:	Revised by:
Approved by:	Date:

32 Birch Street, Old Bridge, NJ 08857 • *732-613-1660* • *Fax 732-613-1536* • *www.awtenv.com*

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1. Safety Policy

AWT Environmental Services, Inc.

Safety Policy

Safety is of primary importance in our operation. Our goal is Zero tolerance. Each of us has the responsibility to make the safety of our co-workers and ourselves a basic concern. This objective is fundamental to well-being, as well as to the efficient operation of our business. This safety plan is intended to assist you in performing your work safely. With few exceptions, every safety rule or practice in this safety plan has evolved from experience and knowledge gained over many years of accident and injury prevention. Every employee has the responsibility to prevent accidents and injuries by observing established working rules, by following the directions of supervisors, by practicing the safety rules of AWT and by providing new ideas on how our safety efforts might be further strengthened.

AWT management recognizes its responsibility to provide healthful and safe working conditions, safe working rules based upon experience and safety knowledge, and competent work direction. AWT and its employees have the responsibility to comply with all federal, state, and local regulations related to safety, health, and environmental programs.

If you think something you are about to do is unsafe, do not do it. Stop Work and correct the situation. If you cannot correct the situation, ask your supervisor for assistance. This is important; it is your life that may be in danger. If you witness someone about to commit an unsafe act, stop him or her and discuss it with them. Help your co-worker. Make your work environment safe for everyone.

Employees working for AWT shall be required to comply with health and safety laws and regulations and to adopt the safety practices for AWT. If you do not follow the safety rules, you could be dismissed.

Any recommendations to improve our safety program are encouraged.

Thank you and welcome to the AWT family.



Peter J. Postorino

President-AWT Environmental Services, Inc.

2. Purpose:

- This Site-Specific Health and Safety Plan (SSHASP) was developed for the following project: **MIPC Chelsea Tank Farm Facility**
- It is designed to supplement our AWT Corporate Health and Safety Policy and Procedures.
- The information found in this SSHASP is cross-referenced with the applicable sections of our corporate policy and procedures relevant to the scope of work performed by AWT Environmental Services, Inc., and our subcontractors.
- All AWT employees and subcontractors working under the direct instructions of AWT shall adhere to this Site-Specific Health and Safety Plan (SSHASP).
- Any deviation from this plan must be approved and incorporated into the plan with applicable safety practices and procedures.

3. Site Information:

3.1 Site Description

- MIPC Chelsea Tank Farm.
- The facility is a storage and distribution center.

4. Scope of Work

4.1 Activities performed by AWT employees and/or subcontractors:

☒ Excavation	☐ Vapor Extraction/Mitigation	☐ Dewatering
☒ Drilling	☐ Trench box Installation	☒ Heavy Equipment Operation
(☐ Direct Push ☒ Rotary ☒ Sonic)	☐ Slide Rail Installation	☐ Hoisting and Rigging
☐ Coring	☐ Structural Support Installation	☐ Crane Lift
☐ Soil Injection	☐ Concrete Saw Cutting/Grinding	☐ Working at Heights/Elevated Work
☐ Remediation	☐ Asphalt Saw Cutting	☐ Use of Ladders
☐ Waste Removal	☐ Concrete Restoration	☒ Sampling/Assist in Collection
☐ Groundwater Treatment	☒ Air Knife/Soft Digging	☐ Hydrostatic Testing
☐ Well Installation	☐ Vacuum Excavation	☐ Air Monitoring
☐ Well Replacement/Mod.	☐ Lockout/Tagout	☐ Site Clearing (Brushing & Grubbing)
☐ Well Abandonment	☐ Hot Work	☐ Drum Collection
☐ UST/AST Cleaning/Removal	☐ Confined Space Entry	☐ Lab Packing
☐ UST Abandonment	☐ Pipe Installation	☐ Site Restoration
☐ Erosion Control	☐ Electrical	☐ Soil Capping
☐ Barrier Installation	☒ Use of Pneumatic Tools	☒ Decontamination (if needed)
☐ Asbestos Removal	☐ Use of Powered Tools	☐ Grading/leveling
☐ Other (Describe):		
Equipment: ☐ Excavator ☐ Bulldozer ☐ Roller/Compactor ☐ Skid Steer ☐ Brush Hog ☒ Drill Rig ☐ Forklift ☐ Aerial Lift/Scissor Lift ☐ Dump Truck ☐ Other:		
Use of subcontractors? ☐ Yes ☒ No (If yes provide): Services:		

Name	Address	Contact Name/Number

4.2 Site Preparation

- Includes provisions for:
  - Necessary utilities
  - Procurement of all necessary permits to perform the work.
  - Notification of proposed excavation activities to One Call for utility mark outs
  - Private utility mark outs
  - Equipment and material staging areas.
  - Personnel decontamination and hygiene facilities (if applicable)
  - Access control to the site, and construction areas
  - Establishing appropriate traffic control
  - Environmental Protection

5. Organization

AWT ORGANIZATION			
Name	Title	Contact #	Email
Geovany Ramos	Supervisor/Sonic Rig Operator	973-620-7400	gramos@awtev.com
Grant Loew	Project Manager	201-264-6947	gloew@awtenv.com
Baxter Duffy	Division Manager	908-451-7150	Bduffy@awtenv.com
Junior Aponte	Health and Safety Manager	862-755-4562	Jhernandez-aponte@awtenv.com
CLIENT ORGANIZATION			
Name	Title/Company	Contact #	Email
Cortney Savidge	Senior Project Manager/Langan	610-202-9523	csavidge@langan.com

6. Responsibilities

6.1 Project Manager:

- Will be responsible for the overall progress of the project.
- Will hold weekly review and planning meetings with all technical staff, during which the current progress and future direction will be discussed.

6.2 Site Supervisor:

- Is responsible for the overall safety and work operation of the project
- Must ensure the safety requirements and procedures in this plan are adhered to by all employees and subcontractors.
- Must report all incidents regardless of their severity to the Project Manager and Safety Manager.
- Must ensure employees working under the scope of work of this plan have read and signed the Acknowledgment Form attached to this plan.
- Understand that any work that constitutes a deviation of this plan must have the proper authorization to do so.
- All changes of work must be documented and approved prior to being performed.
- Is expected to conduct a Safety Inspection at least weekly and document findings.
- Any negative findings must be reported promptly to the Health and Safety Manager.

6.3 Site Safety Representative

- Is responsible for ensuring that the safety requirements and procedures in this plan are adhered to by all AWT employees and Subcontractors.
- Must ensure that a proper Daily Safety Tailgate is completed prior to the commencement of the workday.
- Conduct daily and periodic safety inspections/audits.
- Report and document all findings to the AWT-Health and Safety Manager
- Maintain copies of the inspections/audit reports on site.
- Assist management with weekly and monthly inspections; reviewing the inspection findings and corrective actions for applicability and thoroughness; providing the Owner's representative with summary of inspection promptly following each inspection.

7. Health and Safety

7.1 Daily Safety Tailgate

- Prior to any work activity, AWT employees will complete a Daily Safety Tailgate (DST) form as a team.
- Our DST form is designed to be used as a tool to identify any site-specific hazards and their controls to mitigate accordingly.
- The information filled in the DST form must be legible.
- Crew members must all print their names and sign as acknowledgement portions.
- The form shall be kept on site and will be available upon request. (See Appendix -DST Form)
- Job Safety Analysis (JSA) shall be used in conjunction with this HASP. (See Appendix-JSAs).

7.2 Employee Training

7.2.1 HAZWOPER

- All AWT employees have received an initial 40-hour training in accordance with 1910.120(e)(3)(i)
- All AWT employees are current with their 8-hour annual refresher in accordance with 1910.120(e)(8).

7.2.2 Heavy Equipment

- Any AWT employee assigned to operate heavy equipment has been deemed competent to operate the specific type of equipment.
- Only authorized and properly trained employees are allowed to operate heavy equipment.
- Periodic evaluation is conducted to ensure competency.
- Equipment must be thoroughly inspected prior to it being operated.
- If any defects are found during inspection, equipment must not be used until all issues have been corrected, repaired, or replaced to ensure proper and safe functioning of the equipment.

7.2.3 Excavation Competent Person

- A trained and qualified competent person will identify safe working conditions in/and around excavations to ensure the safety of all personnel.

7.3 Supervisor Training

- Onsite management and supervisors directly responsible for employees in hazardous waste operations will have received an additional 8 hours of HAZWOPER supervisor training.
- The training program satisfies 29 CFR 1910.120 (e)(4).

7.4 Site Specific Training

- Site-specific training will be provided to all site personnel when applicable.
- This training shall be provided before beginning site activities.
- The training will include site-specific hazards and protective measures as described in this SSHASP.
- Attendance must be documented and maintained.

7.5 Visitor Training

- All visitors to the site will be briefed by the designated site supervisor or the Health and Safety Manager on the specifics of this SSHASP.
- The visitors will be provided with the appropriate sections of the SSHASP to review and will sign a certification that the plan has been provided and reviewed.
- The site supervisor will control visitor entry to any work zones established at the site.
- No visitors will enter these zones unless accompanied by authorized personnel.
- The site Health and Safety coordinator will ensure that all visitors have the proper level of PPE and training in the use of that equipment.
- If visitors do not have the appropriate training, they will not be permitted in areas where site conditions require the use of PPE.

7.6 Medical Surveillance Program (MSP)

- AWT's MSP consists of three main individual medical examinations:
    - Pre-Placement or Baseline
    - Periodic
    - Termination
- Each of these examinations consists of:
    - Occupational and Medical History
    - Biological Monitoring

7.6.1 Post-Exposure Examination

- Following an emergency response activity, a post-exposure examination may be required.
- The post-exposure examination will be the same as outlined for the annual exam except a detailed profile exam will be developed to assess exposure effect.
- Tests that monitor possible tissue damage will be done annually and at specific post exposure times.
- The best determinant of chronically developing tissue damaged to the cardia and/or nervous systems are annual exams and quarterly exams post incidents suspected of causing abnormalities to these systems.
- This should ensure that everyone will not develop a problem later due to low level chronic exposure or from those disorders that have a latent period.

7.6.2 Medical Contingency Plan

- In the event of an exposure incident or injury due to accident.
- Any accidental exposure to a material will necessitate a full analysis of the material to enable implementation of appropriate responses to protect the health of the employee involved.
- Any employee developing any abnormality during the site work will be removed from the site until they are certified to recover and in good health.
- All injuries, skin contact with water or unsafe procedures, or conditions will be reported immediately to the Health and Safety Manager.
- Local ambulances will be made readily available from short distances away (phone numbers shall be posted).
- Emergency first-aid treatment will be administered as appropriate by properly trained, certified, and authorized personnel only.
- Injured workers will proceed through decontamination immediately if ambulatory.
- If it is not ambulatory, injured workers will be removed from the work zone to await medical assistance.
- Emergency and medical contact information will be posted on the site.

7.6.3 Reporting

- All injuries, skin contact with contaminated waste. unsafe work procedures, or conditions will be reported immediately to the site supervisor.
- For all injuries resulting from accidents or unsafe practices the site supervisor will prepare an Incident Report.
- The Health and Safety manager must be notified as soon as possible.

7.7 Stop Work Authority (SWA)

- Any person on site may shut down a work operation that poses imminent danger or a situation arises which is Immediately Dangerous to Life of Health (IDLH).
- When such precautions must be immediately taken, the Site Supervisor shall be immediately notified and actions to rectify the situation shall be implemented.
- All employees have the authority and obligation to stop unsafe work operations where concerns or questions regarding the control of safety, health or environmental risk exist.
- Employees are responsible for initiating stop work intervention where warranted and management is responsible for addressing all concerns accordingly and effectively.

7.8 Ergonomic

- To help the employees protect themselves from back injuries, proper lifting techniques are encouraged to reduce strain.
- The following steps may help reduce the potential of unnecessary strain:
    - Prior to lifting the load, assess the load’s characteristics.
    - Assess the area.
        - Check your surroundings in which the handling of the object will take place to ensure that the area is clear of obstructions that may hinder the safe handling (i.e., tripping hazards, etc.).
    - Establish and maintain proper grip and ensure the grip is firm and secure before attempting to lift.
    - Position your feet to set a good foundation to support your balance.

- Keep the load close to your body.
- Think of your arms and the load as a pry bar.
- The further the load is from your body, the longer the bar and the more force will be placed on your back.
- Avoid twisting your upper body especially during lifting.
- Practice the buddy system.
  - Both parties should discuss and decide how to lift the load congruently.
- If as you are lifting, grip is compromised, warn your partner to reestablish a proper grip before continuing to lift.

Note: Always consider mechanical options if/when available.

7.9 Power Tools

- Select the proper tools for the job.
- Inspect all the wires to ensure there is no damage.
- If damage is discovered during the inspection, the tool shall not be used until properly repaired.
- GFCI must be used at the source.
- Before you plug in any power tool, make sure the power switch is off.
- Ensure all appropriate guards are in place and working.
- Never use electrical tools near water.
- If the tool comes with a ground prong, the prong must be intact.
- Always turn off and unplug the tool before you make any adjustments or change accessories.
- Never use any accessory except those specifically supplied or recommended by the manufacturer.
- Make sure the cutters of blades are clean, sharp, and securely in place.
- Never use bent, broken, or warped blades or cutters.
- Always keep a firm grip with both hands.

7.10 Hand Tools

- Use the proper tool for the job. (i.e., A wrench is not to be used as a hammer, a screwdriver shall not be used as a chisel, etc.)
- Never use damaged tools.
- Never carry tools up ladders. (Maintain 3-points of contact whenever ascending and descending).
- Inspect wood handle tools to avoid splinters.
- Store tools properly when not in use.
- No tool is to be modified or altered.
- If a tool needs to be decontaminated, proper decontamination procedures must be followed.

7.11 Pneumatic Tools

- Equipment must be inspected thoroughly prior to being used.
- Ensure that the stand is in proper working order.
- All hoses must have whip checks and/or safety pins.
- Any hose with damages must be taken out of service and replaced.

- The compressor must be secured with shocks as necessary.
- Proper hearing protection must always be used when working with pneumatic tools and equipment.
- Equipment must be set up so that the exhaust is not aimed at the work location.
- Whenever pneumatic tools are being used indoors, proper ventilation must be maintained.

8. General Site-Specific Hazards

☐ Overhead Powerlines	☒ Entanglement	☒ Respiratory	☐ Toxic Metals:
☒ Underground Utilities	☐ Falls to lower levels	☐ Stored Energy	☐ Arsenic
☒ Exposure to Noise	☐ Electrical	☒ Chemical Hazards	☐ Beryllium
☐ Insects	☐ Radiation	☐ Corrosives	☐ Hexavalent Chromium
☐ Animals	☒ Trips and Falls	☐ Caustics	☐ Lead
☐ Poisonous Plants	☒ Moving Parts	☐ Working at Heights	☐ Mercury
☐ Traffic	☐ Overhead Work	☐ Confined Space	☐ Other: _____
☐ Visibility	☐ Adjacent Work	☐ Structural	☐ PCBs/PCE
☐ Heat Advisory	☒ Uneven Surfaces	☐ Fire/Combustibles	☐ Asbestos
☒ Cold Weather	☐ Ergonomics	☒ Flammables	☐ PHAs
☐ Low Lighting	☐ Pedestrian Traffic	☐ Slips and Falls	☒ Volatile Organic Compounds (VOCs)
☒ Other (Describe): Non-Aqueous Phase Liquid (LNAPL) (Gasoline-based)			

CHEMICAL	PHYSICAL DESCRIPTION	EXPOSURE ROUTES	PEL/STEL	IDLH
Gasoline	Colorless to yellow; liquid	Skin, eye, inhalation, ingestion	500 ppm	

8.2 Site Controls

8.2.1 Entry

- To maintain a safe working environment, each person who enters the site shall be informed of the following procedures:
  - The presence of potentially hazardous materials onsite.
  - The site emergency response procedures.
  - Any potential fire, explosion, health, or safety hazards.
  - Protective measures planned for the site.
  - Methods used to designate the boundaries of the Support Zone (SZ), the Contamination Reduction Zone (CRZ), and the Exclusion Zone (EZ), if necessary.
  - Standard safety rules and personal hygiene procedures.
  - Names of personnel responsible for the site safety and health program.
  - Additional task-specific requirements outlined in this SSHASP.

8.2.2 Work Zones

- If it is necessary to restrict access during work activities, three general work zones will be established which consists of the EZ, CRZ, and the SZ.
- The need for work zones will be based on the site conditions, historical analytical results, air monitoring data more than PELs, and type of activities to be performed and will be determined by the site Health and Safety Coordinator.

- The purpose of the work zones is to minimize and control the transfer of hazardous substances from contaminated to uncontaminated areas.
- Inside the EZ, a CRZ will be established through which all workers must enter and exit.
- Personnel leaving the EZ will undergo the decontamination procedure while in the CRZ.
- The CRZ will have a caution tape barrier around it.
- Lined garbage cans, buckets, wash basins, soap solutions, rinse water, and scrub brushes will be provided in the CRZ.
- The following procedures will be strictly adhered to.

8.2.2.1 Exclusion Zone (EZ)

- EZ is defined as the area where contamination is either known or likely to be present, or because of planned activity, will provide potential to cause harm to personnel.
- Entry into the EZ requires the use of specific PPE.
- If necessary, an EZ will be established around each intrusive activity using either an air monitor or by determining safe distance based on visual observations.
- Personnel in this area will wear the appropriate PPE as specified in the SSHASP and the Site Health and Safety Coordinator.

8.2.2.2 Contamination Reduction Zone (CRZ)

- The CRZ is the area were personnel conduct personnel and equipment decontamination.
- It is essentially a buffer zone between contaminated areas and clean areas.
- Activities to be conducted in this zone will require PPE.

8.2.2.3 Support Zone (SZ)

- The SZ is situated in clean areas where the chance of encountering hazardous materials or conditions is minimal.
- Upgraded or specific PPE is therefore not required.
- Permission to enter the SZ will only be granted to all authorized persons, including visitors, after they have received the information listed in this section and have signed the acknowledgement form.

8.2.3 Buddy System

- The implementation of a buddy system is mandatory for all activities performed in an EZ or CRZ and all confined space work.
- A buddy system requires a team consisting of at least two people to maintain constant sight or voice (including radio) contact with each other.
- The size of the team depends on the level of PPE that is worn by any one team member.

8.2.4 Site Communication

- Successful communication between field teams and personnel in the temporary office is essential.
- Personnel in the EZ should remain in constant radio communication or within sight of others.
- The following standard hand signals will be used in case of failure of radio communications:
    - Hand gripping throat - Out of air, cannot breathe.
    - Grip partners wrist or both hands around waist - Leave area immediately.

  - Hands on top of head - Need assistance.
  - Thumbs up - Okay, I am all right, I understand.
  - Thumbs down - No, negative
- In addition, a series of three extended horn blasts will be the emergency signal to indicate that all personnel should leave the work area.

8.2.5 Decontamination

- Decontamination involves the orderly controlled removal of contaminants.
- Standard decontamination sequences for PPE and heavy equipment are outlined in the appendix section.
- All site personnel should minimize contact with contaminants in order to minimize the need for extensive decontamination.
- Equipment decontamination will take place on a temporary decontamination pad/area.
- All heavy operating equipment that is required to be cleaned will be decontaminated at the decontamination area.
- The site supervisor will oversee all decontamination procedures to ensure proper decontamination procedures are followed.

9. Personal Protective Equipment (PPE)

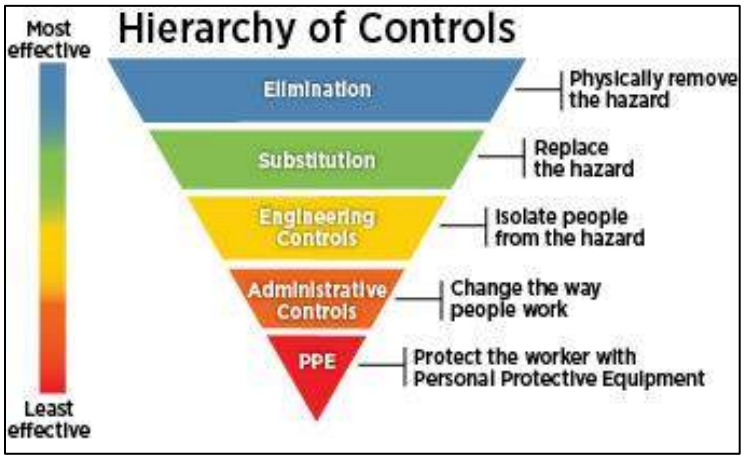
☒ Hard Hat	☒ Leather Gloves	☒ Coverall/Tyvek	☒ Safety-Toed Boots
☐ Chin Strap	☐ Chem Resistant Gloves [3]	☐ Chem Resistant Clothing [2]	☒ Boot Covers (Booties)
☒ Safety Glasses	☒ Cut Resistant Gloves	☐ Raingear	☐ Slip Resistant Cleats
☐ Sealed/Spoggles	☒ Disposable (Nitrile)	☒ High Viz Vest/Clothing	☐ Air Purifying Respirator [5]
☐ Splash Goggles	☐ Impact Resistant Gloves	☐ FR Clothing	☐ SCBA[6]
☐ Face Shield [1]	☐ Specialty Gloves	☒ Full Body Harness [4]	☐ N95
☒ Ear Plugs	☐ Electrical Gloves	☐ Lanyard [4]	☐ PAR
☒ Earmuffs	☐ Winter Gloves	☐ SRL[7]	☐ Other:

Additional Information:

[1]- When splashes with chemical or impact to the face from particulates are a hazard.
[2]- When handling or working with/near chemicals that can impact the body/skin.
[3]- When handling or working with/near chemicals that can impact the hands/skin
[4]- When working in a Confined Space (for retrieval) and/or where fall protection is required.
[5]- When potential exists for exposure over the OSHA PEL.
[6] – When readings for exposure exceeds the OSHA and/or NIOSH recommended PEL and upgrade is warranted.
[7]- When working at heights or when operating an aerial lift.

10. Levels of Protection

AWT will follow the Hierarchy of Controls to determine appropriate measures whenever possible.



10.1 Elimination:

- Elimination and substitution, while the most effective at reducing hazards, also tend to be the most difficult to implement in an existing process.
- If the process is still at the design or development stage, elimination and substitution of hazards may be inexpensive and simple to implement.
- For an existing process, major changes in equipment and procedures may be required to eliminate or substitute for a hazard.

10.2 Engineering Controls:

- Are favored over administrative and personal protective equipment (PPE) for controlling existing worker exposures in the workplace because they are designed to remove the hazards at the source, before it meets the worker.

10.3 Administrative Controls and PPE

- Administrative Controls and PPE are frequently used with existing processes where hazards are not particularly well controlled.
- Requires significant effort by the affected workers.
- PPE is the last line-of-defense.

If the control measures above are not feasible and AWT must resort to Personal Protective Equipment (PPE), the following levels must be adhered to:

Level D	Modified Level D	Level C	Level B
•Coveralls/Long Sleeve Shirt •Leather Gloves •High Viz Vest •Safety Toe Boots •Safety Glasses or Chemical Splash Goggles •Hard Hat •Faceshield (as needed)	•Coveralls •Tyvek QC or equivalent •Gloves •Appropriate Foot Protection •Proper eye protection •Filtering mask	•Full Face APR •Chemical Resistant Clothing •Chemical Resitant Gloves •Boots with outer Chemical Resistance •Hard Hat	•Positive Pressure, full Face Piece PAPR/SCBA Hybrid System •Hooded Chemical Resistant Suit •Inner/Outer Chemical Resistant Gloves •Booties •Hard Hat

Note: In the event where hazards exceed the protection factors mentioned above, work will not continue until proper assessment is complete and protocols are established accordingly.

Additional training will be required prior to commencing any activity that would necessitate Level B or A protection.

10.4 Respiratory Protection

- In the event where AWT employees will need to upgrade their PPE to Respiratory Protection, work will stop, and all employees will be:
    - Medically Cleared to wear and work with a respirator.
    - Trained on how to properly select, don, doff, clean, disinfect, and store their respirator(s).
    - Fit Tested on the specific type, model, and size of the respirator with either a Qualitative or Quantitative test method.
    - Fit Test annually

11. Hazardous Communication (HAZCOM)

The HAZCOM Program covers the following components:

- Written Hazard Communication Program
- Safety Data Sheet (SDS)
- Hazard Identification
- Labeling of Containers
- Hazardous Chemical List
- Employee Information and Training

AWT has developed this program to ensure that all employees are aware of chemical hazard information.

- This program is implemented and accessible to employees at all worksites.
- Each component has been developed to cover activities which do not expressly fall under CFR 1910.120.

11.1 Hazard Identification:

- Information on hazard identification and determination of hazardous chemicals used or stored by AWT, will be provided by the manufacturer/importer of the chemical.
- AWT does not manufacture, distribute, nor import chemicals and is not able to make hazard determination.

11.2 Labeling:

- Containers of hazardous chemicals stored in the workplace or in use at sites will be labeled as follows:
    - Chemical Name
    - CAS #
    - Manufacturer name and address, if possible
    - Hazard Information

- Employees are not to deface or remove any label or tag unless authorized to do so by the site supervisor or the Safety Manager.
- Labeling of in-house containers is the responsibility of the supervisor or designated person.
- All containers containing hazardous chemicals shall be dispensed from dedicated containers except those chemicals for immediate use.
- All labels must always be legible, in English, and prominently displayed on the container or readily available in the work area throughout each work shift.

11.3 Safety Data Sheets (SDS):

- SDS for each chemical used or stored will be compiled and maintained to be readily accessible to all employees upon request.
- The site supervisor has the responsibility of procuring the necessary SDSs for the field team (prior to departure) for hazardous chemicals that will be utilized or stored in the field.
- Employees will be trained in reading and understanding the information on the SDS prior to handling or working with hazardous chemicals.
- If additional PPE is required as per the SDS, employees will be trained in the type of PPE, discussing its limitations and proper donning and doffing of the equipment.

11.4 HAZCOM Training

- AWT employees will be informed of the hazardous chemicals used and present in the workplace or work site using the following methods:
    - Hazard Communication Training will be provided: initially, annually, and as changes need to be.
    - Daily Safety Tailgate Form DST-Form covering:
        - the location of hazardous chemicals
        - chemical hazard information
        - SDS (availability and location)
        - methods and observations used to detect the presence or release of hazardous chemicals.
        - Physical and health hazards
        - safe handling
        - PPE required.
        - corporate hazard communication program location and accessibility
        - any non-routine tasks, chemicals, hazards, and control methods for these tasks, and hazards associated with any unlabeled pipes or equipment in the immediate work area.

12. Lifting Safety (if applicable)

12.1 Crane Safety

Note: AWT does not own, operate, inspect, nor perform any type of maintenance on cranes.

The following is applicable to any subcontractors hired by AWT and any AWT employees designated to assist in Crane Operations or any other Lifting Equipment (i.e., Drill Rigs, Excavator, Sonic Rig, etc.):

12.1.1 General Safety

- Crane operators shall be qualified/licensed/certified to the specific type of crane being used.
- Pre-use and monthly inspections must be performed by a competent person.
- Annual inspections are to be conducted by a qualified person.
- Records to ensure appropriate inspection of equipment must be available upon request.
- Operator's manual must be in the cab at all times.
- The manufacturer's specifications and limitations applicable to the operation of all cranes and lifting equipment shall be complied with at all times.
- Rated load capacity charts recommended operating speeds, special hazards warnings, and other essential information must be conspicuously posted in all cranes and lifting equipment. They must be followed at all times.
- Never attempt to lift more than the rated capacity of the equipment or the attached rigging device and equipment.

12.2 Lifts work near Overhead Powerlines

- If a crane or lifting equipment is operated near powerlines, the following table A must be followed: **1926.1408 (h)**

TABLE A- MINIMUM CLEARANCE DISTANCES

Voltage (Nominal, kV, alternating current)	Minimum Clearance Distance (feet)
Up to 50	10
Over 50 to 200	15
Over 200 to 350	20
Over 350 to 500	25
Over 500 to 750	35
Over 750 to 1,000	45
Over 1,000	As established by the utility owner/operator or registered professional engineer who is a qualified person with respect to electrical power transmission and distribution.

Note: The value that follows "to" is up to and includes that value. For example, over 50 to 200 means up to and including 200 kV.

- No part of the crane or lifting equipment, including the load, may be allowed to get closer to bare live circuits or apparatus than the spacing indicated in the table above.
- The power company should be asked if it is possible to de-energize the power line or install temporary sleeves and visibly verify that the power line has been grounded at the worksite.
- All overhead lines are considered energized unless disconnected and physically grounded.
- If the line is not de-energized:
    - At the Daily Safety Tailgate, review measures to prevent encroachment.
    - A pre-operational assessment shall identify the work zone and determine if any part of the equipment/load will be within the minimum clearance distance.

- Use only nonconductive tag lines.
- Designate a spotter, a proximity alarm, a range control warning device, an automatic limit device, or an elevated warning line/barrier in view of the operator.

12.2 Rigging Equipment

- The proper selection of rigging equipment will be completed by a competent rigger.
- Manufacturers' tag must be legible at all times describing the capability, capacity and limits of the equipment.
- All lifting equipment and slings must be visually inspected for defects before each use.
- Do not use items found to be defective.
- Each sling must have a thorough and documented periodic inspection not to exceed 12 months conducted by a competent person.
- Slings found to be defective cannot be repaired and must be destroyed and discarded.

13. Asphalt and/or Concrete Cutting/Grinding/Coring/Drilling

- In the event where AWT employees perform work activities with potential of being exposed to Respirable Crystalline Silica, compliance with **1926.1153 Table 1 (ii) & (iv)** will be followed and maintained.
- Upgrade on Personal Protective Equipment (PPE) shall be documented on the Daily Safety Tailgate form.

13.1 Table-3

Equipment/Task	Engineering/Control Method	Required Respiratory Protection and Minimum Assigned Protection Factor (APF)	
		≤ 4 hours/shift	≥ 4 hours/shift
(ii) Handheld power saws (any blade diameter) (iv) Walk-behind Saws	Use saw equipped with an integrated water delivery system that continuously feeds water to the blade. Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.		
	When used outdoors	None	APF 10
	When used indoors or in an enclosed area	APF 10	APF 10

13.2 Operation

- Only trained employees will be allowed to operate cutting tools and equipment.
- Proper inspection will be performed by a competent person who understands the safe operation and functionality of the tool and equipment being used.
- When installing or replacing the blade, the tool or equipment will be turned off.
- Proper hand protection will be used (i.e., cut resistant gloves, leather gloves, etc.)
- Ensure no leaks are detected prior to operating.

- If defects are found during inspection, remove the tool/equipment from service, tag it, and report it to the site supervisor immediately.
- Emergency spill kits must be readily available.
- Ensure that the area to be cut is **CLEARLY MARKED OUT.**
- Ensure that the area to be cut is clear of any debris or other obstruction that may hinder the safe operation of cutting tools or equipment.
- All safeguards must be in place as per the manufacturer's recommendations.
- To protect bystanders/community or adjacent work personnel, establish a safe zone to keep unauthorized personnel clear.
- If a handheld saw (i.e., demo saw) is used, both hands will be on the saw during operation.
- If using a walk-behind saw, always operate standing clear of the blade.
- Never stand or walk parallel while operating, nor allow anyone else to stand or walk parallel to the saw.

13.3 PPE

- The Job Safety Analysis (JSA) for this type of activity will provide a breakdown of the Hazards Associated, Mitigation/Controls to be used, and PPE required while performing Asphalt/Concrete Cutting activities.
- Whenever face-shields are used, safety glasses must also be worn.
- Face-shield lenses must be clear of scratches or dust that would obstruct the wearer.
- If respiratory protection is required, proper selection, maintenance, and storage will be maintained for the duration of the project.
- Proper hearing protection will be worn by not only the operator, but employees near saw cutting area as well.

13.4 Site Protection/Preparation

- Ensure the area is clear of combustibles.
- If adjacent work is in progress, proper containment must be installed.
- Legible signage and barricades must be installed to keep unauthorized personnel in the area.
- Proper ventilation (i.e., exhaust fans, air movers, etc.) will always be maintained during cutting operations and/or any operations that may create airborne hazards (i.e., sweeping debris, etc.)
- Ensure that everyone in the immediate area has proper PPE (i.e., proper hearing protection, safety glasses, etc.)

14. Excavation

14.1 Definition

- Any man-made:
  - Cut
  - Cavity
  - Trench
  - Or Depression in the Earth's surface formed by earth removal.

14.2 Utility Mark-Outs

- Site preparation activities will include:

- Arrangement of a utility mark-out through the One Call Utility notification center (811) to identify public utility underground service lines within or near the work zones.
- The delineation of work and support zones.
- And the construction of temporary soil staging, and equipment areas used for decontamination.
- No soil disruption activities or driving equipment into the ground will begin prior to confirming that mark-outs have been completed.
- Caution tape and safety fencing will be used to establish the boundaries of the exclusion zone, contamination reduction zone, and the support zone (if required).
- A site meeting will also be conducted which will include the review and acknowledgement mark-outs and precautions for digging by site personnel.

14.3 Heavy Equipment Operation

- Potential Hazards associated with operating the specific Heavy Equipment must be identified and noted on the Daily Safety Tailgate form (DST-Form).
- A thorough inspection of the equipment must be conducted prior to operation.
- Only trained and competent employees will be permitted to operate Heavy Equipment.
- Swing Radius protection must be established to ensure clearance.
- Must follow Table-A when working near overhead powerlines.
- When spotters are required, the operator shall only take signals from the designated signal person.
- Proper communication must be consistent between the operator and the signal person.
- No one will be permitted to stand or perform work under any suspended load.
- If rigging equipment is used, all components (straps, slings, shackles, etc.) must be inspected and in good working condition.
- Any rigging equipment found with a defect must be removed for service and disposed of properly.

14.4 Access and Egress

- Stairways, ladders, and ramps will be in trenches or excavations that are 4 feet or greater in depth and will require no more than 25 feet of lateral travel.
- Structural ramps used in lieu of steps will be constructed to prevent tripping, and with surface treatments to prevent slipping.
- Structural ramps that are used solely by employees and equipment as a means of access or egress from an excavation will be designed and constructed by competent persons.

14.5 Working inside an excavation/trench

- The atmosphere in the excavation greater than **4 feet** in depth will be tested using a multi-gas monitor before employees enter to ensure safe and acceptable atmospheric conditions.
- Flammable or combustible vapors may be present in the work area.
- The concentration of vapors in the excavation or the work area may reach the flammable (explosive) range before venting is completed and a safe atmosphere is reached.

Therefore, precautions will be taken to:

- Eliminate all potential sources of ignition from the area (i.e., put out all smoking materials, explosion-proof electrical and internal combustion equipment).
- Prevent the discharge of static electricity during venting of flammable vapors; and
- Prevent the accumulation of vapors at ground level.
- All open flames and spark producing equipment within the vapor hazard area will be shut down.
- Electrical equipment (for example, pumps and portable hand tools) used in the area will be explosion-proof in accordance with the NFPA 70B Class 1, division 1, Group D or otherwise approved for use in potentially explosive atmospheres.

14.6 Water Accumulation

- Employees will not work in an excavation that has accumulation or accumulating water unless adequate precautions have been taken.
- The precautions include, but are not limited to:
    - Special support, shield systems, diversion ditches, dikes, and/or water removal may be used to prevent surface water from entering an excavation.
    - If the water is controlled or prevented from accumulating by use of a water removal system (i.e., submersible pump, etc.), the competent person will monitor the operations.
- If water is to be pumped out, site-specific requirements for discharge must be adhered to.

14.7 Adjacent Structure

- Where the stability of adjacent buildings, walls, sidewalks, pavement, and appurtenant structures is endangered by excavation operations, support systems such as shoring, bracing, or underpinning will be installed to ensure the stability of such structures.
- The need for support systems as described above may be waived if a registered professional engineer has determined that the excavation activity will not create a hazard to employees.

14.8 Employee Protection

- Excavations and trenches that are **5 feet** or greater in depth will be protected by sloping, benching or support systems designed and constructed by a competent person according to the requirements of **29 CFR 1926 Subpart P**.
- Some excavations less than 5 feet deep may still need protection systems in unstable soil conditions.
- The following details are the methods to be utilized for each type:
    - Sloping must be accomplished by establishing sidewall angles not greater than 34° from the horizontal.
    - Benching is accomplished by excavating in a series of steps to create multiple 90° angles down the sidewall of the excavation.
    - Sheeting involves driving piles below the proposed depth of the excavation bottom and placing either approved wood or steel plates to brace the sidewall soils.
- Protective systems for excavations greater than **20 feet** in depth will be designed and approved by a registered professional engineer.
- A competent person will inspect the excavation prior to employees accessing it each day and after each significant weather event.
- The inspections will be documented and kept on file for at least one year.

- AWT will maintain proper dust control (i.e., water spray/mist) to reduce/eliminate potential exposure to airborne chemical contaminants.

14.8.1 PPE

- Employees working near areas within the excavation where there is confirmed potential exposure to Hexavalent Chromium, PPE will be upgraded to either Modified Level D or Level C.
- Respiratory protection will consist of a full-face respirator with either P100 or Combo of P100 and Organic Vapor protection.
- Crews working near areas where potential for asbestos exposure exist within the excavation will have a minimum of Level C.
- Respiratory protection will consist of a full-face respirator with either P100 or Combo of P100 and Organic Vapor protection.

14.9 Community Protection

- The perimeter of the excavation will be protected by a system to prevent unauthorized personnel from entering the site and being exposed to site specific hazards.
- When using fencing, AWT will ensure its stability to assure effectiveness.
- The work area will be demarcated and properly lit as needed.
- If a flag person is used, proper communication must be maintained.

14.10 Working in a trench box

- Proper access and egress must be maintained.
- If using a straight ladder, the ladder must extend 3 feet on top of the trench box.
- The Tabulated Data for the Trench Box must be readily available and must reflect the specific specs of the Trench Box being used (not a generic table).
- If the area is deemed a Confined Space by the competent person, the air quality inside must be tested and confirmed safe prior to allowing any employees to enter the trench box.

14.11 Inspection

- The designated “competent person” will perform inspections each day before employees enter the excavation, after every rainstorm, as needed throughout the shift, and as soil conditions change.
- During the inspection, the “competent person” must determine the protective system is adequate for the soil classification and the external loads placed on the adjacent area.
- The soil will be classified to determine proper protective systems.

He/she will evaluate the:

- Excavation
- Adjacent area
- Protective system

For:

- Hazardous atmosphere
- Potential situations that could lead to cave-in
- Indications of failure of a protective system
- Cracks in the ground parallel to the top of the excavation
- Any other potentially hazardous conditions.

Note: The competent person will verify that ladders or other means of access/egress to excavations are provided at a maximum spacing of 100 feet on the perimeter of open excavations and maximum travel distance of 25 feet for trench excavations greater than 4 feet in depth.

The competent person will stop work or remove workers from the excavation if any hazards are identified during the inspections that could create a danger to employees.

15. Evacuation Plan

- Prior to work activities, the site-specific muster/safe areas will be established and communicated to the crew involved.
- Information must be included in the Daily Safety Tailgate (DST) form.
- AWT personnel understand that the designated areas may vary on wind-direction, type of event that may warrant evacuation, and weather related hinderance.

15.1 Procedures:

- An emergency evacuation alarm (air horn, etc.) will always be available on site.
- This alarm should be of enough power to be audible by personnel operating heavy equipment in the area.
- The crew will discuss the types of blasts and their meaning so that all employees understand the emergency procedures.
- A series of repeated blasts signifies all personnel need to evacuate and congregate at the nearest designated muster point.
- This area must be determined and discussed during the daily safety tailgate meeting.
- If possible, the muster area should be identified using signs or demarcation.

16. Accident/Incident Reporting

16.1 Accident/Incident
In the event of an accident/incident:

- The site supervisor must be made aware immediately.
- All accidents, incidents, and/or near misses are to be reported to immediately; this will allow the proper assistance with the response/notification to others in the area and and create a path for emergency personnel/equipment.
- The supervisor and/or project manager are to complete the company Incident Report form with the affected employee, any witnesses, and/or relevant personnel as soon as possible after the Incident is reported.
- The supervisor is to immediately notify the Operations Manager and/or Safety Manager as soon as possible.
- When an Incident is reported to an onsite safety officer, he/she must report to AWT's Safety Manager as soon as possible after the Incident is reported to them.
- A copy of the completed Incident Report will be provided to the client/customer as soon as possible after a complete investigation and report has been completed.
- All corrective actions will be reviewed with employees involved and followed up to ensure the effectiveness of the corrective actions is determined.

16.2 Spills
The following factors will be considered in the event of any spill (small or large):

- The volume of the hazardous substance released and the rate of release.
- The nature of the spilled material.
- What danger exists to personnel in the immediate area.
- Nature of damage and possibilities of repair.
- If the transfer of material to an alternate container is advisable.
- Feasibility of the construction of a containment dike.
- Nature of spill area.
- Whether the spilled substance has reached a watercourse of sewer.
- Danger of explosion or fire.
- Equipment and supplies necessary to contain the substance and carry out proper treatment.

AWT's first attempt at spill containment will be at the point of discharge.

This is usually accomplished by:

- Closing valves
- Repairing damaged containers, or
- Moving material to a temporary holding container/vessel.

When necessary, the proper individuals will be notified.

This would include The National Response Center, and/or local authorities.

17. First Aid

17.1 Employee Responsibilities:

- Know where the nearest first aid kit or station is located.
- Know who the people on your job site are First Aid, CPR, and emergency response trained.
- Be aware of the nearest medical facility and the emergency procedures on this SSHASP.
- Report all injuries immediately, no matter how minor, to the Site Supervisor and Safety Manager to receive proper medical care.
- AWT employees shall NOT go to their own doctor for any workplace injury.
- Do NOT provide any first aid treatment that is beyond that for which you have been trained and certified to perform.
- Treating all blood and body fluids is hazardous and follows proper precaution. At minimum, this means ALWAYS wearing disposable gloves when assisting an injured person and preventing direct skin contact with any body fluids.

17.2 Supervisor Responsibilities:

- Ensure that all employees are aware of the nearest medical facility and emergency procedures on this SSHASP.
- Ensure that urgent care and hospital route have been driven by site personnel to familiarize themselves prior to commencement of work.
- Verify that first aid kits are present at the work locations.
- Regularly check and frequently inspect the contents of first aid kits to assure that all necessary suppliers are available and within their expiration date.

- Arrange for replacement and refill of kits as necessary to maintain compliance with this SSHASP.

18. Stop Work Authority (SWA)

- Any person on site may shut down a work operation that poses imminent danger or a situation arises which is Immediately Dangerous to Life or Health (IDLH).
- When such precautions must be immediately taken, the Site Supervisor shall be immediately notified and actions to rectify the situation shall be implemented.
- All employees have the authority and obligation to stop unsafe work operations where concerns or questions regarding the control of safety, health or environmental risk exist.
- Employees are responsible for initiating a Stop Work intervention where warranted and management is responsible for addressing all concerns accordingly and effectively.

Note: No work will commence until all questions or concerns have been appropriately addressed.

19. Emergency Contact Information

EMERGENCY CONTACT		AWT EMERGENCY CONTACT INFORMATION		
Organization		Name	Title	Cell Number
LOCAL POLICE	911	Geovany Ramos	SS	973-620-7400
FIRE DEPT.		Baxter Duffy	DM	908-967-0435
EMS		Jose Hernandez-Aponte	SM	862-755-4562
PADEP	800-541-2050	*SS-Site Supervisor/DM-Division Manager/SM-Safety Manager*		
Poison Control	800-968-1253	**OFFICE**		
CHEMTREC	800-424-9300	**1-800-732-7701**		

MEDICAL FACILITIES

Nearest Urgent Care Center:

american family care URGENT CARE

5024 Pennell Rd.
Aston, PA 19014
(484) 766-3502
Mon-Fri 8am-8pm
Sat & Sun- 8am-5pm

Nearest Emergency Room:

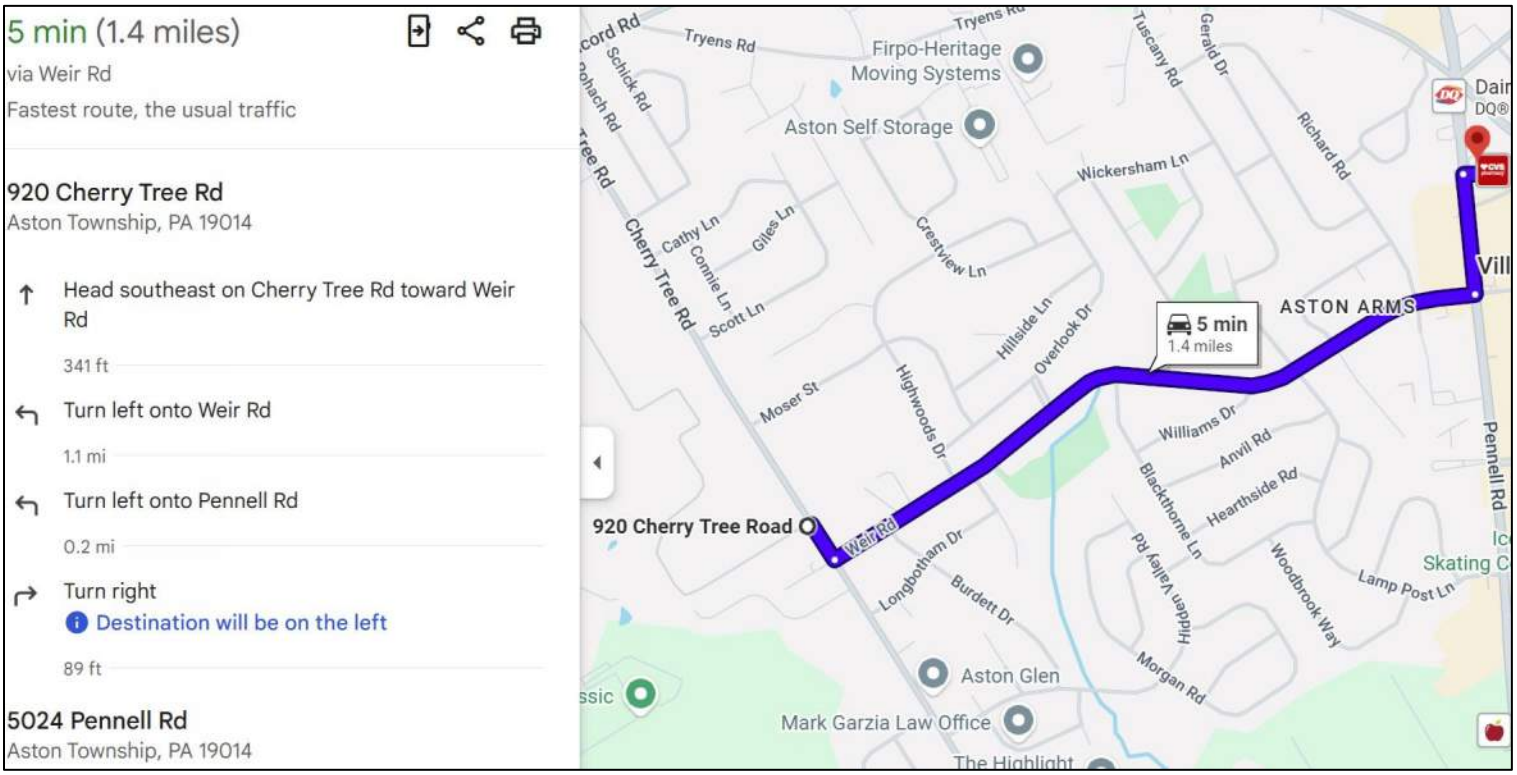
Riddle Hospital
Main Line Health

1068 W Baltimore Pike
Media, PA 19063
(484) 227-9400

Open 24 hours a day, 7 days a week

20.1 Directions

20.1.1 To the Urgent Care



20.1.2 To the nearest Emergency Room

16 min (5.3 miles)

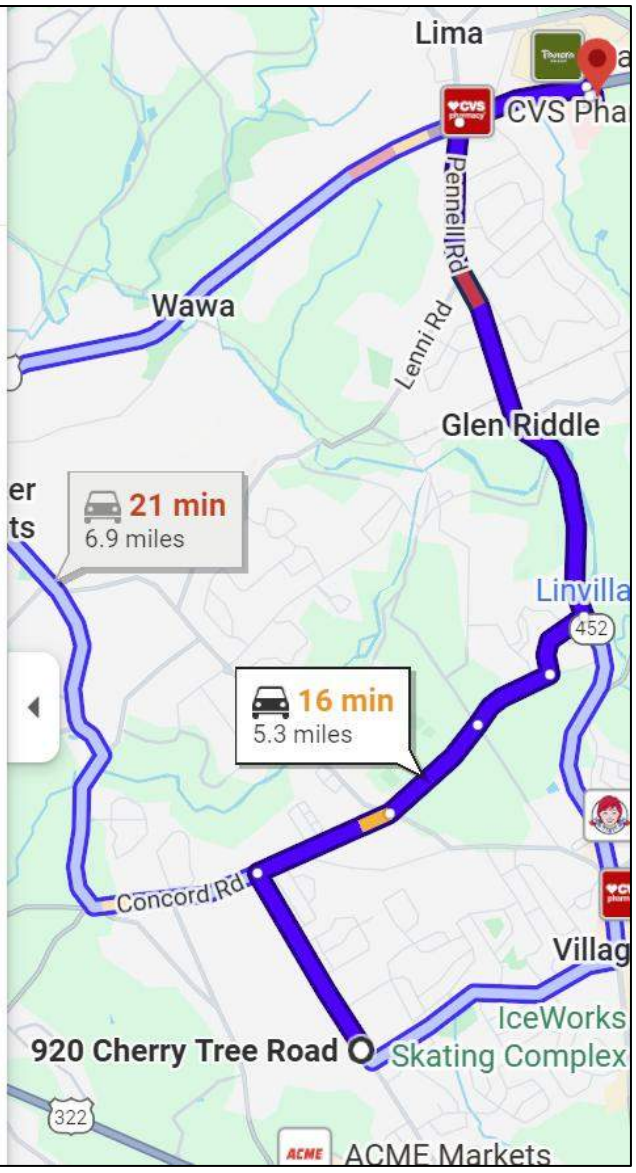
via PA-452 N/Pennell Rd

Fastest route now due to traffic conditions

920 Cherry Tree Rd
Aston Township, PA 19014

- Take Cherry Tree Rd to Convent Rd in Aston Township
  4 min (1.4 mi)
- Continue on Convent Rd to PA-452 N/Pennell Rd
  4 min (1.2 mi)
- Continue on PA-452 N/Pennell Rd to Middletown Township
  6 min (2.6 mi)
- Drive to your destination
  31 sec (440 ft)

1068 W Baltimore Pike
Media, PA 19063



21. Acknowledgement Form

The following signatures of AWT employees indicate that they have read and understand this Site-Specific Health and Safety Plan and will comply with all requirements documented within the plan.

Name (Print)	Name (Signature)	Date

22. APPENDICES

- JSAs
- Daily Tailgate Form (DST)
- Incident Report Form
- Other

Job Safety Analysis (JSAs)

AWT ENVIRONMENTAL SERVICES, INC.

JOB SAFETY ANALYSIS (JSA)				
Date:	**Job #:**	**Supervisor Name:**	**Project Manager:**	
Developed by: Jose "Junior" Hernandez, CHST- AWT Health and Safety Manager			**Last Review:** 8/2022, 10/2024, 12/2024	
Scope of Work: Load Equipment onto trailer/flatbed		**Client Name:**	**Location:**	
TASK		**POTENTIAL HAZARDS**	**CONTROLS**	**PPE**
1. Set trailer/flatbed up for equipment load out		1.1 Struck-by/Crushed-by	1.1.a Ensure area is clear of pedestrians, incoming traffic, any other site encumbrances	Level D
			1.1.b Designate a spotter to assist set up	
2. Manually lower ramp		2.1 Injuries to hands/fingers	2.1 Identify potential pinch points and always keep hands clear	
3. Drive equipment onto trailer		3.1 Equipment tip over	3.1.a Have a spotter help guide the operator	
		3.2 Struck-by/Crushed-by	3.2.aDrive equipment slowly onto and up the ramp and be mindful of rear tires to ensure they never leave the ground.	
			3.2.b If applicable, ensure that the equipment's parking/emergency brakes are engaged/locked to avoid inadvertent movements during transfer.	
			3.2.c Keep personnel clear	
4. Secure/Tie equipment down		4.1 Injuries to hands/fingers	4.1 Keep hands clear	
		4.2 Trips/Falls	4.2.a Be aware of chains/straps while walking on platform/trailer	
			4.2.b Use 3 points of contact when coming down off the trailer (if using a ladder, ensure ladder is secured before descending. If using fixed steps on trailer, maintain 3 points of contact and no jumping off equipment.)	
5. Drive out of site		5.1 Struck/Crushed-by	5.1.a Ensure area is clear before exiting area and that the bed/trailer is clear of any debris that may roll/get blown away during transport.	

		5.1.b Have a spotter continuously assist operator out and ensure constant clearance	
Level D: Hard hat, Safety Glasses, Sleeved Shirt, Safety Toe Boots, High Visibility Vest/Clothing, Leather Gloves (outer) *Level C: Level D + Air Purifying Respirator* *Optional (must be always available): Nitrile Gloves (inner), Disposable Coveralls/Tyvek, Cut Resistant Gloves, Goggles, Face Shield, Rain Gear*			
Comments:			

AWT ENVIRONMENTAL SERVICES, INC.

JOB SAFETY ANALYSIS (JSA)				
Date:	**Job #:**	**Supervisor Name:**	**Project Manager:**	
Developed by: Jose "Junior" Hernandez, CHST- AWT Health and Safety Manager			**Last Review:** 6/2022	
Scope of Work: General Site Activities		**Client Name:**	**Location:**	
TASK		**POTENTIAL HAZARDS**	**CONTROLS**	**PPE**
1. Off-Load materials for work activity		1.1 Hands/Fingers injuries during off-loading	1.1 Be aware of hand placement and keep clear of identified pinch points	Level D + Cut Resistant Gloves if sharp tools/equipment are expected
		1.2 Back/Muscle strains/injuries while lifting heavy tools/equipment	1.2.a Use the buddy system whenever possible and lift with a partner	Level D
			1.2.b Use mechanical methods to lift components	
			1.2.c Proper ergonomics when lifting manually	
2. Mobilizing to site/work area		2.1 Injuries from being struck by loose materials during or after travel	2.1 Secure all equipment and materials prior to departure from shop	
		2.2 Accident while driving to site location	2.2 Take the following steps to ensure safe travel to and from the work site: • Plan route • Practice Defensive Driving Techniques • Allow sufficient travel time when adverse weather conditions are anticipated • Do not drive with distractions	
		2.3 Strike and damage site equipment/structures	2.3.a Assess access into the work area	
			2.3.b Designate and use a spotter	
			2.3.c Perform a 360 walk-around to ensure proper clearance	

3. Walk on uneven surfaces	3.1 Trips and Falls resulting in sprains/injuries	3.1.a Assess the area to ensure safe walking/working path	Level D
		3.1.b Maintain 3 point of contact if using a catwalk/staircase/fixed ladder	
<u>Level D</u>: Hard hat, Safety Glasses, Sleeved Shirt, Safety Toe Boots, High Visibility Vest/Clothing, Leather Gloves (outer) *<u>Level C:</u> Level D + Air Purifying Respirator* *<u>Optional (must be always available):</u> Nitrile Gloves (inner), Disposable Coveralls/Tyvek, Cut Resistant Gloves, Goggles, Face Shield, Rain Gear*			
Comments:			

AWT ENVIRONMENTAL SERVICES, INC.

JOB SAFETY ANALYSIS (JSA)				
Date:	**Job #:**	**Supervisor Name:**	**Project Manager:**	
Developed by: Jose "Junior" Hernandez, CHST- AWT Health and Safety Manager			**Last Review:** 7/2022	
Scope of Work: Air Knife/Soft Dig		**Client Name:**	**Location:**	
TASK		**POTENTIAL HAZARDS**	**CONTROLS**	**PPE**
1. Mobilizing/Setting up Equipment		1.1 Struck-by/Crushed-by injuries to personnel	1.1a Keep unauthorized personnel away	Level D
			1.1.b Designate/utilize a spotter as needed	
		1.2 Property/site equipment damage	1.2 Perform a proper site assessment prior to mobilization and set up to ensure clearance	
2. Connect air hoses		2.1 Injuries to hands/fingers by pinching or twisting	2.1 Be aware of pinch points and use proper ergonomics	
		2.2 Trip and fall hazards	2.2 Properly set up the hoses so that they do not pose a trip hazard (i.e., away from heavy traffic and walking path)	
3. Operate Equipment		3.1 Bodily injury by being struck by loose hose/connectors	3.1 Secure hoses using whip checks and/or safety pins	
		3.2 Exposure to high noise levels	3.2 Wear the proper PPE	Level D + Proper Hearing Protection (earplugs/earmuffs)
		3.3 Equipment malfunction	3.3 Ensure proper inspection of equipment has been performed and assure equipment is in good working condition before use	Level D
		3.4 Damages to near by building structures, equipment, or windows due to flying particles	3.4.a Secure property using effective barriers (i.e., plywood, tarps, screens, etc.)	
			3.4.b Contain the flying particles at the source	
		3.5 Injuries to face or eyes by flying particles and/or dust	3.5 Wear proper PPE	Level D + Face shield over safety glasses

4. Vacuum loose spoils into 55-gal Drum	4.1 Exposure to excessive noise levels	4.1 Wear proper PPE	Level D + Proper Hearing Protection (earplugs/earmuffs)
	4.2 Bodily injuries from kickbacks of suction hose	4.2 Ensure proper grip and control of suction hose is maintained	Level D
5. Handle drum	5.1 Back/Muscle strains	5.1.a Avoid overfilling drum	
		5.1.b Use proper ergonomics during manual handling	
		5.1.c Consider using mechanical methods if feasible and available to substitute manual handling	
	5.2 Injuries to hand/fingers	5.2 Be aware of identified pinch points and hand placement	
Level D: Hard hat, Safety Glasses, Sleeved Shirt, Safety Toe Boots, High Visibility Vest/Clothing, Leather Gloves (outer) *Level C: Level D + Air Purifying Respirator* *Optional (must be always available): Nitrile Gloves (inner), Disposable Coveralls/Tyvek, Cut Resistant Gloves, Goggles, Face Shield, Rain Gear*			
Comments:			

AWT ENVIRONMENTAL SERVICES, INC.

JOB SAFETY ANALYSIS (JSA)

Date:	**Job #:**	**Supervisor Name:**	**Project Manager:**
Developed by: Jose "Junior" Hernandez, CHST- AWT Health and Safety Manager		**Original Version:** 10/2022	**Last Rev:** 11/2025
Scope of Work: Sonic Drilling		**Client Name:**	**Location:**

TASK	POTENTIAL HAZARDS	CONTROLS	PPE
1. Mobilize to site	1.1 Contact and damage with site structures and/or equipment.	1.1a Perform a proper site assessment prior to mobilization.	Level D
		1.1.b Designate a spotter when maneuvering equipment into/out of narrow or congested areas.	
	1.2 Electrocution from overhead powerlines	1.2.a During the site assessment, ensure clearance from any overhead power/communication lines prior to setting up the mast of the rig.	
		1.2.b Keep equipment at least 10 feet clear of any power or communication lines. If any defects are found during inspection, the rig is not to be operated until any issues are concerns are addressed and corrected.	
2. Set sonic rig on site	2.1 Equipment failure	2.1 Inspect all equipment parts, filters, sensors to ensure their safe functionality.	
	2.2 Environmental impact (leaks, spills, etc.)	2.2.a During mobilization, ensure that emergency spill components are readily available.	
		2.2.b Set containment/decon pad	
3. Set tug/gantry	3.1 Pinch points	3.1 Communicate pinch points observed with crew members and keep clear of identified points.	
	3.2 Muscle injuries from strains	3.2.a Work as a team whenever heavy lifting is performed.	
4. Operate rig	4.1 Excessive noise	4.1 Wear proper hearing protection.	
	4.2 Moving parts/Entanglement	4.2.a Keep clear of moving parts and keep unauthorized personnel away from the area.	

		4.2.b Avoid wearing loose clothing near moving parts.	Level D
	4.3 Struck-by detached pneumatic hoses while connecting casings.	4.3.a Ensure all connections have been properly inspected prior to operation.	
		4.3.b Do not over load the equipment.	
	4.4 Hand injuries from sharp edges on casings	4.4 Wear proper hand protection.	Level D + Cut Resistant Gloves
Level D: Hard hat, Safety Glasses, Sleeved Shirt, Safety Toe Boots, High Visibility Vest/Clothing, Leather Gloves (outer) *Level C: Level D + Air Purifying Respirator* *Optional (must be always available): Nitrile Gloves (inner), Disposable Coveralls/Tyvek, Cut Resistant Gloves, Goggles, Face Shield, Rain Gear*			
Comments: AWT SPILL KIT- Standard Spill Kill will include: absorbent pads, booms, additional PPE/gloves.			

JOB HAZARD ANALYSIS (JSA)				
Date:	**Job #:**	**Supervisor Name:**	**Project Manager:**	
Developed by: Jose "Junior" Hernandez, CHST- AWT Health and Safety Manager			**Last Review:** 8/2022	
Scope of Work: Drum Handling		**Client Name:**	**Location:**	
TASK		**POTENTIAL HAZARDS**	**CONTROLS**	**PPE**
1. Lift drum cart		1.1 Bodily injuries due to improper lifting of heavy equipment	1.1 Use proper ergonomics when lifting cart (i.e., lift using knees and not the back)	Level D
2. Place drum onto hand cart		2.1 Bodily injuries do to being crushed, pinched, or caught-in between the drum being loaded and the cart	2.1.a Be constantly aware of body positioning and keep clear of identified pinch points	
			2.1.b Work with a partner when loading drums onto cart	
		2.2 Exposed to contents inside the drums	2.2.a Inspect drum prior to handling and look for damages that may caused inadvertent exposure to contents.	
			2.2.b Read label affixed to drums to identify contents and review SDS (if applicable)	
			2.2.c Wear personal protective equipment	If applicable, see Section 8. Exposure Controls/PPE on Safety Data Sheet (SDS) and upgrade PPE as necessary.
3. Moving drums with the hand cart		3.1 Environmental impact/spills	3.1.a Before moving the cart, ensure that the drum is secured to avoid shifting, sliding, bouncing, or tilting. (i.e., fastening straps)	Level D
			3.1.b Pace yourself and move slowly especially around uneven surfaces or areas that may have and incline/decline, bumps,	

		gravel, or other ground conditions that could affect the safe mobility of the hand cart	
	3.2 Bodily injuries due to crushed/pinched-by drum	3.2.a Keep body (especially toes) clear of the area where drum is being lifted	
		3.2.b Keep body clear of identified pinch points	
4. Load drums onto the rack truck for relocation	4.1 Back/Muscle strains	4.1 Use rack truck's lift gate to position drum onto truck's bed	Level D
	4.2 Environmental impacts/spills	4.2 Ensure drum is secured prior to lifting gate	
	4.3 Bodily injuries from being crushed/pinched-by	4.3.a Keep body clear of moving parts	
		4.3.b Keep hands clear of pinch points	
	4.4 Trips/falls on uneven surfaces	4.4 Ensure lift gate is even with the bed of the truck to avoid creating a trip hazard	
5. Lower lift gate to continue loading	5. Crushed-by	5. Keep body clear while operating lift gate	
Level D: Hard hat, Safety Glasses, Sleeved Shirt, Safety Toe Boots, High Visibility Vest/Clothing, Leather Gloves (outer) *Level C: Level D + Air Purifying Respirator* *Optional (must be always available): Nitrile Gloves (inner), Disposable Coveralls/Tyvek, Cut Resistant Gloves, Goggles, Face Shield, Rain Gear*			
Comments:			

Daily Safety Tailgate Form

AWT ENVIRONMENTAL SERVICES, INC.

Incident Reporting: (732) 613- 1660

I HAVE STOP WORK AUTHORITY

Daily Safety Tailgate (DST) Form

Job #:

Date	Time	Site Location	Customer	Project Manager	Safety Topic Discussed	Emergency Safe Area

Work Type

☐ Remediation ☐ Site Clearing ☐ Tank Cleaning ☐ Tank Removal ☐ Tank Closure ☐ Drilling ☐ Direct Push Sampling ☐ Injection ☐ Well Install ☐ Well Abandonment ☐ Drum Run ☐ Lab Pack
☐ Vapor Barrier Installation ☐ Vapor Extraction System Install ☐ Shop/Yard Work ☐ Confined Space Entry ☐ Other:

PPE

Head/Face
☐ Hard hat
☐ Safety glasses
☐ Splash goggles
☐ Face shield
☐ Earplugs/muffs

Body
☐ FR Clothing
☐ Tyvek
☐ Tychem
☐ Raingear
☐ HiViz gear
☐ Reflective vest
☐ PFD
☐ Welding gear

Gloves
☐ Leather
☐ Cut Resistant
☐ Nitrile
☐ Chemical Resistant
☐ Impact Resistant
☐ Welding

Feet
☐ Safety toe
☐ Booties
☐ Metatarsal
☐ Rubber/PVC
☐ Traction(ice)

Respiratory
☐ N95
☐ APR
☐ SCBA
☐ Supplied Air
☐ ½ Face
☐ Full face

Cartridge
☐ P100
☐ OV
☐ Combo
☐ Other:

Fall Protection
☐ Harness
☐ SRL
☐ Lanyard

Potential Site Hazards
☐ Low lighting
☐ Uneven surfaces
☐ Trip/falls
☐ Excessive noise
☐ Overhead work
☐ Adjacent work
☐ Overhead Powerlines
☐ Chemical
☐ Biological
☐ Vehicle traffic
☐ Pedestrian traffic
☐ Heat stress
☐ Cold stress
☐ High winds
☐ Fog
☐ Icy conditions
☐ Slippery surfaces
☐ Lightning in the area
☐ Falls to lower level
☐ Unmarked utilities
☐ Electrocution
☐ Other:

Permits

Hot work
☐ Welding
☐ Grinding
☐ Cutting
☐ Brazing
☐ Butt fusion
☐ Electro fusion
☐ Power tools
☐ Portable heater

Excavation
☐ One call verified
☐ Utility marked out
☐ Permit complete
☐ Competent person
☐ Sloped ☐ Stepped
☐ Shoring ☐ Sheeting

Confined Space
☐ Permit required
☐ non-Permit

Other
☐ Site specific
☐ Crane lift

Equipment

Heavy
☐ Excavator
☐ Dozer
☐ Loader
☐ Skid steer
☐ Roller
☐ Dump truck
☐ Drill rig
☐ Forklift
☐ Boom lift
☐ Vac truck
☐ Aerial lift
☐ Scissor lift

Pneumatic
☐ Air knife
☐ Jackhammer
☐ Chipping gun
☐ Rivet buster
☐ Fan/Blower
☐ Drill
☐ Saw
☐ Drum pump

Gas-powered
☐ Trimmer
☐ Compactor
☐ Roller
☐ Mixer
☐ Saw
☐ Pump
☐ Generator
☐ Compressor
☐ Heater

Safety Equipment
☐ First aid kit
☐ Eye wash station
☐ Saline bottles
☐ Handwipes
☐ Fire Extinguisher ____lbs.
☐ Safety pins
☐ Whip-checks
☐ Spill Kit

Detector/Meter:
☐ Multi-Gas ☐ PID ☐ Dust
☐ Personal ☐ Noise

☐ Phone
☐ 2-way radio
☐ Airhorn
☐ Tripod
☐ Winch
☐ Pulley
☐ Insect Repellant
☐ Lighting

Site Protection
☐ Barricades
☐ Traffic cones
☐ Caution tape
☐ Danger tape
☐ Fence
☐ Barriers
☐ Fire blankets
☐ Screens
☐ Warning signs
☐ Signal person
☐ Water tote
☐ Traffic Flags
☐ Hole Covers

Tools
☐ Hand tools
☐ Electric tools
☐ Battery-operated
☐ Ladder(s)
  ☐ A-frame
  ☐ Extension
  ☐ Fixed
☐ Dolly
☐ Pallet jack
☐ Cylinder cart
☐ Drum grabber
☐ Pipe cutter
☐ Utility knife
☐ Hoist
☐ Rigging
☐ Straps
☐ Sprayer
☐ Sampling
☐ Manual auger
☐ Wrenches
☐ Core drill
☐ Other:

Supervisor Name/Signature	Attendees Name: Print/Signature
	1. _____ 4. _____ 7. _____ 2. _____ 5. _____ 8. _____ 3. _____ 6. _____ 9. _____

AWT ENVIRONMENTAL SERVICES, INC.

Incident Reporting: (732) 613- 1660

I HAVE STOP WORK AUTHORITY

Daily Safety Tailgate (DST) Form

If the scope of work or the conditions change significantly, STOP THE WORK/SHUT DOWN. Revise this Job Safety Analysis (JSA) to address the NEW HAZARDS before proceeding.			
Discuss, identify, and record the significant task steps, Potential Hazards, and Hazard Controls PRIOR to commencing work activities.			
Specific Task Steps *(What are we doing?)*	**Potential Hazard(s)** *(What could go wrong?)*	**Controls/Mitigation** *(How can harm be prevented?)*	**Assigned Person** *(Specific person or crew)*

Incident Report Form

AWT Environmental Services, Inc.
INCIDENT REPORT

INCIDENT DETAILS				
Date	Job Number	Client/Project Name	Time	Site Location
Project Manager	Division Manager	Report Author	Specific Location/Area	

Employee Involved (EI)/Witnesses(W)	Title	Signature
1		
2		
3		
4		
5		

Incident Type:		Description
☐	Near Miss	
☐	Injury	
☐	Illness	
☐	Vehicle Accident	
☐	Equipment Accident	
☐	Property Damage	
☐	Other:	

Injury/Illness		Driver/Operator Information	Equipment
☐	First Aid	Driver's Name:	Equipment:
☐	Beyond First Aid		
Urgent Care Facility		Police Investigation? ☐ Yes ☐ No	Rental? ☐ Yes ☐ No
		Summons Issued? ☐ Yes ☐ No	Operator Name:
		Truck/Plate #:	
		DOT #:	Damages:

Describe injury/illness:

Contributing Factors:

Immediate Actions Taken:

Additional Supportive Information:

AWT Environmental Services, Inc.
INCIDENT REPORT

Corrective Actions

(Note: All corrective actions must be entered, tracked, and effectiveness verified by H&S)

	Person Responsible:	Verified by:
Corrective Action 1-		
Corrective Action 2-		
Corrective Action 3-		

*****Attach: Witness Statements, photos &/or sketches that would support this report*****

Division Manager's Signature: **Supervisor's Signature:**

HEALTH AND SAFETY PLAN

SONIC DRILLING

MIPC CHELSEA FACILITY

920 CHERRY TREE RD

ASTON PA 19014

Prepared for:

Langan Engineering & Environmental Services, LLC

1818 Market St, Ste 3300

Philadelphia, PA 19103

Prepared by Ben Schafer,COSM

Summit Drilling LLC

Building 81A, Chimney Rock Road

Bridgewater, NJ 08807

Date: 1/16/2026 ,

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HEALTH AND SAFETY PLAN

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DO NOT TRANSPORT SERIOUSLY INJURED
CALL LOCAL RESCUE

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HEALTH AND SAFETY PLAN

1.0 Project Organization and Responsibilities

Prepared by: Denis Crayon, CHST

Date: 1/16_____, 2026

Date revised: 1/16_____, 2026

Introduction

Site Name: MIPC Chelsea Tank Farm Client Project Number: 220240201

Original Safety Plan: Yes _____ No ___X___ (adapted from client SSHASP)

Location: 920 Cherry Tree Rd
Aston PA 19014

Site/Incident Description

A.	Urban	_____	Residential	_____	Commercial	_____
	Industrial	___X___	Rural	_____	Remote	_____
	Active	___X___	Inactive	_____	Landfill	_____
B.	Spill	___X___	Air Release	_____	Fire	_____
	Brownfield	_____	Superfund:	_____	Other:	_____
C.	Containers involved?		Yes _____		No _____	
			Drums: ___x___		# ___TBD___	
D.	Map attached:		Yes ___X___		No _____	

Summit Drilling Key Personnel

Title	Name	Office Phone	Cell Phone
Project Manager:	Nick King	7324034306	
Director of Health & Safety:	Ben Schafer	4845236047	On-Site
Lead Air Knife Crew:	NA		
On-Site Lead Driller:	Mike Wilson		

Client

Title	Name	Office Phone	Cell Phone
Project Manager	Nick King	7324034306	

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1.1 Corporate Health and Safety Policy / Commitment to Safety

Summit Drilling recognizes that our people drive the business. As the most critical resource, employees will be safeguarded through training, provision of appropriate work surroundings, and procedures that foster protection of health and safety. All work conducted by Summit Drilling's employees will take into account the intent of this policy. No duty, no matter what its perceived result, will be deemed more important than employee health and safety.

Summit Drilling is firmly committed to the safety of our employees. We will do everything possible to prevent workplace incidents and we are committed to providing a safe work environment for all employees.

We value our employees not only as employees but also as human beings critical to the success of their family, the local community, and Summit Drilling.

A key factor in implementing this policy will be the strict compliance to all applicable federal, state, local, and company policies and procedures. Failure to comply with these policies may result in disciplinary actions.

Respecting this, Summit Drilling will make every reasonable effort to provide a safe and healthful workplace that is free from any recognized or known potential hazards. Additionally, Summit Drilling subscribes to these principles:

1. All incidents are preventable through implementation of effective health and safety control policies and programs.
2. Health and safety controls are a major part of our work every day.
3. Incident prevention is good business. It minimizes human suffering, promotes better working conditions for everyone, holds Summit Drilling in higher regard with customers, and increases productivity. Summit Drilling will comply with all health and safety regulations that apply to the course and scope of our operations.
4. Management is responsible for providing the safest possible workplace for employees. Consequently, management of Summit Drilling is committed to allocating and providing all of the resources needed to promote and effectively implement this health and safety policy.
5. Employees are responsible for following safe work practices and company rules, and for preventing incidents and injuries. Management will establish lines of communication to solicit and receive comments, information, suggestions and assistance from employees where health and safety are concerned.
6. Managers and supervisors of Summit Drilling will set an exemplary example with good attitudes and

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strong commitment to health and safety in the workplace. Toward this end, management must monitor company health and safety performance, working environments and conditions to ensure that program objectives are achieved.

7. Our health and safety program applies to all employees and persons affected or associated in any way by the scope of this business. Everyone's goal must be to constantly improve safety awareness and to prevent incidents and injuries.

8. All Summit Drilling employees have the responsibility to ensure that all on-site employees adhere to this established plan for all work activities to occur on this site.

Everyone at Summit Drilling must be involved and committed to health and safety. This must be a team effort. Together, we can prevent incidents and injuries. Together, we can keep each other healthy and safe in the work that provides our livelihood.

Stacia Edwards Director of Health & Safety

1.2 Work Site Lines of Authority/Project Personnel Responsibilities

On site personnel designations/responsibilities are defined as follows:

Site Contact: Jean-Paul

Antoine (832)208-7398)

Project Manager:

The Site/Project Managers (PMs) will be on-site for all site activities. She/he has Stop Work Authorization, which she/he will execute upon determination of an imminent safety hazard, emergency situation, or other potentially dangerous situation. Authorization to proceed with work will be issued by the PM after such action.

Industrial Hygiene Technician/Health & Safety Manager (HSM): TBD

Site Supervisor(s):

The Site Supervisor(s) will be responsible for conducting work zone air monitoring, managing the perimeter air monitoring stations, and providing health and safety oversight for client and Summit Drilling personnel. The Site Supervisor(s) will obtain and review applicable health and safety documents for client and Summit Drilling site personnel. The Site Supervisor(s) will determine the level of personal protective equipment and have stop-work authority when situations arise regarding health and safety or air monitoring results dictate

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that work stoppage is required. He/she will ensure that the level of personal protection by the workers follows those dictated by the action levels set in Section 7.

Summit Drilling Health & Safety Personnel:

When a requirement for the constant and direct supervision by the Summit Drilling Director of Health & Safety exists for a specific project, he will have the direct and overall responsibility to dictate and ensure compliance with all requirements required by OSHA and any additional, more stringent, company requirements, as they apply. This includes Stop Work & Show Hands Policies, and the Disciplinary Program. When this requirement does not specifically exist, the responsibility will be delegated to the client Site Supervisor/Site Health & Safety Officer and the Summit Drilling Supervisors.

Summit Drilling Supervisors (Drillers): TBD

The Summit Drilling Supervisor (Driller) will be on site for all work activities. He also has Stop Work authority and will not permit work activity to continue until all unsafe conditions have been resolved. The Driller in conjunction with the Summit Drilling Project Manager is responsible for ensuring that labor personnel have the appropriate training and medical surveillance. The Driller is responsible for enforcing labor personnel compliance with personal protective equipment (PPE) requirements and for enforcing compliance with this SSHASP.

Summit Drilling Site Personnel (Labor): TBD

Summit Drilling labor personnel in conjunction with and under the direct supervision of the Driller will perform all job task as directed by the Summit Drilling Supervisor (Driller). All Summit Drilling personnel are responsible for adhering to the requirements of this HASP, and following the direction of the Site Project Manager, SSO/HSO (if applicable) and the Supervisor (Driller). All Summit Drilling labor personnel have Stop Work Authority and must report any potentially unsafe condition to their Supervisor, Site Project Manager and the SSO/HSO (if applicable). They will not be permitted or required to work until all unsafe conditions have been resolved.

1.3 Management of Change (MoC)

Change is necessary to meet varying circumstances, make needed improvements or respond to emergency conditions. Careful consideration must be given to the safety and environmental implications that result from any change. Without proper review, a change may result in unsafe conditions, hazards, or operating issues.

Our program is intended for the review and approval of defined changes or management of processes (e.g. drilling technologies and personnel changes).

This section only notes the need for a MoC procedure for our operations on all sites.

The purpose of MOC is to ensure that changes are recognized, documented, formally reviewed, and

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approved by qualified personnel (VPs, PMs, and/or DoHS) prior to their implementation in order to avoid potential safety or operational problems and to comply with federal, state regulations and client standards and requirements.

This MOC Procedure provides guidance for the following:

- How to recognize a change.
- Use of the Management of Change procedure to properly manage change.
- Establishing Hazards Analysis Reviews or formal Risk Assessments.
- Documenting and communicating information associated with a change.

This MOC procedure is not intended to replace existing programs that track injury/illness reporting, non-compliance, fleet/equipment maintenance or training/scheduling programs.

2.0 Emergency Action Plan

2.1 Identify location of the following during the site orientation:

X First Aid Kit: Summit Drilling vehicle

X Eye Wash: Summit Drilling vehicle

_____ Stretcher: _____

_____ Emergency Shower: _____

X Bloodborne Pathogen Kit: Summit Drilling vehicle

X Fire Extinguisher: Summit Drilling vehicle

_____ Public Telephone: _____

_____ Site Telephone: _____

X Mobile Telephone: with Summit Drilling field crews

_____ Two-Way Radios: _____

X Telephone Contact lists: with this HASP on-site, in client & Summit Drilling vehicles

_____ SCBA's: _____

_____ Escape Packs: _____

Evacuation Routes: _____

2.2 Personal Injury within the Exclusion Zone

Site operations shall be temporarily halted and all site personnel shall assemble in the Contamination Reduction Zone. The Site Supervisor shall evaluate the nature of the injury and, if indicated by the hazards present on site, the injured person shall be decontaminated to the extent possible prior to movement to the Support Zone.

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Contact shall be made for an ambulance if necessary and with the designated medical facility (if required). An individual certified in Standard First Aid and Adult CPR may choose to initiate the appropriate first aid. No persons shall reenter the Exclusion Zone until:

a. The conditions resulting in the emergency have been corrected;
b. The hazards have been reassessed;
c. The Site Safety Plan has been reviewed; and
d. Site personnel have been briefed on any change to the Site Safety Plan.

2.3 Personal Injury within the Decontamination Zone

The Site Supervisor shall evaluate the nature of the injury and, if indicated by the hazards present on site, the injured person shall be decontaminated to the extent possible prior to movement to the Support Zone. Contact shall be made for an ambulance and with the designated medical facility (if required). An individual certified in Standard First Aid and Adult CPR may choose to initiate the appropriate first aid. If the injury increases risk to other site workers, all site personnel shall move to the Contamination Reduction Zone and site activities will stop until the risks can be assessed and either removed or minimized.

2.4 Personal Injury within the Support Zone

The Site Supervisor shall evaluate the nature of the injury and determine if the cause of injury or loss of the injured person will affect continuation of site operations. If the injury will not affect the safety or performance of other site workers, operations may continue, with the person certified in first aid initiating the appropriate first aid and necessary follow up as stated above. If the injury increases risk to other site workers, all site personnel shall remain in the Support Zone and site activities will cease until the risks can be assessed and either removed or minimized.

2.5 Personal Protective Equipment Failure

If any site worker experiences a failure or alteration of protective equipment that affects the protection factor that person and his/her buddy, if applicable, shall immediately leave the Exclusion Zone. Reentry shall not be permitted until the equipment has been repaired or replaced.

2.6 Fire/Explosion

If a fire is observed in the incipient phase (i.e., when it begins) and if the site personnel witnessing the fire feel secure in attempting to control the fire, the individual can attempt to extinguish the fire by using the on- site fire extinguisher. The fire extinguisher should be a minimum 20 pound dry chemical, Class A, B, and C extinguisher and adequate for paper and wood based products (A), flammable (B), and electrical (C) type fires.

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If there is no fire extinguisher available or if site personnel do not feel secure in attempting to extinguish the fire, site personnel shall perform the following:

- Secure the site, if possible but do not lock doors
- Evacuate the area using the nearest safe pathway from the area
- Proceed to the nearest phone and call 911 and provide the emergency operator all required information and this will activate the emergency response system
- PERSONNEL NOT TRAINED IN FIRE EXTINGUISHER USE ARE PROHIBITED FROM ATTEMPTING TO FIGHT A FIRE

If more than one individual is on the site team, the individual activating the evacuation plan shall verbally communicate to the other site personnel that there is an emergency condition and that they should evacuate from the work area. An agreed upon evacuation point with planned route and alternate shall be determined during the Tailgate Safety Meeting. If contact cannot be made verbally with the other site personnel, any of the following systems can be used as long as the system is audible above background noise. The system can be a vehicle horn, whistle, air horn, or other acceptable device. The system used for initiating an evacuation from the site shall be discussed during the tailgate meeting with the other site personnel prior to beginning the workday. The system that is decided upon shall be documented on the site health & safety tailgate meeting form for the shift.

2.7 Equipment Failure

If any equipment on site fails to operate properly, the Site Supervisor shall be notified and then determine the effect of this failure on continuing operations. If the failure will affect the safety of personnel, all personnel shall leave the Exclusion Zone until the situation is evaluated and appropriate actions are taken.

2.8 Emergency Contact/Notification System

All incidents, injuries and near-losses must be reported to the Summit Drilling DoHS (908-422-7266/cell: 908-801-4301) as soon as possible. In the event of an incident, injury or near loss, all work will immediately stop, and the incident will be immediately reported to the client HSO and Project Manager and Summit Drilling DoHS (908-422-7266/cell: 908-801-4301). All contact information can be found in Table 2. The client site representative will be made aware of any incident, injury or near loss as soon as possible. Work will resume once the incident is reported, the cause of the incident is determined, and work practices are modified to eliminate the potential hazard(s). The client Incident/Injury Report and Summit Drilling Incident/Injury, Loss or Near Loss Report must be completed by the affected employee and any witnesses and returned to the Summit Drilling DoHS within 24 hours of the incident.

2.9 Medical Emergencies

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This information shall be immediately available to all on-site personnel. A copy of this SSHASP shall be located on the dash board of the primary support vehicle for the project to protect it from environmental conditions that may damage it. Any person who becomes ill or injured must be decontaminated to the maximum extent possible. First aid should be administered, if necessary, while awaiting an ambulance or paramedics. A map with directions to the nearest hospital follows:

Hospital Name

920 Cherry Tree Rd
Aston Township, PA 19014

↑ Head toward Weir Rd



341 ft

↰ Turn left onto Weir Rd



1.1 mi

↰ Turn left onto PA-452 N/Pennell Rd

Pass by

Wendy's (on the right in 0.5 mi)



3.6 mi

↰ Turn right onto W Baltimore Pike



0.3 mi

↰ Turn right



0.2 mi

↖ Slight right

Destination will be on the right

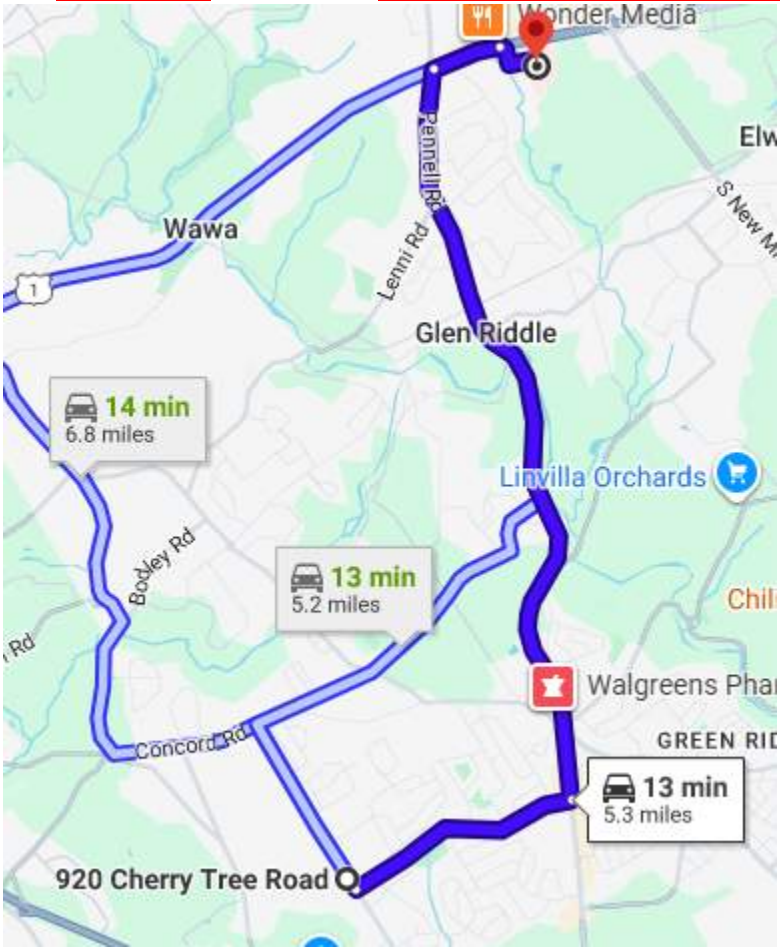


190 ft

Riddle Hospital
1068 W Baltimore Pike, Media, PA 19063

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HOSPITAL DRIVING DIRECTIONS AND MAP:



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2.10 Spills or Leaks Spills and/or Leak Response and Containment

Summit Drilling will not bring hazardous materials to site. Safety data sheets (SDSs) for all materials shall be brought to site by the Summit Drilling lead crew member included in their JSA/SDS binders.

In the event of a spill or a leak, such as hydraulic fluid or equipment fuel, site personnel will:

- Inform their supervisor immediately.
- Locate the source of the spillage and stop the flow if it can be done safely; and,
- Begin containment and recovery of the spilled materials with sorbent (vermiculite, etc.), absorbent pads, booms (included in equipment spill kits), etc.
- Keep unnecessary people away from the spilled material.
- Do not allow anyone to make physical contact with the spilled material.
- Stay upwind; keep out of low areas.
- Keep combustibles away from the spilled material.

Summit Drilling will maintain a supply of spill control and countermeasure materials and personnel protective equipment for use during a release from, or a situation caused by our equipment. The quantity of on-site spill control materials shall be appropriate to manage the maximum possible spill event. In the event of a spill, Summit Drilling shall take immediate measures to control and contain the spill within the Site boundaries.

Summit Drilling will comply with all Federal, State, and local oil and hazardous waste regulations, including reporting and documenting releases and spills of materials. Summit Drilling shall be responsible for all liabilities related to a release from equipment owned, operated, or controlled by Summit Drilling or caused by the actions of Summit Drilling.

2.11 Pandemic Procedures

Effective Monday, April 8, 2020, the Office of the Governor of New Jersey is enacting new guidelines for essential businesses – including essential construction. Many of the guidelines we have already been following in an abundance of caution. Full details are located here: https://www.nj.gov/governor/news/news/562020/20200408e.shtml

All employees, including office personnel, if they cannot maintain a 6' distance from others, must wear masks or facial coverings while on the worksite.

TRENTON – Governor Phil Murphy today signed Executive Order No. 122, ceasing all non-essential construction projects and imposing additional mitigation requirements on essential retail businesses and essential industries to limit the spread of COVID-19 in New Jersey. The order also outlines specific

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protections and policies for all essential retail, manufacturing, and warehousing businesses, as well as businesses engaged in essential construction projects.

"We must continue to work together to flatten the curve of new COVID-19 cases in New Jersey," said Governor Murphy. "By ceasing all non-essential construction projects and imposing additional mitigation requirements on essential businesses, we are furthering our aggressive efforts to enforce social distancing and limiting our public interactions to only the most essential in order to reduce the spread of COVID-19."

Governor Murphy's executive order directs the following:

Manufacturing businesses, warehousing businesses, and *businesses engaged in essential construction projects* must adopt policies that include, at minimum, the following requirements:

- Prohibit non-essential visitors from entering the worksite;
- Limit worksite meetings, inductions, and workgroups to groups of fewer than ten individuals;
- Require individuals to maintain six feet or more distance between them wherever possible;
- Stagger work start and stop times where practicable to limit the number of individuals entering and leaving the worksite concurrently;
- Stagger lunch breaks and work times where practicable to enable operations to safely continue while utilizing the least number of individuals possible at the site;
- Restrict the number of individuals who can access common areas, such as restrooms and breakrooms, concurrently;
- Require workers and visitors to wear cloth face coverings, in accordance with CDC recommendations, while on the premises, except where doing so would inhibit the individual's health or the individual is under two years of age, and require workers to wear gloves while on the premises. Businesses must provide, at their expense, such face coverings and gloves for their employees. If a visitor refuses to wear a cloth face covering for non-medical reasons and if such covering cannot be provided to the individual by the business at the point of entry, then businesses must decline entry to the individual. Nothing in the stated policy should prevent workers or visitors from wearing a surgical-grade mask or other more protective face covering if the individual is already in possession of such equipment, or if the businesses is otherwise required to provide such worker with more protective equipment due to the nature of the work involved. Where an individual declines to wear a face covering on the premises due to a medical condition that inhibits such usage, neither the business nor its staff shall require the individual to produce medical documentation verifying the stated condition.
- Require infection control practices, such as regular hand washing, coughing and sneezing etiquette, and proper tissue usage and disposal;

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- Limit sharing of tools, equipment, and machinery;
- Provide sanitization materials, such as hand sanitizer and sanitizing wipes, to workers and visitors; and
- Require frequent sanitization of high-touch areas like restrooms, breakrooms, equipment, and machinery.

All essential retail businesses, warehousing businesses, manufacturing businesses, and *businesses performing essential construction projects* must also adopt policies that include, at minimum, the following requirements:

- Immediately separate and send home workers who appear to have symptoms consistent with COVID-19 illness upon arrival at work or who become sick during the day; and
- Promptly notify workers of any known exposure to COVID-19 at the worksite, consistent with the confidentiality requirements of the Americans with Disabilities Act and any other applicable laws;
- Clean and disinfect the worksite in accordance with CDC guidelines when a worker at the site has been diagnosed with COVID-19 illness;
- Continue to follow guidelines and directives issued by the New Jersey Department of Health, the CDC and the Occupational Health and Safety Administration, as applicable, for maintaining a clean, safe and healthy work environment.

3.0 Training Requirements

3.1 OSHA and General Training Requirements

All personnel performing activities covered by this plan must be trained in accordance with the requirements of 29 CFR 1910.120(e) & 1926.65. The Project Manager will verify and document that all Summit Drilling personnel meet the applicable training requirements prior to the start of site work, including:

- OSHA 1910.120 initial 40-hour training
- OSHA annual eight-hour refresher training within the last year
- At least one Summit Drilling personnel will have National Safety Council (or equivalent) First Aid and CPR training, and will be present on-site at all times
- Loss Prevention System Training within the last three years – behavior-based training system includes seven tools:
    - Safe Performance Self-Assessment (SPSA): unwritten last-minute risk assessment.
    - Job Safety Analysis (JSA): written risk assessment developed by team of job experts.
    - Safety Performance Observations (SPO): scheduled and written peer to peer, manager to employee, employee to manager safety observation based on standards (JSAs).

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- Near Loss Investigations (NLI): investigations of incident that could have resulted in injury or property damage.
- Loss Investigations (LI): investigations of incidents that did result in injury or property damage.
- Root Cause Analysis (Factors and Solutions Flow Chart - FSFC): identifies factors contributing to losses and near losses and will also lead to the development of solutions that will reduce the likelihood of future losses/near losses.
- Stewardship: stewarding by supervisors and managers to conduct SPSA discussions, quality reviews, verification and validation of LPS tools and conduct quarterly meetings.

Documentation for training certification will be maintained by the Director of Health & Safety.

Subcontractors chosen to perform well drilling, excavation, materials disposal, etc, and any other site activities where the potential exists for contact with contaminants must provide written documentation of HAZWOPER training, for each of his employees who will be involved in activities at this site before the start of work.

3.3 Tailgate Meeting

A tailgate meeting reviewing the SSHASP for all proposed work location personnel shall be held. This meeting shall be prior to the commencement of any on-site activities. The Tailgate Meeting will include, but is not limited to:

- Site history
- Utility clearance information
- Scope of work
- Location of nearest medical facility (both hospital and emergency care clinic)
- SSHASP/APP, JSAs, JHAs, PSAs, SOPs, or other definitive job/task specific guidelines
- Facility specific training to include Contaminants of Concern (CoCs) on-site, evacuation routes, alarm systems, support zones, and rally points.

3.4 First Aid/CPR Training

At least one member of the Summit Drilling staff assigned to the project will have National Safety Council (or equivalent) first aid and cardiopulmonary resuscitation (CPR) training. At least one trained individual will be present on-site at all times. Training documentation will be maintained by the Summit Drilling Director of Health & Safety and available to the Summit Drilling Project Manager to provide to client upon request.

4.0 Medical Surveillance Requirements

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4.1 General Medical Surveillance Requirements

All personnel performing activities covered by this plan must be active participants in an ongoing medical monitoring program in accordance with the requirements of 29 CFR 1910.120(f). Subcontractors chosen to perform selected site activities must provide written documentation of such, for each employee who will be involved in activities at this site, before the start of work.

4.2 Drug and Alcohol Compliance

All personnel performing activities covered by this plan must have had a negative drug and alcohol screen performed within the last 12 months. All personnel are expected to maintain a current status with respect to Summit Drilling's drug and alcohol testing program. Summit Drilling maintains an annual schedule of updated medical examinations to include annual drug and alcohol screening. Additional testing will be performed based on the following: Upon hire, employees will be subject to a pre-employment drug screen. During employment, employees whether CDL licensed or not may be subject to 10 panel client-required, post- incident/property damage, reasonable suspicion, just cause, and/or random drug screening.

4.3 Accident/Incident Medical Surveillance

As a follow-up to a work-related injury, all employees are entitled and encouraged to seek medical attention. All accidents and potential exposures must be reported immediately to the Summit Drilling project manager, who will coordinate with the DoHS to arrange for appropriate medical attention. Depending on the type of incident, it may be critical to perform drug and alcohol tests immediately or within 24 to 48 hours. *Failure to report an injury or incident immediately will result in disciplinary action.*

4.4 Fatigue Management

Summit Drilling has set work hour limitations and will control job rotation schedules to control fatigue, allow for sufficient sleep, and increase mental fitness in an effort to control employee turnover and absenteeism. These limitations are outlined as follows:

- Hours of Work
  - No person shall work longer than 14 hours including travel (home to home).
  - No person shall work longer than 10 days without a minimum 2 day (48 hour) break.
- Work/Rest Breaks
  - No work period shall exceed 4.5 hours.
  - All worker to have a minimum 30 minutes break after each 4.5 hour work period.
  - In extreme conditions (agreed and recorded at tailgate meetings) high energy use tasks will have an additional 15 minute break between work periods.
  - All work schedules can be further tailored (shortened) based on weather conditions.
- Signs of Fatigue and Stress

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- Sore or aching muscles or feeling of muscle weakness
- Headache
- Moodiness, irritability or easily agitated
- Dizziness and blurred vision
- Loss of appetite
- Difficulties with short term memory
- Inability to concentrate or focus on tasks
- Slowed reflexes or difficulty making decisions
- Feeling as if your actions are useless or that you can't change your situation
- Lack of motivation

Fatigue from physical exertion can be easily managed with proper food and rest and workers should be rotated through tasks that require high physical exertion. By contrast fatigue from emotional financial or other stressors is not so easily managed and can be very debilitating.

Everyone will have a different ability to cope with stress and their symptoms of stress fatigue will be different. Workers performing high stress tasks should be monitored regularly for signs of fatigue and stress.

- Supplies
  - The Lead Driller/Drill Crew Leader shall ensure all work crew staff has access to sufficient water. That includes extra water coolers/water bottles available during warm weather conditions.
  - The Lead Driller/Drill Crew Leader shall ensure workers take sufficient breaks to gain sustenance at intervals sufficient to prevent fatigue or heat related illnesses.
  - Work vehicles will be the primary workplace setting for breaks for field employees for heat delivery in cold weather and shade/air conditioning in hot weather.
- Ergonomic Considerations
  - All company employees from the highest levels of management to the newest employee shall be engaged in the process of identifying and introducing ergonomically friendly initiatives that includes:
    - Purchasing equipment and tooling that allows for safer equipment handling and team lifting.
    - Identifying and reporting suggested better/improved body positioning, lifting, and equipment handling techniques to determine efficacy.
- Work tasks to control fatigue must be analysed and evaluated periodically

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- When preparing to perform a work task, the Job Safety Analysis (JSA) for that task shall be reviewed. During Safety Performance Observations (SPOs) all levels of employees are required to evaluate these tasks to ensure they are being analysed and evaluated to ensure gaps in equipment and processes are being identified and corrected. Additionally, positive feedback shall be provided when tasks are being identified as performed safely and properly. If changes or shortcomings are identified, they shall be reported to the DoHS for revision.

- Review of Duties/Responsibilities
  - In the event of Fatigue and/or Stress being identified as a significant safety issue at a work site, alternative duties will be sought for affected worker(s). If no alternative duties exist, the worker will be relieved of work duties and a rehabilitation plan developed.
  - Employees must not chronically use over-the-counter or prescription drugs to increase mental alertness. Employees should be discouraged from taking any substance known to increase fatigue in that employee, including fatigue that sets in after the effects of the drug wear off.
    - All employees shall be trained to consult with their local pharmacist regarding the effects of over-the-counter medications at time of purchase.
    - All employees shall be trained to consult with their primary physician regarding the effects of doctor-prescribed medications at time of prescription.
    - All employees shall be trained to understand the nature, hazards, and dangers of alcohol use/abuse and its acute and chronic effects to include resources available through the Company Employee Assistance Program (EAP) for assistance.
    - All employees shall be trained to understand the nature, hazards, and dangers of illicit, illegal drug use to include resources available through the Company EAP for assistance.
  - Employees in all positions regardless of consideration of safety critical positions shall report fatigue/tiredness and/or lack of mental acuity to the available supervisor to avoid making poor safety critical decisions that could result in a loss.
  - Employees are required to report via phone to their regional VP if they are fatigued PRIOR to reporting for work, i.e., call from home prior to putting themselves or general public at risk by attempting to report for work.

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- Supervisors that are contacted by employees reporting fatigue are required to remove the employee from the work schedule and inform the Regional VP as soon as reasonable and if the Regional VP is unavailable, the Company President shall be informed.

5.0 Hazard Assessment

5.1 Chemical Hazards

5.1.1 Contaminant Characterization and Potential Routes of Exposure

A. The main routes of exposure for field personnel include:

- Inhalation of contaminant vapors
- Inhalation of contaminated particulate matter
- Inhalation of contaminated material
- Injection of contaminated material
- Absorption of contaminated material
- Ingestion of contaminated material

B. Site personnel can reduce their exposure potential by:

- Using the proper PPE
- Practicing contamination avoidance
- Following proper decontamination procedures
- Observing good personal hygiene

C. Safety Data Sheets (SDSs) for all chemicals brought on site by Summit Drilling shall be included in the employee JSA/SDS binder. Any chemicals on-site not introduced by Summit Drilling shall have SDSs made immediately available to Summit Drilling employees by client/contractor responsible for project oversight.

5.1.2 Introduction to Work Site

5.1.3 Summary Site History and General Description

Site Description: Tank field

Site History: Gasoline Release

Constituents of Environmental Concern (Contaminants of Concern): Site-specific chemicals of concern (COCs) for this site include gasoline constituents based upon previous investigations at the Site and have determined that soils and groundwater are contaminated with COCs which are likely to only be present in soil and groundwater below the water table, or in cuttings or water brought to the surface. Exposure Limits, Potential Routes of Entry, Symptoms/Health Effects, Chemical Properties, and Physical Characteristics shall be provided to the Summit Drilling employees upon arrival/prior to commencement of intrusive activities.

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Volatile Organic Compounds: Volatile organic chemicals (VOCs), including benzene, toluene, ethylbenzene, xylenes, isopropyl benzene, and styrene (BTEX) are present as soil and groundwater contaminants, and in some cases chemical components in non-aqueous phase liquids (NAPL) such as oil or tar within soils and abandoned pipelines. These compounds generally have a depressant effect on the Central Nervous System (CNS), may cause chronic liver and kidney damage, and some are suspected human carcinogens. Benzene is a known human carcinogen. Acute exposure may include headache, dizziness, nausea, and skin and eye irritation. The primary route of exposure to VOCs is through inhalation and therefore respiratory protection is the primary control against exposure to VOCs.

Listings of CoCs identified on this site follows as a table excerpt taken from Client SSHASP:

- Benzene
- Toluene
- Ethylbenzene
- Xylenes
- MTBE
- Naphthalene
- Cumene
- 1,2,4-TMB
- 1,3,5-TMB

Safety Data Sheets (SDSs) for the chemicals of concern shall be made available on site by client personnel when necessary by way of potential contact – defined as contact made or potential for contact to be made.

General Description: EXCERPT from client SSHASP:

5.1.4 Scope of Work

A. Task(s)

Sonic Drilling	X	Air Rotary Drilling		Mud Rotary Drilling	
Hollow Stem Auger Drilling		Direct Push Drilling		Soil Gas Sampling	
Split Spoon Sampling		Vacuum Excavation	X	Groundwater Sampling	
Decon	X	Grouting	X	Hand Sampling	X
Submersible Pump Removal		Temp Well Install		Chemical Injection	
Well Development	X	Site Walk Through		Well Abandonment	

B. Sonic drilling

This scope of work consists of the following requirements:

Install 30 4 inch wells up to 55 ft using sonic

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Pre clear locations using vac/air knife

6.0 Physical Hazards

A variety of physical hazards may be present, but these hazards are similar to those associated with any field project (detailed in Table 1 and JSAs). Caution should be taken in and around the property, as risks still pose a threat to human safety. Additional physical hazards which may be encountered during site operations for this project are included in Table 1.

6.1 Airborne Particulates (Eyes, ears, nose, mouth)

- Safety glasses (ANSI 87.1) are to be worn at all times on site.
- Personnel with prescription eye wear may wear side shields attached to their eyeglasses provided the lenses meet ANSI 87.1 specifications.
- Spoggles have been issued to all employees and are required to be worn in dusty environments.

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- Monogoggles and visor carriers/visors (face shields) have been issued to all employees performing air knife activities, chemical injections, and grouting.
- Respiratory protection is to be worn when site activities cause excessive particulates, such as air rotary drilling and mixing of Portland or gravel mix. If windy conditions exist/persist sufficient to remove nuisance dusts, respiratory protection is not required.
- For Silicates: see Silica Exposure Control Plan, Appendix 2

6.2 Air Compressors

- Eye protection and hearing protection is to be worn at all times on site.
- Whip checks and cotter pins shall be used on all connections as required.
- Compressed air can damage skin upon contact.
- Use proper pressure relief valves before performing O&M on an air compressor.

6.3 Back Strain

- Utilize proper lifting procedures when loading and unloading heavy equipment.
- Get a firm footing.
- Keep feet apart (shoulder width) for a stable base.
- Point toes out.
- Bend the knees.
- Face the object squarely.
- Don't bend at the waist.
- Keep the principles of leverage in mind.
- Do not exert more than necessary.
- Maintain the three natural back curves (of a straight back).
- Place one foot beside the load, the other behind it.
- Tighten stomach muscles.
- Abdominal muscles support the spine when lifting, to offset the force of the load.
- Train muscle groups to work together.
- Grip the load with both hands.
- Lift with the legs.
- Let the powerful leg muscles do the work of lifting, not the weaker back muscles.
- Maintain the three natural back curves (of a straight back) – 2nd mention.
- Keep the load close.
- Don't hold the load away from the body.

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- The closer the load is to the spine, the less force it exerts in the back.
- Use your pre-planned carry route, keep your view.
- Keep the back upright.
- Whether lifting or putting down the load, don't add the weight of the body to the load.
- Avoid twisting, which can cause injury.
- To change directions, turn the entire body.
- Set the load down carefully.
- Use a mechanical lifting device or a lifting aid such as handcarts, drum dollies or lift gates when lifting heavy objects.

6.4 Biological Hazards (Insects, snakes, poisonous plants and animals)

- Wasp/Bee/Hornet Stings: Determine if any field crew members are allergic to wasp/bee stings and ask if an Epinephrine® pen (Epi-pen®) is available.
    - If Epi-pen is administered, anaphylactic shock is still a *MEDICAL EMERGENCY (CALL 911)*
    - Spray any wasp/bee/hornet nests with an insect repellant from a safe distance recommended by the product's manufacturer.
- Poisonous Plants: Do not touch or contact poisonous plants, such as poison ivy and poison oak, poison sumac or giant hogweed. If available, apply an over-the-counter barrier cream, such as Ivy Block® to prevent contact with plant oils.
    - Spray paint all poisonous plants upon identification to alert others of their existence.
    - Wash hands and arms immediately with soap and water if skin contacts the plants.
    - Wear long pants with socks pulled over legs to prevent skin contact with plants and insects.
- Do not approach, touch, or antagonize snakes or wild animals. This includes domestic pets such as cats and dogs. If there are animals in the work area/property, Stop Work and notify local pest control authority with the assistance of client Project Manager.
- Brown Recluse and Black Widow Spiders: Be aware both spiders are native to the northeast and contacts with both have been documented. Both spiders have the potential to cause serious injury to humans and should be avoided at all costs. If visual contact is made, maintain a minimum distance of at least ten feet and inform all other affected/impacted individuals. If physical contact is made (i.e., you have been or believe you may have been bitten), attempt to take a photo of the spider or collect the specimen and report immediately to the nearest medical facility for treatment.

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- Lyme Disease / Tick Contact
    - Lyme's Disease is a bacterial infection transmitted by the bite of a deer tick. About 50 percent of deer ticks carry the bacteria. To prevent the bite of a deer tick, stay on pathways, avoid overgrown or grassy areas when possible. Wear protective clothing (light colored) with long sleeves and pants tucked inside of socks. In potentially heavily infested areas, wear white non-laminated tyvek or use duct tape to seal socks to pants. Apply repellent containing "Permethrin" or "Deet" to clothing only and not directly on the skin. Perform self-inspections immediately following exposure to an area which may contain deer ticks.
        - Symptoms: headache, flu-like symptoms, a spreading ring-like rash, swelling and pain of the joints. The distinctive bulls-eye rash is NOT always present at a bite site.
        - Tick removal: remove attached tick immediately using tweezers to grasp the tick's head, near the skin, and slowly pull straight out. Save the tick for laboratory analysis, if possible.
- Report any incidents involving contact with poisonous plants, wasp/bee stings, and spider or deer tick bites to the Director of Health & Safety immediately upon discovery, regardless of presence of allergic reaction(s).

6.5 Cold Stress/Hypothermia

- Know and recognize the signs and symptoms of cold-related illnesses, as follows:
    - Lack of feeling in the affected area.
    - Skin that appears waxy, is cold to the touch or is discolored (flushed, white, yellow or blue).
- Hypothermia:
    - Shivering
    - Numbness
    - Glassy stare

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- Apathy
- Loss of consciousness

- Have appropriate clothing available and dress in layers to protect against cold weather.
- Adjust work schedules to provide sufficient rest periods in a heated area for warming up during operations conducted in cold weather.

Wind Chill Temperature Table

Wind Speed (mph) ↓	Air Temperature (°F)																	
	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
0	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95

GREEN LITTLE DANGER (frostbite occurs in >2 hours in dry, exposed skin)
YELLOW INCREASED DANGER (frostbite could occur in 45 minutes or less in dry exposed skin)
RED GREAT DANGER (frostbite could occur in 5 minutes or less in dry, exposed skin)

6.6 Confined Space (CS) Entry: N/A

- Confined space entry is prohibited unless authorized by the project manager or DoHS.
- Confined space entry is only permitted by those trained to perform this duty and awareness training documentation will be maintained by the DoHS.
- Protective clothing shall be worn when working in confined or enclosed work spaces where electrical hazards may exist.
- Employees may not enter spaces containing exposed energized parts unless illumination is provided that enables the employees to work safely.
- All Confined Space Entry procedures must be followed, including and not limited to air monitoring, presence of attendant and permit completion.

6.7 Electrical with Lock Out/Tag Out

- Inspect all electrical equipment and extension cords prior to use.
- All electrical circuits and equipment must be grounded in accordance with the NEC regulations.
- Employees may not enter spaces containing exposed energized parts unless illumination is provided that enables the employees to work safely.
- Lockout/Tagout procedures will be in effect if equipment is to be removed/repaired.

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- Use three-pronged plugs and heavy-duty extension cords.
- A GFCI is required on any extension cord not attached to a GFCI protected outlet.
- A GFCI is required on any power tool that uses water (core drill).
- Workers must not have wet hands or be standing in water while plugging/unplugging energized equipment.
- Plugs and receptacles will be kept out of water (unless they are approved for submersion).

6.8 Excessive Noise

- Use hearing protection during loud mechanical operations such as operating drill rig, jackhammer, and compressor operations.
- Ear muffs (NRR 28) and ear plugs (NRR 33) are issued to all employees, training is performed annually, and audiograms performed annually during medical surveillance.
- If you need to raise your voice within 3 feet of hearing/speaking, hearing protection is required.

6.9 Fall Hazards: N/A

- Fall protection equipment may only be worn by trained personnel.
- ANSI-approved man-lifts and ladders will be used for access to elevated locations.
- Employees must wear a harness with lanyard attached to the boom or basket when working from a man-lift. Employees must wear a harness with lanyard attached to the boom or basket when working from a man-lift. Scissor lifts may/may not require fall protection depending upon manufacturer.
- If the elevated location is inaccessible by a man-lift or ladder, the DoHS shall be contacted to determine the appropriate fall protection.

6.10 Hand Tools

- Use hose cutters when cutting piping.
- Use self-retracting-blade-guarded issued utility knives when cutting electrical tape, plastic sheeting, well material bags, etc.
- Use Geoprobe® liner cutters when opening acetate soil sample liners.
    - Use Geoprobe® liner cutter guard when using Geoprobe® liner cutters.
- Class 4 Kevlar® gloves must be worn when cutting.
- Do not tape wooden handles of any hand tool to allow for inspection.

6.11 Heat Stress/Hyperthermia

- Know and recognize the signs and symptoms of heat-related illnesses, as follows:
    - Heat cramps
    - Heat exhaustion:

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- Cool, moist, pale, or flushed skin
- Headache
- Nausea
- Dizziness, weakness and exhaustion

- Heat stroke is a *MEDICAL EMERGENCY (CALL 911):*
  - Red, hot, dry skin
  - Rapid, weak pulse
  - Rapid, shallow breathing
  - Incoherence
  - Lack of muscle control
  - Loss of consciousness

- Hydration for anticipated high heat/humidity should begin the evening before and the recommended water intake is 8 ounces every 15 minutes of work activity.
- Adjust work schedules to provide time intervals for intake of juices, juice products and water in an area free from contamination using the chart below. Schedules are subject to change based upon an individual's acclimatization and level of activity.

NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

6.12 Heavy Equipment Operation

- The use of drill rigs, vacuum excavating equipment, probes, pump hoists and other heavy equipment represent potentially serious construction hazards. Whenever such equipment is used, personnel in the vicinity should be limited to those who must be there to complete their assigned duties. All personnel must avoid standing within the turning radius of the equipment or

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below any suspended load. Job sites must be kept as clean, orderly and sanitary as possible. When water is used for dust control, care must be taken to avoid creating muddy or slippery conditions. If slippery conditions are unavoidable, barriers and warning signs must be used to warn of these dangers.

- Never turn your back to operating machinery. Never wear loose clothing, jewelry, hair or other personal items around rotating equipment or other equipment that could catch or ensnare loose clothing, jewelry, hair or other personal items. Always stand far enough away from operating machinery to prevent accidental contact which may result from mechanical or human error.
- Additionally, the following basic personal protective measures must be observed: Hard hats must be worn to protect against bumps or falling objects. Safety glasses must be worn by all workers in the vicinity of drill rigs or other sources of flying objects. Goggles, face shields or other forms of eye protection must be worn when necessary to protect against chemicals or other hazards. Steel-toed boots are also required. The boots must be chemically resistant or protected with appropriately selected boots/coverings where necessary. Unless otherwise specified, normal work clothes must be worn. Long sleeves and gloves are also required whenever necessary to protect against hazardous contact, cuts, abrasions or other possible skin hazards.

6.13 Hot Work

- Hot work is defined as any activity creating sparks or open flames: use of a torch (oxygen/acetylene, MAP gas, or propane), welding, cutting steel with a cut saw or grinder, or grinding any material that creates or has the potential to create sparks.
- A Hot Work permit will be completed prior to the start of any hot work.
- The Driller will conduct a safety briefing on Hot Work rules and procedures, and all Hot Work participants will sign the permit.
- Hot Work will not be performed if there is a possibility of an explosive atmosphere or an oxygen-enriched atmosphere.
- The Driller will designate a person for fire watch duty, who will have access to a properly rated fire extinguisher and will remain on-duty for one-half hour after the Hot Work is complete.
- All Hot Work equipment will be inspected daily prior to use and if the equipment is found to be defective, it will be removed from the site and tagged with a “Do Not Use” sign until repaired.
- All welding and cutting personnel will be trained in the safe operation of their equipment.

6.14 Illumination: N/A

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- If work activities occur before sunrise and/or after sunset, lighting should be provided at each work area to meet the requirements of 29 CFR 1910.120(m). The Standard states that while any work is in progress:
- General site areas shall be lighted to not less than 5 foot-candles.
- Drilling areas, excavation, waste areas, access ways, active storage areas, loading platforms, and field maintenance areas shall be lighted to not less than 3 foot-candles.
- First aid stations shall be lighted to not less than 30 foot-candles.

6.15 Ladder Safety: N/A

- Ladders must be inspected prior to use and any damaged ladder will be discarded immediately.
- Painted ladders are forbidden.
- Never stand on the top (cap) or top step of the ladder.
- Extension ladders must extend 36" beyond landing.
- Pitch ladders at a 4:1 ratio.
- Extension and straight ladders must be tied off.

6.16 On-Site Traffic

- Hi-viz safety vest shall be worn and safety cones with flags placed around the work area.
    - ANSI Class 2 vests for speeds in work zones between 25mph – 49mph
    - ANSI Class 3 vests for speeds in work zones at or above 50mph
- Use 36" traffic cones, 6' double pendant flags, and caution tape and vehicles to delineate work zones.
    - Whenever possible, use work vehicles as barriers to prevent vehicles from contacting workers.
- Use fencing or barricades where warranted preventing unauthorized personnel from entering work areas.
- Hi-viz safety vests shall be worn in wooded areas to alert hunters.

6.17 Overhead Power Lines and Grounding

- A ground shall be provided for equipment such as drill rigs when operated within the proximity limits of 29 CFR 1910.333 as noted below. The placement of the grounding lead and attachment to equipment shall occur BEFORE all/any activities are permitted to be performed. The requirements of 1910.333 and all other requirements are as follows:
    - 1910.333(c)(3)(iii)"Vehicular and mechanical equipment."
    - 1910.333(c)(3)(iii)(A) Any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines shall be operated so that a clearance of

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10 ft. (305 cm) is maintained. If the voltage is higher than 50kV, the clearance shall be increased 4 in. (10 cm) for every 10kV over that voltage. However, under any of the following conditions, the clearance may be reduced:

- 1910.333(c)(3)(iii)(A)(1) If the vehicle is in transit with its structure lowered, the clearance may be reduced to 4 ft. (122 cm). If the voltage is higher than 50kV, the clearance shall be increased 4 in. (10 cm) for every 10 kV over that voltage.
- 1910.333(c)(3)(iii)(A)(2) If insulating barriers are installed to prevent contact with the lines, and if the barriers are rated for the voltage of the line being guarded and are not a part of or an attachment to the vehicle or its raised structure, the clearance may be reduced to a distance within the designed working dimensions of the insulating barrier.
- 1910.333(c)(3)(iii)(A)(3) If the equipment is an aerial lift insulated for the voltage involved, and if the work is performed by a qualified person, the clearance (between the uninsulated portion of the aerial lift and the power line) may be reduced to the distance given in Table S-5.
- 1910.333(c)(3)(iii)(B) Employees standing on the ground may not contact the vehicle or mechanical equipment or any of its attachments, unless:
- 1910.333(c)(3)(iii)(B)(1) The employee is using protective equipment rated for the voltage; or
- 1910.333(c)(3)(iii)(B)(2) The equipment is located so that no uninsulated part of its structure (that portion of the structure that provides a conductive path to employees on the ground) can come closer to the line than permitted in paragraph (c)(3)(iii) of this section.
- 1910.333(c)(3)(iii)(C) If any vehicle or mechanical equipment capable of having parts of its structure elevated near energized overhead lines is intentionally grounded, employees working on the ground near the point of grounding may not stand at the grounding location whenever there is a possibility of overhead line contact. Additional precautions, such as the use of barricades or insulation, shall be taken to protect employees from hazardous ground potentials, depending on earth resistivity and fault currents, which can develop within the first few feet or more outward from the grounding point.

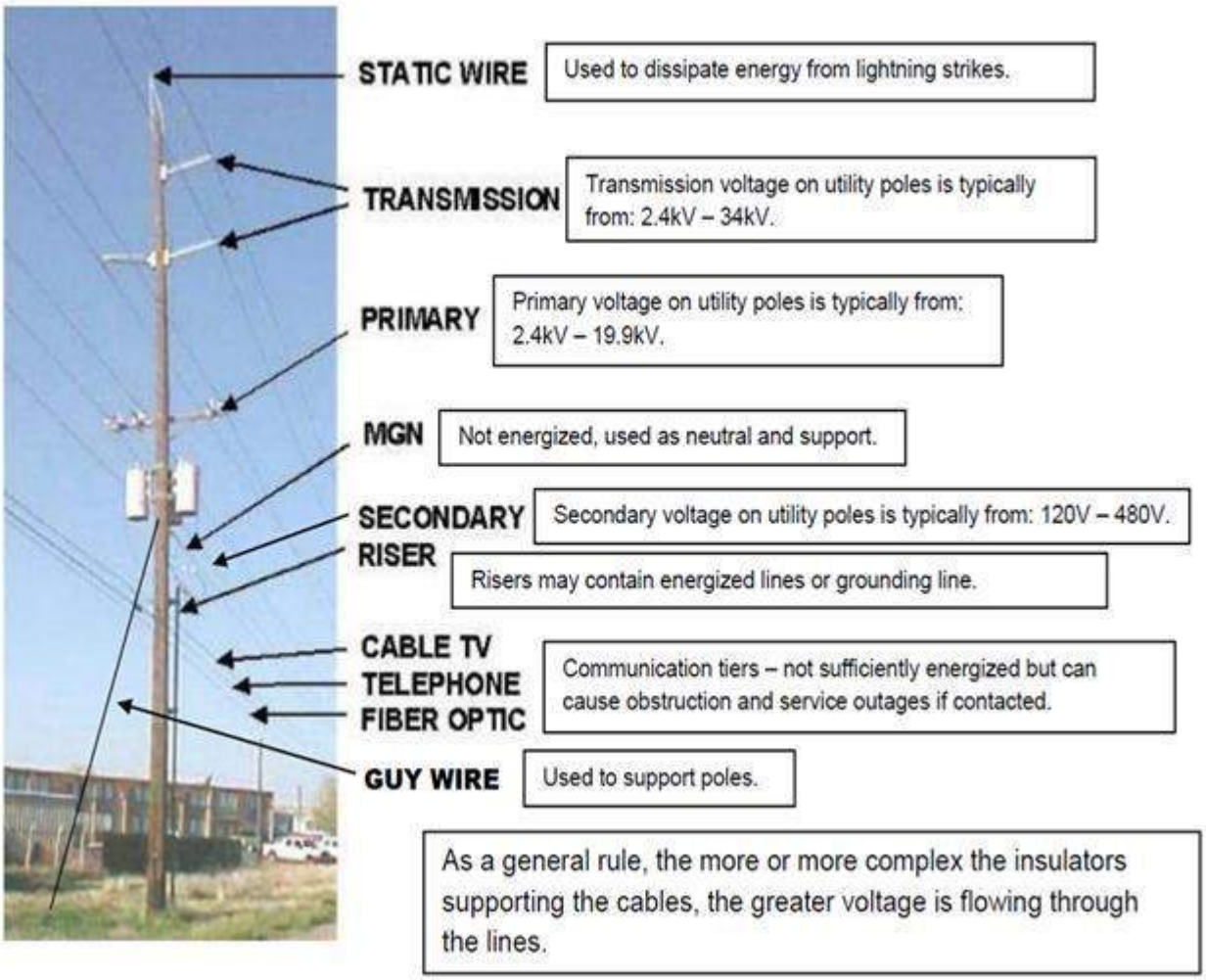
- Grounding rod, connectors, and leads – minimum size requirements and placement:
  - Size Requirements: grounding rods shall be made of copper, a minimum ½" (12mm) diameter, 6' in length, with a bolted (not clamped) connector from the grounding rod to

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the grounding lead. The grounding lead shall be a minimum of 50' in length and minimum wire gauge of 00 (2/0), (0.3648" diameter).

- The grounding lead shall be bolted (not clamped) to the equipment (drill rig) from the furthest point on the equipment (drill rig) of workers area (e.g., mobile truck rig will be bolted at/near front truck bumper, and on a track unit will be bolted on the opposite long end of the rigs control panel) to the maximum length of the grounding lead away from workers, work area/zone/property permitting.
    - 'Call Before You Dig (811) requirements shall be followed prior to placement of grounding rod into ground to ensure no underground utilities are contacted. When necessary, vacuum excavation of location shall be performed and backfilled around grounding rod after placement. If vacuum excavation is not required or performed, hammering of the grounding rod shall be performed and driven to the maximum possible depth while leaving the grounding rod exposed to allow for removal.
        - Traffic cones shall be placed along the pathway of the grounding lead to highlight the tripping hazard to workers.
        - One traffic cone with 6' flag shall be placed to highlight the location of the grounding rod in place. This location will be communicated to all site personnel and shall not be approached during the course of the work until the grounding lead has been disconnected from the equipment (drill rig).
- The grounding rod shall be attached to the grounding lead first. The equipment (drill rig) end shall then be attached using insulated tools or other suitable devices.
- When removing grounds, the grounding lead shall be removed from the equipment (drill rig) first, using insulated tools or other suitable devices.

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6.18 Pedestrian Traffic

- The uncontrolled presence of pedestrians on a drilling or excavation site can be hazardous to both pedestrians and site workers. Prior to the initiation of site activities, the site should be surveyed to determine if, when and where pedestrians may gain access. This includes walkways, parking lots, gates and doorways. Barriers or caution tape should be used to exclude all pedestrian traffic. Exclusion of pedestrian traffic is intended to prevent injury to the pedestrians and eliminate distractions which could cause injury to personnel or other site workers.

6.19 Power Tools

- Equipment will be inspected for defects prior to use.
- Eye protection shall always be worn on site.
- Employees using tools that may subject their hands to an injury, such as cuts, abrasions, punctures, or burns will wear protective gloves.
- Loose or frayed clothing, dangling jewelry, or loose long hair shall not be worn when working with power tools.

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- A GFCI will be used with all power tool operations when not plugged into permanent (fixed) wiring.
- Shielding or machine guards will not be removed for any reason.

6.20 Radiological Hazards: N/A

If site-specific potential radiological information is available, the hazards will be addressed in an addendum to the site-specific HASP. Any field personnel designated to work on radiological sites will be trained by the DoHS or a site representative as a competent authority to train.

6.21 Site Security

- Do not permit anyone who is not authorized, properly trained and outfitted with the appropriate PPE to enter the Exclusion Zone or Contamination Reduction Zones (this includes Summit Drilling personnel, clients, etc.).
- Use caution tape or barricade fencing where warranted preventing unauthorized personnel from entering the work area.
- If potential for theft exists, equipment will either be secured or removed from site during off duty work hours.
- Unauthorized personnel (includes transients, homeless, curious visitors, locals) seen on site shall be reported to the client Project Manager immediately. Avoid making contact with visitors and if contact is unavoidable, continue attempting to separate yourself from them and refer them to the client Project Manager. Document all contacts on daily paperwork and verbally inform the specific Summit Drilling Project Manager.

6.22 Sanitation

- Summit Drilling employees are considered mobile crews and must have prompt access to nearby toilet facilities. For example, in general, toilets would be considered "nearby" if it would take less than 10 minutes to get to them and transportation (their work vehicles) is readily available.
- Potable water shall be available and provided by Summit Drilling in the form of 5-gallon coolers with disposable cups. Common drinking cups are prohibited.

6.23 Slip/Trip/Falls

- Utilize proper housekeeping practices, such as removal of debris and tools from the work area to keep the area clear of trip hazards.
- Use caution tape or barricade fencing where warranted preventing unauthorized personnel from entering the work area.
- Replace manhole covers immediately and securely to prevent tripping and vehicle accidents.
- Walkways and work spaces will be kept clear of cords, hoses, pipes, etc. that cause trip hazards.

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- If trip hazards cannot be removed from the work area, they shall be secured and cones shall be placed to identify the hazard. Off-site/property locations: air knife locations shall be backfilled with cuttings and capped with same surface materials (concrete/asphalt/soil, as applies) with cuttings or steel road plates when locations cannot be backfilled. Temporary caps shall be installed on 6" steel casings.

6.24 Water Hazards and Boat Sampling

- The collection of water or sediment samples on or immediately adjacent to a body of water can pose significant hazards. In addition to the slip, trip and fall hazards associated with wet surfaces, the potential for drowning accidents must be recognized. These hazards can be intensified by the use of some personnel protective equipment (PPE), particularly if respiratory protection is worn. OSHA 29 CFR 1926.106 requires that all employees working over or near water, where the danger of drowning exists, shall:
- Wear a U.S. Coast Guard-approved life jacket or buoyant work vest.
- Have ring buoys and emergency standby personnel in place.
- Have a lifesaving skiff immediately available.
- 6.25 Weather

If severe weather occurs that may affect the safety of site workers, any site worker may initiate Stop Work and will stop all site activities. The NOAA 30/30 rule will be followed for resuming operations. The NOAA 30/30 rule requires retreat under shelter in the event of severe weather appearance (heavy clouds, high winds), thunder, and/or lightning. Outdoor work activities can resume 30 minutes following the last thunderclap/lightning strike.

7.0 Site Control Measures

7.1 Site Zones

The need to formally establish specific work zones (Exclusion, Contamination Reduction, and Support Zones) during site activities will be determined by the site HSO. It is important for the safety of all concerned that appropriate barriers (cones, flags, caution tape, wooden horses, plastic fencing etc.) are in place to keep vehicles and pedestrians away from the Work Zone.

A controlled work area should be established in the immediate vicinity of the site activities covered by this plan. Only those persons who can comply with the requirements of this plan should be allowed into this area during any work activities, which may result in exposure to the hazards associated with the specific task being performed. When activities involve invasive activities on sites in which Summit Drilling has determined the

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area to be highly contaminated, a three-zone system will be used to control the potential spread of contamination. For the purpose of this plan, the following definition of terms is provided:

- Exclusion Zone: The immediate area of the work activity to be performed or an area fully enclosing the hazards present.
- Contamination Reduction Zone: The transition area between the contaminated area and the uncontaminated area. Decontamination procedures take place within this zone.
- Support Zone: The uncontaminated area where exposure to hazardous conditions is not anticipated.

7.2 Buddy System: A buddy system is required for all site work involving levels of protection or potentially representing a risk to personnel.

7.3 Site Communications Plan

Emergency numbers are listed in Table 2 of this SSHASP. Work will not be conducted on-site without access to a telephone, and site personnel will be informed of the nearest available telephone. If a telephone is not available on site, a cell phone will be made available for emergency use. Successful communications between field teams and contact with personnel in the Support Zone is also essential and required. The following communication systems will be available within Secure Zones:

• Normal verbal communication, which can include 2-way radios.

Radios	_____	Air Horn	_____
Whistle	_____	Megaphone	_____
Hand Signals	X	Voice	X

• Hand signals for Level B and C are as follows:

Hand Signals		Definition
Hands clutching throat	=	Out of air / cannot breath
Hands on top of head	=	Need assistance
Thumbs up	=	OK / I am all right / I understand
Thumbs down	=	No / Negative
Arms waving upright	=	Send backup support
Grip partners wrist	=	Exit area immediately

Emergency Action Plan: Primary muster point/evacuation routes shall be provided by the controlling employer. All locations shall be upwind of any airborne contaminant source, to include chemical or fire/smoke source whether sourced from on-site or off-site. Secondary evacuation routes and muster points should also be considered depending on workzone locations and limitations. Routes shall be delineated using traffic cones and caution tape or similar devices readily visible to employees. Muster points may contain some or all of the following items: fire extinguishing equipment, communication devices, potable

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water, air monitoring equipment, anemometer, etc. This equipment out of necessity shall be provided, if necessary, by the controlling employer, due to the transitory nature of the Summit Drilling work crews. Both primary and secondary muster points and evacuation routes shall be discussed and demonstrated during 'start-of-shift' health and safety meetings.

8.0 Personal Protective Equipment (PPE)

8.1 General

The level of protection worn by site personnel will be enforced by the Site Supervisor. Levels of protection may be upgraded or downgraded at the discretion of the Local HSO, or DoHS, based on real-time air monitoring data and prior site experience. Any change in the level of protection will be documented. Levels of protection less than those designated in this HASP must first be approved by the Summit Drilling. The Personal Protection Equipment Program, with emphasis on the Hazard Assessment Selection Guide should be referred to concerning types and applicability of PPE offered by Summit Drilling.

8.2 Level D Protection

Level D PPE provides minimal protection against chemical hazards. A respirator is not required. Level D PPE includes:

- FRC Coverall required
- Cotton coveralls or long pants and shirt with sleeves
- Reflective high visibility safety vest of the proper class
- Safety glasses with side shields, spoggles, *monogoggle (if preferable to face shield), and if face shield is worn safety glasses must accompany*
- Steel-toed work boots (disposable over-boots may be required in certain areas).
- Chemical Resistant Gloves/Nitriles will be worn under all primary hand protection (leather, rubber, or Kevlar ®)
- Hearing protection (as required by task): earmuffs, ear plugs, or both
- Hard Hat (as required by task)
- Chemical resistant gloves (as required by task)
- N95 filtering face piece/dust mask for nuisance dust
- Tyvek coveralls (as required by task)
- Flame resistant clothing (FRC) (as required by task/environment)

8.3 Modified Level C Protection (Not Anticipated)

Modified Level C PPE includes the items listed in Section 7.2 above, and the following items:

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- Full-face Air Purifying Respirator or half-face APR respirator equipped with the appropriate chemical cartridge

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- Poly-coated (laminated) Tyvek or fabric Tyvek coveralls

8.4 Level C Protection (Not Anticipated)

Level C PPE provides a higher level of respiratory and skin protection against chemical hazards than Level D. Level C PPE includes the items listed in Section 7.2 above, and the following items:

- Poly-coated Tyvek (yellow, blue, or gray laminated) or Saranex®
- Steel-toed work boots and chemical resistant over-boots, or chemical resistant steel-toed boots
- Inner chemical resistant gloves
- Chemical resistant outer gloves
- Seal arm, leg, and zipper joints with duct tape, as required
- Half-face or full-face, air-purifying respirator equipped with appropriate cartridge

8.5 Level A and B Protection (Not Anticipated)

- Level A PPE should be worn when the highest level of respiratory and skin protection is needed, or if the contaminants of concern are unknown.
- Level B PPE should be worn when the highest level of respiratory protection is required, but a lesser level of skin protection is needed and the tasks covered under this HASP do not cover the guidelines in the use of Level A or B PPE.
- Separate HASPs will be developed for Level A or B investigations and for Emergency Responses, which may involve the use of Level A/B health and safety measures.

8.6 Personal Protective Equipment Failure

- If any site worker experiences a failure or alteration of protective equipment that affects the protection factor that person and his/her buddy, if applicable, shall immediately leave the Exclusion Zone. Reentry shall not be permitted until the equipment has been repaired or replaced.

9.0 Decontamination

9.1 General

At a minimum, the procedures outlined below shall be followed for decontamination as required by client:

- Remove gross contamination from tools, respirator, monitoring equipment, boots, etc., prior to leaving the "exclusion zone", using spray water bottles, brushes, paper towels, handi-wipes, etc.
- Completely decontaminate soiled equipment in the Contamination Reduction Zone using steam cleaners, power washers, detergent and water and dispose of all cleaning materials as follows with approval of on-site client:

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- Lightly contaminated decontamination fluids should either be treated via a site treatment system prior to discharge or disposed of via the sanitary sewer system. Moderately or highly contaminated decontamination fluids must be stored in labeled drums and proper disposal arrangements must be made.
    - The required decontamination sequence will depend on the level of protection worn:
        - Remove and wipe clean hard hat
        - Rinse boots and gloves of gross debris
        - Scrub boots and gloves clean
        - Rinse boots and gloves
        - Remove outer boots
        - Remove outer gloves
        - Remove Tyvek coveralls
        - Remove respirator, wipe clean with isopropyl alcohol and store
        - Remove inner gloves
        - Boots that have been decontaminated can be worn into the support zone.
- Dispose of contaminated gloves, Tyvek suits, used cartridges, paper towels, etc., by placing in a plastic bag and storing in a labeled drum and proper disposal arrangements must be made.

- Wash hands and face thoroughly with soap and water before coffee breaks, lunch, and as soon as practical after finishing work for the day.
- Particular care should be taken to protect any skin injuries. If open wounds exist on hands or forearms, handling chemicals should be restricted or eliminated.
- Shower as soon as possible.
- If injury occurs within the exclusion or decontamination zone and decon is necessary, see Section 9.2 and 9.3 below.

10.0 Standard Operating Safety Procedures, Engineering Controls, and Work Practices

10.1 Work Permits

Work permits are required for permit-required confined space entry, work from heights, control of hazardous energy (Lockout/Tagout) and Hot Work. There are also possibilities permits are client required for ground disturbance, simultaneous operations, and working from heights. Requirements shall be

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confirmed with on-site client supervision prior to beginning work to ensure all permits are accounted for. Permits shall be obtained from the clients Health and Safety Officer or Site Superintendent prior to site work.

10.2 Job Safety Analyses (JSAs)

Job Safety Analyses shall be made available and reviewed prior to each on-site activity. If a JSA is not available to perform a specific routine task where a JSA should be available, one will be created on site in the standard format of all other Summit Drilling JSAs. JSAs for this project shall be provided by the PM to the client prior to project commencement upon client request. All field employees are required to carry a Summit Drilling JSA/SDS binder containing a complete JSA library. All JSAs used/modified/revised/created for this project shall also be included in this SSHASP, Appendix 3.

10.3 General Site Rules

The following general site rules apply to all personnel while on the site:

- Before daily site operation begins, the client daily site safety checklist will be completed, the subcontractor's training documentation will be reviewed (if necessary, as required by section 3 of this plan), and a pre-entry briefing will be held to review the site's health and safety plan concerns and emergency procedures. This meeting will be registered in the site-specific health and safety plan. Attendance will be documented in Appendix 1.
- One site worker will be assigned to keep the daily log for all health- and safety-specific site activities, unless otherwise specified.
- All personnel will wear all required PPE as noted in the JSAs and section 7 of this plan regardless of task.
- Eye protection and reflective high visibility safety vest will always be worn while on site.
- Possession of alcohol or illegal substances on the job site or consumption of same during hours of site operation is strictly prohibited. Any employee taking over-the-counter (OTC) medications that can affect their ability to operate a motor vehicle or equipment shall report the condition to their supervisor immediately and shall be prohibited from performing any work. Any field personnel unfit to work shall not be permitted to leave the facility without contacting their supervisor.
- Food, beverages, tobacco products are not permitted in the site's Exclusion or Contamination Reduction Zones. Food, beverages, and smokeless tobacco products may be permitted in the Support Zone, with permission from the site client and if proper decontamination procedures are being followed.

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- Smoking is not permitted on the site without express permission from the property manager/ owner or client.
- Cell phone use is restricted on all sites at the discretion of the property manager/owner or client.
- Field personnel shall not stand with their head directly over a well when work is being performed.
- First aid kit(s) with 4 oz. eye wash and 20lb fire extinguisher(s) will be available in all company vehicles and/or within 50 feet of the work area.

NOTE: Hot Work activities require that a trained person on-site shall act as a fire watch with a 20lb Class A, B, C dry chemical extinguisher within 10 feet of the activity, and all other required Hot Work requirements are satisfied.

11.0 Air Monitoring Plan

Summit Drilling does not perform air monitoring and will rely upon client to perform this function. A photoionization detector (PID), four gas or five gas combustible gas indicator (CGI) will be used to monitor the breathing space during intrusive field activities, and to field screen all sediment cores once removed from the borehole to determine the potential presence of volatile organic vapors (VOCs), if applicable. Respiratory protection of the proper type will be donned if the PID readings indicate unsafe breathing conditions and Stop Work will be utilized to upgrade from Level D to Level C (B or A) if necessary.

11.1 General

In many instances, it will be necessary to monitor the atmospheric conditions during on-site work activities to identify and quantify airborne contaminants; to assist in defining work zones; and, to determine the level of work protection needed. Air monitoring must be performed wherever the possibility of worker exposure to hazardous substances exists. Air monitoring will be performed at the worker's breathing zone. Upgrades/downgrades to personal protective equipment (PPE) will be made based on air monitoring results in the breathing zone. In general, work shall be initiated in Level D PPE with a contingency to upgrade the level of PPE based on action levels.

12.0 Standing Orders

- No smoking, vaping, eating, drinking, or applying cosmetics (including lip balm) within the formal/informal work zone,
- No horseplay at any time anywhere.
- No matches or lighters within the informal support and work zone.
- Implement the communications system: cell phone use permitted as directed by client.
- Seatbelts required on all moving equipment prior to starting engine.

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- Stop Work Authority is always in place to manage imminent hazards.
- Show Hands Policy is always required when working as a 2 or more man crew.
- No weapons permitted.

13.0 Acknowledgement

I have read, understood, and agreed with the information set forth in this Health and Safety Plan and will adhere to the protocols specified herein.

SUMMIT DRILLING PERSONNEL:

Ben Shaffer

_____ _____, 2025

Ben Shaffer, COSM Date
Director of Health & Safety

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TABLE 1

POTENTIAL PHYSICAL HAZARDS

Aston PA

Hazard	Description	Control Measures
Skin contact with contaminated material	Material falls on skin; gets in eye	Wear proper clothing; follow safe work practices
Lacerations and abrasions	Many opportunities working with hand tools	Inspect equipment being used for sharp edges, wear proper hand protection; follow safe work practices
Lifting	Improper lifting/carrying of equipment and materials causing strains	Follow safe lifting and general material handling techniques
Slips, trips, and falls	Any number of injuries from slips, trips, and falls in carrying out these tasks	Good housekeeping at site, constant awareness and focus on the task
Heat Stress	Stress or exhaustion related to high temperatures	Hydrate and rest as needed
Bites and stings	Bee stings, ticks, snake bites	Wear proper PPE, be watchful, follow safe work practices
Vehicle Traffic	Vehicles traveling on the property	Wear hi- vests at all times and use of protective barriers, cones/flags, caution tape, follow safe work practices

**Employees are required to consult Job Safety Analyses (JSAs) for additional hazards and controls incorporated in Appendix 3 of this SSHASP. Additional JSAs are located in Employee JSA/SDS Binders.*

TABLE 2

EMERGENCY NOTIFICATION LIST

Aston PA

TITLE	CONTACT	PHONE NUMBER
Police	Police Department 3264 Concord Rd, Aston Township, PA 19014	Non-Emergency: (610) 497-2633 (confirmed) Emergency: 911
Fire	Fire Department 2900 Dutton Mill Rd, Aston Township, PA 19014	Non-Emergency: (610) 494-6771 (confirmed) Emergency: 911
Hospital	Hospital Riddle Hospital 1068 W Baltimore Pike, Media, PA 19063	Non-Emergency: (484) 227-9400 (confirmed) Emergency: 911
Emergency (Urgent Care) Clinic	Urgent Care AFC Urgent Care 5024 Pennell Rd, Aston Township, PA 19014	((484) 766-3502
National Response Center (NRC)		800-424-8802
Poison Control Center		800-222-1222
Chemtrec		800-424-9300
Center for Disease Control (CDC)		404-488-4100
NJDEP Hotline		1-877-WARNDEP (877-927-6337)
Project Manager	Nick King	Office: Cell:7324034306
Project Site Safety Officer		Office: Cell:
Corporate HSO		Office: Cell:
Regional HSO		Office: Cell:
Summit Drilling DoHS	Ben Schaffer	Office: 908-722-4266 Cell: 908-914-8301
Summit Drilling Project Manager	Nick King	Office: 7324034306

Appendix 1

Appendix 2

Silica Exposure Control Plan

Definitions

- Action Level: means a concentration of airborne Respirable Crystalline Silica of 25 µg/m3, calculated as an 8-hour TWA.
- Competent Person: means an individual who is capable of identifying existing and foreseeable respirable crystalline silica hazards in the workplace and who has the authorization to take prompt corrective measures to eliminate or minimize them. The competent person must have the knowledge and ability necessary to fulfill the responsibilities set forth in this Exposure Control Plan.
- Objective Data: means information, such as air monitoring data from industry-wide surveys or calculations based on the composition of a substance, demonstrating employee exposure to Respirable Crystalline Silica associated with a particular product or material or a specific process, task, or activity. The data must reflect workplace conditions closely resembling or with a higher exposure potential than the processes, types of material, control methods, work practices, and environmental conditions in the employer's current operations.
- Permissible Exposure Limit (PEL): means an airborne concentration of Respirable Crystalline Silica in excess of 50 µg/m3, calculated as an 8-hour TWA.
- Personal Protective Equipment (PPE): PPE includes respirators, work gloves, hard hats, etc.
    - Client may require that respiratory protection be used for certain work tasks.
- Regulated area: means an area, demarcated by the employer, where an employee's exposure to airborne concentrations of respirable crystalline silica exceeds, or can reasonably be expected to exceed, the PEL. These are fixed locations where RCS materials are being disturbed and controls are not adequate to keep RCS below the PEL.
- Respirable Crystalline Silica (RCS): Silica dust that is composed of crystalline silica (quartz, Cristobalite, and/or Tridymite) small enough (< 10 microns) to be inhaled into the respiratory system.
- Specified Exposure Control Methods: Client outline work practices and personal protective equipment requirements for various tasks as outlined by OSHA.
- Temporary Restricted Area: means an area demarcated by the employer where an employee is required by the client or standard operating procedure (SOP) to wear respiratory protection during the disturbance of RCS materials.

Purpose

The purpose of this document is to establish and implement a written exposure control plan that identifies tasks involving silica exposure and methods used to protect employees. Employers are required to implement the components of the plan needed to ensure compliance with the Occupational Safety and Health Administration (OSHA) standards applicable to respirable crystalline silica, including 29 CFR 1910.1053 (General Industry Standard) and 29 CFR 1926.1153 (Construction Industry Standard).

Scope

The Silica Exposure Control Plan applies to all employees who are exposed to respirable crystalline silica (RCS) at or above permissible limits, as determined by the competent on-site supervisor.

Responsibilities

- Senior Project Managers:
    - Ensure supervisor(s) understand their responsibilities for implementing the Silica Exposure Control Plan at each work site.
    - Ensure all employees are following this plan in compliance with OSHA regulations.
    - Designate a competent person(s) to implement the plan and to provide oversight on site operations to determine when work activities may generate RCS that would require implementation of engineering, work practice controls, or PPE.
    - Ensure the work practices and procedures used to control exposure to RCS comply with this program.
    - Ensure all reasonable precautions are taken to prevent exposure of bystanders and the general public when work involving RCS is performed.
    - Ensure covered employees attend required training, and participate in the medical surveillance program as required.

All work sites performing work where RCS may be created or released shall coordinate with client to have the work activity reviewed and air monitoring performed as necessary. RCS can be created by crushing, drilling, grinding, cutting, sanding or abrading certain types of materials such as sand, stone, mortar and concrete, porcelain and ceramic materials, brick and pottery products, plaster, sheetrock compounds, and refractory materials. RCS may also be found in the clay body and glazes of pottery, released during jewelry production, used in foundries, and may be released when mining, excavating or otherwise disturbing the earth surface. Where exposures of concern are identified by client, they will work with the managers to develop and implement an SOP that describes implementation of this plan.

- Designated Competent Person:
    - Notify client when work activities are planned that may generate RCS where monitoring may be required.
        - Employee exposure monitoring is not required if a task is listed in Table 1 of this program and the engineering controls, work practices and PPE are used as listed.
    - Where the work involving RCS will be performed near the general public and appropriate dust controls cannot be used, area air monitoring may be required. The competent person is to provide advanced notice to client if such monitoring will be needed.
    - Work with supervisors to review all power tool usage to assure compliance with the dust controls established in the plan. Where respirators are required, supervisors shall only allow employees who have been approved by Summit Drilling DoHS within the past twelve months to use respirators to perform those tasks.
    - Assure temporary restricted areas are established, dust controls are used to prevent migration of dust from the worksite, and building air supply and returns in the work area are covered when work will be performed near areas occupied by the general public and where respiratory protection is required.

- Supervisors:
    - Implement and ensure procedures are followed in accordance with this plan.
    - Ensure that staff are aware of this plan, instructed on the details of implementation, and provided with the equipment and methods of control (e.g. engineering controls, work practice controls and respirators) outlined in this plan.
    - Ensure employees have completed Silica Hazard Awareness training.
    - Ensure only employees who have been approved by Summit Drilling DoHS are allowed to use respirators.

- Notify client when a task must be performed that is not covered in the plan.
- Contact client to request technical assistance, and to evaluate health and safety concerns on their projects/work sites.

- Employees:
  - Comply with this plan and any additional safety recommendations provided by supervisors and/or client regarding the Silica Exposure Control Plan.
  - Complete Silica Hazard Awareness training.
  - Contact the supervisor or client to request technical assistance, and to evaluate health and safety concerns on their projects/work sites.

- Contractors/Subcontractors:
  - Contractors and subcontractors shall comply with client Contractor Safety Guidelines and the following:
    - Contractors and subcontractors shall take all necessary steps to comply with the exposure limits for silica established in 29 CFR 1926.1153. The contractor's written Exposure Control Plan must detail how potential exposure to client personnel and the general public in adjacent areas will be kept below allowable limits. A copy of this plan shall be provided to client upon request.
    - Where tasks are performed indoors or in an enclosed area, exhaust ventilation shall be provided as needed to minimize the accumulation of visible airborne dust. If the dust is exhausted inside the building or in an area outside where building occupants or the general public may be exposed, the system must incorporate HEPA-filtration.
    - If the building ventilation system provides air to an area where "restricted work" is being performed, the building air returns shall be blanked or closed while such work is in progress. Contractors and subcontractors must coordinate this with the Project Manager.
    - A "temporary restricted area" must be established where tasks performed in accordance with Table 1 of 29 CFR 1926.1153 require that respiratory protection be used, or where tasks are performed that are not listed in Table 1, and where no historic or objective data exists to prove exposures will be below the action level. Temporary Restricted Areas must be designated with signs, barriers, or other effective means that will ensure unauthorized persons do not enter. If such work is performed in occupied buildings, dust barriers shall be installed as necessary to isolate the restricted area.

- Project Managers Responsible for Health & Safety:
  - Establish and maintain the Silica Exposure Control Plan (SECP).
  - Provide training and guidance to supervisors and competent persons on SECP.
  - Perform air monitoring for employees to evaluate silica exposures, and provide technical assistance with establishing new control measures and developing worksite or task-specific Exposure Control Plans.
  - Perform audits of work performed to assure compliance with required silica control measures, and to ensure Exposure Control Plans are developed and updated as required.

- Plan Requirements:
  - Initial Exposure Assessment Exposure monitoring will be conducted when any employee is or may reasonably be expected to be exposed to respirable crystalline silica at or above the action level. Exposure monitoring may also be performed if work covered by this plan is being performed near areas occupied by the general public where respiratory protection is required by the employees, or where other appropriate dust controls cannot be employed. Employee

exposure monitoring is not required if the task is listed in Table 1 of this plan and the engineering controls, work practices, and PPE are used as listed. Exposure monitoring is also not required if client has either objective or historic data that shows employees will not be exposed above limits for the task being performed.

- If a project manager/contractor purchases tools not listed in the inventory/work plan that incorporates dust controls, notify client in order to obtain their objective data on the effectiveness of the dust controls.
- If a task needs to be performed that is not outlined in Table 1 of this program, please contact client for assistance.

- Periodic Exposure Assessment: If the most recent results are at or above the action level but are below the permissible exposure limit (PEL), exposure monitoring will be repeated every 6 months. If the most recent results are at or above the PEL, exposure monitoring will be repeated within 3 months. Periodic exposure monitoring may be discontinued if results from two consecutive sampling periods taken at least 7 days apart show that employee exposure is below the action level. Monitoring will be conducted whenever a change in the production, process, control equipment, personnel, or work practices may reasonably be expected to result in new or additional exposures at or above the action level.

- Employee Notification: Employee(s) will be notified in writing of the results of the assessment, or the results will be posted in an appropriate location accessible to all affected employees, within 5 workdays. If the result is above the PEL, the notification will include the means that are being taken to reduce the exposure to below the PEL.

- Regulated and Restricted Areas: A regulated area will be established where work exposures at a fixed location are known to be at or above the PEL on a consistent basis. A regulated area must be separated from other areas in a way that will minimize the number of employees exposed. The following sign (or similar facsimile) will be posted at each entrance to the regulated area:

DANGER, RESPIRABLE CRYSTALLINE SILICA, MAY CAUSE CANCER,
CAUSES DAMAGE TO LUNGS, WEAR RESPIRATORY PROTECTION IN THIS AREA
AUTHORIZED PERSONNEL ONLY

Only employees who have work to perform are allowed to enter a regulated area. All employees entering the regulated area must wear a respirator, regardless of the amount of time spent in the area. Air from a regulated area shall not be recirculated by the building ventilation system unless it is first cleaned by HEPA filtration. A temporary restricted area will be established where the task is covered in Table 1 of this plan and the task will not be performed regularly in the same area or location. A temporary restricted area shall be designated by signs, barriers, or other effective means that will ensure unauthorized persons do not enter.

For tasks performed using wet methods, water shall be applied at a rate that is sufficient to minimize the release of visible dust.

- Written Exposure Control Plan:
  - When tasks with potential exposure to RCS are limited to those identified in this plan (see Table 1 below) and are performed in accordance with this plan and the procedures are followed, this plan will serve as the Written Exposure Control Plan. When tasks with potential exposure to RCS are performed that are not identified within this plan, the company, contractor or subcontractor must develop a worksite specific exposure control plan or SOP that describes implementation of

this plan, which includes identifying client, contractor and/or subcontractor responsibilities, as conditions warrant.
    - For fixed worksites where exposures above the action level occur on a routine basis, a worksite-specific written exposure control plan must be developed. The plan must be reviewed at least annually.

- Engineering and Work Practice Controls:
    - For any work task or work location where the exposure to RCS is above permissible limits, engineering controls (i.e. wet work, ventilation) or work practice controls (i.e. housekeeping, inspections, scheduling) will be implemented to lower the exposure as much as possible. When engineering and work practice controls cannot lower the exposure to below permissible limits (or when specified by client) respirators shall be used in accordance with this plan and the Summit Drilling Respiratory Protection Program.
    - Housekeeping: Dry sweeping or dry brushing of dust containing RCS is prohibited. Instead, use a HEPA filtered vacuum cleaner, followed by wet mopping or wet sweeping as necessary. Do not use compressed air to clean an employee's clothes that have become soiled with dust containing respirable crystalline silica. Rather, use a HEPA filtered vacuum to remove dust followed by laundering. Coveralls, launderable or disposable, can be used to minimize the transfer of dust to other areas such as an office, break room, vehicle or home environment. Vacuum the coveralls with a HEPA filtered vacuum before removing and launder or dispose of them as appropriate. Disposable apparel and vacuum filters can be disposed in normal trash.

- Specified Exposure Control Methods:
    - For each employee working with materials containing RCS and engaged in a task using the equipment and machines listed in Table 1, the supervisor and/or competent person shall ensure the engineering controls, work practices, and respiratory protection are used as specified. In all cases, be sure to operate and maintain the tool in accordance with the manufacturer's instructions to minimize dust emissions. If the designated engineering controls are not available or feasible, or if the equipment is not listed in the inventory, the company, contractor, or subcontractor must establish procedures to be included in their plan or SOP. Contact client for assistance and guidance on such plans or SOP. (Note: As data and/or exposure assessments are completed additional tasks or equipment will be included in the client plan.)

- Medical Surveillance:
    - Any employee required to use a respirator for exposure to RCS for 30 or more days (any part of a day) per year will be provided a medical evaluation and other required medical services at no cost to the employee. The medical evaluation is performed initially and at least every 3 years, unless the Occupational Physician requires a more frequent review. The medical evaluation will include medical and work history, a physical exam, chest x-ray, pulmonary function test, tuberculosis test, and any other test recommended by the Occupational Physician. If a respirator is required to be worn by an employee, the employee must be medically cleared, trained and fit tested for a respirator, initial and annually. See Summit Drilling's Respiratory Protection Program.
- Hazard Communication
    - Silica must be included in the hazard communication program as applicable. This includes proper labeling and having a Safety Data Sheet (SDS).

- Training

- Any employee who is exposed to silica above the action level is required to complete Silica Hazard Awareness training and site and task specific training provided by their supervisor. Summit Drilling will provide instructor-led training to supervisors and competent persons on implementation of Silica Exposure Control Plan.

- Recordkeeping
  - Client will make and maintain an accurate record for exposure measurements, objective data, and medical surveillance required under OSHA's RCS standards.

- Review and Audits
  - Reviews
    - Each Project Manager shall review its written exposure control plan on an annual basis for each project. The review shall consist of determining if the tasks and controls are still being used as described and if the plan is effective in reducing silica exposure.
  - Audits
    - Summit Drilling will audit the exposure control plan on a yearly basis. The audit will cover all aspects of the written program to assure they are up to date and complete. The audit will also include walkthroughs of worksites to check equipment, control measures, training records, and other aspects of the plan.

Table 1: Specified Exposure Control Methods When Working With Materials Containing Crystalline Silica

Construction Task or Equipment Operation		**Engineering and Work Practice Control Methods**	**Required Respiratory Protection**	
			≤ 4 hours/shift	**>4 hours/shift**
1	Stationary masonry saws	• Use saw equipped with integrated water delivery system that continuously feeds water to the blade. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None
2a	Handheld power saws (any blade diameter) when used outdoors	• Use saw equipped with integrated water delivery system that continuously feeds water to the blade. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
2b	Handheld power saws (any blade diameter) when used indoors or in an enclosed area	• Use saw equipped with integrated water delivery system that continuously feeds water to the blade. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
3	Handheld power saws for cutting fiber-cement board (with blade	• Use saw equipped with commercially available dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None

Construction Task or Equipment Operation		Engineering and Work Practice Control Methods	Required Respiratory Protection	
			≤ 4 hours/shift	>4 hours/shift
	diameter of 8 inches or less) for tasks performed outdoors only	• Dust collector must provide the air flow recommended by the tool manufacturer, or greater, and have a filter with 99% or greater efficiency.		
4a	Walk-behind saws when used outdoors	• Use saw equipped with integrated water delivery system that continuously feeds water to the blade. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None
4b	Walk-behind saws when used indoors or in an enclosed area	• Use saw equipped with integrated water delivery system that continuously feeds water to the blade. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
5	Drivable saws for tasks performed outdoors only	• Use saw equipped with integrated water delivery system that continuously feeds water to the blade. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None
6	Rig-mounted core saws or drills	• Use tool equipped with integrated water delivery system that supplies water to cutting surface. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None
7	Handheld and stand-mounted drills (including impact and rotary hammer drills)	• Use drill equipped with commercially available shroud or cowling with dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide the air flow recommended by the tool manufacturer, or greater, and have a filter with 99% or greater efficiency and a filter-cleaning mechanism. • Use a HEPA-filtered vacuum when cleaning holes.	None	None
8	Dowel drilling rigs for concrete for tasks performed outdoors only	• Use shroud around drill bit with a dust collection system. • Dust collector must have a filter with 99% or greater efficiency and a filter cleaning mechanism. • Use a HEPA-filtered vacuum when cleaning holes.	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask

9a	Vehicle-mounted drilling rigs for rock and concrete	• Use dust collection system with close capture hood or shroud around drill bit with a low-flow water spray to wet the dust at the discharge point from the dust collector.	None	None
9b	Vehicle-mounted drilling rigs for rock and concrete	• Operate from within an enclosed cab and use water for dust suppression on drill bit.	None	None
10a	Jackhammers and handheld powered chipping tools when used outdoors	• Use tool with water delivery system that supplies a continuous stream or spray of water at the point of impact.	None	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
10b	Jackhammers and handheld powered chipping tools when used indoors or in an enclosed area	• Use tool with water delivery system that supplies a continuous stream or spray of water at the point of impact.	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
10c	Jackhammers and handheld powered chipping tools when used outdoors	• Use tool equipped with commercially available shroud and dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide the air flow recommended by the tool manufacturer, or greater, and have a filter with 99% or greater efficiency and a filter-cleaning mechanism.	None	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
10d	Jackhammers and handheld powered chipping tools when used indoors or in an enclosed area	• Use tool equipped with commercially available shroud and dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide the air flow recommended by the tool manufacturer, or greater, and have a filter with 99% or greater efficiency and a filter-cleaning mechanism.	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
11	Handheld grinders for mortar removal (i.e., tuckpointing)	• Use grinder equipped with commercially available shroud and dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide 25 cubic feet per minute (cfm) or greater of airflow per inch of wheel diameter and have a filter with 99% or greater efficiency and a cyclonic pre-separator or filter-cleaning mechanism.	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask	Powered Air-Purifying Respirator (PAPR) with P100 Filters
12a	Handheld grinders for uses other than	• Use grinder equipped with integrated water delivery system that continuously feeds	None	None

	mortar removal for tasks performed outdoors only	water to the grinding surface. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.		
12b	Handheld grinders for uses other than mortar removal when used outdoors	• Use grinder equipped with commercially available shroud and dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide 25 cubic feet per minute (cfm) or greater of airflow per inch of wheel diameter and have a filter with 99% or greater efficiency and a cyclonic pre-separator or filter-cleaning mechanism.	None	None
12c	Handheld grinders for uses other than mortar removal when used indoors or in an enclosed area	• Use grinder equipped with commercially available shroud and dust collection system. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide 25 cubic feet per minute (cfm) or greater of airflow per inch of wheel diameter and have a filter with 99% or greater efficiency and a cyclonic pre-separator or filter-cleaning mechanism.	None	N95 (or Greater Efficiency) Filtering Facepiece or Half Mask
13a	Walk-behind milling machines and floor grinders	• Use machine equipped with integrated water delivery system that continuously feeds water to the cutting surface. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions.	None	None
13b	Walk-behind milling machines and floor grinders	• Use machine equipped with dust collection system recommended by the manufacturer. • Operate and maintain tool in accordance with manufacturer's instructions to minimize dust emissions. • Dust collector must provide the air flow recommended by the manufacturer, or greater, and have a filter with 99% or greater efficiency and a filter-cleaning mechanism. • When used indoors or in an enclosed area, use a HEPA-filtered vacuum to remove loose dust in between passes.	None	None
14	Small drivable milling machines (less than half-lane)	• Use a machine equipped with supplemental water sprays designed to suppress dust. • Water must be combined with a surfactant. • Operate and maintain machine to minimize dust emissions.	None	None
15a	Large drivable milling machines (half-lane and larger) for cuts of any depth on asphalt	• Use machine equipped with exhaust ventilation on drum enclosure and supplemental water sprays designed to suppress dust.	None	None

	only	• Operate and maintain machine to minimize dust emissions.		
15b	Large drivable milling machines (half-lane and larger) for cuts of four inches in depth or less on any substrate	• Use machine equipped with exhaust ventilation on drum enclosure and supplemental water sprays designed to suppress dust. • Operate and maintain machine to minimize dust emissions.	None	None
15c	Large drivable milling machines (half-lane and larger) for cuts of four inches in depth or less on any substrate	• Use a machine equipped with supplemental water spray designed to suppress dust. • Water must be combined with a surfactant. • Operate and maintain machine to minimize dust emissions.	None	None
16	Crushing machines	• Use equipment designed to deliver water spray or mist for dust suppression at crusher and other points where dust is generated (e.g., hoppers, conveyers, sieves/sizing or vibrating components, and discharge points). • Operate and maintain machine in accordance with manufacturer's instructions to minimize dust emissions. • Use a ventilated booth that provides fresh, climate-controlled air to the operator, or a remote control station.	None	None
17a	Heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition activities involving silica-containing materials	• Operate equipment from within an enclosed cab.	None	None
17b	Heavy equipment and utility vehicles used to abrade or fracture silica-containing materials (e.g., hoe-ramming, rock ripping) or used during demolition activities involving silica-containing materials	• When employees outside of the cab are engaged in the task, apply water and/or dust suppressants as necessary to minimize dust emissions.	None	None
18a	Heavy equipment and utility vehicles for tasks such as grading and excavating but not including demolishing, abrading, or fracturing silica-	• Apply water and/or dust suppressants as necessary to minimize dust emissions.	None	None

	containing materials			
18b	Heavy equipment and utility vehicles for tasks such as grading and excavating but not including demolishing, abrading, or fracturing silica-containing materials	• When the equipment operator is the only employee engaged in the task, operate equipment from within an enclosed cab.	None	None

Appendix 3

Summit Drilling Pandemic Emergency (Continuity) Action Plan

Effective March 2020

Continuity of Operations

I. INTRODUCTION

Organizations across the Nation perform essential functions and services that may be adversely affected in the event of a natural or man-made disaster. In such events, organizations should have continuity plans to assist in the continuance of their essential functions. Continuing to perform essential functions and provide essential services is vital to an organization's ability to remain a viable entity during times of increased threats from all hazards, manmade or natural. Since the threat to an organization's continuity of operations is great during a pandemic outbreak; it is important for organizations, in particular Summit Drilling, to have a Pandemic Continuity of Operations plan in place to ensure it can carry out its essential functions and services. While organizations may be forced to suspend some operations due to the severity of a pandemic outbreak, an effective Continuity of Operations Plan can assist an organization in its efforts to remain operational, as well as strengthen the ability to resume operations.

II. PURPOSE

This plan provides guidance to Summit Drilling and may serve as the plan for maintaining essential functions and services during a pandemic. This guidance neither replaces nor supersedes any current, approved Summit Drilling continuity plan; rather it supplements it, bridging the gap between the traditional, all- hazards continuity planning and the specialized continuity planning required for a pandemic by addressing additional considerations, challenges, and elements specific to the dynamic nature of a pandemic.

This guidance stresses that essential functions can be maintained during a pandemic outbreak through mitigation strategies, such as social distancing, increased hygiene, the vaccination of employees and their families, and similar approaches. A virus may not, in itself, require a traditional continuity response, such as partial or full relocation of the organization's essential functions, although this response may be concurrently necessary due to other circumstances.

III. CONCEPT OF OPERATIONS

Summit Drilling will monitor the severity of the pandemic and establish continuity activation triggers to address the unique nature of the pandemic threat. The Pandemic Continuity Plan will be implemented as needed to support the continued performance of essential functions.

IV. CONTINUITY PLANNING

Organizations must develop operational plans to provide and implement selected mitigation, prevention, protection, or control measures, to decrease the threat of and impact from identified risks, to include pandemic. Organizations must conduct an analysis of the remaining risk based on implemented measures. In accordance with Federal Continuity Directive 1, Federal Executive Branch Continuity Programs and Requirements, October 2012, continuity pandemic plans/guidance should address the following:

- Identification of appropriate mitigation and protective measures, to include measures necessary during a pandemic;
- An operational plan to provide and implement selected mitigation, prevention, protection, or control measures, to include those necessary during a pandemic; and
- For those essential functions that employees must conduct onsite, organizations must classify jobs by exposure risk level to pandemic. Organizations must notify these employees that they are expected to work onsite during a pandemic.

All organization personnel are to be informed regarding protective actions and/or modifications related to this plan. Messaging and risk communications during an emerging infectious disease or pandemic will be conducted by the Director of Health & Safety. Guidance and instructions on established infection control measures such as social distancing, personnel protective equipment and telework polices are provided by the Director of Health & Safety, to assist in limiting the spread at the primary and alternate worksites.

Pandemic Continuity

Within the workplace, social distancing measures could take the form of: modifying the frequency and type of face-to-face employee encounters (e.g., placing moratoriums on hand-shaking, substituting teleconferences for face-to-face meetings, staggering breaks, posting infection control guidelines); establishing flexible work hours or worksite, (e.g., telecommuting); promoting social distancing between employees and customers to maintain six-feet separation between individuals; employee health evaluations; and implementing strategies that request and enable employees with a virus to stay home or seek medical care at the first sign of symptoms.

Organizations are encouraged to communicate with their employees, particularly any who are in harm's way. The messages should follow the Director of Health & Safety's message, should echo that message's themes, and should be in the same voice employees associate with their leaders.
Frequent, daily contact is important to keep employees informed about developments in the organization's response, impacts on the workforce, and to reassure employees that the organization is continuing to function as usual.

V. PANDEMIC PLANNING ASSUMPTIONS

The Assumptions section address the overarching planning assumptions that were used in developing the organizations Pandemic Continuity of Operations Plan.

A. STRATEGY FOR IMPLEMENTATION ASSUMPTIONS

- Susceptibility to a pandemic virus will be universal.
- Efficient and sustained person-to-person transmission signals an imminent pandemic.
- The clinical disease attack rate will likely be 30 percent or higher in the overall population during the pandemic. Generally, illness rates will be highest among school-aged children (about 40 percent) and decline with age. Among working adults, an average of 20 percent will become ill during a community outbreak. This can change depending upon the specific virus.
- Some persons will become infected but not develop clinically significant symptoms. Asymptomatic or minimally symptomatic individuals can transmit infection and develop immunity to subsequent infection.
- While the number of patients seeking medical care cannot be predicted with certainty, in previous pandemic about half of those who become ill sought care.
- Rates of serious illness, hospitalization, and deaths will depend on the virulence of the pandemic virus and differ by an order of magnitude between more and less severe scenarios. Risk groups for severe and fatal infection cannot be predicted with certainty but are likely to include infants, the elderly, pregnant women, and persons with chronic or immunosuppressive medical conditions.
- Rates of absenteeism will depend on the severity of the pandemic. In a severe pandemic, absenteeism attributable to illness, the need to care for ill family members and fear of infection may reach 40 percent during the peak weeks of a community outbreak, with lower rates of absenteeism during the weeks before and after the peak. Certain public health measures (closing organizations, quarantining household contacts of infected individuals, "snow days") are likely to increase rates of absenteeism.
- The typical incubation period (interval between infection and onset of symptoms) for most viruses is approximately two days but can extend up to 14-21 days.
- Persons who become ill may shed virus and can transmit infection for up to several days before the onset of symptoms. Viral shedding and the risk of transmission will be greatest during the first few days of illness but that is subjective to the particular virus.
- On average, infected persons will transmit infection to approximately two other people.
- A pandemic outbreak in any given community will last about six to eight weeks for each wave of the pandemic.
- Multiple waves (periods during which community outbreaks occur across the country) of illness could occur with each wave lasting two-three months. Historically, the largest waves have occurred in the fall and winter, but the seasonality of a pandemic cannot be predicted with certainty.

B. ORGANIZATIONAL ASSUMPTIONS

- Organizations will be provided with guidance and/or direction by Federal, State, or local

governments regarding current pandemic status in its area.

- Organizations will have actionable plans and procedures to assist in the ability to remain operational during a pandemic. Plans and procedures may include social distancing protocols, personal protection equipment (PPE), and temporary suspension of some non-essential activities.

VI. PANDEMIC RESPONSE

A. PANDEMIC COORDINATOR:

The Summit Drilling Pandemic Coordinator will oversee plans to anticipate the impacts of a pandemic on Summit Drilling and to assist with developing strategies to manage the effects of an outbreak.

B. RISK COMMUNICATIONS:

Summit Drilling will develop pandemic risk communications procedures for communicating with all internal and external stakeholders (employees and clients). This includes the use of existing notification rosters with names and telephone numbers of employees and client contacts. These rosters are maintained and updated by the VP, Finance & Administration and kept in the Summit database.

VII. ELEMENTS OF A VIABLE PANDEMIC CONTINUITY CAPABILITY

The Elements of a Viable Continuity Capability section should address the following 10 traditional elements of continuity within the context of a pandemic outbreak. This document is an appendix to the existing Emergency Action Plan (EAP). Any additional elements of the EAP as they apply to this plan should be considered to avoid duplication of efforts and/or resolve differences between the two plans as they relate to responses to other, more physically destructive hazards, such as tornados, hurricanes, floods, and fires.

A. ESSENTIAL FUNCTIONS

Given the expected duration and potential multiple waves of pandemic outbreaks, organizations must review the process involved in carrying out essential functions and services in order to develop plans that mitigate the effects of the pandemic while simultaneously allowing the continuation of operations which support essential functions.

B. ORDERS OF SUCCESSION

At the height of a pandemic wave, absenteeism may be significant. In Line Services has established delegations of authority that are at least three deep to take into account the expected rate of absenteeism and regional nature of the outbreak to help assure continuity of operations over an extended time period. The Delegations of Authority for the senior staff are placed here:

<u>Northern Region:</u>

- Bob Kreilick, Chief Executive Officer
- Roger Logel, Senior Project Manager
- James Stair, VP – Albany Operations

<u>Southern Region:</u>

- Joan Baer, VP – Southern Operations

)

- Rick Davis, VP – Northern Operations
- Dermot Dillon – VP, Major Accounts (Southern Region)

All Administrative Staff:

- Jenn Karen, VP – Finance & Administration

C. DELEGATIONS OF AUTHORITY

At the height of a pandemic wave, absenteeism may be significant, as such, Summit Drilling has established delegations of authority that are at least three deep to take into account the expected rate of absenteeism and regional nature of the outbreak to help assure continuity of operations over an extended time period. The Delegations of Authority for the senior are placed here.

Northern Region:

- Bob Kreilick, Chief Executive Officer
- Roger Logel, Senior Project Manager
- James Stair, VP – Albany Operations

Southern Region:

- Joan Baer, VP – Southern Operations
- Rick Davis, VP – Northern Operations
- Dermot Dillon – VP, Major Accounts (Southern Region)

All Administrative Staff:

- Jenn Karen, VP – Finance & Administration

D. CONTINUITY FACILITIES

The traditional use of continuity facilities to maintain essential functions and services may not be a viable option during a pandemic. Rather, safe work practices, which include social distancing and transmission interventions, reduce the likelihood of contacts with other people that could lead to disease transmission. Summit Drilling has developed preventative practices such as social distancing procedures, hygiene etiquette, and cancellation of organizations non-essential activities to reduce the spread of the pandemic. No alternate facilities are designated to continue operations as the company will use work-at-home procedures for selected employees.

E. CONTINUITY COMMUNICATIONS

Workplace risk can be minimized through implementation of systems and technologies that facilitate communication without person-to-person contact. Summit Drilling has identified communication systems needed to perform essential functions.

F. ESSENTIAL RECORDS MANAGEMENT

Summit Drilling shall identify, protect, and ensure the ready availability of electronic and hardcopy documents, references, records, and information systems needed to support essential functions during a

pandemic outbreak. Summit Drilling has identified systems, databases, and files that are needed to ensure essential functions remain operational.

G. HUMAN RESOURCES

Although a pandemic outbreak may not directly affect the physical infrastructure of an organization, a pandemic will ultimately threaten all operations by its impact on an organization's human resources. The health threat to personnel is the primary threat to maintaining essential functions and services during a pandemic outbreak. Summit Drilling has established plans to protect the entire employee population and their families, with additional guidance for key personnel and other essential personnel, should a pandemic outbreak occur.

H. TEST, TRAINING AND EXERCISES

Testing, training, and exercising are essential to assessing, demonstrating, and improving an organization's ability to maintain its essential functions and services. The organization conducts annual tests, training, and exercises to ensure sustainable social distancing techniques, and to assess the impacts of reduced staff on the performance of essential functions during its spring EAP drill. The organization conducts continuity exercises to examine the impacts of pandemic on performing essential functions, and to familiarize personnel with their responsibilities. The organization has identified resources and trained continuity personnel, needed to perform essential functions.

I. DEVOLUTION OF CONTROL AND DIRECTION

Devolution is the process of transferring operational control of one or more essential functions to a pre-determined responsible party or parties. Pandemic outbreaks will occur at different times, have variable durations, and may differ in the severity; therefore, full or partial devolution of essential functions may be necessary to continue essential functions and services. Summit Drilling has established plans and procedures for devolution, which identifies how it will transfer operations, if pandemic renders leadership and essential staff incapable or unavailable.

J. RECONSTITUTION

Reconstitution is the process whereby an organization has regained the capability and physical resources necessary to return to normal (pre-disaster) operations. The objective during reconstitution is to effectively manage, control, and, with safety in mind, expedite the return to normal operations. Summit Drilling has developed reconstitution plans and procedures to ensure facilities/buildings are safe to return. The organization's reconstitution plan should consider the possibility that not all employees may be able to return to work at the time of reconstitution and that it may be necessary to hire temporary or permanent workers in order to complete the reconstitution process.

VIII. CONCLUSION

Maintaining essential functions and services in the event of pandemic requires additional considerations beyond traditional continuity planning. Unlike other hazards that necessitate the relocation of staff performing essential functions to an alternate operating facility, a pandemic may not directly affect the physical infrastructure of the organization. As such, a traditional "continuity activation" may not be required during a pandemic outbreak. However, a pandemic outbreak threatens an organization's human resources by removing essential personnel from the workplace for extended periods of time. Accordingly, Summit Drilling continuity plan addresses the threat of a pandemic outbreak. Continuity Plans for maintaining

essential functions and services in a pandemic should include implementing procedures such as social distancing, infection control, personal hygiene, and cross-training (to ease personnel absenteeism in a critical skill set). Protecting the health and safety of key personnel and other essential personnel must be the focused goal of the organization in order to enable the organizations to continue to operate effectively and to perform essential functions and provide essential services during a pandemic outbreak.

APPENDIX 1: PRESCREENING QUESTIONNAIRE

Confidential Summit Drilling (Summit) COVID-19 Questionnaire

All employees, contractors or visitors to any Summit facilities are required to respond to the following questions prior to entry or mobilizing to the offices/sites. Entry and/or reporting to your assignment will be denied if the person refuses to respond the questionnaire.

Please respond as carefully as you can to ensure that we best protect you and your colleagues.
Have you recently developed, and are still experiencing, one or more of the following symptoms?

1) Fever ≥ 99.14°F YES / NO
2) Cough YES / NO
3) Shortness of breath YES / NO
4) Muscle pain or fatigue YES / NO
5) Sputum or mucous YES / NO
6) Diarrhea YES / NO
7) Other flu-like symptoms YES / NO

If any YES: In the past 14 days since first onset of symptoms have you had...?
If all NO: In the past 14 days have you had...?

8) Contact with a confirmed or suspected case of Coronavirus (COVID-19) YES / NO

9) Visited an area with an outbreak of Coronavirus (COVID-19), for example:
Mainland China, Hong Kong, Taiwan, South Korea, Italy, Japan, Iran, Singapore, etc. YES / NO

IF you answered YES to ONE or more of these questions inform the reception or your manager and don't proceed to your work location.

Employee name: _____

Employee signature: _____

Date: _____

Phone: _____

APPENDIX 2: WORLD HEALTH ORGANIZATION PHASES

The World Health Organizations (WHO) developed an alert system to help inform the world about the seriousness of a pandemic. The alert system has six phases, with Phase 1 having the lowest risk of human cases and Phase 6 posing the greatest risk of pandemic. Organizations are encouraged to monitor the WHO phases and establish continuity "triggers" as deemed appropriate.

The phases are applicable globally and provide a framework to aid countries in pandemic preparedness and response planning. The use of a six-phased approach has been retained. However, the pandemic phases have been re-defined (Table 1). In addition, the time after the first pandemic wave has been elaborated into post peak and post pandemic periods.

The WHO phases of pandemic alert (more specific to Influenza):

Table 1: World Health Organization Pandemic Influenza Phases

Phase 1	No animal influenza virus circulating among animals has been reported to cause infection in humans.
Phase 2	An animal influenza virus circulating in domesticated or wild animals is known to have caused infection in humans and is therefore considered a specific potential pandemic threat.
Phase 3	An animal or human-animal influenza reassortant virus has caused sporadic cases or small clusters of disease in people, but has not resulted in human-to-human transmission sufficient to sustain community-level outbreaks.
Phase 4	Human-to-human transmission (H2H) of an animal or human-animal influenza reassortant virus able to sustain community-level outbreaks has been verified.
Phase 5	The same identified virus has caused sustained community level outbreaks in two or more countries in one WHO region.
Phase 6	In addition to the criteria defined in Phase 5, the same virus has caused sustained community level outbreaks in at least one other country in another WHO region.
Post-Peak Period	Levels of pandemic influenza in most countries with adequate surveillance have dropped below peak levels.
Possible New Wave	Level of pandemic influenza activity in most countries with adequate surveillance rising again.
Post-Pandemic Period	Levels of influenza activity have returned to the levels seen for seasonal influenza in most countries with adequate surveillance.

In the 2009 revision of the phase descriptions, WHO has retained the use of a six-phased approach for easy incorporation of new recommendations and approaches into existing national preparedness and response plans. The grouping and description of pandemic phases have been revised to make them easier to understand, more precise, and based upon observable phenomena.

Phases 1–3 correlate with preparedness, including capacity development and response planning activities, while Phases 4–6 clearly signal the need for response and mitigation efforts. Furthermore, periods after the first pandemic wave are elaborated to facilitate post pandemic recovery activities.

In nature, influenza viruses circulate continuously among animals, especially birds. Even though such viruses might theoretically develop into pandemic viruses, in Phase 1 no viruses circulating among animals have been reported to cause infections in humans.

In Phase 2 an animal influenza virus circulating among domesticated or wild animals is known to have caused infection in humans, and is therefore considered a potential pandemic threat.
In Phase 3, an animal or human-animal influenza reassortant virus has caused sporadic cases or small clusters of disease in people, but has not resulted in human-to-human transmission sufficient to sustain community-level outbreaks. Limited human-to-human transmission may occur under some circumstances, for example, when there is close contact between an infected person and an unprotected caregiver. However, limited transmission under such restricted circumstances does not indicate that the virus has gained the level of transmissibility among humans necessary to cause a pandemic.

Phase 4 is characterized by verified human-to-human transmission of an animal or human-animal influenza reassortant virus able to cause "community-level outbreaks." The ability to cause sustained disease outbreaks in a community marks a significant upwards shift in the risk for a pandemic. Any country that suspects or has verified such an event should urgently consult with WHO so that the situation can be jointly assessed and a decision made by the affected country if implementation of a rapid pandemic containment operation is warranted. Phase 4 indicates a significant increase in risk of a pandemic but does not necessarily mean that a pandemic is a forgone conclusion.

Phase 5 is characterized by human-to-human spread of the virus into at least two countries in one WHO region. While most countries will not be affected at this stage, the declaration of Phase 5 is a strong signal that a pandemic is imminent and that the time to finalize the organization, communication, and implementation of the planned mitigation measures is short.

Phase 6, the pandemic phase, is characterized by community level outbreaks in at least one other country in a different WHO region in addition to the criteria defined in Phase 5. Designation of this phase will indicate that a global pandemic is under way.

During the post-peak period, pandemic disease levels in most countries with adequate surveillance will have dropped below peak observed levels. The post-peak period signifies that pandemic activity appears to be decreasing; however, it is uncertain if additional waves will occur and countries will need to be prepared for a second wave.

Previous pandemics have been characterized by waves of activity spread over months. Once the level of disease activity drops, a critical communications task will be to balance this information with the possibility of another wave. Pandemic waves can be separated by months and an immediate "at-ease" signal may be premature.

In the post-pandemic period, influenza disease activity will have returned to levels normally seen for seasonal influenza. It is expected that the pandemic virus will behave as a seasonal influenza A virus. At this stage, it is important to maintain surveillance and update pandemic preparedness and response plans accordingly. An intensive phase of recovery and evaluation may be required.

APPENDIX 3: WEBSITES FOR PLANNING AND PREPAREDNESS

- http://www.opm.gov/pandemic/index.asp - Links to policies on leave, pay, hiring, alternative work arrangements and other critical human capital issues in relation to pandemic influenza.
- http://www.pandemicflu.gov - pandemic influenza related information (e.g., signs and symptoms of influenza, modes of transmission, developing individual and family plans, etc.).
- http://www.flu.gov/planning-preparedness/federal/index.html# Pandemic influenza related information for Federal Government agencies to use for planning and preparedness. Links to other federal government agencies.

Appendix 4

APPENDIX U
Health & Safety Schedule

Health Safety Security and the Environment (HSSE) Schedule

Project Commencement	Daily	Weekly	Project Conclusion
Project kick-off meeting, including scope review and table top ERP drill	Morning tailgate and twilight meetings	Jobsite inspection including First Aid Kits, AED, fire extinguishers, PPE	HSSE paperwork review, back-up, and compiling
Site orientation for new site workers	JSA review or development	LFI Review	
HASP acknowledgement with all site workers	Equipment inspections		
Site walk, Hazard Hunts in work areas	BASE observations		
	Hazard hunts in work areas		
	Key Performance Indicator (KPI) Tracking		

APPENDIX V
Health & Safety Equipment Inspection Log

2020 Health and Safety Equipment Monthly Inspection Form																
		January	February	March	April	May	June	July	August	September	October	November	December			
Item	*Location*	*Inspector Initials*												*Notes*	*Remove from Service*	*Replacement*
Fire Extinguisher A																
Fire Extinguisher B																
Fire Extinguisher C																
Fire Extinguisher D																
AED A																

2020 Health and Safety Equipment Monthly Inspection Form																
		January	February	March	April	May	June	July	August	September	October	November	December			
Item	*Location*	*Inspector Initials*												*Notes*	*Remove from Service*	*Replacement*

2020 Health and Safety Equipment Weekly Inspection Form

Inspection Week / Date		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52			
Item	*Location*	*Inspector Initials*																																																				*Notes*	*Remove from Service*	*Replacement*
First Aid Kit A																																																								
First Aid Kit B																																																								
First Aid Kit C																																																								
First Aid Kit D																																																								
First Aid Kit E																																																								
Eye Wash A																																																								
Eye Wash B																																																								
Eye Wash C																																																								
Eye Wash D																																																								

2020 Health and Safety Equipment Weekly Inspection Form

Inspection Week / Date		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52			
Item	*Location*	*Inspector Initials*																																																				*Notes*	*Remove from Service*	*Replacement*

APPENDIX W
Ladder Use

19.3.12 Ladders

Langan safety procedures shall be used to ensure employee safety when using ladders in the office or work sites. All ladders shall be coated or repaired to prevent injury to the employee from punctures or lacerations and to prevent snagging or clothing. Any wood ladders used must have an opaque covering except for identification or warning labels, which may be placed on one face only of a side rail.

19.3.12.1 Ladder Use

Employees shall only use ladders for the purposes, which they were designed and shall not be used as scaffolding. Ladders will be maintained and inspected prior to use for slip hazards including oil and grease. Employees shall use ladders only on stable and level surfaces unless the ladder is secured to prevent possible displacement. Ladders should not be used on slippery surfaces unless secured or provided with slip resistant feet to prevent accidental displacement. Ladders should not be used in locations where they could be displaced by workplace activities or traffic. Ladder rungs, cleats and steps shall be parallel, level and uniformly spaced when the ladder is in the use position.

Employees should not be carrying anything including equipment that could cause injury if there was a fall while utilizing the ladder. The top and bottom of the ladder area must remain clear while in use. When ascending and descending the ladder, employees must face the ladder.

Ladders shall not be loaded beyond the maximum intended load for which they were built or the manufacturer's rated capacity.

19.3.12.2 Portable Ladders

Rungs, cleats and steps for portable ladders and fixed ladders shall be spaced not less than 10 inches apart, nor more than 14 inches apart, as measured between center lines of the rungs, cleats and steps. When used to access an upper landing surface, the ladder side rails must extend at least three feet above the upper landing surface to which the ladder is used to gain access. If this is not possible, due to the ladders length, then the top of the ladder shall be secured at its top to a rigid support.

19.3.12.3 Step Stools

Rungs, cleats and steps of step stools shall not be less than 8 inches apart, nor more than 12 inches apart, as measured between center lines of the rungs, cleats and steps.

19.3.12.4 Extension Ladders

Rungs, cleats and steps of the base section of extension trestle ladders shall be spaced not less than 8 inches apart, nor more than 18 inches apart, as measured between center lines of the rungs, cleats and steps. The rung spacing on the extension section of the extension trestle ladder shall not be less than 6 inches nor more than 12 inches, as measured between center lines of the rungs, cleats and steps. Ladders shall be used at an angle such that the horizontal distance from the top support to the foot of the ladder is approximately one-quarter of the working length of the ladder (the distance along the ladder between the foot and the top support).

19.3.12.5 Inspection

Ladders will be inspected for visible detects periodically, prior to utilization or after any occurrence that could have negatively affected the ladder. Portable ladders with defects including broken or missing rungs, cleats, or steps, broken or split rails, corroded components or other faulty or defective components shall not be used. The ladder will be immediately marked as defective, tagged as “Do Not Use” or blocked from being used and removed from service until repaired.

APPENDIX X
Lone Worker Policy for Perimeter Air Monitoring

LANGAN

Memorandum

2400 Ansys Drive, Suite 403 Canonsburg, PA 15317 T: 724.514.5100 F: 724.514.5101

To: MIPC Project Staff

From: MIPC Project Management

Info: **Langan / MIPC Lone Worker Policy for Perimeter Air Monitoring – Chelsea Facility**

Date: February 5, 2025

Re: Lone Worker Policy – Perimeter Air Monitoring
MIPC
Aston Twp, PA
Langan Project No.: 220240201

Perimeter Air Monitoring Program (Aston, Pennsylvania)

Document Status: Draft – For project use; subject to Client HSSE approval.
Applies To: Company staff and subcontractors performing perimeter air monitoring or related perimeter routes.
Revision: 0

1. PURPOSE AND INTENT (GOAL ZERO MINDSET)

This policy defines minimum requirements for planning, authorizing, monitoring, and escalating lone-worker activities associated with perimeter air monitoring. The intent is consistent with a "Goal Zero" approach—no harm and no leaks—and with strong "control of work" expectations commonly used in oil and gas operations.

Key principle: If the work cannot be performed safely, it will not proceed. Stop Work Authority applies at all times.

2. SCOPE

This policy applies to perimeter activities performed alone, including:

- Perimeter PID screening and similar boundary monitoring
- Odor/vapor boundary walks and complaint response at the perimeter (non-confrontational, scripted)
- Instrument set-up, calibration checks, and data logging performed alone
- Visual inspections of perimeter routes and monitoring points
- Perimeter air monitoring sample container set-up and swap-out

This policy does not replace Client HSSE requirements or site rules; the most stringent requirement governs.

3. OPERATING PRINCIPLES *(SHELL-LIKE STRUCTURE; NOT PROPRIETARY)*

1. **Comply:** Comply with the law, standards, and procedures.
2. **Intervene:** Intervene on unsafe or non-compliant situations (Stop Work / Intervention).
3. **Respect:** Respect our neighbors and the community (professional conduct; avoid escalation).

Control of work: Lone work must be risk assessed, authorized, and actively monitored with a defined response plan.

4. DEFINITIONS

- **Lone worker:** A worker who is not in visual/verbal contact with another worker and is not under close supervision.
- **Buddy work:** Two-person minimum presence (or more) for specified higher-risk tasks.
- **Check-in:** A scheduled confirmation of status and location with a designated monitor.
- **Lone Work Authorization (LWA):** Supervisor approval confirming hazards and controls are in place for lone work.

5. ROLES AND RESPONSIBILITIES

5.1 Project Manager / Site Supervisor

- Approve or deny LWA; ensure staffing supports buddy work where required.
- Confirm check-in monitor coverage, escalation contacts, and response capability.
- Ensure workers are trained/competent, properly equipped, and medically fit for the conditions.

5.2 Lone Worker

- Complete a pre-task "Take-5" / dynamic risk assessment before leaving a safe staging area.
- Follow check-in intervals and escalation instructions without exception.
- Stop work and withdraw to a safe area if conditions change or controls are not effective.
- Report hazards, near misses, and any significant public interaction promptly.

5.3 Check-in Monitor (Designated)

- Receive and log check-ins; initiate escalation if check-ins are missed.
- Maintain an incident-ready call tree and dispatch instructions (facility security, supervisor, emergency services).
- Remain available for the full duration of authorized lone work.

6. AUTHORIZATION REQUIREMENTS (LWA)

Lone perimeter air monitoring may proceed only when ALL of the following are met:

- Defined task plan (route, monitoring points, duration, and boundaries).
- Dynamic risk assessment completed (weather, lighting, footing, traffic, public activity, wildlife).
- Communications confirmed (device, coverage, check-in intervals, emergency contacts).
- Worker competency confirmed (instrument use, data integrity, de-escalation basics, cold stress and slip awareness).
- Stop-work triggers reviewed for the day and understood.

7. COMMUNICATIONS, MONITORING, AND ESCALATION

7.1 Minimum Required Equipment

- Primary communications device (fully charged phone) with sound ON plus backup power bank.
- Secondary communications where practical (StarLink/ Satellite comms, lone-worker app with SOS); radios are not permitted for use on site.
- High-visibility outerwear; headlamp for low-light conditions.
- Footwear suitable for conditions; traction aids if approved by site HSSE.
- Basic first-aid kit.

7.2 Check-in Requirements

Unless otherwise specified by the Supervisor (more stringent controls may apply):

- Start-of-task check-in: starting location, route, expected duration, and next check-in time.
- Rolling check-ins: every 15–30 minutes (shorten during ice, extreme cold, low light, or public activity).
- End-of-task check-in: confirm task complete and worker safely off-route.

7.3 Missed Check-in Escalation (Minimum)

Elapsed Time Past Check-in	Required Action
T+5 minutes	**Monitor calls/texts worker; confirms last known location.**
T+10 minutes	**Monitor notifies Supervisor and secondary contact; continues attempts.**
T+15 minutes	**Initiate site response: dispatch buddy/security to last known area; maintain communications attempts.**
T+20 minutes	**If still no contact and location uncertain, contact emergency services and provide last known details.**

Escalation times may be tightened based on site layout, known dead zones, or higher-risk conditions.

8. PROHIBITED ACTIVITIES FOR LONE WORKERS (BUDDY REQUIRED)

The following activities are prohibited for lone workers and require buddy work (two-person minimum):

- Working around moving heavy equipment or within equipment operating/swing radius.
- Entering excavations, trenches, pits, vaults, or any confined space (or confined-space-like structure).
- Work at height (ladders, elevated platforms) or tasks requiring fall protection.
- Energized electrical work or work near exposed energized conductors.
- Roadside monitoring where traffic exposure exists (unless traffic control is in place and Supervisor approves).
- Night work in poorly lit areas or outside controlled facility property lines.
- Any task requiring carrying loads that compromises balance on potentially icy surfaces.
- Any situation where hostile or unpredictable public interaction is reasonably foreseeable.

9. PERIMETER AIR MONITORING–SPECIFIC HAZARD CONTROLS

9.1 Slips, Trips, and Falls (Winter / Wet Conditions)

- Use designated, treated walking routes where feasible; do not step off stable surfaces when alone.
- If glaze ice, refreeze conditions, or unstable footing is observed: stop work, retreat, and notify the Supervisor.
- Do not step over berms, guardrails, secondary containment edges, or debris piles while alone.

9.2 Vehicles / Line of Fire

- Park in approved areas; avoid backing when possible; maintain situational awareness in drive lanes.
- Maintain separation from operating equipment; do not cross active equipment paths.

9.3 Cold Stress / Reduced Dexterity

- Plan short exposure blocks with warm-up breaks; increase check-in frequency during extreme cold.
- Stop work if dexterity is compromised (cannot safely operate instruments, open/close cases, or maintain stable footing).
- Use buddy system whenever conditions significantly increase cold-stress risk.

9.4 Public Interaction / De-escalation

- Remain professional; use an approved script; do not argue or speculate.
- If approached aggressively: disengage, withdraw to a safe area/vehicle, and call Supervisor/Monitor.
- Do not enter private property while alone; property access requires documented consent and buddy work.

10. STOP-WORK TRIGGERS (CONVERT TO BUDDY WORK OR STAND DOWN)

Any of the following triggers requires buddy work or immediate stand-down, as directed by the Supervisor:

- Recent site slip incidents or active icy conditions affecting travel routes.
- Low light/dusk/darkness or poor visibility.
- Communications failure or unreliable coverage.
- Monitoring point access requires leaving treated/controlled surfaces.
- Any reading that triggers the project notification protocol or indicates an abnormal condition at the perimeter.
- Any credible concern regarding hostile public interaction.

11. TRAINING AND COMPETENCY (MINIMUM)

- Instrument operation and calibration checks; documentation and data integrity expectations.
- Dynamic risk assessment ("Take-5"), Stop Work Authority, and escalation process.
- Slip prevention and cold-stress recognition (including limits of PPE).
- Public interaction basics and approved communication script.
- Emergency response: contacts, muster, and location reporting.

12. RECORDS AND DOCUMENTATION

Maintain the following records for each day or shift, as applicable:

- Lone Work Authorization (LWA) approvals (route, points, times, worker, monitor).
- Check-in log (times, locations, issues).
- Instrument calibration/field sheets and any deviations.
- Hazard observations, near misses, and corrective actions (especially slip hazards and public interaction events).

13. REFERENCES (LINKS)

- Shell – Safety (Goal Zero ambition; contractor safety leadership context)
- Shell Contractor – HSSE Golden Rules (Comply / Intervene / Respect)
- Shell Contractor Safety Leadership (PDF)
- IOGP – Life-Saving Rules (overview)
- IOGP – Life-Saving Rules work card (PDF)
- UK HSE – Manage risks of working alone
- UK HSE – Monitoring and keeping in touch (lone working)
- OSHA – Working alone (29 CFR 1915.84; accounting for employees working alone – sector example)
- OSHA – Cold stress guidance
- OSHA – Wind chill chart (PDF)
- Lawrence Berkeley National Laboratory – Stop Work Policy (example of SWA elements)

14. CAVEATS

This document is not a Shell proprietary policy and must not be represented as an official Shell standard. It is structured to mirror common, publicly described Shell-like HSSE expectations (Goal Zero intent, Golden Rules framing, and a strong Stop Work / Intervention culture) and to align with widely recognized lone-worker risk management practices with the International Association of Oil and Gas Producers (IOGP).

This policy must be reviewed against Client HSSE requirements, site rules, union/insurance requirements, and applicable laws. Where requirements conflict, the most stringent requirement governs.

Lone work suitability is site- and task-specific. Conditions such as severe weather, active icing/refreeze, public interface, or communications dead zones may require upgrading to buddy work or standing down entirely.

Appendix B

Standard Operating Procedures (SOPs)
for Site Characterization

1. Purpose

The purpose of this Standard Operating Procedure (SOP) is to describe the procedures for installation of sub-slab and exterior soil vapor probes for temporary or permanent use prior to soil vapor sampling. These are standard (i.e., typically applicable) operating procedures which may be varied or changed as warranted, dependent on site location and project type. In all instances, the procedures employed should be documented.

2. Limitations

The procedures described herein shall be followed to assure compliance with Langan's Quality Management System and Quality Management Plan ("QMS/QMP"). Note, however, that regulatory, client-specific, health & safety, or field conditions ("overriding conditions") may necessitate deviations from the procedures in this SOP to address such overriding conditions. Any proposed deviation shall be consistent with the Langan QMS/QMP and the professional standard of care, and shall be reviewed and approved by the project manager and the principal-in-charge before being implemented. All approved deviations shall be documented in the final report for the associated phase of the project.

3. Health & Safety

When working on-site, comply with the site's health and safety procedures, Langan's Corporate Health and Safety Plan (HASP), and Langan's Injury and Illness Prevention Program. All proper personal protection clothing and equipment (PPE) are to be worn. A job safety analysis (JSA) should be performed to review the specifics of the activities and equipment and materials used that may pose additional specific health and safety concerns and could require certain other protective actions to be implemented. In addition, Langan's utility clearance procedures must be adhered to at all times.

4. Methods

The methods for soil vapor probe installation will depend on the site and scope of the project. In general, soil vapor points will be installed sub-slab by Langan personnel or outdoors by contracted drillers. Permanent and temporary points will vary in installation as outlined in this SOP. Be aware that Langan may be subject to confidentiality or nondisclosure agreements, which can prohibit discussing activities with occupants; confirm with the project manager (PM) if these conditions apply.

Field Preparation Activities:

Prior to performing field activities, utility clearance must be conducted at the planned installation points. Langan's Underground Utility Clearance Guidelines are located on the company intranet website under the Health and Safety Business Operations. Prior to the installation of soil vapor probes, complete the following steps:

1. Obtain proposed sample points and all required planning documentation from the PM. The field sampling team is responsible for verifying sample locations in the field and adherence to project planning documentation.
2. Prepare a plan for confirming utility clearance at proposed probe locations with PM, in accordance with Langan's Underground Utility Clearance Guidelines.
3. Coordinate equipment rentals and driller availability (including confirmation of driller equipment).
4. Obtain Langan-provided Equipment, dependent on type of installation (see next section)
    - Personal Protection Equipment
    - Project Dedicated Field Book, if one exists
    - Personal field book (if not using a project-dedicated field book)
5. Request utility drawings from the owner/client and operator, showing aboveground and underground utilities for the areas where subsurface work will be performed. Consider reviewing the proposed locations on-Site with a person knowledgeable of facility operations prior to point installation.
6. Confirm the proper One-Call system has been notified (either by Langan, or a drilling subcontractor, if using). Note: the One-Call should be placed with sufficient time for utility clearance (most One-Call systems require three business days). The One-Call ticket information should be retained for reference in the field and saved to the project folder.
7. If necessary, retain a geophysical subcontractor to clear each location of potential utilities and subsurface obstructions prior to intrusive work. Note, if performing sub-slab point installation, you must specify to the geophysical contractor that the locations are inside of a building and concrete scanning equipment must be used (traditional GPR often does not work on reinforced concrete slabs).

Methods for soil vapor probe installation will vary depending on the scope of work. Each method is described below. Prior to conducting field activities a tailgate safety meeting must be performed with all Langan employees and subcontractors and all applicable health and safety requirements for the site must be understood and agreed to by all parties.

<u>Permanent Sub-Slab Soil Vapor Probe Installation</u>

Equipment needed for Vapor Pin® installation:

- Assembled Vapor Pin® (Vapor Pin® and silicone sleeve)
- Hammer drill
- 5/8-inch (16 mm) diameter hammer drill bit
- 1 ½-inch (38 mm) diameter hammer drill bit
- ¾-inch (19 mm) diameter bottle brush
- Wet/dry vacuum (for example, Shop-Vac®) with HEPA filter (optional)
- Vapor Pin® installation/extraction tool
- Dead blow hammer
- Vapor Pin® flush mount/Secured Cover
- Vapor Pin® Spanner for Secured Cover

- Vapor Pin® protective cap or Cole-Palmer (or similar) Four-Way valve. Note, the selected cap or valve must fit under the Secured Cover
- Vapor Pin® drilling guide (optional)
- VOC-free hole patching material (hydraulic cement) and putty knife or trowel for repairing the hole.
- Circuit interrupter
- Calibrated photoionization detector (PID) or five-gas meter (dependent on site health and safety requirements)
- Extension cords, if necessary
- Generator and lanterns, if necessary. Note, if using a generator indoors, a five-gas meter with carbon monoxide and PID sensors to screen ambient air for health and safety purposes.

Method:

1. If the building does not have power, set up lanterns and start the generator. Use caution and ensure proper ventilation. It is advisable to set the generator up as far away from the sampling locations as possible. Preferably, the generator will be set up outside or in a doorway. Discuss ventilation requirements with the project manager prior to beginning field work.
2. Plug the hammer drill into the nearest outlet or generator using the circuit interrupter (and extension cord, if necessary).
3. Fit the 1.5-inch bit into the hammer drill. Drill a 1.5-inch diameter hole approximately 1.75-inch into the slab. Do not over-drill. Insert vapor pin drilling guide into the hole and fit the hammer drill with a 5/8-inch bit. Drill a 5/8-inch hole through the slab and approximately 1-inch into the underlying soil. Upon penetration of the slab, the pressure necessary to drive the hammer drill will dramatically decrease and there will most likely be soil on the drill bit when removing from the hole. These conditions are indicative of penetration into the soil beneath the slab. Remove the vapor pin drilling guide if using. Record the approximate slab thickness on the vapor sampling log.
    - Note: use caution when operating the hammer drill. ALWAYS WEAR SAFETY GLASSES. Make sure that the drill is set to the hammer and spin settings. Hold the drill firmly and upright to ensure the hole is drilled perpendicular to the slab. Do not put all your weight against the drill or it may slip and cause injury. Unplug the drill after use. A heavier drill can make vapor pin installation easier because the heavier drill does not require as much force to push the drill through the slab and the drill is less likely to become jammed in the slab.
4. Remove the drill bit and brush the hole with the bottle brush. Use the wet/dry vacuum to collect dust and debris from around and inside the vapor pin hole.
5. After the 5/8-inch hole has been drilled, fit a vapor pin with a silicon sleeve. Place the wider end into the drilled hole. Place the vapor pin installation/extraction tool over the vapor pin. The barbed fitting should fit inside the hollow end of the tool. Use the dead blow hammer to tap the solid end of the installation/extraction tool until nearly the entire silicon sleeve is below the slab. Make sure the installation/extraction tool is aligned

properly to avoid damaging the barbed fitting. The top of the sleeve protruding from the borehole should form a slight bulge between the slab and the Vapor Pin® threads. Place Vapor Pin® protective cap or four-way valve on the vapor pin to prevent vapor loss. If using four-way valve, ensure it is installed properly to seal the probe when not in use and fits below the flush mount cover.

6. Secure a flush mount cover by placing it over the vapor pin and/or screwing it onto the vapor pin using the spanner tool. **STOP, installation process is complete.**

Temporary Sub-Slab Soil Vapor Probe Installation

Equipment needed:

- Vapor Pin® materials, if using:
    a. Assembled Vapor Pin® (Vapor Pin® and silicone sleeve)
    b. Vapor Pin® installation/extraction tool
    c. Vapor Pin® drilling guide (optional)
- Hammer drill
- 5/8-inch (16 mm) diameter hammer drill bit
- ¾-inch (19 mm) diameter bottle brush
- Wet/dry vacuum (for example, Shop-Vac®) with HEPA filter (optional)
- Dead blow hammer
- Vapor Pin® protective cap or Cole-Palmer (or similar) Four-Way valve
- VOC-free modeling clay for temporary hole patching during sampling
- HDPE or Teflon tubing
- VOC-free hole patching material (hydraulic cement) and putty knife or trowel for repairing the hole following extraction of the vapor probe.
- Circuit interrupter
- Calibrated photoionization detector (PID) or five-gas meter (dependent on site health and safety requirements)
- Extension cords, if necessary
- Generator and lanterns, if necessary. Note, if using a generator indoors, a five-gas meter with carbon monoxide and PID sensors to screen ambient air for health and safety purposes.

Method:

1. If the building does not have power, set up lanterns and start the generator. Use caution and ensure proper ventilation. It is advisable to set the generator up as far away from the sampling locations as possible. Preferably, the generator will be set up outside or in a doorway. Discuss ventilation requirements with the project manager prior to beginning field work.
2. Install Plug the hammer drill into the nearest outlet or generator using the circuit interrupter (and extension cord, if necessary).
3. Fit the hammer drill with a 5/8-inch bit. Drill a 5/8-inch hole through the slab and approximately 1-inch into the underlying soil. Upon penetration of the slab, the pressure

necessary to drive the hammer drill will dramatically decrease and there will most likely be soil on the drill bit when removing from the hole. These conditions are indicative of penetration into the soil beneath the slab. Remove the vapor pin drilling guide if using. Record the approximate slab thickness on the vapor sampling log.

- Note: use caution when operating the hammer drill. ALWAYS WEAR SAFETY GLASSES. Make sure that the drill is set to the hammer and spin settings. Hold the drill firmly and upright to avoid installing a slanted hole. Do not put all your weight against the drill or it may slip and cause injury. Unplug the drill after use. A heavier drill can make vapor pin installation easier because the heavier drill does not require as much force to push the drill through the slab and the drill is less likely to become jammed in the slab.

4. Remove the drill bit and brush the hole with the bottle brush. Use the wet/dry vacuum to collect dust and debris from around and inside the vapor pin hole. **If installing a Vapor Pin®, proceed to step 5. If a vapor pin is not being installed, proceed to step 6.**
5. After the 5/8-inch hole has been drilled, fit a vapor pin with a silicon sleeve. Place the wider end into the drilled hole. Place the vapor pin installation/extraction tool over the vapor pin. The barbed fitting should fit inside the hollow end of the tool. Use the dead blow hammer to tap the solid end of the installation/extraction tool until nearly the entire silicon sleeve is below the slab. Make sure the installation/extraction tool is aligned properly to avoid damaging the barb fitting. The top of the sleeve protruding from the borehole should form a slight bulge between the slab and the Vapor Pin® threads. Place Vapor Pin® protective cap or four-way valve on the vapor pin to prevent vapor loss. If using four-way valve, ensure it is installed properly to seal the probe when not in use and fits below the flush mount cover. **STOP, installation process is complete.**
6. If not using a Vapor Pin®, cut a length of tubing which will penetrate beneath the slab while maintaining sufficient length above the slab to connect to the sampling apparatus. Place the tubing into the drilled hole, ensuring the tubing is located in the soil beneath the slab. Place modeling clay around annulus of drilled hole and tubing to ensure a complete seal from sub-slab vapor to ambient air. Place a cap or four-way valve on the tubing to prevent vapor loss. If using four-way valve, ensure it is installed properly to seal the probe when not in use and fits below the flush mount cover. **STOP, installation process is complete.**
7. Following sampling, use either the Vapor Pin® extraction tool to remove a Vapor Pin®, or remove tubing and modeling clay. Patch the drilled hole with VOC-free hole patching material (e.g. hydraulic cement or similar).

<u>Exterior Soil Vapor Probe Installation</u>

Equipment needed:

- HDPE or Teflon tubing
- Cole-Palmer (or similar) Four-Way valve
- Six-inch stainless steel vapor point
- Sand
- Granulated bentonite

- Road box (or similar) flush mount cover, if necessary
- Calibrated photoionization detector (PID) or five-gas meter (dependent on site health and safety requirements)

For exterior vapor probe installation, the equipment listed above should be inventoried with the contracted driller prior to mobilization to the site. Langan field personnel should have extra vapor probe equipment available in case the driller does not provide the necessary items. Discuss the targeted depth of vapor probe installation with project manager, as well as contingencies for encountering the ground water table in the vapor probe soil boring.

Method:

1. Direct the contracted driller to advance a borehole to the desired depth. Care should be taken during the planning stages to ensure vapor probes are not installed within the ground water table. If the desired depth cannot be reached or water is observed in the soil boring contact your project manager for further instruction.
2. Once the appropriate depth is reached, the driller will install a 6 inch stainless steel soil vapor point with ¼" tubing to the surface. The soil vapor screen will be surrounded with sand to 6 inches above the top of screen (approximately 1 foot of sand total). The remainder of the hole will be backfilled with granular bentonite to the surface. The bentonite should be hydrated at the surface to seal the point from the ambient air.
3. Upon completion, confirm that the soil vapor probe tubing is capped with a valve in the "off" direction.
4. Confirm and record the installation details of the vapor point with the driller (depth, seal, etc.)
5. If installing a permanent point, direct the driller to install a road box (flush mount cover) after verifying the soil vapor point has been installed correctly and soil vapor can be drawn from the point.
6. If the soil vapor probe is for temporary sampling, remove tubing following completion of sampling. Restore the ground surface flush to the existing grade with a material to match the surrounding surface (e.g. asphalt, concrete, bentonite).

5. Resources

Vapor Pin® Installation Video, https://vaporpin.coxcolvin.com/resources/

Vapor Pin® Installation SOP https://www.vaporpin.com/wp-content/uploads/2016/09/Vapor-Pin-SOP-09-2016-Web.pdf

United States Environmental Protection Agency Technical Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air: https://www.epa.gov/vaporintrusion/technical-guide-assessing-and-mitigating-vapor-intrusion-pathway-subsurface-vapor

6. Documentation

The probe borehole diameter, slab thickness, type of probe installed, and equipment used to install the probe should be recorded on the Vapor Intrusion Sampling form. In addition, any non-conformance or variations from standards or expectations should be documented.

Vapor Intrusion Sampling Form

7. Troubleshooting and Considerations

[Reserved]

8. Related Documents

[Reserved]

9. Version/Revision History

Version 1.0 – 27 January 2023. J. Francis, J. Flagg. A. Statkiewicz.

10. References

https://teams.langan.com/sites/HS/Programs%20and%20Policies/Underground%20Utility%20Clearance%20Guidelines%20-%20FINAL%20Rev%2012-10-13.pdf#search=utility

1. Purpose

The purpose of this standard operating procedure (SOP) is to describe the collection of soil vapor samples. The goal of this soil vapor sampling procedure is to collect soil vapor samples that reflect ambient conditions of contaminants (e.g., volatile organic compounds [VOCs], radon, methane) in the subsurface. This SOP for collecting soil vapor samples will help ensure that the project's data quality objectives (DQOs) are met. This SOP is only for soil vapor sampling; refer to the Soil Vapor Probe Installation SOP for guidance prior to sampling activities.

2. Limitations

The procedures described herein shall be followed to assure compliance with Langan's Quality Management System and Quality Management Plan ("QMS/QMP"). Note, however, that regulatory, client-specific, health & safety, or field conditions ("overriding conditions") may necessitate deviations from the procedures in this SOP to address such overriding conditions. Any proposed deviation shall be consistent with the Langan QMS/QMP and the professional standard of care, and shall be reviewed and approved by the project manager and the principal-in-charge before being implemented. All approved deviations shall be documented in the final report for the associated phase of the project.

3. Health & Safety

When working on-site, comply with the site's health/safety procedures, Langan's Corporate Health and Safety Plan, and Langan's Injury and Illness Prevention Program. All proper personal protection clothing and equipment (PPE) are to be worn. Permanent soil vapor sampling points may contain biological hazards, and some samples may contain chemical hazards. These samples must be handled with suitable protection to skin, eyes, etc. Care should also be taken to mitigate any situational hazards (i.e., traffic, equipment operation, public interaction) during sampling.

4. Methods

The methodology for soil vapor sampling includes equipment preparation, sample manifold assembly, shut-in testing, and leak-check testing. This methodology assumes that the soil vapor sampling point has been previously installed and the point is prepared with a closed valve (sample port valve) able to connect to 1/4-inch outside diameter (OD) High Density Polyethylene (HDPE) or Teflon tubing. Refer to **Section 4 Resources** for a list of the required field supplies and procedures.

Pre-Sample Collection: Construct the Helium Shroud and Sample Manifold

1. Cut three equal lengths of tubing approximately 18 inches long. Insert two of the sections of tubing through the predrilled holes on the side of a 5-gallon bucket or other appropriate plastic bucket (helium shroud), and one through the predrilled hole through the top of the helium shroud. The tubing on the sides of the helium shroud will be used to introduce and monitor helium inside the shroud. The tubing through the top of the shroud will connect to the **sample manifold**.
2. Connect a length of 1/4-inch OD tubing to the sample port valve and then to the silicone tubing through the top of the helium shroud.
3. Connect a length of 1/4-inch OD Teflon tubing to the silicone tubing outside the top of the helium shroud. Connect the other end of the tubing to a closed four-way valve. Ensure that the tubing is connected to the inlet side of the four-way valve.
4. Connect a purge pump and vacuum gauge to the perpendicular end of the four-way valve via 1/4-inch OD Teflon tubing.
5. Place the helium shroud on the ground surface and seal with modeling clay or hydrated bentonite, as necessary. Refer to Figure 1 below.

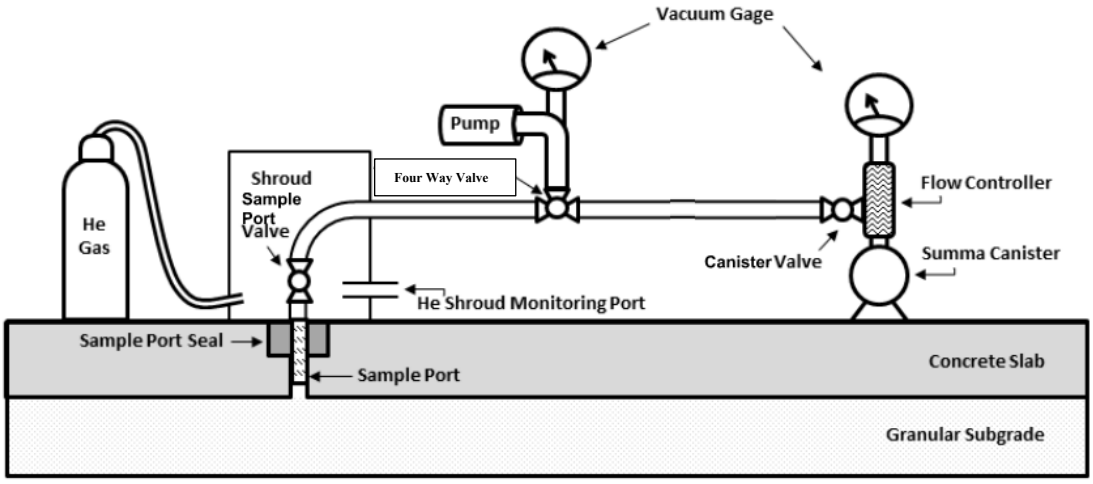


Figure 1 – Generalized Helium Shroud and Sample Manifold Diagram, Source: Wisconsin Department of Natural Resources, Sub-Slab Vapor Sampling Procedures (July 2014)

Sample Manifold Purge and Shut-In Test

1. Open the sample port valve and open the four-way valve to the purge pump. Turn the purge pump on and ensure the flow meter on the purge pump is reading 200 milliliters per minute (mL/min). Let the pump run for one minute to allow purging of potential contaminants from the sample manifold.
2. The shut-in test will involve isolating the tubing between the hand pump or purge pump and the Summa® canister. This can be achieved one of the two following ways:

a. Close the sample port valve while running the purge pump to achieve a vacuum gauge reading between 10 and 15 inches of mercury (" Hg). Close the four-way valve and shut the pump off. If the vacuum in the manifold has not changed after one minute the manifold is considered leak free. If not, repair any leaks and recheck the manifold.
b. Alternatively, use a handheld vacuum pump to induce a vacuum of between 10 and 15" Hg. If the vacuum in the manifold has not changed after one minute the manifold is considered leak free. If not, repair any leaks and recheck the manifold.

3. If the manifold is leak free, proceed to Step 4 below. If the vacuum decreases more than 10% from steps 2a and 2b above, repeat the test after taking the following steps:
    a. Inspect the sample point tubing couplings and close all valves. Check that they are snug and that there are no apparent defects in the tubing (i.e., tears or holes).
    b. Run test again with no four-way valve (only tubing between the hand pump and Summa® canister) to determine if the flow regulator is faulty and should be replaced.
    c. Run test with the valve closed toward the hand pump to check the valve itself has a tight seal.
4. Record the shut-in test data on the Soil Vapor Sampling Log.

Sample Port Purge and Leak Check (Helium Detection Method)

1. Following completion of the shut-in test, turn the sample port valve so flow is open between the installed sample probe and the purge pump. Connect either a piece of silicone tubing or a Tedlar® bag (whichever is appropriate for the type of pump) to the purge pump exhaust.
2. Assemble the MGD-2002 Helium Detector as shown in the following photograph. The tool is sensitive to vibrations so try not to move it after turning it on. After the helium detector self-calibrates to zero, insert the helium probe into the silicone tubing on the side of the shroud.



3. Attach a helium tank to the silicone tubing on one side of the helium shroud. Open the helium tank regulator and allow the shroud to fill with helium. Once the concentration reaches between 10% and 20%, turn off the helium, and

either seal the open hole with clay or fold over the tubing and secure it with a binder clip.

4. Three air volumes of soil vapor need to be purged prior to sampling. The purge time is 5-15 minutes at a flow rate of 200 mL/min. Turn the purge pump and start timing for the purge volume. Place the helium detector at the purge exhaust during the purge to observe for indications of sample port leakage (e.g. infiltration of helium-rich shroud air into the point). If a reading of greater than 10% of the concentration inside the shroud is observed, then the leak check has failed, and corrective action is required.
5. Periodically monitor the helium concentration inside the shroud with the helium gas detector and add helium, as necessary, to maintain a concentration of 10 to 20%
6. At the end of the purge, record the photoionization detector (PID) reading and maximum helium concentration of the pump exhaust on the Soil Vapor Sampling Log.
7. Optional (depending on project/client): Attach a Tedlar® bag to the exhaust of the purge pump and fill. When the Tedlar® bag is full, turn the pump off, close the four-way valve. Attach the helium detector to the Tedlar® bag to check helium concentration. If the helium detector reads less than 10% of the helium concentration in the shroud then the system is leak free and ready for sampling. Turn off the helium tank and remove.
8. If helium is detected in the pump exhaust at a concentration greater than 10% of the concentration in the helium shroud, repeat the purge after taking the following steps:
    a. Upend the helium shroud and inspect the sample point tubing couplings. Check that they are snug and there is hydrated bentonite/clay sealing any penetrations of the helium shroud.
    b. Apply a thin coat of modeling clay to the helium shroud footprint to seal the ground surface, then reseal the shroud above the sample point.
    c. If after the repeat purge, there is still helium in the sample tube, contact the project manager (PM) for further instructions.

Alternative Leak Test (Water Dam Method)

If choosing the Water Dam Method for leak detection, be sure to check that the state in which the work is being performed allows the Water Dam Method. For example, New York and Michigan do not allow this method. Additionally, note that the Water Dam Method can only be used on an impervious surface.

1. After installing the Vapor Pin®, clean a 3-inch radius around the Vapor Pin® to remove dust. Avoid wetting the concrete or wait until it is dry before proceeding.
2. Roll a 1-inch diameter ball of clay to form an approximately 7-inch long log and press it against one end of the Water Dam (PVC fitting). Press the Water Dam (end with clay) against the floor around the Vapor Pin®. Smooth out the clay as

necessary to form a tight seal against the concrete.
3. Attach the Teflon sample tubing to the top of the Vapor Pin® with silicone tubing.
4. Connect the sample tubing to a four-way valve with a small piece of silicone, and attach the other end of the valve with another piece of silicone and Teflon sampling tubing to the sample canister.
5. Carefully pour enough distilled/deionized water into the Water Dam to immerse the base of the Vapor Pin®. Make note of the height of the water column inside of the Water Dam. Some of the water may be initially absorbed by the concrete.
6. If water is lost to the sub-slab abandon the location and reinstall a new borehole and repeat test.

5. Sample Collection

1. Following successful shut-in test and leak check, the sample may be collected. To collect the sample, open the four-way valve to the sample canister and then slowly open the canister valve approximately one full turn. Record the start time on the Soil Vapor Sampling Log.
2. The sample duration is determined by the volume of the Summa® canister, the setting of the flow controller, and the underlying geology. Be aware of the anticipated sample duration and monitor the vacuum gauge closely. End the sampling by closing the canister valve when the gauge indicates the vacuum is between 2-5" Hg. This prevents any loss of vacuum in the canister and maintains the integrity of the sample during shipping. Record the sample end time and final pressure of the canister on the Soil Vapor Sampling Log. Disconnect the canister from the sampling system.
3. Remove the gauge and flow controller from the canister and tighten the canister cap on with a wrench.
4. Record the sampling date, time, canister ID, flow controller ID, and any other pertinent observations on the Soil Vapor Sampling Log.
5. Fill out the appropriate sample documentation (chain of custody, sample tracking form, etc.).
6. Disconnect the sample manifold and helium shroud from the sample port. Close the cap to the sample port (if permanent) or remove temporary ports and restore, as necessary.

6. Resources

Field resources are provided below:

Paperwork/Field Files:

- Site-specific HASP
- Project-dedicated Field Book, if one exists, or personal field book
- Sample Location Map/Collector App Loaded with Sample Locations
- Sample port construction data
- Field data from last sampling event (if applicable)

Personal Protection Equipment

- Hard hat
- Safety glasses
- Safety shoes
- Reflective vest
- Latex/Nitrile gloves
- Hearing protection

Hand Tools:

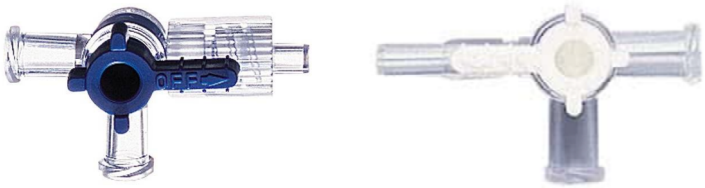
- 9/16th ratchet for removing bolts from flush-mounted road boxes (if sampling permanent vapor points)
- Field equipment:
    - Small hammer/dead blow hammer
    - Small hand brush for clearing loose material from around the soil vapor sample location
    - Leatherman® type multitool, or
        - Sharp Knife
        - Flat Head Screwdriver
        - Phillips Head Screwdriver
        - Pliers
- Adjustable wrench
- Hand pump

Sample Supplies

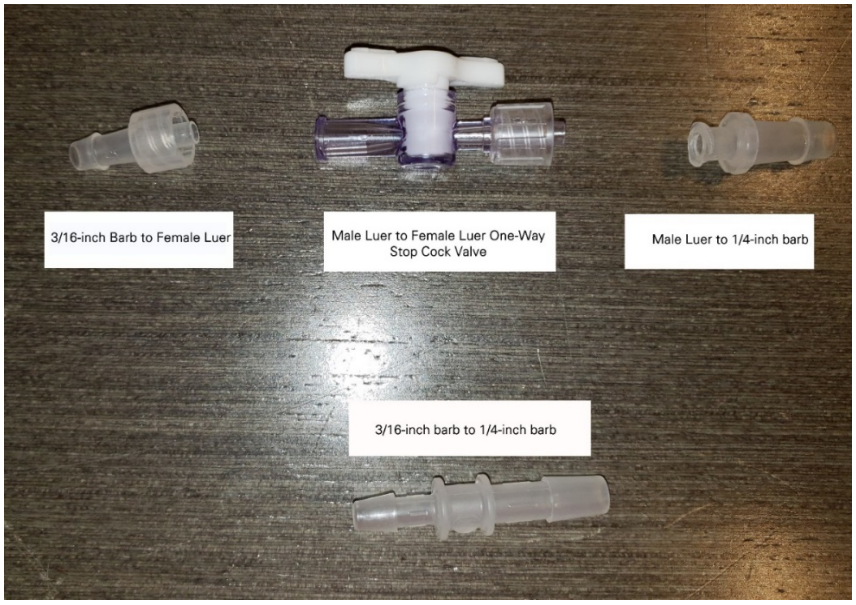
- Laboratory-provided Summa® canisters and flow controllers
- Calibrated PID
- Gillian Air Pump Plus or similar (**purge pump**). The pump must be set to 200 mL/min
- Water dam (if not using helium detection test)
- MGD-2002 Helium Detector or similar
- 99% Ultra-Pure Helium tank (103L or equivalent) *with* appropriate regulator

- **Helium Shroud**: 5-gallon bucket/6-inch PVC cap with barb fittings installed or other appropriate plastic container with three (3) precut holes or fittings:
    a. One on the side for introducing helium gas into the shroud,
    b. One on the opposite side of shroud for measuring helium concentrations with the helium detector, and
    c. One through the bottom of the bucket/PVC cap (top of shroud when inverted into the sample position).

  Depending on office location, shrouds may be available for use. Sampling kits and can also be rented through environmental rental companies. If needed, the shrouds can also be constructed.
- Tubing apparatus
    a. HDPE or Teflon tubing (1/4-inch OD, 3/16-inch inside diameter [ID])
    b. Silicone tubing (3/8-inch OD, 3/16-inch ID – small piece to make connections as necessary).
    c. Cole-Palmer **Four-Way valves** (one per sample). *Note these are called four-way valves because the valve operates in four positions, the valve actually has only three connection points.* See photo. These are one-time use only and should be discarded following use.



    d. Additional fittings which may be used include: **female and male luer fittings**, **barb fittings** and **one-way stop cock valves**:



Miscellaneous Items:
Please check with in-house supply prior to purchasing any of the following:

- No-VOC Modeling Clay (can be purchased at Walmart or a craft store) OR granulated bentonite and water for hydration
- Several 2-gallon zip lock bags
- Several garbage bags
- Tedlar® bag, optional
- Binder Clips

7. Documentation

Record field data on Soil Vapor Sampling Log Sheet, attached for reference.

8. Troubleshooting and Considerations

[Reserved]

9. Related Documents

[Reserved]

10. Version/Revision History

Version 1.0 – 4 May 2023. J. Flagg, J. Francis, J. Barger

11. Reference

USEPA Region 4. 7 February 2020. Operating Procedure – Soil Gas Sampling. Document ID LSASDPROC-307-R4.

USEPA Office of Solid Waste and Emergency Response. June 2015. OSWER Technical Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. OSWER Publication 9200.2-154.

Wisconsin Department of Natural Resources. July 2014. Sub-Slab Vapor Sampling Procedures. Document RR-986.

1. Purpose

The purpose of this standard operating procedure (SOP) for well gauging is to describe the technique for measuring depth to groundwater and non-aqueous phase liquid (NAPL) in monitoring wells and piezometers. This SOP will help ensure that depth to and thickness of NAPL and depth to groundwater are recorded consistently and accurately for subsequent determination of groundwater elevations and flow potentials.

2. Limitations

The procedures described herein shall be followed to assure compliance with Langan's Quality Management System and Quality Management Plan ("QMS/QMP"). Note, however, that regulatory, client-specific, health & safety, or field conditions ("overriding conditions") may necessitate deviations from the procedures in this SOP to address such overriding conditions. Any proposed deviation shall be consistent with the Langan QMS/QMP and the professional standard of care, and shall be reviewed and approved by the project manager and the principal-in-charge before being implemented. All approved deviations shall be documented in the final report for the associated phase of the project.

3. Health & Safety

When working on-site, comply with the site-specific Health and Safety Plan (HASP), Job Safety Analyses (JSAs), Langan's Corporate HASP, and Langan's Injury and Illness Prevention Program. All proper personal protection clothing and equipment (PPE) are to be worn. Some wells may contain biological, chemical, and pressure hazards. These wells must be opened with caution and handled with suitable protection to skin, eyes, etc.

4. Methods

Field methodology for well gauging planning, field instrument calibration, photoionization detector (PID) screening, depth to NAPL and water measurement, and equipment decontamination is provided below.

1. Develop well gauging plan – Prior to gauging wells, review field data from the last event or well installation logs if available. Wells should be gauged in order of least to most potential impact to prevent cross-contamination of wells. Evidence of impacts include known concentrations of contaminants, sheen, NAPL observed previously in wells or soil borings, or proximity to a known or suspected contamination source. The order of wells to be gauged should be planned out logistically, especially if working on a tidally influenced site where groundwater elevations have the potential to change over shorter periods of time.

2. Inspect oil/water interface probe (IP*) prior to use. Test battery and audible alarm(s). Decontaminate the probe and measuring tape if necessary. Always thoroughly rinse the probe and measuring tape with distilled water prior to every use. Surfactant residue on the probe or measuring tape can cause a NAPL reading to be missed.

   *Note, a water level indicator may be used in place of an IP only in wells with no known or suspected NAPL, as a water level indicator cannot recognize the top of NAPL. Confirm with the project manager as to which equipment should be used prior to mobilization.

3. Field instrument calibration (if applicable) – If using a PID, calibrate properly per local and manufacturer's requirements.

4. PID screening (if applicable) – Mobilize to well, donning necessary PPE per the HASP. Unlock and open well. Upon opening well, immediately measure the headspace and record the highest reading observed over a 30-second interval.

5. Equilibration time – Unlock and open the well(s). Allow sufficient time for pressure and water level in well(s) to equilibrate. A standard for equilibration time has not been established and can vary based on short/long-term climate conditions, geology, and well recharge. A suggested best management practice is to visit each monitoring well location prior to gauging to unlock and open each well and to observe and record the conditions of each well, its pad, and the adjacent surface areas. Once observations and notes are complete for all wells, return to the first well opened to begin gauging.

6. Gauge depth to light NAPL (LNAPL) and depth to water – Slowly lower decontaminated and rinsed IP into the well. The point of measurement shall be consistent across monitoring events (typically north side of the well casing or otherwise marked datum). While lowering the probe, listen for an audible alarm (check manufacturer instructions to determine type of audible alarm) to indicate presence of LNAPL, if present, above the water surface. If an alarm is sounded to indicate presence of LNAPL, slowly raise and lower the probe to observe the exact depth at which the alarm sounds and/or changes and record the depth from the top of well casing to the nearest hundredth of a foot and record the depth to LNAPL. Further lower the IP until the audible alarm changes (check manufacturer instructions for type of alarm), indicating presence of water. Slowly raise and lower the probe to observe the exact depth at which water is indicated and record the depth from the top of casing to the nearest hundredth of a foot.

7. Calculate LNAPL thickness and length of water column – Subtract the depth to LNAPL from the depth to water to obtain the LNAPL thickness. Subtract the depth to water measurement from the total depth of the well (obtained from well completion report) to calculate length of water column.

8. Total depth/dense NAPL (DNAPL) measurement – A total depth measurement should be taken after sampling of groundwater is complete (if necessary) to track well sedimentation. Measuring total depth after sampling avoids cross contamination and resuspension of settled sediments.

   If the presence of DNAPL is suspected at the bottom of a well, record the depth to water. Perform sampling as necessary, and then measure the depth to the DNAPL followed by total depth.

9. Decontaminate equipment – Decontaminate IP or water level indicator and any tools used before continuing measurements at the next well.

10. Close and lock well.

5. Resources

Field resources are provided below:

- Planning Documentation
  - HASP
  - Job Safety Analyses
  - Sampling and Analysis Plan
  - Quality Assurance Project Plan (if applicable)
  - Well location map
  - Well construction data
  - Field data from previous gauging event(s) (if applicable)
- Equipment
  - Well keys and tools to open wells
  - PID (if applicable)
  - Oil/water IP
  - Water level meter (if applicable)
  - Record keeping supplies/field tablet
  - Decontamination supplies (buckets, non-phosphate detergent, and distilled water)
  - PPE

6. Documentation

The following conditions should be noted in the field:

- Project name and number
- Well IDs
- Gauging date and time
- Depth to NAPL to the nearest 0.01 foot (if applicable)
- Depth to water to the nearest 0.01 foot

- PID reading
- Notes
    - Odors
    - Condition of well (i.e. condition of well lid, J-plug, PVC, any bolts missing or stripped)
    - Weather conditions

7. Troubleshooting and Considerations

- Instrument will not turn on (Hyperlink to Solinst Manufacturer's Guide).
- When instrument is turned on, it immediately sounds product tone or intermittent water tone (Hyperlink to Solinst Manufacturer's Guide).
- Instrument does not detect water (Hyperlink to Solinst Manufacturer's Guide).

8. Related Documents

[Reserved]

9. Version/Revision History

Version 1.0 – 23 September 2022. J.Dallmeyer, J.Flagg, C.McCarthy, C.Kakolewski, B.Blum

10. Reference

Scientific, Engineering, Response & Analytical Services (SERAS). 10 December 2002. Standard Operating Procedures, Manual Water Level Measurements. 8 pages.

USGS Office of Groundwater. 2011. Groundwater Technical Procedures of the U.S. Geological Survey. 162 pages.

STANDARD OPERATING PROCEDURE FOR MONITORING WELL INSTALLATION/ WELL DEVELOPMENT

MONITORING WELL INSTALLATION AND DEVELOPMENT PROCEDURES

Monitoring wells are installed to provide access to groundwater for collecting samples, as well as for obtaining water-level and other field data. Because monitoring wells are used to collect samples, it is important that construction materials not interfere with sample quality either by contributing contaminants. Construction materials must be compatible with (i.e., not degraded by) contaminants present in soils or groundwater.

Monitoring wells are potential contaminant migration routes between aquifers or from the surface to the subsurface. Construction procedures and standards must ensure that introduction of contaminants will not occur. Properly installed seals and locking well covers reduce the potential for cross-contamination of monitoring wells.

Equipment needed:

- Drilling or auguring equipment appropriate to site conditions, drilling depth, and other project requirements.
- Drill bits appropriate for the expected soil and rock type(s) to be encountered.
- Sufficient threaded flush-joint riser pipe of an approved material [stainless steel, polyvinyl chloride (PVC), Teflon] in convenient lengths.
- Sufficient threaded flush-joint slotted screen of an approved material (stainless steel, PVC, Teflon) to meet design criteria.
- Properly sized and washed filter pack material (quartz sand) in sufficient volume to meet well design criteria.
- Bentonite.
- Photoionization detector.
- Protective casing with locking cap.
- PPE as required.
- Weighted measuring tape.

The following steps will be followed when installing monitor wells:

1. Advance the borehole to the required depth.

2. Make up the screen for installation. The casing and screen must be decontaminated.

3. Lower the casing string into the drill casing.

4. Install the filter pack. Six inches or more of filter pack material should be spotted at the bottom of the hole, under the screen. Filter pack will be installed to 2 to 3 feet above the top of the screen.

5. Check the depth to the top of the filter pack with a weighted tape.

6. Feed bentonite onto the top of the filter pack.

7. Pure bentonite grout will be used as the annular seal, grout will be mechanically mixed with the appropriate amount of water.

8. Finish the concrete pad so that it slopes away from the wellhead. If weather conditions warrant, cover the concrete until cured. Lock the well cover.

9. Record the appropriate construction/completion information in the field logbook and on the appropriate monitoring well installation.

10. The well identification should be marked on the protective casing and PVC cap.

WELL DEVELOPMENT

Monitoring wells are developed to settle and remove fines from the filter pack. Wells should not be developed for 24 hours after completion when a bentonite grout is used to seal the annular space. Wells are purged immediately before groundwater sampling to remove stagnant water and a sample representative of groundwater conditions. Wells should be sampled within 3 hours of purging (optimum) to 24 hours after purging (maximum, for low recharge conditions).

Equipment needed:

- Pump, pump tubing, or bailer and rope or wire line.
- Water-level meter.
- Temperature, conductivity, DO, ORP, TDS, turbidity, and pH meters.
- Personnel protective equipment as specified in the site-specific HASP.
- Decontamination supplies.
- Disposal drums, if required.
- Photoionization Detector

Procedures. The following steps will be followed when developing wells:

1. Put on personnel protective clothing and equipment as specified in the site-specific HASP.

2. Open and check the condition of the wellhead, including the condition of the surveyed reference mark, if any. Use photoionization detector at wellhead to determine the presence of VOCs (if applicable).

3. Determine the depth to static water level and depth to bottom of the casing.

4. Prepare the necessary equipment for developing the well. There are a number of techniques that can be used to develop a well. Some of the more common methods are bailing and low-flow pumping.

5. Continue well development until produced water is clear and free of suspended solids.

6. Remove the pump assembly or bailers from the well, decontaminate, and cleanup the site.

7. Lock the well cover before leaving. Dispose of produced water as required by the project work plan.

SOP #08 – MONITORING WELL DEVELOPMENT

INTRODUCTION

Monitoring wells are integral to assessing groundwater conditions. View individually or as part of a well field, monitoring wells provide important data defining the quantity and quality of a groundwater aquifer. However, to provide this critical data they need to be installed and then developed correctly. Well development serves a dual purpose: it removes the residual materials remaining in the monitoring well after construction and reestablishes the natural hydraulic flow conditions of the formation that has been disturbed by the well construction. Ultimately through well development, the monitoring well becomes a transparent window into the aquifer such that the groundwater samples collected are truly representative of the quality of groundwater of the aquifer at that location.

SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to provide guidance and a methodology for Langan staff to follow when undertaking well development. As the field staffer, you may be called upon to either supervise the drilling subcontractor in meeting the well development task outline in their contract or directly charged to develop groundwater monitoring wells. Site-specific conditions may warrant modifying field practices performed in accordance with this SOP. Therefore, guidance provided in this SOP is presented in terms of general steps and strategies that should be applied when developing a well.

Developing monitoring wells follows procedures devised for the petroleum and potable well drilling industries. Both of these industries have a multitude of tools they can use for well development. However, the application envisioned in this SOP only discusses surging and pumping (overpumping) which applies directly to the development of monitoring wells typically encountered by the Langan environmental group in New York City; specifically, relatively shallow monitoring well on the order of 20 feet deep with saturated screen thicknesses between 5 and 7 feet[1].

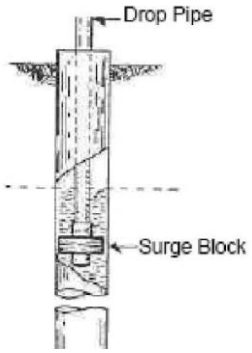
While all monitoring wells benefit from some degree of well development (removing of fines within the well itself), there isn't a large discussion in the literature of developing narrow gauge wells (less than 2 inches inside diameter). This is due in part to the origins of well development being in the petroleum and potable well drilling industries where well diameters are on the order of more than 4 inches wide and having saturated zones thicknesses extending for tens of feet. It is also due to the dearth of both the equipment and experience in developing narrow gauge wells. The smallest commercially available surge blocks are on the order of slightly less than 2 inches in diameter and there are limited options for pumping one inch diameter wells.

Surging a well entails forcing groundwater from the monitoring well across the screen back into the well pack[2] through the downstroke of the surge block and then pulling water back into the monitoring well in

[1] In selected areas of Brooklyn, depth to the groundwater table is on the order of 130 feet; nevertheless the proposed method of well development is applicable but will need to be done with a driller provided wireline rig.
[2] Sand filled zone between the well screen and the borehole, this space is commonly referred to as the well annulus and when filled with sand, the sand packed annulus is commonly referred to as the well pack.

the upstroke of the surge block. Ideally the diameter of the surge block (pictured below, left) should not be more than a ¼ inch less than the inside diameter of the monitoring well.





The surging disrupts sand bridges (voids created because the sand settles unevenly) facilitating a more uniformly compacted well pack. Surging also pull fines into the well (upstroke) which can subsequently be pumped from the well itself. On the cartoon above (right), the surge block is connected to a tremie pipe ("drop pipe") running to the surface where the driller can manually or by using the wireline on a rig, push down and pull up on the surge block.

Surging a well without a driller uses a surge block (left picture below) coupled to a foot valve (pictured on the right) connected to the surface through semi-rigid high density polyethylene tubing (HDPT). Since there is no overwork rig, surging the well is done by pulling up and pushing down on the tubing (either manually or using an inertial type pump).





Pumping (overpumping) removes sediments that have accumulated in the monitoring well. Overpumping is defined as a rate greatly in excess of what would normally be assigned for collecting groundwater samples for laboratory analysis. Recall from the Low Flow Groundwater Sampling SOP, low flow groundwater sampling attempts to maintain the groundwater level in the well within about 1/3 of a foot of the undisturbed groundwater table. Overpumping by definition is drawdowns in excess of this, the goal of which is to induce a faster rate of groundwater inflow through the screen thereby driving fines out of the well pack and clearing the screen itself.

The timing for well development and subsequent sampling is not well documented. Rather there are "rules of thumb" that have arisen within the drilling industry:

- There are a couple of items to consider when determining a wait period:

    - Wells completed in the overburden or fill with direct push technologies can be developed immediately after completion;
    - Wells completed in the clay rich unconsolidated stratigraphy using a hollow stem auger (HSA) or mud rotary may require a rest period to allow the clays some degree of relaxation before development; and
    - Wells completed in boreholes advanced using air (rotary or percussion) should be allowed to rest up to a week to allow entrapped air to be absorb into the groundwater or escape through natural buoyancy.
- Groundwater sampling should be initiated post development after a wait period of 1 to 14[3] days.

As stated earlier, developing groundwater monitoring wells is influenced by site specific conditions. Successfully developing a well can depend on how one defines development, a topic that needs to be clearly discussed and agree upon with the project manager (PM). Successfully developed monitoring wells can be defined as:

- Pumped groundwater discharge is consistently visually clear;
- Pumped groundwater discharge is demonstrably stable with respect to some or all of the water quality parameters defined by the Low Flow Groundwater Sampling SOP; or
- Achieving a certain volume of groundwater discharge.

In certain environments, groundwater is naturally stained by organic or inorganic dyes. Conventional well packing is too coarse to filter natural dye out of the groundwater. Groundwater pumped during development remains tainted or too turbid to achieve the clarity defined by conventional well development criteria. In such cases, groundwater development may be defined by either a subset of stable water quality parameters or by purged volume alone.

REQUIREMENTS FROM CONTRACTORS AND SUPPLIERS

Well development requires that materials and services be provided by outside contractors and suppliers. Conventional shallow wells can be developed without the assistance of a well driller. An exception is for deep monitoring wells where a hoist is necessary to manipulate the long tremie tube. A drilling contractor may be convenient if well development is concurrent with well installation. This should be discussed with the PM in the planning stage.

An environmental equipment rental company is required to provide the necessary equipment and disposables for Langan staff to surge and overpump the monitoring well[4]. They will also provide the water quality measuring devices if such data is required by the scope of work. Groundwater sampling is not envisioned as a part of well development; therefore, there is no laboratory requirement. This section outlines the requirements from the drillers (if used) and the environmental equipment rental company.

From the driller:
The drilling contractor can implement more traditional well development (2 inches inside diameter or greater) because they either have in their inventory the correct diameter surge block and tremie tube or have easy access to these items. Since tremie tubes are rigid, there is no need for stiff tubing to insure a sufficient downward thrust of the surge block. On the downside, unless instructed otherwise they will develop the well with worn downhole equipment (surge block, tremie tube, and plastic submersible

[3] NJDEP Field Sampling Procedures Manual, (August 2005), page 136
[4] Langan NYC uses Pine Environmental Services (Pine) for nearly all of its field environmental equipment and disposable needs

pump). These tools cannot be decontaminated and should be used with caution. Perhaps their greatest drawback is that most New York City environmental drillers use a version of the 12 volt plastic Monsoon pumps (Cyclone®, pictured below).



In addition to being plastic and nearly impossible to decontaminate, this type of pump may not be capable of creating the magnitude of drawdown sufficient to meet the overpumping requirements:

- The pump is rated at a maximum pumping rate of 1 gallon per minute (gpm) at 10 feet (depth to water [DTW]) which decreases to 0.35 gpm at 20 feet DTW; and
- Is not recommended by most resellers for well development due to their increased inefficiency when applied to wells with highly turbid water.

If the driller is contracted to develop monitoring wells, discuss with the PM whether the drillers are to use disposable equipment (or stainless steel equipment that can be decontaminated) for each well to be developed. In addition, have the drillers bring to the site the required pump (discussed below) or indicate to them that Langan will provide the pumping equipment.

From the environmental equipment rental company:

- Pump – Generally, there are three styles of pumps that can be used for well development: 1) vacuum pump (Peristaltic); 2) submersible (Monsoon, Grundfos, or Geotech); or 3) inertial (Waterra™ Hydro Lift). As a rule of thumb, pumps are not ideal for developing monitoring wells with limited recharge.[5]
    - Vacuum Pumps – The standard vacuum pump used in the environmental industry is the peristaltic pump. In general, the rental company will deliver either the Geotech Easy Load II or the Solinst 410 models (shown below left and right respectively).





The advantage of the peristaltic pump is its simple controls and ease of set up and use in the field. In addition, the pump itself does not come in contact with groundwater so there is no requirement to decontaminate. The Geotech requires 1 foot of disposable silicon tubing having an outside diameter (OD) of 3/8-inch and an inside diameter (ID) of 3/16-inch. The Solinst peristaltic pump requires 1.5 feet of silicon tubing have an OD of 5/8-inch and an ID of 3/8-inch. A new length of silicon tubing is required for each monitoring well to be developed.

The disadvantage of a peristaltic pump is its rather low pumping rate. The peristaltic pumps optimum pumping rate is between 1 and 3.5 Liters per minute (L/m) (equivalent

[5] For low recharge monitoring wells, disposable bailer to evacuate fines from the well remains an option.

to 0.26 and 0.94 gallons per minute [gpm], respectively). While peristaltic pumps are defined as constant rate, maintaining a constant discharge rate at increasing depth requires increased the rotational rate. If the groundwater is turbid, the high suspended sediment load adversely affects the silicon tubing flexibility thereby decreasing the sustained flow rate. In addition, the intake depth for the peristaltic pump is limited. Manufacturer suggests that the maximum depth ranges from 27 feet to 33 feet at sea level.

Unfortunately, there are few options for developing narrow gauged monitoring wells (1-inch diameter or less) so peristaltic pumps are generally considered the default for developing these wells. If using a peristaltic pump, order low density polyethylene tubing (LDPT). Since there is no groundwater sampled to be collected and analyzed, you need not use the more expensive LDPT Teflon™-lined tubing.

If using a Geotech peristaltic pump, order either 3/8-inch OD by ¼-inch ID LDPT or ¼-inch OD by 0.17-inch ID LDPT. If using the Solinst peristaltic pump, order ½-inch OD by 3/8-inch ID LDPT.

- Submersible Pumps – The submersible pump has been the standard for developing monitoring wells having inside diameters greater than 2 inches. While they have the capacity to initially pump at rates to meet the goal of overpumping, submersible pumps do have significant disadvantages which decrease their applicability to well development and indirectly increase the project cost to develop the monitoring wells.
    - As stated above, plastic submersible pumps are questionable to use because they usually have low discharge rates and cannot be decontaminated;
    - Pumping rates are highly dependent on groundwater head. As drawdown increases, pumping rates drop relatively quickly.
    - Most submersible pumps must be cooled by water in the monitoring well. When used to overpump the well there is the tendency for for the electric motors to burn out. The time cost to repair or change out a pump can be significant. This can be especially prevalent in turbid groundwater.
    - Sediments on the bottom of the well can clog or even jam the pump's internal impellor assembly. Again, the time to clean or repair the pump can be significant.
- Inertial Pumps – The inertial pump (Waterra™, photographed below) is ideally suited for removing both suspended and settled sediments in a monitoring well. In addition, they can be easily equipped to develop narrow gauged wells (1-inch diameter).



    - The pump requires a foot valve (shown below and equipped with a surge block) which essentially serves as a check valve connected to high density polyethylene tubing (HDPT).[6]

[6] For 1-inch ID wells, use the stainless steel foot valve #GW14008 without a surge block



On the downward thrust, the check valve opens allowing water to be pushed into the tubing while on the upward thrust, the check valve closes securing the water in place. Repeating the downward thrust force more water into the tubing pushing the water column through the tubing to the surface. Under most suspended sediment conditions the check valve will successfully close.

- The cycling up and down movement keeps sediments in suspension.
- When used with a surge block the combination can surge and pump the well simultaneously.

The disadvantages of the Waterra pumps are that they run on alternating current requiring either an outlet or generator and that they are also relatively heavy and clumsy to position over a well. Although not usually a problem for job sites in New York City, the Waterra set-up is not ideal for deep wells as the long HDPT, by virtue of its length, will retain too much flexible to efficiently pump the well.

- High Density Polyethylene Tubing (HDPT) – High density insures a suitable level of rigidity for shallow wells necessary for pushing the tubing down during the downstroke of well development. The diameter selected is based on anticipated volume of flow and the diameter of the well. Larger diameters will deliver higher flow rates but may not be suitable for anticipated low recharge wells.
- Check Valves – Constructed of either acetal thermoplastic or stainless steel. The thermoplastic valves cannot be decontaminated and are designed for single use when used in contaminated wells. The stainless steel valves can be decontaminated but require additional effort to properly decontaminate the interior portion housing the check valve mechanism. They are sized to fit the tubing selected.
- Surge Blocks – Constructed of acetal thermoplastic, the check valve fits snuggly into the center opening. However, their thermoplastic construction limits them to single use in contaminated wells.
- 5-gallon plastic buckets, at a minimum order six (6).
    - Three (3) for collecting and transporting development groundwater to drums; and
    - Three (3) for proper decontamination of field equipment.
- Distilled Water for Decontamination – Usually five (5) 2.5-gallon jugs per day.
- Decontamination cleaning agent –Alconox® is usually delivered in 4- pound (1/2-gallon) cartons, sufficient to make 52 gallons of cleaner. Check to see if there is Alconox in the environmental closet before ordering.
- 55-gallon drums – Generally, a 2-inch ID monitoring well will meet the development criteria after overpumping approximately 10 gallons. Then again, a poorly completed well or one completed in an unconsolidated fine stratigraphy may not meet the development criteria even after overpumping 25 gallons. Order drums accordingly.
- Interface probe
- PID – MiniRAE 3000 (Confirm with PM whether head space surveying is necessary)
- Multi-Parameter Water Quality Monitoring System (YSI, Horiba or equivalent) - Specify to the environmental rental company that this tool should be equipped with sensors for pH,

temperature, turbidity, dissolved oxygen, specific conductance, and ORP/Eh. (Confirm with the PM whether one is required for determining stability.)
- Bailers – Monitoring wells with poor recharge may require manually bailing.
- Nylon String – String is necessary when using bailers.

EQUIPMENT AND OTHER ITEMS NECESSARY TO BRING TO THE SITE:

- Site-specific HASP
- Site Map with well locations
- Personal Protection Equipment
    - Hard Hat
    - Safety Glasses
    - Safety Shoes
    - Reflective Vest
    - Latex/Nitrile gloves
    - Work gloves for handling drums
- Project Dedicated Field Book, if one exists
- Personal field book (if not using a project-dedicated field book)
- 9/16th ratchet for removing bolts for flush mounted road boxes
- 15/16th wrench for loosing bolt on 55-gallon drum
- Field equipment:
    - Leatherman® type multitool, or
        - Sharp Knife
        - Flat Head Screwdriver
        - Phillips Head Screwdriver
        - Pliers
    - Small hammer
- Drum labels (green Non-Hazardous) and indelible-ink pens
- Alconox (check the environmental closet)
- Clean rags for washing equipment during decontamination (environmental closet)
- Large diameter funnel for controlled pours of development water into 55-gallon drums (you can convert the 2.5 gallon DI water containers to a funnel, refer to the appendix at the end of this document).
- Absorbent Pads in the event product is encountered (environmental closet).
- Plastic sheeting (environmental closet or purchase a drop sheet from a local hardware store)
- Garbage bags (environmental closet)
- Camera

ON-SITE ACTIVITIES:

On-Site Preparation:
- Sign the HASP; have the sub-contractor sign the HASP if they are hired by Langan.
- Turn on and calibrate the MultiRAE PID and the Multi-Parameter Water Quality Monitoring tool; record calibration data in the field book.

Set Up Equipment Decontamination Wash:
- Prepare the three bucket decontamination station: wash, rinse and final rinse. If development does not include a submersible pump and all downhole equipment is disposable, you will only need to set up a wash and rinse bucket for the interface probe.

  - Prepare a 3±-gallon solution of decontamination fluid in a 5-gallon bucket. Alconox is concentrated, use the minimum amount in accordance with the manufacturer's instructions and mix with the DI water provided by the equipment supplier.
  - Pour 3± DI water into a second 5-gallon bucket "Rinse Bucket"
  - Pour 3± DI water into a third 5-gallon bucket "Final Rinse Bucket"
- Immerse the interface probe and pump into decontamination solution. Use a clean rag to wipe down the equipment with decontamination solution.
- The submersible pump must pump decontamination fluid through its interior during decontamination. Connect the pump to the controller and the controller to the battery (REMEMBER **RED** IS **POSITIVE** AND **BLACK** IS **NEGATIVE**) and start the pump at a low setting. Allow decontamination fluid to circulate through the pump for a minute or so.
- Complete a rinse and final rinse using the appropriately identified buckets. Again you must run the both solutions through the submersible pump.
- Place decontaminated equipment on a clean sheet of plastic.

Gauge Depth to Water:

- Remove the covers from each well box and inspect the well box condition. Note in the field book the road box's overall condition, whether it was correctly bolted down when you arrived and whether it had debris or water collecting around the well riser. Remove any debris or water that may slip into the well prior to removing the well cap. Have an absorbent pad handy (photographed below).



- If headspace data is required, remove the well cap, insert PID tip into well and record PID reading. Note that the PID reading might drift somewhat because of the well's interior high humidity.
- Insert interface probe and record depth to water. Depth to water should be recorded from the survey mark at top of casing. If the well has not been surveyed, record depth to water from the top of casing at the north direction point of the casing. Mark that point on the casing and record the depth in the field book. Whenever possible, record depth to water for all wells specified in the work plan for gauging prior to developing.

Surging the Well:

If the drillers are surging the well, they should attach a surge block to tremie pipe; otherwise:

- Couple the surge block and check valve assembly. Connect the surge valve assembly to the HDPT and insert into the well.
- The following is the recommended procedure for surging the well:
  - If the thickness of the saturated zone is less than 5 feet, gently lower and raise the surge block through the saturated zone.
  - If the thickness of the saturated zone is greater than 10 feet, gently lower and raise the surge valve through 5 feet intervals starting on from the top segment of the saturated zone working your way to the bottom.
  - You will notice a decrease in the resistance to the downward and upward motion of the surge block. As the resistance decreases, increase the frequency of the surging motion.

If developing in sections, move down to the next section after the resistance to surging minimizes to a constant.

Pumping the Well:

- If using the surge block coupled with the check valve proceed to the subsection below for using the Waterra™ pump.
- Submersible Pump
    - Attached tubing to the hose barb at the top of the pump.
    - Carefully lower pump into well. When lowering pump, feed the tubing and electrical line as a unit. Do not handle either separately as you might disconnect the tubing or short the electrical line, see below:



    - Set pump approximately 2-feet off bottom. Secure pump.
    - Cut the tubing about 3 feet above the road box.
- Peristaltic Pump
    - Insert the silicon tubing into the roller pump driver (refer to manufacturer's instructions).
    - Lower the tubing to within 2 feet of the wells total depth.
    - Secure tubing using twist ties to the rabbit ears on the well box or other secure surface item. Cut the tubing about 3 feet above grade. Clear burrs from the cut tubing end and secure to one side of the silicon tubing you connect to the pump in the previous step.
- Waterra™ Pump
  Having used the surge block-check valve assembly to surge the well, attach the HDPT to the lever of the Waterra™ pump. Refer to the owner's manual for instructions.
- Initiate Pumping
    - Peristaltic and Submersible Pump
        - Connect either pump to their battery source. The submersible pump has a control box that links to the 12 volt marine battery. When connecting the 12 volt battery to the control box connect positive to positive and negative to negative (recall: **RED** is **POSITIVE** and **BLACK** is **NEGATIVE)**
        - Check that the control box reads zero volts and then connect the control box to the pump.
        - The peristaltic pump uses a cigarette type junction for connecting the battery to the pump. Inspect the connectors to see that they are dry and free of debris and then join the connectors.
        - The submersible pump is controlled by increasing or decreasing voltage. The peristaltic pump has a dial that controls both the rotation direction and speed of the rollers.
    - The Waterra™ pump connects directly to the generator (or standard 120 volt outlet). Before connecting to the generator, start the generator following the manufacturer's instructions. Prior to connecting the Waterra™ power cord to the generator, check that

the pump power switch is off, and then plug into the generator's standard 120 volt outlet.

- Adjust the pump controls to induce significant drawdown in the well (approximately ¼ the saturated depth). If using a submersible pump, it is recommended that you chase the falling water level with the interface probe. Do not allow the water level to fall within a foot of the submersible pump to prevent overheating. When there is a layer of sediments on the bottom of the well, the sediments need to be agitated to disperse into the water column to avoid blocking the pump intake or impellor. Too high a turbidity can cause the pump to overheat and burn out, so agitate in short discrete intervals.
- Pump the well until the discharge water runs clear.
- Record total water volume pumped from monitoring well during each cycle of development.

Repeat Surging and Pumping the Well:

- Pull the submersible or peristaltic pump and reinsert the HDPT/surge block into the well and repeat the surging motion.
- This process of surging and pumping should continue until initial water quality after surging is clear.

Collect Water Quality Data (If Required):

- If collecting water quality data is required by the scope of work, after the final surging cycle is completed, collect the pump discharge into the calibration cup of the Water Quality Indicator.
- Insert water quality tool into the calibration cup and allow the temperature to equalize.
- Record data

Proceed to Next Monitoring Well to be Develop

- Upon completing well development reinstall well cap. Be sure that the lip onto which the road box lid sits is clean of dirt and debris. Place the lid on the road box and bolt it to hand tight level. Please do not torque it down as this will make the next person's job that much harder and will damage the rabbit ears. Prior to developing the next monitoring well, the pump, interface probe and stainless steel check valve (if used) must be decontaminated following the procedure specified earlier.
- Repeat set up, well development and decontamination procedures for each monitoring well development location.

Well Completion Summary

This SOP incorporates a modified Well Construction Log Form titled Well Completion Summary (WCS). In addition to the information required on the well completion form, the WCS has a section summarizing the well development completed. The form in located on the server under Well Completion Summary. The first plate is the form and the second plate is a brief set of instructions. Complete a WCS for each well developed.

Post Well Development:

- All used tubing, gloves and assorted disposables should be packaged in doubled lined plastic garbage bags and disposed of in the nearest sanitary waste receptacle.
- Seal drums and check that all drums are properly labeled
- End of Day Actions
    - Complete the daily report with attached site photographs and forward to PM.
    - Transfer all environmental rental equipment back to office, log into return inventory and email environmental rental agency to end contract and notify of pick-up. Unopened materials obtained from environmental rental agency should be returned to them, log in each and note this on email. Your account will be credited.
    - Scan field notes to the project folder

APPENDIX

Create a Funnel Using the 2.5 gallon DI Water Container

All development purge water needs to be transported to a 55-gallon drum and the drum must be labeled with a green Non-Hazardous Waste label in accordance with the Drum Label SOP. If the 55-gallon drum has a bung fitting on the top lid, it is best to pour water into the bung opening. You can create a funnel from the Distilled/DI water box provided by the environmental rental company.

1) Open the bottom of the DI cardboard container.
2) Cut off the bottom of the plastic liner.
3) Fold the flabs from the bottom of the DI container inside to hold the sides of the plastic liner in place.
4) Place the spout opening of the DI container (the top) on the bund opening of the drum and pour the development purge water into the box opening.
5)



REFERENCES AND ADDITIONAL MATERIALS

A list of links discussed in this SOP and links for owner's manuals for equipment specified is provided below:

MultiRAE Owner's Manual

The RAE PID Handbook

Geotech Easy Load II Peristaltic Pump Manual

Solinst 410 Peristaltic Pump Manual

U-50 Manual – Water Quality Meter Probe

Waterra™ Hydrolift Manual

Waterra™ Hydrolift Tear Sheet

Waterra™ Lever Pump Tear Sheet

Well Development Checklist

Drum Label SOP

1. Purpose

The purpose of this Standard Operating Procedure (SOP) is to describe soil-sampling methods using "Direct-Push" (DP) techniques, such as Geoprobe®, Enviro-core®, and cone penetrometer testing (CPT). DP technology is effective for application in unconsolidated formations consisting primarily of sand, silt, and clay with some gravel. DP machines advance sampling and logging tools into the subsurface using a percussion hammer and vehicle weight, sometimes to depths exceeding 100 ft. DP tools are not for use in consolidated rock like limestone, granite or gneiss. This procedure gives descriptions of equipment, field procedures, and quality assurance/quality control (QA/QC) procedures necessary to collect soil samples using DP techniques. The soil sampling techniques described in this SOP are generally suitable for samples analyzed for chemical characterization and physical classification tests. However, because of the narrow diameter of the DP probe, the resulting soil samples should generally be considered "disturbed" with respect to physical structure and may not be suitable for measuring sensitive physical parameters, such as strength and compressibility.

This SOP provides protocols and procedures for initial scoping/planning/preparation, pre-sampling procedures, sampling methods using DP techniques, post-sample collection procedures and documentation, other resources and considerations, and select reference materials. These are SOPs (i.e., typically applicable), which can be varied or changed as required, depending on site conditions, equipment limitations, or other procedural limitations, as encountered. In all instances, any deviations from the SOPs should be discussed with the field team leader/project manager before proceeding and the ultimate procedures should be documented.

2. Limitations

The procedures described herein shall be followed to assure compliance with Langan's Quality Management System and Quality Management Plan ("QMS/QMP"). Note, however, that regulatory, client-specific, health & safety, or field conditions ("overriding conditions") may necessitate deviations from the procedures in this SOP to address such overriding conditions. Any proposed deviation shall be consistent with the Langan QMS/QMP and the professional standard of care, and shall be reviewed and approved by the project manager and the principal-in-charge before being implemented. All approved deviations shall be documented in the final report for the associated phase of the project.

3. Health & Safety

When working on-site, comply with the site's health/safety procedures, Langan's Corporate Health and Safety Plan (HASP), and Langan's Injury and Illness Prevention Program. All proper personal protection clothing and equipment (PPE) are to be worn and should be documented in the project HASP, Job Safety Analysis (JSA), etc. Sampling activities must follow proper health & safety protocols and samples shall be handled with suitable protection to skin, eyes, etc.

4. Scope, Application, and Planning

Site-specific conditions may warrant modifying field practices performed in accordance with this SOP. Therefore, guidance provided in this SOP is presented in terms of general steps and strategies that should be applied when approaching an investigation involving soil sampling using DP techniques.

The project manager (PM) and field development team are responsible for providing the proposed soil sample locations. Coordinate site access with the client or site manager and ensure you have access to each soil sample location.

5. Methods

Common DP methods for the collection of soil samples include single-tube and dual-tube approaches. Single-tube methods use a single string of rods or casing to advance the sampler into the subsurface and samples are recovered incrementally as the boring is advanced. These methods are typically quicker and more efficient for shallow applications (<20 ft). Samples are tripped out of the boring through the uncased borehole so formation collapse and cross contamination in non-cohesive and saturated formations may be problematic. However, closed piston, single-tube samplers can provide high-integrity samples under most formation conditions. Dual-tube samplers utilize concentric casings to advance the borings. The outer casing remains in place as the inner casing is used to trip out the sample as the boring is advanced incrementally. The outer casing prevents borehole collapse and generally reduces the potential for cross contamination between sampling intervals.

A certified driller will use the appropriate drilling equipment to advance the DP probe and sampler to the appropriate depth. The driller will retrieve the soil boring acetate liner from within the sampler. The Langan personnel will then log the lithology of the boring in the field book, boring log form, Collector App, etc., and screen the soil boring with a photoionization detector (PID) for potential environmental impacts, as prescribed in the site-specific work plan(s). Once the analytical sample intervals and method(s) have been confirmed, volatile organic compounds (VOCs) samples will be collected first, and the remaining analytical samples will be collected using clean, stainless steel or disposal spoons from the prescribed sample interval.

On-Site Preparation:

- Sign the HASP; have the sub-contractor review/sign the HASP if they are hired by Langan.
- If not already calibrated by the environmental equipment rental company, turn on and calibrate PID in accordance with the manufacturer's instructions, and record calibration in the field book.

DP Soil Sampling Protocol

- Direct the driller where to advance the soil boring and at what depth the soil boring should be advanced. This information is based on the site-specific work plan(s). Wear proper

head (i.e., hard hat) eye, hearing and hand protection. Stay clear of equipment during operation.

- The driller will advance and extract the soil sampler and acetate liner. When removed, confirm with the driller which end is the top and which end is the bottom. Record the time of core collection, the soil boring ID, and the depth interval (in feet below ground surface [bgs]) in the field book, boring logs, Collector App, etc.
- With proper personal protective equipment and the utmost caution and safe procedures, vertically cut (with the cut directed away from your body) the acetate liner using a retractable safety blade and proper glove wear (i.e., Kevlar gloves, cut resistant gloves, etc.). Set the liner with the exposed soil sample on a clean sheet of poly sheeting for proper classification and description and screening. There are available cutting tools that are designed for safe and easier cutting of the acetate liner. The driller may open the liner on your behalf.
- Measure the length of recovered soil and record in the field book, boring logs, Collector App, etc.
- Log soil lithology in half-foot intervals or wherever there is a change in lithology or other observed physical characteristic and record PID readings at each half-foot interval. Soil should be classified using the system specified in the site-specific work plan(s) (modified Burmister Classification System, USCS, or other) and recorded in the field book, boring logs, Collector App, etc.
- Use fresh, clean nitrile gloves between individual sample collection.
- Screen soil with the PID in accordance with the requirements of site-specific work plan(s). Transfer soil to a driller's jar, cover the jar with aluminum foil, and seal. Alternatively, transfer soil to a re-sealable plastic bag and seal the bag. Label each sample container/archive sample container using the boring location ID, sample depth, date and other sample nomenclature as per the project work plan or Langan SOPs. Allow the headspace to volatilize for 5 to 15 minutes. Puncture the aluminum foil or re-sealable bag with the PID to measure the approximate volatility of the sample location. Record screening measurements in the field book, boring logs, Collector App, etc.
- Use laboratory-provided sample containers specific to required analytical parameters, and label appropriate sample containers according to the site-specific work plan(s), Langan's sample nomenclature SOPs, etc.
- Use dedicated, disposable sampling equipment for each sample location. If this is not possible, thorough decontamination of stainless steel sampling equipment is required prior to use and in between sampling locations. A rinsate blank(s) may be required each day; refer to site-specific work plans. See Equipment Decontamination SOP.
- Collect soil for VOCs analysis:
    - Samples for VOCs should not be homogenized/composited and should be collected in-situ, if possible, or directly from the opened acetate liner.
    - When sampling for VOCs, do not agitate the soil sample matrix to minimize the loss of VOCs during collection.
    - Collect samples for VOCs using laboratory-provided TerraCrore samplers or EnCore samplers, and place into the appropriate, labeled sample containers.

- Following the collection of VOCs samples, the remaining samples for analyses should be prepared:
    - Stones, gravel, vegetation, and other large clasts should be removed from the soil sample as much as possible prior to placement in analytical sample containers.
    - When collecting grab samples, use clean/uncontaminated tools to transfer the soil from the sample location (or acetate liner) to the sample container with as little disturbance as possible.
    - When collecting composite soil samples, use a decontaminated stainless steel bowl or a re-sealable plastic bag to homogenize soil prior to placing soil into a sample container.
    - Place the sample into the appropriate, labeled sample containers using the alternate shoveling method: place a similar volume of soil into each container in sequence and repeat until all containers are full.
    - Wipe the sample container lid clean to ensure a tight seal when closed.
- Collect QA/QC samples in accordance with the site-specific work plan(s). These may include, but are not limited to, duplicates, matrix spike/matrix spike duplicates (MS/MSD), field blanks, temperature blanks, trip blanks, rinsate blanks, etc.
    - Typical QA/QC protocols are 1 duplicate sample per 10 samples, 1 MS/MSD sample per 20 samples, 1 temperature blank per cooler, 1 trip blank per cooler with samples for VOCs, and 1 field blank/rinsate blank per day when sampling tools are decontaminated.
- Ensure sample container lids are secure and confirm sample label includes:
    - Project name,
    - Sample ID,
    - Sample date,
    - Sample time of collection (each sample receives a unique sample time, there should not be two or more samples with the same sample time),
    - Analysis,
    - Preservative, and
    - Sampler's initials.
- Document sample information in field book, boring logs, Collector App, etc., as prescribed in the site-specific work plan(s). The sample collection time, sample ID, sample parameters, and sample container used should be legibly marked in the field book and match the information on the sample container label and Chain of Custody (CoC).
- Document sample information on CoC. Refer to CoC SOP for additional information.
- Place sample containers into a clean re-sealable plastic bag, then place the bag in a cooler with ice to preserve sample quality. Refer to the site-specific work plan(s) or ask the PM for additional information regarding sample preservation, packing, and shipping.

Between DP Soil Sampling Locations and End of Day:

- Decontaminate any tools used to collect the sample between each sample location to mitigate potential cross-contamination of samples. Refer to the site-specific work plan(s) or Decontamination SOP for additional information.

- Dispose of disposable tools in trash bag and as specified by site-specific work plan(s).
- Following sample collection and boring completion, backfill boring with bentonite chips, bentonite slurry, drill cuttings, etc., or as specified in the site-specific work plan. Excess soil should be managed per the Langan Investigation Derived Waste (IDW) SOP. Management of IDW will be conducted in accordance with applicable Federal and State regulations, as well as regulations set at a county or municipal level.
- End of Day Actions:
    - Complete the daily report with attached site photographs, including a photograph of the completed CoC and forward them to PM. Transfer all environmental rental equipment back to office, log into return inventory (if available) and email environmental rental agency to end contract and notify of pick-up. Unopened materials obtained from environmental rental agency should be returned to them. Record each item and note them in an email to the vendor or supplier of equipment and request a credit for any unused equipment.
    - Scan field notes and printed borings logs (if completed) and save them to the project folder.

6. Resources

DP soil sampling requires that materials and services be provided by outside contractors and suppliers. The drilling subcontractor will provide the appropriate drilling and sampling tools and driller's jars. An environmental rental company may provide a PID to screen the soil for potential environmental impacts. Laboratory suppliers will provide the sample containers and perform analytical testing of the samples. This section outlines the requirements from each entity.

From the drilling subcontractor:

- Direct-push drill rig with appropriate drilling and sampling tools.
- Driller's jar. These are not analytical soil sampling jars.
- Sampling method:
    - Thin-walled tub sampler, and
    - Acetate liners.

From the environmental equipment rental company:

- PID: Use a PID with a 10.6 eV lamp (or as appropriate for screening VOCs) and a measurement range of 1 ppm to 10,000 ppm with a 1 ppm resolution.
    - PID user manual, and
    - PID calibration gas and equipment (regulator).

From the laboratory contractor:

- Sampling jars – before ordering, check work plan(s) and confirm the scope with the PM. While not required, it is advisable and good practice to order spare sampling jars as a contingency but there may be incremental costs.
- QA/QC Sampling – QA/QC samples include collection of duplicate, trip blank, rinsate/equipment blank, field blank, and MS/MSD samples in accordance with the site-

specific work plan(s). Refer to the site-specific work plan(s) and ask your PM which QA/QC samples will be collected and for what analyses.

- CoC Form – follow standard sample nomenclature when completing the CoC and the sample identification of the soil sample jars. Sample nomenclature is defined in the work plan, Quality Assurance Project Plan (QAPP), or Langan's sample nomenclature SOP.

From Langan personnel:

- Planning Documentation:
    - Health and Safety Plan – inquire about any site-specific safety requirements/policies,
    - Sampling and Analysis Plan/work plan(s)/proposal,
    - QAPP (if applicable),
    - Printed sample location maps and figures,
    - Printed field sheets/boring logs, and/or
    - Client contact and site contact for coordinating access.

- Equipment:
    - PPE, as specified in the HASP (at minimum, Level D),
    - Project-dedicated Field Book, if one exists,
    - Personal field book (if not using a project-dedicated field book),
    - GPS or survey equipment,
    - Mobile field tablet with GIS maps and Collector App,
    - Steel pin flags, or wooden stakes and spray paint/high-visibility flashing,
    - Measuring tape or field ruler,
    - Stainless steel pocket knife,
    - Stainless steel mixing bowl,
    - Stainless steel or disposal scoops,
    - Retractable safety blade (to open acetate liners, often provided by driller),
    - Kevlar or cut-resistant gloves (if you are cutting open acetate liners),
    - Disposable nitrile or latex gloves,
    - Paper towels,
    - Waterproof and permanent marking pens/marker (e.g., Sharpie® markers),
    - Re-sealable plastic bags (to screen soil with PID, to composite soil samples, and/or store sample containers),
    - Aluminum foil,
    - Appropriate decontamination supplies:
        - Distilled water,
        - Alconox or equivalent (e.g., Simple Green),
        - Decontamination brush,
        - Plastic sheeting,
        - Trash bags or container for waste (drum or bucket, 5-gallon), and
        - Labels for waste container,
    - Camera, and/or
    - Thin-wall tube sampler.

7. Documentation

Soil sample information (field observations, soil lithology, PID screening, sample depth, sample time, etc.) should be recorded on appropriate field sampling form(s) and/or entered into the Collector App. An example boring log is attached. Document non-conformances or variances from SOPs, if any.

8. Troubleshooting and Considerations

a. Improper sample collection:

   Improper sample collection can involve using contaminated equipment/PPE, an incorrect ratio of soil to preservative (where required), or poor/inadequate homogenization of the samples (where required), resulting in non-representative results. Care should be taken to use clean equipment/PPE, achieve the appropriate soil to preservative ratio, and fully homogenize samples. If improper sample collection is suspected while still in the field, re-collect soil samples.

b. Poor sample recovery:

   If the acetate sleeve does not have a sufficient amount of soil to fill sampling jars, direct the drilling subcontractor to advance a boring that is offset within 1 foot of the completed boring location. Advance the offset boring to the proposed sampling depth to recover additional soil for preparing samples to complete required analyses. Continue to advance offset borings until a sufficient amount of soil is recovered at the proposed sampling depth to fill sampling jars. Note the fact that offset borings were used and for which samples/analytical parameters.

c. Improper sample management:

   Ensure all sample information (sample ID, sample times, analytical parameters) are correct and consistent between the sample label, field book, CoC, and Collector App in accordance with site-specific work plans and sample nomenclature. Incorrect sample identification could result in re-sampling if the location information of the sample is unknown.

d. Poor-quality sample containers:

   If sample container is damaged (broken, cracked, appears to lack the appropriate amount of preservative, etc.) replace the damaged/inadequate sample container with an extra sample container, if available. It is a good practice to bring a few additional sampling containers above the minimum required by the work plan(s) to compensate for damage or otherwise inadequate sampling containers. If extra containers are not available, contact the laboratory immediately to see if they can deliver a replacement in time to meet required sampling. Evaluate timing and options, and then discuss approach with PM before abandoning sampling or modifying scope.

9. Related Documents

[Reserved]

10. Version/Revision History

Version 0.0 – 27 October 2022. C. Sobchuk, C. Chin Fatt

11. Reference

Langan teams should research and review local and state agency guidance documents and/or regulatory requirements that may be relevant for their projects and could potentially slightly differ from the procedures specified herein. The references below are provided as they have been found to be worthy resources; however, this is not an exhaustive list of applicable references.

ASTM D6282/D6282M-14
Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations

1. Purpose

The purpose of this standard operating procedure (SOP) is to outline low flow sampling (LFS). LFS procedure, when properly applied, should collect a sample of groundwater that most closely resembles the water quality in the screened zone. LFS minimizes stress imposed on groundwater in the well that may affect the chemical and colloidal signature of groundwater. As a biproduct of LFS sampling, the volume of purge water collected is generally minimized, reducing the cost of waste disposal (ASTM International, 2002 [updated 2021]; Puls & Barcelona, 1996). This SOP for collecting groundwater samples will help ensure that the project's data quality objectives (DQOs) are met under low-flow conditions.

2. Limitations

The procedures described herein shall be followed to assure compliance with Langan's Quality Management System and Quality Management Plan ("QMS/QMP"). Note, however, that regulatory, client-specific, health & safety, or field conditions ("overriding conditions") may necessitate deviations from the procedures in this SOP to address such overriding conditions. Any proposed deviation shall be consistent with the Langan QMS/QMP and the professional standard of care and shall be reviewed and approved by the project manager (PM) and the principal-in-charge (PIC) before being implemented. All approved deviations shall be documented in the final report for the associated phase of the project.

This SOP is not intended for sampling emerging contaminants including per- and polyfluoroalkyl substances (PFAS). Refer to Section 8 (Related Documents) for guidance and best practices for PFAS sampling.

3. Health & Safety

When working on-site, comply with the site's health/safety procedures, Langan's Site Specific Health and Safety Plan (HASP), and Langan's Injury and Illness Prevention Program. All proper personal protection clothing and equipment (PPE) are to be worn. Some samples may contain biological and chemical hazards. These samples must be handled with suitable protection to skin, eyes, etc.

4. Methods

Field methodology for field instrument calibration, depth to water measurement, pump installation, well purging, water quality monitoring, sampling procedures, and equipment decontamination are provided below. Prior to sampling, review the project sampling plan, Recommended Practices, and Technical Guidance reports, where cited, and ensure the location and well construction data are available for reference. If possible, sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred. Refer to Section 5 (Resources) for a list of the required field supplies, equipment, and procedures. *Reminder: ice must be on-hand before the start of sampling. Langan requires all samples to be put on ice when collected.*

1. Well inspection and gauging - follow the Well Gauging SOP.
2. Equipment setup.
    a. Each morning prior to 1st use, decontaminate all non-dedicated sampling equipment that contact sampling media (e.g., submersible pump, or bladder pump [excluding disposable bladder]), using the 3-bucket method:
        i. 1st bucket: Alconox™ (or other approved cleaner) dissolved in tap or standard bottled water with clean rag
        ii. 2nd bucket: tap or bottled water rinse bucket
        iii. 3rd bucket: Deionized water rinse bucket.
    b. Instrument Calibration
        i. The water quality meter and photoionization detector (PID) shall be properly inspected and calibrated per local and manufacturers requirements. Record calibration information in the field book and post the PID calibration information to the HASP Calibration Log (HASP/CHASP Attachment D).
    c. Install submersible pump or tubing intake (peristaltic pumps).
        i. The pump intake should be placed about 1 foot above the bottom of the well when saturated portion of the screen is less than 8 feet, or the well is expected to undergo significant dewatering before the head stabilizes (limited recharge). The US Environmental Protection Agency (USEPA) recommends pump intake should be in the middle of the saturated screened interval (Puls & Barcelona, 1996); however, this may not be practical for most wells completed as part of an investigation.
        ii. Take care to minimize the disturbance of sediments at the well bottom.
3. Well purging – begin pumping.
    a. Set your purge pumping rate.
        i. The USEPA recommends a flow rate within the range of 100 to 500 milliliters per minute (mL/min), depending on site-specific hydrogeology (Puls & Barcelona, 1996). As many investigation wells are generally characterized as having limited recharge, this SOP recommends biasing flow rates to the lower end of this spectrum. At a minimum for LFS, pumping must be continuous; setting the pumping rate so low as the pump ceases to discharge while operating, or the pump shuts down (insufficient voltage) disqualifies LFS.
        ii. Calculate and record pumping rate when purging starts and whenever the pumping rate is modified during purging:
            - The field form calculation based on the volume of water in the discharge bucket is an estimate and is not considered a viable representation of pumping rate.

iii. Calculate flow rate by recording the time, in seconds, it takes to fill a container of known volume with water and report the value in milliliters per minute.

b. Monitor relative groundwater head.
   i. The USEPA defines LFS stability as a head loss of less than 1/3-ft. This standard of head loss is generally unachievable for wells completed as part of an investigation.
   ii. Head is to be monitored and recorded, along with other water quality parameters; however, it is not a consideration in determining stability, provided the well does not run dry during purging.

c. Monitor water quality parameters.
   i. Monitor and record head and water quality parameters (i.e., temperature, specific conductance, dissolved oxygen (DO), potential of hydrogen (pH), oxidation reduction potential (ORP), and turbidity) every five minutes until readings are stable. Stability is defined as having three consecutive readings within the following limits for all parameters (Reinhart, 1996):

      3% for temperature
      3% for specific conductance
      10% for DO, or three consecutive values are less than 0.5 mg/L
      10% for turbidity, or three consecutive values less than 5 Nephelometric Turbidity Units (NTU)
      ± 0.1 for pH
      ± 10 millivolts for ORP

   ii. Turbidity must be below 50 NTU prior to groundwater monitoring well sampling for metals analysis (NYSDEC, 2010).
   iii. If parameter stability is not achieved after 1 hour (including if drawdown stability not achieved), contact the PM. The options are to (1) immediately sample or (2) continue to pump until stability is achieved. Purging a well dry, allowing recharge, and taking a sample is not an equivalent to LFS, but may be an acceptable alternative if decided by the PM. Any sampling deviation from LFS must be done in consultation with the PM and documented in the field book. If these decisions are discussed prior to field mobilization (e.g., during kickoff), this should be documented in field notes.

4. Sample collection.

   a. Upon stabilized, begin to collect groundwater.
   b. The flow rate during sampling is not to be accelerated or otherwise modified, from the purge rate.

c. Unless otherwise directed by the project team, the sampling order of collection is:
    i. Volatile Organic Compounds (VOCs)
    ii. Semi-Volatile Organic Compounds (VOCs)
    iii. Herbicides, Pesticides, PCB
    iv. Total Metals
    v. Dissolved Metals, collected through the 0.45-micron filter.
d. Samples are never collected from the flow cell. When filling sampling glassware, the discharge tubing from the pump should not extend below the rim of the sample bottle.

5. Post Sampling
    a. Remove pump and tubing from well
        i. Discard tubing; tubing cannot be used at another well.
        ii. Pumps:
            - Peristaltic Pump – silicon tubing must be replaced between wells.
            - Submersible Pump – decontaminated using the 3-bucket method, described above (see Section 4.2a).
            - Bladder Pump – Replace bladder and other disposable parts, use the 3-bucket method to clean non-disposable parts.
            - Note: after sampling the last well of the day, non-dedicated sampling equipment may be rinsed, to be decontaminated at the start of the next sampling day.
    b. Secured the J-plug and road box lid with bolts - If bolts, bolt washer, or lid seal are missing, replace them. All bolts must be completely flush with the road box lid.
6. Review and verify all field documentation and chain-of-custody forms.
7. Transport samples under ice to the laboratory in accordance with the Chain of Custody COC.

5. Resources

Field resources are provided below:

- <u>Paperwork/field files:</u>
    - Site-specific HASP
    - Project-dedicated Field Book, if one exists, or personal field book
    - Sampling and Analysis Plan
    - Quality Assurance Project Plan (if applicable)
    - Additional appropriate SOPs (see Section 8, below)
    - Sample Location Map/Collector App Loaded with Sample Locations
    - Well construction data
    - Field data from previous sampling event(s) (if applicable)

- Equipment:
  - Well keys
  - 9/16- or 3/8th-inch ratchet or wrench (to remove bolts)
  - PID
  - Water quality meter and flow-through cell
  - Water pump and tubing
  - Safety cable (if using a submersible pump)
  - Oil/water interface probe
  - Flow measurement device
  - Sample bottles/Labels/Cooler/Ice/Chain of custody
  - Record keeping supplies/Electronic field tablet
  - Decontamination supplies
  - Drums and buckets (including drum labels)
  - PPE
  - 1- and/or 2-gallon zip lock bags
  - Garbage bags
  - Tedlar® bag (or bypass valve) for PID calibration
  - Spring clips
  - Spare well box bolts, washers, gasket, and J-plug

6. Documentation

Groundwater quality parameters should be recorded on the Low Flow Sampling Form until stability or time-limits are reached. Document any non-conformances or variances from standards. Refer to the Sample Nomenclature and Chain of Custody SOPs.

7. Troubleshooting and Considerations

[RESERVED]

8. Related Documents

- Low Flow Sampling Form (LINK)
- Sample Nomenclature SOP (LINK)
- Well Gauging SOP (LINK)
- Drum Label SOP (LINK)
- Chain of Custody SOP (LINK)
- Recommend Practices for PFAS Sampling of Groundwater (LINK)

9. Version/Revision History

Version 1.0 – April 2015. W. Bohrer, T Stanley
Version 2.0 – September 2025. M. Frankel, W. Bohrer

10. References

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NYSDEC. (2010). *DER-10 Technical Guidance for Site Investigation and Remediation*.

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HYDROCARBON BAILDOWN TESTING SOP

for

MIPC
Aston, PA

Prepared By:

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DECEMBER 2025
220240201

LANGAN

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1 INTRODUCTION

1.1 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) describes the procedures, equipment, and important considerations for conducting a Hydrocarbon Baildown Test (baildown test). This test is used to estimate the transmissivity of Light Non Aqueous Phase Liquid (LNAPL[1]), or product, for assessing the recoverability of the product (Hawthorne and Kirkman, 2011; Charbeneau et al., 2012; ASTM, 2013; Hawthorne, 2013; Hawthorne and Kirkman, 2013)

This SOP should not constitute the documentation given to field staff to implement a baildown test. A shorter, more focused document providing clear instructions on the specific tasks to be implemented should be prepared from the information presented in this SOP. Specific project requirements, as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Job Hazard Analysis (JHA), or Site-Specific Health & Safety Plan (HASP), will take precedence over the procedures described in this document.

1.2 SUMMARY OF METHOD

The baildown test can be performed on wells that exhibit accumulation of product floating on the groundwater in the well. The test is conducted by rapidly removing the product from a test well with a pump, vacuum truck, or bailer, followed by measuring and recording the product and water levels and times of measurement (product rebound data) until pre-evacuation levels are attained or nearly attained. Typically, this test is completed on wells exhibiting greater than 0.5 feet of product thickness and with a borehole diameter that is not large relative to the casing and screen diameter.

1.3 RESPONSIBILITIES

The field staff performing this test are responsible for contacting the project-sampling leader if there are any uncertainties about the test procedures or unusual observations in the field. The project-sampling leader has the responsibility to oversee the tests and ensure that the tests are performed in accordance with the project-specific sampling program and this SOP.

1.4 HEALTH AND SAFETY CONSIDERATIONS

This section presents the generic hazards associated with conducting baildown tests and is intended to provide general guidance in preparing site-specific health and safety documents. The site-specific HASP and JHA address additional requirements and take precedence over this document. Note that baildown testing usually requires modified Level D personal protective

[1] Commonly referred to as free-phase hydrocarbon, separate-phase hydrocarbon, free-product, liquid hydrocarbon (typically refined petroleum hydrocarbons such as gasoline, diesel, and other fuel products

equipment (PPE) (i.e., Tyveks and chemically resistant gloves), unless there is a potential for exposure to airborne site contaminants.

Health and safety hazards include, but are not limited to, the following:

- Slip, trip, and fall hazards in tall grasses over obstacles and berms near well locations. Review terrain hazards prior to conducting these operations. Ensure there is a safe means of access/egress to the wellhead.
- Hand cuts. Ensure the use of protective gloves.
- Dermal exposure to product. Ensure that proper personal protective equipment (PPE) is used to mitigate the impacts of product splashes to skin and/or eyes.
- Exposure to site contaminants. Take all precautions necessary to prevent fire, explosion, and/or exposure to airborne vapors from product in the well (especially gasoline).
- Ergonomics. Use appropriate ergonomic techniques when inserting or retrieving equipment in the wells to preclude injury to the arms, shoulders, or back.

1.5 PERSONNEL QUALIFICATIONS

Because this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all Langan personnel must be adequately trained. Field personnel qualifications and protective and monitoring equipment should be consistent with the HASP requirements. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These training requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training.
- 8-hour HAZWOPER Supervisor training.
- First Aid/CPR training.

2 EQUIPMENT

The following equipment may be utilized to perform a standard baildown test. Project-specific conditions or requirements may warrant the use of additional equipment or omission of items from this list.

- Appropriate level of PPE, as specified in the site-specific HASP
- Health and safety equipment: appropriate air quality monitoring equipment (e.g., photoionization detector [PID], flame ionization detector [FID], multi-gas meter, etc.), caution tape or cones, etc.
- Equipment to evacuate product in the well (See Section 2.1):
    - Peristaltic pump and tubing;
    - Bailer and rope;
    - Vacuum truck; or
    - Other purging device.

- Decontamination solutions and equipment
- Spill control/containment material
- Measuring devices, including (See Section 2.2):
    - Electronic interface probe;
    - Pressure transducer (in addition to interface probe) — optional for use with rapid product rebound;
    - Time piece (e.g. watch or other device)
    - Container for water and product collection that is graduated to measure within 10% of total estimated product recovery volume (unit conversion: 1 gallon = 3.785 liters = 0.134 cubic feet)
        - A container that can measure 0.1 gallon (~400 ml) for an expected 1 gallon (~4,000 ml) of recovered product;
        - A container that can measure 1 gallon (~4,000 ml) for an expected 10 gallons (40,000 ml) of recovered product.
    - Project Field Book for recording field observations

2.1 PRODUCT REMOVAL EQUIPMENT

If the depth to product in the well is not too great, it is preferable to remove product with a peristaltic pump. Peristaltic pumps are intrinsically safe and low maintenance. The product should not contact the pump, unless the tubing ruptures with age, a preventable condition with regular inspection. Additionally, water extraction can be minimized by controlling the depth of the tubing, with the benefit that the volume of recovered product can be accurately measured.

The theoretical suction (vacuum) lift limit of pure water at sea level is 33.9 feet (14.7 pounds per square inch [psi] atmospheric). However, this limit would only be obtained if a perfect vacuum were achieved in the pump. Typically, peristaltic pumps have a maximum working depth of 27 feet at sea level, 80% of the theoretical suction limit. This depth limit can be calculated for other liquids by dividing the maximum working depth by the specific gravity of the liquid.

- Gasoline, for example, with a specific gravity of 0.75, has a corresponding maximum working lift limit of 36 feet at sea level (27/0.75).

Atmospheric pressure and, therefore, suction lift diminishes with increase in elevation. At 2,000 feet, 4,000 feet, 6,000 feet, and 8,000 feet above sea level, the reductions in pure water suction lift are 2.3 feet, 4.8 feet, 6.9 feet, and 9.0 feet, respectively. The maximum working depth of the peristaltic pump at 4,000 feet, for example, would be reduced to about 22 feet for pure water (27 - 4.8), and to about 31 feet for gasoline (36 - 4.8).

A limitation of the peristaltic pump is the low rate of product removal at product depths near the suction lift limit, which may prevent attainment of near-instantaneous product removal (see Section 4.1). If the depth to product is too great for a peristaltic pump, then bailing or other removal methods can be used, if they are safe.

- Whale pumps and some other down-hole electric pumps cannot be used with product.

- Bailers and vacuum trucks extract some water. The removal of water generally introduces minimal error into the test data, if the equivalent water level in the well rebounds faster than the product thickness.

In some cases when attempting to completely purge product from the well, the available product removal equipment will not be able to remove product at a rate at least as high as the inflow rate. In these cases, a modified test approach is needed (see Section 4.4, Test Modifications).

2.2 MEASURING DEVICES

Typically, the air/product and product/water interfaces will be gauged using an interface probe. With this procedure, there is an unavoidable variable time lag between the two measurements that could introduce significant error in the calculated thickness for the recorded time.

When the product rebound occurs rapidly (i.e., less than one hour), tests should be conducted with a data logger (pressure transducer) set near the bottom of the well (in the water phase). In this case, the field staff will only need to measure the depth to the air/product interface following removal of product, resulting in less measurement error, as well as less error in the calculated thickness. Measuring the air/product interface is simpler and results in more accuracy than measuring the product/water interface when using a pressure transducer.

If a pressure transducer is used, it should be a gauge pressure (vented) type, especially if the product occurs under confined conditions. A pressure transducer measures the pressure, or total head, above it. The head attributed to the water and to the product must be calculated. The density of the product must be known in order to calculate the head of each phase contributing to the total head. With measurements of the depth to the air/product interface, the following equations are used to estimate the depth to the product/water interface:

$$PW = AP + b_o$$

$$b_o = \frac{(PT - H_t - AP)}{1 - (\frac{\rho_{product}}{\rho_{water}})}$$

Where:

PT = Depth to pressure transducer measuring point (feet)
H_t = Total head in terms of water measured by pressure transducer (feet)
AP = Depth to air/product interface as gauged (feet)
PW = Depth to product/water interface (feet)
$\rho_{product}$ = Density of product (g/cm^3)
ρ_{water} = Density of water (g/cm^3)
b_o = Measured product thickness in well (feet)

The error associated with the rebound rate calculations is directly related to the error in gauged product/water and/or air/product interfaces. Small pre-test equilibrium product thickness either results in few data points collected (for rapid rebound) or data points representing very small

changes in product thickness. Based on the accuracy of estimating the product/water and air/product interfaces with available interface probes, it is possible, but not recommended, to perform baildown tests at wells with a gauged equilibrium product thickness less than 0.5 feet Baildown testing should not be performed at wells with a measured product thickness less than 0.2 feet.

3 PRE-TEST PREPARATION

Refer to the project-specific plans, if applicable, for site-specific procedures. Other state or federal requirements may be beyond the scope of this SOP and will be followed, if applicable. In all instances, the actual procedures used should be documented and described in the field book.

The following assumptions and conditions are necessary to perform a valid test:

- The thickness or volume of product in the well is not affected by the volume of the measuring device inserted into the floating layer of product.
- The volume of removed product can be accurately measured.
- There must be equilibrium between the product in the well and the product in the geologic media (formation sediment or rock).
- For product that occurs under unconfined conditions, the air/product and product/water interfaces must be within the screened interval of the well.
- The borehole diameter must not be excessively large relative to the casing and screen diameter.

The following well construction information needs to be obtained and recorded prior to initiating the baildown test:

- Borehole diameter of well to be tested
- Casing and screen diameter
- Depth to top of screen from top of casing
- Depth to top of filter pack/base of seal
- Bottom of screen interval
- Total well depth

3.1 WELL BOREHOLE DIAMETER

Baildown test data analysis is typically based on an assumption of "instantaneous removal" of product from the well. Instantaneous is relative to the rate of product rebound due to inflow from the geologic medium (see Section 4.1). Rapid removal of product in the well cannot be accomplished if there is a large volume of product stored in the filter pack. Product in the filter pack of a well does not drain instantaneously into the casing and well screen, and the rate of drainage decreases as the product saturations and relative permeability decrease. Furthermore, for unconfined conditions, if the water rebounds quickly (with or without water removal), the water will impede product drainage from the filter pack below the water table elevation. The extended time required to evacuate enough product from a large diameter well with a small casing and screen diameter to attain significant product drawdown to begin rebound

measurements may violate the assumption of instantaneous removal. Therefore, the well diameter must not be excessively large relative to the casing and screen diameter.

The ratio of casing volume/drainable filter pack volume decreases from approximately 1.6 for 2-inch casing and screen in a 4.25-inch diameter borehole to approximately 0.38 for the same well materials in an 8-inch diameter borehole (assuming filter pack product storage coefficient of 0.175). Baildown testing in wells with a large casing/borehole diameter ratio is preferred for the following reasons:

1. Less pumping/bailing time to achieve a given product drawdown in the well,
2. Faster attainment of product inflow from the geologic medium without simultaneous filter pack drainage and, therefore, faster generation of the appropriate data for analysis of transmissivity, and
3. More product inflow from the geologic medium for a given baildown volume (given the limited spatial influence of the test, the more influence the better).

3.2 EQUILIBRIUM CONDITIONS

Because baildown tests are used to evaluate the transmissivity of product in the subsurface, equilibrium between the product in the well and the product in the geologic media is essential for a valid test result. Periodic product removal events can generate nonequilibrium conditions and result in inappropriate liquid levels at the start of the test. Equilibrium liquid levels are required for accurate product drawdown calculations.

For product occurrences under confined conditions, the proper equilibrium conditions include the column of product accumulation in the well extending to the base of the zone of mobile product in the confined stratum, potentially well below the top of the screen. Transmissivity calculations using the American Petroleum Institute (API) spreadsheet for confined product cannot be performed without specifying initial conditions in the input that include the product/water interface below the top of the screen.

The depth to product (DTP) and depth to water (DTW) should be measured at least 8 hours before the test and then immediately before the start of the test to confirm that liquid levels are stable and in equilibrium with the geologic media. The ASTM standard (ASTM, 2013) recommends collecting pre-test gauging data for a time period that is equal to the length of the expected rebound period based on previous evacuation events. These pre-test data should show consistent equilibrium liquid levels. If the well has not been previously tested, record post-rebound liquid levels for the same length of time as the rebound period to confirm equilibrium conditions. Avoid conducting the test during precipitation.

If the length of time for full product rebound is known from previous extraction events and subsequent gauging, it is good practice to remove product from the well before the test day to ensure stable and equilibrium liquid levels on the test day. If the rebound rate is high (i.e., the product in the well rebounds in an hour or less), the testing procedures described in Section 4.4 should be considered.

4 TEST PROCEDURES

The following general protocol should be followed to conduct a baildown test:

1. Start the baildown portion of the test early in the day, because the measurement frequency is highest in the first 8 hours of the product rebound.
2. Measure and record the static depth to product and the static depth to water. Record the time of measurements.
3. Calculate the volume of mobile product in the well (casing and filter pack).
4. If there is potential for equivalent groundwater levels to vary during testing, depths to groundwater can be measured in a nearby product-free control well before and during testing. Variations in equivalent groundwater levels during the product rebound affect depths to product and product thickness that may potentially invalidate the test.
5. To start the test, remove all (or a substantial fraction) of the mobile product in the well casing and filter pack in a short time frame. Note that the method of analysis does not require removal of the entire volume of mobile product, but removal of as much product as possible in a relevant time frame is recommended (see Section 4.1). Fully removing the mobile filter pack volume results in observing the correct trend of drawdown versus discharge for analysis sooner than partial removal, but the time required for complete removal may be inappropriate (see Sections 3.1 and 4.1).
6. Record the start and finish times of product removal. Record the total volumes of product and water removed. If large volumes (over 5 gallons) of product are removed, or product removal occurs over an extended period of time (more than 30 minutes should generally be avoided, but may be acceptable for wells that rebound very slowly), record several interim measurements of the product and water volumes removed and the times. To minimize groundwater removal, use transparent tubing for monitoring the liquid being extracted to indicate which liquid, product or water, is being removed. The length of time required for product removal should be small relative to the product rebound time. As a general rule, remove a volume of product up to the calculated mobile product volume. Smaller volumes of product removed result in a closer approximation to an instantaneous head change, but filter pack recharge affects increase. Larger removal volumes minimize filter pack recharge effects, but may result in a substantial deviation from an instantaneous head change.
7. Begin measurements and recording of the times and the depths to the air/product and product/water interfaces immediately after removing the product. If the product thickness appears to be decreasing at any time during the product rebound measurements, re-measure and/or check the product/water interface probe.
8. In the first 100 minutes of product rebound, try to take measurements at every change in product thickness of I percent of the equilibrium thickness (The minimum practical time interval for gauging measurements is generally 1 minute). After 100 minutes, take measurements at every change in product thickness of 5 to 10 percent of the equilibrium thickness. The following measurement frequencies are recommended as an alternative to the thickness change criteria, particularly if adherence is not achievable early in the rebound:

    - First 10 minutes of rebound: every 1 minute (10 measurements)

- 10 to 20 minutes: every 2 minutes (5 measurements)
- 20 minutes to 40 minutes: every 5 minutes (4 measurements)
- 40 minutes to 2 hours: every 10 minutes (8 measurements)
- 2 hours to 4 hours: every 30 minutes (4 measurements)
- 4 hours until the end of the first day (8 hours or greater): every 1 hour
- Second day: 2 to 3 measurements
- After second day: 1 measurement per day until the product thickness stabilizes

During the test, accurate measurements of the depths to product and water are critical. Ensure that these readings are consistent and reliable. Do not simply record numbers - study them and determine if they make sense.

- Product thickness should increase (or remain the same) from one measurement to the next, not decrease.
- Depths to the air/product interface should be decreasing (or remain the same), and depths to the product/water interface should be increasing (or remain the same).

Re-measure and report any readings that seem anomalous. Make notes regarding the methodology used to confirm or revise anomalous data. The test data should be faxed, phoned, or e-mailed to the office for review and analysis on a daily basis, if possible.

When the product transmissivity or rebound time length is not known, plan to start the baildown portion of the test early in the workday and on a day when you will be able to return frequently to the well. This precaution will ensure that a sufficient number of measurements can be obtained within the first 8 hours of the test.

If tidal fluctuations are expected, the DTP and DTW must be measured regularly for at least a week leading up to the test. The test should be conducted at high or low tide and repeated at the other extreme of the tide. Depending on the product transmissivity, the product rebound time may be longer or shorter than the tidal cycle. If the rebound is shorter than the tidal cycle (high product transmissivity), there will likely be a substantial difference in transmissivity at high and low tides. Testing at both low water table and higher water table conditions may also be appropriate at sites where groundwater levels are affected by river stages.

4.1 PRODUCT BAILDOWN

The evacuation of product from the well for initiation of the test should be rapid (near "instantaneous"), and performed in a manner that removes as little groundwater as possible. Product in the casing/screen and filter pack must be removed. Commercial pumps such as a peristaltic pump or equivalent are preferred for product removal because the pump intake can be located to remove only the product during the baildown stage of the test. If a bailer is used, then additional precautions are necessary to (1) remove as little water as possible and (2) minimize liquid disturbance during product removal.

Good judgment must be used for the product evacuation time, which is based on an estimate of the total volume of mobile product in the casing and filter pack, an estimate that is likely conservative, especially considering the decreasing relative permeability as the product drains

from the filter pack. The ASTM standard (ASTM, 2013) specifies that the "instantaneous" evacuation should occur in a time that is 1/l00th or less of the total expected test duration (rebound period), a duration that should be based on previous extraction events and subsequent gauging. Unless the product transmissivity is very low, significant drainage of product into the well from the geologic medium may occur before the estimated volume of mobile product in the well can be evacuated, especially with large storage in the filter pack, violating the conditions for testing. A different method of evacuation may be required.

The following equations can be used to estimate the mobile volume of product within the well for unconfined conditions with the screen across the interval of product in the well:

$$V_c = \pi r_c^2 b_o$$

$$V_a = 0.175\pi(r_b^2 - r_c^2)b_o$$

$$V_t = V_c + V_a$$

Where:

V_c = Volume of product in the casing and screen (feet3)
V_a = Volume of product in the well annulus (feet3)
V_t = Total effective volume of product in the well (feet3)
r_c = Well casing or screen radius (feet)
r_b = Well borehole radius (feet)
b_o = Measured product thickness in well (feet)

The factor 0.175 is an estimate of mobile product storage in the filter pack, assuming that 50 percent of the filter pack porosity (assumed 35 percent) is occupied by drainable product, with the other 50 percent occupied by residual (immobile) product and/or water and air. It is also assumed that the filter pack product saturations are uniform throughout the corresponding interval of product occurrence in the screen.

For confined product, the following procedures may be applicable for estimation of the volume of mobile product in the well:

- If the screen extends across the confined unit only or also partly into the confining unit, the estimated volume of mobile product in the well is calculated based on the casing and screen volume plus the drainable product in the filter pack from the top of the filter pack to the base of the product column in the well.
- If the screen extends across and above the confining unit into overlying sand, and the air/product interface is within the screened interval, the length of the product column in the well is used to estimate the volume of mobile product in the filter pack.

For perched product intersecting the screen, the filter pack volume is based on the length of the product column across the screened interval (assuming no filter pack below the screen and no product extending below the screen).

There are many well constriction and product occurrence scenarios, therefore it is prudent to consult LNAPL experts within Langan, and to sketch the site-specific relationships to properly calculate filter pack product volumes.

Depending on the well construction and product thickness, it may take more than 1 hour to remove the mobile volume of product in the casing and filter pack. Note that for unconfined conditions, if the water rebounds quickly (with or without water removal), the water will likely impede product drainage from the filter pack below the water table elevation, and obtaining the calculated volume may not be realistic. An extended time period may be acceptable for wells that require several days to a couple of weeks to rebound. However, excessive removal times should be avoided. Removal of a product volume less than the calculated volume of mobile product in the casing and filter pack may be sufficient. The filter pack drainage effect can be recognized during data analysis, and the data representing this drainage can be avoided in the analysis.

If four hours of product removal efforts have passed without obtaining the mobile product volume, rebound measurements should begin, if the volume of product removed is at least 50% of the objective. The well construction and product volume calculations should be checked. The rebound data could potentially represent'on1y drainage of the filter pack, if the casing and screen diameter are small in a large diameter borehole. If the analysis suggests a repeat of the test should be undertaken, a different evacuation method may be necessary.

4.2 PRODUCT REBOUND DATA COLLECTION

Following the removal of product from the well, rebound measurements begin immediately. The rate of product thickness change during rebound is typically logarithmic; therefore, measurements must be closely spaced in time during the early phase of the rebound. The minimum practical time interval for gauging measurements is generally 1 minute. Measurements may be taken at progressively greater time intervals as the rates of change of the depths of the air/product and product/water interfaces diminish. Complete rebound may take several weeks or months. In later stages of rebound, measurements may only need to be taken weekly or even monthly.

API guidance (Charbeneau et al., 2012) suggests that a record of 20 to 30 measurements (each for DTP and DTW [if a data logger is not used]) is generally adequate for data analysis. When possible, these measurements should be evenly spaced in terms of the rebound thickness. For example, if the initial product thickness in a well is 3 feet, and the product thickness after baildown is 0.5 feet, then measurements might be taken when the product thickness attains the following sequence of values: 0.5, 0.6, 0.7, 0.8 0.9, ... 2.9, 3.0 feet. Another "rule of thumb" is measurement each time the product thickness increases no more than 5 to 10 percent of the original equilibrium product thickness (e.g., if the initial product thickness is 3 feet, measurements should be taken every time the product thickness increases 0.15 to 0.3 feet). The rapidity of rebound may dictate the minimum thickness increment and the number of measurements attainable.

After the first 100 minutes of rebound, the data should be reviewed and a schedule generated by the field staff for additional measurements. For example, if the product rebounded less than 5 percent of its initial thickness in the first 100 minutes, the next measurement would be at least

100 minutes from the last measurement. After 4 hours of rebound, the data should be reviewed again for revision of the measurement schedule. If previous knowledge of the rebound behavior of a given well is available, this information can be used to revise the schedule. An example of measurement intervals is provided in Attachment B.

4.3 TEST DURATION

The scope of work may include planning for gauging to be conducted for several days or even weeks, especially if the pre-test equilibrium thickness and liquid levels are uncertain. This scope may be feasible, if other work is being performed on the site, or the site is local and the client is willing to fund periodic site visits. Plan on obtaining rebound measurements until the product thickness stabilizes, optimally to its pre-test thickness to confirm it was at equilibrium. Otherwise, a one-day test or two-day test may be proposed (depending on the client and/or stability of the potentiometric surface), with a measurement on the morning of departure from the site. These data could be evaluated, with recommendations for longer testing, if necessary, if the data are inadequate to make a defensible determination of transmissivity. In extremely low product transmissivity cases, it is possible that no product rebound would be observed in this time frame, potentially leading to the wrong conclusion of no mobile product. A provision of the work scope should include a recommendation for return to the site after weeks or even months to establish either the absence of mobile product or extremely low transmissivity. If product finally appears or very slowly rebounds during an extensive time, this information is valuable in negotiations with regulators and/or determinations of product recovery feasibility. However, the stability of the potentiometric surface during the extended period of observation must be taken into consideration for the interpretation.

Also, for low product transmissivity, the time requirement for gauging until equilibrium might be excessive, and early termination of measurements will be necessary. In this case, before terminating rebound measurements, the partial data set could be evaluated to assess adequacy for calculating transmissivity. If the data are inadequate, a plan could be developed based on the rebound rate for subsequent visits to the site to obtain the requisite data, including the equilibrium liquid levels. Full rebound may be especially important for confined and perched product conditions, to verify the conceptual site model and to correctly estimate transmissivity, if equilibrium liquid levels are unknown.

A typical indication that the product thickness is stabilizing is a product thickness that is nearly constant for about a half log cycle of time. This stabilization should be verified with three measurements during that half log cycle. A semi-log plot of the rebounded product thickness versus time (e.g., Attachment B) will assist in the assessment of stabilization and test completion.

4.4 TEST MODIFICATIONS

In some cases, the product in a well rebounds faster than it can be removed. This phenomenon becomes apparent after the calculated well volume has been removed. In these cases, a manual skimming test should be conducted.

The manual skimming test consists of the removal of product from a well on a repeated basis, without permitting more than approximately 25% product rebound to occur between removal

events. The objective is continued purging of the product until a steady-state product inflow rate is attained. The frequency of removal is, therefore, dependent on the well inflow rate. Product transmissivity is calculated from the steady-state product inflow rate and the drawdown corresponding to that rate. Note, however, that very specific criteria are used to determine the drawdown for the transmissivity analysis (ASTM, 2013), which is not simply the length of the column of product removed at 20 or 25% rebound.

A manual product-skimming test can be conducted in any well with a gauged product thickness. The manual skimming test provides an advantage over a standard baildown test because the repeated product removal events result in stressing a larger area of the formation.

A manual skimming test can be conducted with a peristaltic pump or a pneumatic skimmer pump. Two people would be needed if a bailer is used. The procedures for this test are outlined below:

- The pre-test liquid levels are measured and recorded. These levels must represent equilibrium.
- The product is removed from the well, permitted to rebound at least 20%, removed again, permitted to rebound the same amount, etc. until a constant inflow rate is attained. The inflow rate can be low, but must be measurable and documented.
- The start and end times of product removal are recorded.
- The volume of product from each removal event is measured and recorded.
- Liquid levels are measured between removal events, and the levels and times of measurement are recorded.
- The product inflow rate is determined from the volume of product removed during each purging event and the time for the product to rebound 20 to 25%.
- If a bailer is used for product removal, then one person bails while the second person measures the liquid levels. The liquid level measurements are taken immediately before and immediately after a bailer is removed, then subsequently during product rebound.
- For fast rebounding wells that preclude complete product removal, after the product thickness and elevation of the air/product interface stop decreasing, terminate product removal efforts and start measuring the liquid levels as frequently as possible.
- After completion of the testing, gauge the liquid levels until they stabilize at the pre-test equilibrium levels.
- If product rebound is very fast, the test could be repeated to improve execution or for verification. Perform the repeat test by removing the product over the same time period as the previous test. The test could be repeated several times, if it is necessary to improve the techniques and data collection.

5 INVESTIGATION-DERIVED WASTE DISPOSAL

A plan must be developed for disposal of investigation-derived waste (IDW). Recovered product and groundwater and other wastes produced during the testing should be handled, containerized, labelled, stored, and transported in accordance with the HASP, hazard communication plan, and state and Department of Transportation (DOT) requirements. Field personnel should be familiar with the project-specific requirements for IDW.

6 QUALITY ASSURANCE/ QUALITY CONTROL

When a pressure transducer/data logger is used, take periodic manual measurements of the depth to the product/water interface as a check on the transducer readings and the calculated levels. All equipment should be decontaminated between tests on different wells according to Langan SOPs. The rope used for the bailer should be replaced between tests on different wells.

7 DATA MANAGEMENT AND RECORDS MANAGEMENT

The field baildown test data form (Attachment A) must be completed for each test. A project field book should also be used for recording relevant information. These documents provide a summary of the test method and data, site conditions, and weather conditions. These documents will be kept in the project files for reference and reports. Attachment B provides an example data set of product thickness vs. time.

8 DATA INTERPRETATION

Guidance on the interpretation of test data and estimation of product transmissivity can be obtained from Charbeneau et al. (2012), and ASTM (2013).

9 REFERENCES

ASTM, 2013. ASTM E2856-13. Standard Guide for Estimation of LNAPL Transmissivity, ASTM International, West Conshohocken, PA, 2013, www.astm.org

Charbeneau, R.J., Kirkman, A., and Muthu, R., 2012. User Guide for API LNAPL Transmissivity Workbook: A Tool for Baildown Test Analysis. API Publication 46xx (pre-publication draft). Prepared for: American Petroleum Institute.

Hawthorne, J.M. and Kirkman, A, 2011. Discharge vs. Drawdown (DvD) Graphs: Graphical Analysis of Unconfined LNAPL Baildown Test Data. Applied NAPL Science Review (ANSR), Volume 1, Issue 4; April 2011.

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Hawthorne, J.M. and Kirkman, A., 2013. LNAPL Transmissivity from Total Fluids Recovery Data; Part 2: Application and Interpretation of Results. Applied NAPL Science Review (ANSR), Volume 3, Issue 3; April, 2013.

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Standard Guide for Estimation of LNAPL Transmissivity[1]

This standard is issued under the fixed designation E2856; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides field data collection and calculation methodologies for the estimation of light non-aqueous phase liquid (LNAPL) transmissivity in unconsolidated porous sediments. The methodologies presented herein may, or may not be, applicable to other hydrogeologic regimes (for example, karst, fracture flow). LNAPL transmissivity represents the volume of LNAPL (L^3) through a unit width (L) of aquifer per unit time (t) per unit drawdown (L) with units of (L^2/T). LNAPL transmissivity is a directly proportional metric for LNAPL recoverability whereas other metrics such as apparent LNAPL thickness gauged in wells do not exhibit a consistent relationship to recoverability. The recoverability for a given gauged LNAPL thickness in a well will vary between different soil types, LNAPL types or hydrogeologic conditions. LNAPL transmissivity accounts for those parameters and conditions. LNAPL transmissivity values can be used in the following five ways: *(1)* Estimate LNAPL recovery rate for multiple technologies; *(2)* Identify trends in recoverability via mapping; *(3)* Applied as a leading (startup) indicator for recovery; *(4)* Applied as a lagging (shutdown) indicator for LNAPL recovery; and *(5)* Applied as a robust calibration metric for multiphase models (Hawthorne and Kirkman, 2011 (**1**)[2] and ITRC ((**2**)). The methodologies for LNAPL transmissivity estimation provided in this document include short-term aquifer testing methods (LNAPL baildown/slug testing and manual LNAPL skimming testing), and long-term methods (that is, LNAPL recovery system performance analysis, and LNAPL tracer testing). The magnitude of transmissivity of any fluid in the subsurface is controlled by the same variables (that is, fluid pore space saturation, soil permeability, fluid density, fluid viscosity, the interval that LNAPL flows over in the formation and the gravitational acceleration constant). A direct mathematical relationship exists between the transmissivity of a fluid and the discharge of that fluid for a given induced drawdown. The methodologies are generally aimed at measuring the relationship of discharge versus drawdown for the occurrence of LNAPL in a well, which can be used to estimate the transmissivity of LNAPL in the formation. The focus, therefore, is to provide standard methodology on how to obtain accurate measurements of these two parameters (that is, discharge and drawdown) for multi-phase occurrences to estimate LNAPL transmissivity.

1.2 *Organization of this Guide:*

1.2.1 Section 2 presents documents referenced.

1.2.2 Section 3 presents terminology used.

1.2.3 Section 4 presents significance and use.

1.2.4 Section 5 presents general information on four methods for data collection related to LNAPL transmissivity calculation. This section compares and contrasts the methods in a way that will allow a user of this guide to assess which method most closely aligns with the site conditions and available data collection opportunities.

1.2.5 Sections 6 and 7 presents the test methods for each of the four data collection options. After reviewing Section 5 and selecting a test method, a user of this guide shall then proceed to the applicable portion of Sections 6 and 7 which describes the detailed test methodology for the selected method.

1.2.6 Section 8 presents data evaluation methods. After reviewing Section 5 and the pertinent test method section(s) of Sections 6 and 7, the user of this guide shall then proceed to the applicable portion(s) of Section 8 to understand the methodologies for evaluation of the data which will be collected. It is highly recommended that the test methods and data evaluation procedures be understood prior to initiating data collection.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

1.5 *This document is applicable to wells exhibiting LNAPL consistently (that is, LNAPL transmissivity values above zero). This methodology does not substantiate zero LNAPL transmissivity; rather the lack of detection of LNAPL within the well*

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

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

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combined with proper well development and purging procedures are required to confirm zero LNAPL transmissivity.

1.6 *This document cannot replace education or experience and should be used in conjunction with professional competence in the hydrogeology field and expertise in the behavior of LNAPL in the subsurface.*

1.7 *This document cannot be assumed to be a substitute for or replace any laws or regulations whether federal, state, tribal or local.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D5088 Practice for Decontamination of Field Equipment Used at Waste Sites

D5521 Guide for Development of Groundwater Monitoring Wells in Granular Aquifers

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

3. Terminology

3.1 *Definitions:*

3.1.1 *air/LNAPL interface (Z_{an})*—The surface shared by air and LNAPL in a control well. (L)

3.1.2 *calculated water-table elevation (Z_{CGW})*—the theoretical location of the air/water surface based on a density correction if LNAPL were not present in a well. (L)

3.1.3 *confined LNAPL*—LNAPL trapped in an aquifer beneath a layer that exhibits a pore entry pressure greater than the capillary LNAPL head, thereby impeding the upward migration of LNAPL limits the upward movement of the LNAPL. The term confined LNAPL is used because the mobile LNAPL is under pressure greater than gauge pressure against the underside of the LNAPL confining layer.

3.1.4 *control well*—well by which the aquifer is stressed or tested.

3.1.5 *discharge*—the flow of a fluid into or out of a well. (L^3/t)

3.1.6 *drawdown*—a pressure differential in terms of fluid head. (L)

3.1.7 *effective well radius*—the radius that represents the area of the well casing and the interconnected porosity of the filter pack. (L)

3.1.8 *equilibrium fluid levels*—gauged fluid levels that represent the oil head and the water head or the calculated water-table elevation of the formation. Under equilibrium fluid levels no net oil or water flow occurs between the formation and the well.

3.1.9 *fluid level*—the level of a fluid interface (either air/oil, LNAPL/water, or potentiometric surface).

3.1.10 *formation thickness (b_{nf})*—the interval that LNAPL flows over in the formation. For unconfined conditions this is approximately equal to the gauged LNAPL thickness. Confined and perched conditions the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

3.1.11 *gauged LNAPL thickness (b_n)*—The difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)

3.1.12 *hydraulic conductivity (derived via field aquifer tests)*—the volume of water at the existing kinematic viscosity that will move in a unit time, under a unit hydraulic gradient, through a unit area, measured at right angles to the direction of flow. (L/t)

3.1.13 *LNAPL*—Light Non Aqueous Phase Liquid.

3.1.14 *LNAPL baildown test*—a procedure which includes the act of removing a measured LNAPL volume from a well and filter pack to induce a head differential and the follow-up gauging of fluid levels in the well.

3.1.15 *LNAPL borehole volume*—the volume of LNAPL existing within the casing and the drainable volume existing within the filter pack of a well. Based on effective radius and gauged thickness of LNAPL. (L^3)

3.1.16 *LNAPL slug test*—a procedure which includes the act of removing or displacing a known volume of LNAPL from a well to induce a head differential and the follow-up gauging of fluid levels in the well.

3.1.17 *LNAPL specific yield (S_{yn})*—the volume of LNAPL an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in LNAPL head for gravity drainage conditions. (unitless)

3.1.18 *LNAPL specific yield filter pack (S_{yf})* —the volume of LNAPL released or takes into storage per unit surface area of the filter pack per unit change in LNAPL head for gravity drainage conditions. (unitless)

3.1.19 *LNAPL storage coefficient (S_n)* —the volume of LNAPL an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in LNAPL head. For a confined aquifer, it is based on the volume of fluid released due to decompression. For an unconfined aquifer, the storage coefficient is approximately equal to the LNAPL specific yield. (unitless)

3.1.20 *LNAPL transmissivity (T_n)*—the volume of LNAPL at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer. (L^2/t)

3.1.21 *observation well*—a well screened across all or part of an aquifer.

3.1.22 *oil/water interface (Z_{nw})*—The surface shared by LNAPL and water in a control well. (L)

3.1.23 *perched LNAPL*—mobile LNAPL that accumulates in the vadose zone of a site for some time period above a layer that exhibits a pore entry pressure greater than the capillary LNAPL head, thereby impeding the downward migration of LNAPL.

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

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3.1.24 *potentiometric surface*—see *calculated water-table elevation*.

3.1.25 *radius of influence*—the distance from a well that the pumping induced head differential from non-pumping conditions is zero, head differentials due to background gradients may still exist at this radius. (L)

3.1.26 *slug*—a volume of water or solid object used to induce a sudden change of head in a well.

3.1.27 *test well*—a well by which the aquifer is stressed, for example, by pumping, injection, or change of head.

3.2 For definitions of other terms used in this test method refer to Terminology, Guide D653.

4. Significance and Use

4.1 *Application:*

4.1.1 LNAPL transmissivity is an accurate metric for understanding LNAPL recovery, is directly proportional to LNAPL recoverability and tracking remediation progress towards residual LNAPL saturation.

4.1.2 LNAPL transmissivity can be used to estimate the rate of recovery for a given drawdown from various technologies.

4.1.3 LNAPL transmissivity is not an intrinsic aquifer property but rather a summary metric based on the aquifer properties, LNAPL physical properties, and the magnitude of LNAPL saturation over a given interval of aquifer.

4.1.4 LNAPL transmissivity will vary over time with changing conditions such as, seasonal fluctuations in water table, changing hydrogeologic conditions and with variability in LNAPL impacts (that is, interval that LNAPL flows over in the formation and LNAPL pore space saturation) within the formation.

4.1.5 Any observed temporal or spatial variability in values derived from consistent data collection and analysis methods of LNAPL transmissivity is not erroneous, rather is indicative of the actual variability in subsurface conditions related to the parameters encompassed by LNAPL transmissivity (that is, fluid pore space saturation, soil permeability, fluid density, fluid viscosity, and the interval that LNAPL flows over in the formation).

4.1.6 LNAPL transmissivity is a more accurate metric for evaluating recoverability and mobile LNAPL than gauged LNAPL thickness. Gauged LNAPL thickness does not account for soil permeability, magnitude of LNAPL saturation above residual saturation, or physical fluid properties of LNAPL (that is, density, interfacial tension, and viscosity).

4.1.7 The accurate calculation of LNAPL transmissivity requires certain aspects of the LNAPL Conceptual Site Model (LCSM) to be completely understood and defined in order to calculate LNAPL drawdown correctly. The methodologies for development of the LCSM are provided in Guide E2531. The general conceptual site model aspects applicable to this guide include:

4.1.7.1 Equilibrium fluid levels (for example, air/LNAPL and LNAPL/water).

4.1.7.2 Soil profile over which LNAPL is mobile.

4.1.7.3 LNAPL hydrogeologic scenario (for example, unconfined, confined, perched, macro pores, and so forth).

4.1.7.4 LNAPL density.

4.1.7.5 Hydraulic conductivity for each soil type within the well screen interval.

4.1.7.6 Well screen interval in the vadose and saturated zones.

4.1.8 Incorporation of LNAPL transmissivity can further LCSMs by providing a single comparable metric that quantifies LNAPL recoverability at individual locations across a site.

4.1.9 Each of the methods provided in this document is applicable to LNAPL in confined, unconfined, and perched conditions. Any differences in evaluation are discussed in Section 5.

4.2 *Purpose*—The methods used to calculate LNAPL transmissivity have been published over the past 20 years; however little effort has been focused on providing quality assurance for individual tests or refinement of field procedures. In addition to summarizing the existing methods to calculate LNAPL transmissivity, this document will provide guidance on refined field procedures for data collection and minimum requirements for data sets before they are used to calculate LNAPL transmissivity.

4.2.1 *Considerations*—The following section provides a brief review of considerations associated with LNAPL transmissivity testing.

4.2.1.1 *Aquifer Conditions (confined, unconfined, perched)*—In general, each testing type is applicable to confined, unconfined, and perched conditions; however, consideration should be given to how LNAPL drawdown is calculated from well gauging data relative to formation conditions. Calculation of LNAPL transmissivity for confined and perched conditions is possible; however, the soil profile needs to be considered in combination with the fluid levels to accurately calculate drawdown. Drawdown values for perched and confined conditions can easily be overestimated without proper consideration. This results in LNAPL transmissivity being underestimated. The calculations of drawdown under perched and confined conditions are discussed within this document. Tidal influences or a vertical gradient on the water table also affect measurements and could distort the transmissivity results. Tidal influences are discussed in more detail in Appendix X1.

4.2.1.2 *Well Construction*—Any well being tested should be screened over the entire mobile interval of LNAPL. For locations where multiple discrete mobile intervals exist, it may be preferable to screen individual wells across each mobile interval. This will simplify the calculation of drawdown and derivation of LNAPL transmissivity. The interval of mobile LNAPL does not always correspond to the elevation of the air/LNAPL interface (for example, the mobile interval can be beneath the base of a confining layer under confined conditions). Appropriately screened wells can be substantiated based on vertical delineation of the entire LNAPL impacted interval (see Guide E2531).

4.2.1.3 *LNAPL Type*—No limitations have been identified for LNAPL type. However, the specific gravity of the LNAPL must contrast with that of the water to be measurable with an interface probe.

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4.2.1.4 *Well Development*—In order to derive the most accurate LNAPL transmissivity value, appropriate well development should be conducted to ensure connectivity between LNAPL in the formation and the well (Hampton 2003) (**3**). Industry experience has observed that LNAPL can require up to several months following well installation to saturate the filter pack and establish connectivity within the well. Well development can help to reduce this time frame and should be completed in accordance with Guide D5521.

4.2.2 *Analysis Method*—An understanding of the analysis method and theory is necessary prior to the field testing to ensure that all appropriate dimensions and measurements are properly recorded.

4.3 *Precision and Bias*—At this time this document aims to provide methodologies for data collection and analysis to yield an accuracy of LNAPL transmissivity values within a factor of two (compared with the unknown actual value). This modest accuracy is reasonable based on the overall industry experience in implementing these procedures and the lack of comparison studies. The objectives initiated through development of this document are to provide improved guidance for more consistent data collection and analysis methodology, which in turn will provide a larger and more accurate data set on which to base future methodology revisions and improvements.

5. Method Selection

5.1 The following section describes each of four test methods for the user to evaluate which methodology best fits their data objectives, site setting, and hydrogeologic conditions. An overview of this section is provided in Table A2.1 and Table A2.2. A review of the required parameters to be measured is provided in Tables A2.3-A2.9.

5.2 *Baildown/Slug Testing:*

5.2.1 *Overview*—The LNAPL baildown/slug test consists of either removing the entire LNAPL from the well casing and filter pack or the displacement of a partial volume to induce a head differential, respectively. Following the induction of the head differential, fluid levels are gauged during recovery.

5.2.2 *Data Analysis*—The LNAPL baildown/slug test field procedure is used in conjunction with LNAPL slug test analytical procedures to provide estimates of LNAPL transmissivity at any well exhibiting sufficient LNAPL thickness (that is, at least 0.5 ft/15.2 cm).

5.2.3 *Waste Disposal*—The baildown/slug test provides an advantage over other tests in that it does not typically require the disposal of large quantities of LNAPL or water that may be produced, nor does it require specialized equipment.

5.2.4 *Aquifer Extent Represented*—LNAPL baildown/slug tests reflect conditions near the well, and therefore represent a limited radius of influence. LNAPL transmissivity values from baildown/slug tests may not compare well with transmissivity values estimated using recovery system-based data (5.3) because of the differences in scale of evaluation between the two methods. However, increasing or decreasing trends in transmissivity will be seen in both recovery system-based data and baildown testing-based data.

5.2.5 *Capital Cost*—The capital cost for this method is low because it can be implemented on existing wells exhibiting LNAPL, does not require the construction of a recovery system nor does it require specialized equipment above and beyond other methods.

5.2.6 *Test Duration*—The test length timeframe is inversely related to the transmissivity of LNAPL and directly related to the effective well radius. LNAPL baildown/slug tests may require minutes to months to completely recover as LNAPL transmissivity may vary by several orders of magnitude across sites. However, in cases of slow recovery (that is, greater than a month) and where high confidence exists that the initial fluid levels represent equilibrium conditions, it is not necessary to allow the well to fully recover. A data set representing partial recovery combined with substantiated equilibrium fluid levels can be used to estimate an LNAPL transmissivity or at a minimum place an upper bound on recoverability.

5.2.7 *Special Considerations:*

5.2.7.1 Existence of a vertical gradient or tidal influences on the water table may limit the accuracy of the slug and/or baildown test, because the initial thickness in the well may be exaggerated (downward hydraulic gradient) or thin (upward hydraulic gradient), compared with static conditions. The relationships between LNAPL thickness, vertical gradient, and LNAPL recovery (recharge) rate may be complex and distort test data and the interpretation and are beyond the scope of this guide.

5.2.7.2 Periodic LNAPL removal events from wells have historically resulted in wells in a continual state of non-equilibrium and result in inaccurate equilibrium fluid levels. Equilibrium fluid level data is required for accurate drawdown calculations. LNAPL drawdown has historically been one of the primary variables inducing significant error to LNAPL baildown/slug tests.

5.2.7.3 The baildown test methodology provided minimizes filter pack recharge effects and is applicable where formation storativity effects are not significant in test results. Slug tests will exhibit larger borehole storage effects at a given well because the slug represents a relatively small percentage of the LNAPL volume in the well and filter pack. However, slug tests are more ideal for an instantaneous removal event, which is needed where steady state conditions are not well approximated due to formation storage effects. The advantage of baildown test methods with their larger removal volumes and stresses is the minimization of borehole storage induced errors. The advantage of slug test methods with their smaller, faster removal is the minimization of non-instantaneous effects. The quantified magnitude of these individual differences has not been widely studied.

5.2.7.4 The error associated with the recharge rate calculations is directly related to the error in gauged LNAPL thickness measurement. Smaller equilibrium thicknesses either result in fewer data points being collected or data points representing smaller changes in well recovery. Based on the accuracy of estimating the LNAPL/water and air/water interface with available interface probes, it is possible but generally not recommended to complete baildown tests at wells with a gauged LNAPL thickness of less than 0.5 ft (for 2-in. or 4-in. wells). Baildown/slug testing should not be attempted at wells with a measured thickness of LNAPL less than 0.2 ft.

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5.3 *Manual LNAPL Skimming Tests:*

5.3.1 *Overview*—The manual LNAPL skimming test is conducted by removing LNAPL at a rate that maintains drawdown in the well until a consistent LNAPL recovery rate is achieved.

5.3.2 *Data Analysis*—This manual LNAPL skimming test field procedure is used in conjunction with a skimming test analytical method, to derive estimates of LNAPL transmissivity.

5.3.3 *Waste Disposal*—The manual LNAPL skimming test typically generates more waste than baildown/slug or tracer tests and less than recovery system methods.

5.3.4 *Aquifer Extent Represented*—The manual LNAPL skimming test provides an advantage over other tests in that; the longer period of time the test is performed, the larger the area of the formation it represents and the accuracy of recovery volume estimates increase, which are used in the calculation of LNAPL transmissivity.

5.3.5 *Capital Cost*—The capital cost of this method is relatively low as it can be completed at existing wells with LNAPL and typically requires similar equipment to baildown tests. If LNAPL transmissivity is sufficiently high then the use of a pump could incur additional costs. This method requires less capital cost than recovery system-based or tracer tests.

5.3.6 *Test Duration*—The length of the manual skimming tests is inversely related to the LNAPL transmissivity and directly related to the well diameter and LNAPL storativity in the formation. The manual skimming test duration is similar or longer in time frame compared with baildown/slug tests and a shorter timeframe than tracer tests.

5.3.7 LNAPL skimming tests may be completed at any well exhibiting a gauged LNAPL thickness. This test is especially useful for wells exhibiting a gauged thickness less than 0.5 ft because it allows the measurement of LNAPL volume above-ground. In addition, the error associated with estimating the recharged LNAPL volume at this initial gauged thickness can be more accurately estimated above-ground than in-situ.

5.3.8 Recovery system based-data transmissivity values may not compare identically with “instantaneous” and “point” transmissivity method results (for example, manual skimming test results) because of the differences in scale of evaluation between the two methods. However, increasing or decreasing trends in transmissivity will be seen in both recovery system-based data and manual skimming testing-based data.

5.3.9 Manual LNAPL skimming tests may be conducted in all types of aquifer materials.

5.3.10 Manual LNAPL skimming tests do not provide data to graphically estimate equilibrium fluid levels. Therefore, a good understanding of fluid level behavior (for example, hydrograph) is required to ensure initial fluid levels represent equilibrium conditions for accurate calculation of LNAPL drawdown.

5.4 *Recovery Data-Based Methods:*

5.4.1 This guide provides general procedures for deriving LNAPL transmissivities using data obtained from continuous operation of LNAPL skimmer pumps and/or other types of product recovery systems where aquifer conditions approach steady-state conditions. These recovery systems are designed to extract LNAPL, groundwater and/or formation air/vapor from a recovery well.

5.4.2 Because LNAPL transmissivity is being continually reduced through product recovery, steady-state conditions can be approached but not reached. Steady-state conditions are approximated when the maximum radius of influence (ROI) is reached for the current drawdown induced via the given technology.

5.4.3 The derivation of LNAPL transmissivity using recovery system data is based on the theory of radial fluid flow. Subsurface barriers (for example, building foundations) or significant heterogeneities can result in an under-estimation of LNAPL transmissivity when calculation methods involve the use of the radius of influence parameter. The equation for radial fluid flow will provide an average LNAPL transmissivity for all directions. However, it will under estimate LNAPL transmissivity in directions away from a subsurface barrier. Changes in soil type or lithologic properties affecting the hydraulic or pneumatic permeability of the formation and occurring within the recovery system radius of influence can affect the accuracy of the LNAPL transmissivity results. This effect is not significant when the fluid production ratio equations are used and the changes in subsurface conditions affect all extracted fluids and phases similarly. Accounting for such variability via site characterization data and accurate site conceptual models is necessary to achieve the most accurate results.

5.4.4 If the recovery system is operating consistently and the LCSM is well developed and understood, this method can provide high accuracy and repeatability of transmissivity calculations. However, use of recovery system-based data for estimation of LNAPL transmissivity requires a well-defined LCSM and frequent monitoring of recovery system operational parameters. LNAPL transmissivity values estimated from recovery data are representative of a region within an area of mobile LNAPL that is proportional to drawdown induced, recovery well spacing, and operational time. In other words, the area represented by an LNAPL transmissivity value is proportional to the drawdown induced, length of time run and distance between recovery well locations. As a result, recovery data transmissivity values may differ significantly from those obtained using “instantaneous” and “point” transmissivity method results (for example, baildown/slug test results) because of the differences in scale of evaluation between the methods. However, increasing or decreasing trends in transmissivity will be seen in both recovery system-based data and baildown testing-based data.

5.4.5 LNAPL transmissivity measurement by long-term operation of a skimming device or other LNAPL recovery system assumes continuous operation over the temporal interval of interest. Complete knowledge and maintenance of the system operation representing optimal conditions (for example, pump depth corresponds to the interval of mobile LNAPL or ensuring sufficient storage tank capacity) is necessary to obtaining representative LNAPL transmissivity values.

5.4.6 The LNAPL transmissivity values derived by recovery system data are based on fluid flow through a porous media and not karst environments or fractured rock. Attempts to apply this

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document to estimate LNAPL transmissivities in fractured rock, karst environments or other non-porous media may result in inaccurate LNAPL transmissivity values.

5.4.7 Fluctuations of water table elevation during the LNAPL recovery data collection period that significantly change the relationship between the groundwater/LNAPL interface (or the air/LNAPL interface) relative to the location of the recovery pump(s) can result in inaccurate transmissivity determinations. In addition, both horizontal and vertical pneumatic formation permeability must be determined when estimating the air radius of influence for determining transmissivity using LNAPL systems that incorporate vacuum-enhanced recovery.

5.4.8 The relative depths of the recovery well screen intervals, the groundwater/LNAPL interface, the air/LNAPL interface, and the depth of pump(s) intake(s) must be known. In addition, the configuration of the well construction, interfaces, and pump(s) intake(s) must be appropriate for the specific recovery system used to derive LNAPL transmissivity.

5.4.9 This guide provides analytical equations to calculate LNAPL transmissivity (T_n) using recovery system-based data from four types of remediation technologies:

5.4.9.1 LNAPL only liquid removal (skimming).

5.4.9.2 Vacuum-enhanced LNAPL only liquid removal (vacuum-enhanced skimming).

5.4.9.3 Water-enhanced LNAPL removal (total fluids pumping, single or dual pump).

5.4.9.4 Water and vacuum-enhanced LNAPL removal (multi-phase fluid extraction [MPE]).

5.5 *Tracer Test-Based Methods:*

5.5.1 *Overview*—This tracer test field procedure shall be utilized in conjunction with a tracer test analytical procedure to derive LNAPL flux and estimates of LNAPL transmissivity at any properly screened well exhibiting LNAPL thickness greater than 0.2 ft.

5.5.2 Tracer tests can be conducted under conditions of a natural or imposed gradient. Imposed gradient test can be conducted about active recovery wells. Natural gradient tests do not require fluid extraction.

5.5.3 *Test Duration*—Natural gradient tests are conducted over several weeks or months and, therefore, provide temporally-averaged and vertically-averaged transmissivity values. Imposed gradient tests can be conducted in period of hours to days.

5.5.4 *Waste Disposal*—LNAPL or water disposal is not required since the testing method does not generate water or LNAPL.

5.5.5 *Data Analysis*—Data reduction methods assume steady-state conditions, which can occur under natural or ambient conditions, or during steady-state recovery.

5.5.6 The LNAPL flux measurement is representative of a few feet outside the borehole. The LNAPL gradient is representative of the LNAPL surface within the well network density.

5.5.7 Although the flux measurement does not require a uniform flow field, it is combined with the LNAPL gradient to calculate an LNAPL transmissivity value. The LNAPL gradient estimates assume a uniform flow field between wells. Therefore, this method is more applicable to a uniform LNAPL flow field. Uniform LNAPL flow fields occur in homogenous conditions and can be induced by active recovery.

5.5.8 LNAPL tracer tests may be conducted in unconfined, perched and confined aquifer materials where the fluid levels are in equilibrium with the formation.

5.5.9 Inputs for data analysis (analytical procedure) should be known prior to the field testing to ensure that all appropriate dimensions and measurements are properly recorded.

5.5.10 *Specialized Equipment Needed*—A hydrophobic fluorescent tracer and a UV/VIS spectrometer with a down hole fiber optic cable are needed to make measurements of tracer concentration through time.

5.5.11 *Screening Factors for Test Method Selection:*

5.5.11.1 Using hydrophobic tracers to determine LNAPL transmissivity is a relatively new method, and it is expected that this method will become more refined in the future. The following methods have been proven at a laboratory scale (Smith et al, 2011) (**4**) and at seven field sites (Mahler et al, 2011) (**5**).

5.5.11.2 *Measurement of LNAPL Gradient*—The local LNAPL gradient must be measured or estimated as an input to the equation for LNAPL transmissivity using tracer tests.

TEST METHODS

6. Short-Term Aquifer Testing-Based Methods

6.1 *Baildown/Slug Testing Field Methods*—This test method describes the field procedures involved in conducting an instantaneous LNAPL baildown/slug test. The LNAPL baildown/slug test method involves causing a sudden change in LNAPL head in a control well and measuring the fluid level response within that control well. Head change is induced by removing a known and measurable LNAPL volume from the control well.

6.1.1 *Apparatus*—This test method describes the types of equipment that can be used. Since there can be an infinite variety of testing conditions and because similar results can be achieved with different apparatus, engineering specifications for testing equipment are not discussed in this document. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this guide.

6.1.1.1 *LNAPL Displacement Equipment*—Because a variety of equipment can be used to induce a change in LNAPL head, this method will not provide engineering specifications of the exact means in which head is changed, but will rather identify how common types of equipment can affect the final results. Single slug displacement or removal methods such as solid slugs or bailers, respectively, will provide a more instantaneous change in LNAPL head. This is useful at well locations exhibiting higher LNAPL transmissivities. The use of solid slugs is acceptable since their volume can easily be measured. However use of equipment such as peristaltic pumps to remove the entire volume of LNAPL in the well casing and borehole will result in minimizing filter pack recharge effects. It is strongly recommended to use equipment that can remove LNAPL from the well and allow the use of graduated containers to measure the total volume within 10 %. Vacuum trucks at best have a detection limit of 5 gal and an accuracy of 1 gal

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above 5 gal (19 L). Down-hole non-intrinsically safe electrical pumps need to remain submerged below the air/LNAPL interface to prevent explosions; therefore down-hole electrical pumps used to evacuate LNAPL to zero thickness, for example, are not acceptable practices.

6.1.1.2 In some cases the LNAPL removal equipment available will not be able to remove LNAPL at a high enough rate to completely purge the control well. If this occurs during the test, a slug test or any of the other LNAPL transmissivity test methods discussed in this document can be applied.

6.1.1.3 *Fluid Level Measurement Equipment*—Typically, the air/LNAPL and LNAPL/water interfaces will be gauged using an interface probe. Currently the most precise available interface probes utilize optical and electrical resistivity technologies. Additionally, current technology allows for probes to be relatively small (⅝-in.) in diameter. The optical and electrical resistivity type interface probes increase the ability to measure fluid interfaces to typical accuracies from 0.01 to 0.02 ft (0.3 to 0.6 cm). The small probe diameter causes less displacement to fluids in the well. When the recovery of LNAPL occurs rapidly (that is, less than 1 h), tests can be conducted with an intrinsically safe pressure transducer, where the pressure transducer is set near the bottom of the well (in the water phase). Then the field staff only will be required to measure the depth to the air/LNAPL interface following removal of LNAPL. By only measuring the air/LNAPL interface less disturbance will be introduced to the well during recovery since the probe does not need to penetrate the fluid column to measure the LNAPL/water interface. Two pressure transducers can still be used, where one transducer is placed in the water phase and a second within the LNAPL phase; however, they are not necessary.

6.1.1.4 *Time Piece*—Used to record the elapsed time of the test.

6.1.1.5 *Graduated Container*—A container for water and LNAPL collection that is graduated to measure within 10 % of total estimated recovery volume (unit conversion: 1 gallon = 3.825 litres = 3,825 millilitres (mL) = 0.134 cubic feet). For example, a container that can measure 0.1 gal (~400 mL) intervals for an expected 1 gal (~4000 mL) of recovered product, or a container that can measure 1 gal (~4000 mL) intervals for an expected 10 gal (40 000 mL) of recovered LNAPL.

6.1.1.6 *Decontamination Equipment*—Typically, LNAPL in a well can foul measuring devices and should be cleaned with an appropriate cleaning agent. If multiple wells are tested, equipment should be cleaned of well fluids between testing separate wells.

6.1.1.7 *Test Forms*—Test forms should be used to record the parameters listed in 6.1.2 and 6.1.3 (that is, Conditioning & Procedure). Semi-log graph paper should be used to plot data during the test in order to understand when equilibrium is reached and the test is completed. Fig. 1 provides an example of LNAPL thickness reaching equilibrium during a test.

6.1.2 *Conditioning:*

6.1.2.1 *Pre-Test Well Information*—The following well construction information needs to be obtained prior to initiating the baildown tests:

(1) Borehole diameter of well to be tested (feet).

(2) Casing and screen diameter (inches).

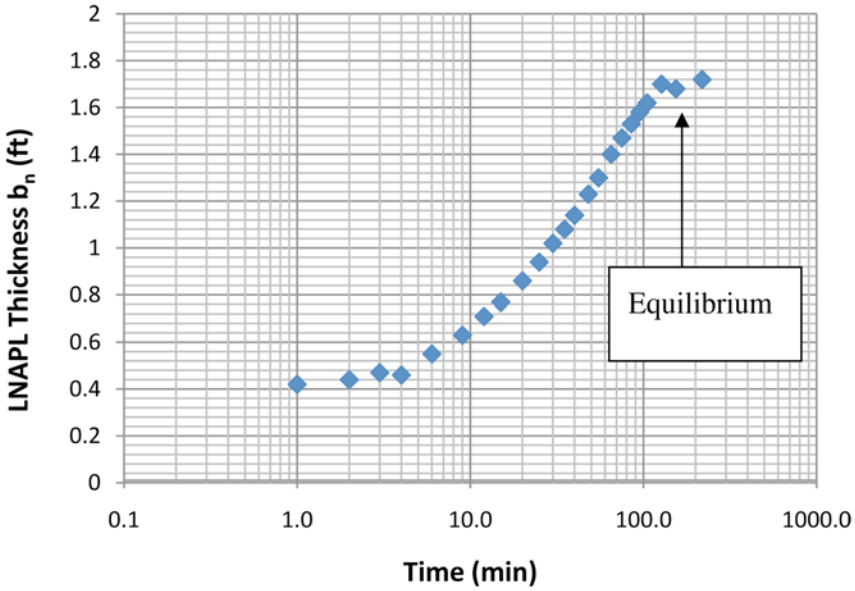
(3) Top of screen relative to top of casing (feet).

(4) Bottom of screen interval relative to top of casing (feet).

(5) Total well depth (feet).

(6) Verify interval that the well is screened over the formation thickness.

6.1.2.2 Baildown/slug tests are used to evaluate the transmissivity of LNAPL in the aquifer. It is recommended that the



Graph illustrating how the frequency of gauging data should be based on consistent changes in LNAPL thickness rather than time, and demonstrating the attainment of recharge equilibrium conditions.

FIG. 1 Gauging Data Graph

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LNAPL existing within the well and borehole need to be occasionally evacuated prior to the baildown test in order for the LNAPL to stay in communication with the formation. The maximum lag time between removal events is two years.

6.1.2.3 Prior to the test, the well being tested should be fully recharged; this will ensure the starting LNAPL thickness, LNAPL head, and potentiometric surface head are all representative of equilibrium formation conditions.

6.1.3 *Pre-Test Procedure:*

6.1.3.1 *Measuring Pre-Test Fluid Levels*—Measure the fluid levels in the well before the test for a period longer than the time it will take the well to recover in order to ensure equilibrium fluid levels are known and to calculate the effective well volume. This should be established during the initial evacuation of LNAPL from the well prior to the test (see 6.1.2.2).

6.1.3.2 Errors associated with erroneously assumed equilibrium fluid levels will reduce test accuracy and may invalidate the test.

6.1.3.3 Plan on gauging the well until complete equilibration occurs (Fig. 1) for wells where recovery behavior is not well understood or the pretest gauging data is realized not to represent equilibrium conditions.

6.1.3.4 The scope of work should plan for gauging to potentially be conducted over days or even weeks.

6.1.3.5 For unconfined conditions, the filter pack typically holds the majority of the stored LNAPL volume within the effective well radius. Partial displacement or removal of the LNAPL will result in the test being dominated by filter pack recharge.

6.1.3.6 Filter pack effects can be reduced through larger displacement volumes for slug tests or the complete removal of LNAPL in the filter pack and casing during baildown tests. The following equations can be used to approximate the volume of LNAPL within the well casing and borehole.

$$V_b = S_{yf} b_b \pi (r_b^2 - r_c^2) \quad (1)$$

$$V_c = b_n \pi r_c^2 \quad (2)$$

$$V_t = V_c + V_b \quad (3)$$

where:

V_t = total effective borehole LNAPL volume (L^3),
V_b = volume of LNAPL in the borehole (L^3),
V_c = volume of LNAPL in the casing (L^3),
b_b = LNAPL thickness existing within borehole (L),
b_n = gauged LNAPL thickness (L),
r_c = well casing radius (L),
r_b = well borehole radius (L), and
S_{yf} = specific yield or storage coefficient of well filter pack.

6.1.3.7 To account for borehole porosity and LNAPL saturation, a storage coefficient needs to be estimated. Empirical data suggest that 0.175 to 0.190 is a good value for this parameter at any site. If viscosity of the LNAPL is known, an alternate method of estimating storage coefficient that has been tested between viscosities of 0.7 and 2 centipoises can be derived by using Eq 4 (Lundy, 2005) (**6**). Using Eq 2 combined with viscosities of 0.5 cp and 5 cp results in a range in storativity of 0.23 to 0.13 where the geometric mean is 0.175. The empirical data and Eq 4 suggest an average value of 0.175 and the range should not vary by more than a factor of 50 %.

$$S_{yf} = -0.0418 ln(\mu_n) + 0.2007 \quad (4)$$

where:

S_{yf} = filter pack LNAPL specific yield, and
μ_n = dynamic viscosity of LNAPL (M/Lt).

6.1.3.8 Well construction data will need to be reviewed to evaluate if the filter pack exists over the entire gauged interval of LNAPL. If the well screen and filter pack do not exist across the entire gauged thickness, then the filter pack thickness, used in Eq 1 will have to be reduced from the gauged thickness value.

6.1.4 *Test Procedure:*

6.1.4.1 Where the LNAPL transmissivity or recharge behavior is not well known, plan to start the baildown portion of the test early in the work day and on a day when you will be able to return frequently to the well. This will ensure that sufficient measurement frequency can be obtained within the first 8 h of the test.

6.1.4.2 Remove the known LNAPL volume up to a maximum as calculated using Eq 3. Smaller removal volumes will exhibit larger filter pack recharge effects and be more instantaneous. Larger removal volumes will minimize filter pack recharge effects although may not be instantaneous relative to the test duration.

6.1.4.3 Baildown/slug test LNAPL head change rate must be induced in a time that is $1/100^{th}$ or less of the total test duration, in order to approximate instantaneous head change. If full removal of LNAPL from filter pack and well casing requires longer time and an analysis method that relies on instantaneous withdrawal is being used (for example, Cooper-Jacob), then a slug method or alternative method should be used.

6.1.4.4 Instantaneous removal or slug introduction is relative to total length of test. For example 15 min of purging can be considered instantaneous if the length of the test is 1 day or more. Non-instantaneous removals can potentially be corrected in conjunction with steady state based slug test solutions (that is, Bouwer-Rice), which is discussed in Section 8. However, efforts should be made to complete the slug/fluid removal in as short of a timeframe as is practical so that removal approximates an 'instantaneous' head change.

6.1.4.5 Record the start and finish time of LNAPL removal. Record the total volume of LNAPL and water removed or slug length and volume. If large volumes (over 5 gal/ 19 L) of LNAPL are removed or removal occurs for a relatively long period of time (over 30 min), record several interim measurements of volume removed and time.

6.1.4.6 Baildown tests conducted in wells containing low viscosity LNAPL (that is, <1 centipoise) generally require 30 min or less for purging, while higher viscosity LNAPL (that is, >2 centipoises) can require a few hours. This is acceptable if the baildown test takes days to complete, the time for removal in this case would approximate instantaneous head change relative to the test duration.

6.1.4.7 Following LNAPL removal, begin recording the time and measuring the depth to the air/LNAPL and LNAPL/

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water interfaces. Depth to the air/LNAPL interface should be decreasing (or remaining the same). The gauged LNAPL thickness should be increasing. Re-measure and report any readings that do not match these trends. Record notes regarding the methodology taken to confirm or revise anomalous data.

6.1.4.8 The depth to the air/LNAPL interface could decrease if the overall groundwater elevation at the site is dropping. To verify whether the water-table elevation is dropping, a nearby control well can be measured prior to and during testing.

6.1.4.9 The best practice for gauging fluid levels during the baildown test is to collect a measurement at a maximum frequency of every 0.05 to 0.1 ft (1.5 cm) change in LNAPL thickness from static. A minimum change in thickness that is reasonable for use in data analysis is 0.05 to 0.1 ft (1.5 cm) of change in thickness.

6.1.4.10 The best practice also consists of gauging fluid levels at a minimum frequency corresponding to a change in thickness that represents 5 % of the equilibrium gauged LNAPL thickness or 0.05 ft (that is, 1.5 cm), whichever is less. This methodology is conducted for the first 100 min of recovery. The remainder of the test can be completed by gauging measurements on a frequency corresponding to a change of 5 to 10 % of the equilibrium thickness. This methodology will result in data being collected on a logarithmic timescale which is appropriate for data analysis. Because the recovery rate will drop as the well recovers, measurements can be collected on a logarithmic time scale (that is, at some point, the well may only have to be gauged weekly or monthly).

6.1.4.11 The minimum practical time for measuring fluid levels with a single interface probe is at 1-minute intervals since two interfaces need to be gauged.

6.1.4.12 After the first 100 min of a test, the data should be reviewed and a schedule should be prepared by the field staff based on the collected data set.

6.1.4.13 Plotting the recovered LNAPL thickness versus the log of time will help to forecast future events and help to provide data to support the conclusion of the test (see Fig. 1).

6.1.4.14 The time point representing the next change in thickness of 5 to 10 % of the static thickness or 0.05 ft (1.5 cm), whichever is less, can then be forecast based on the graph. For example, if over the initial 100 min the well has recovered less than 5 % of its initial thickness, the next measurement would be at least an additional 100 min from the current time.

6.1.4.15 In order to ensure that equilibrium fluid levels are understood and can be used to calculate LNAPL drawdown, gauging data representing consistent equilibrium fluid levels must exist for a period that is equal to the length of a completed test. This data can represent fluid levels prior to start of test or following test.

6.1.4.16 If the initial gauging data is insufficient to ensure equilibrium fluid levels (for example, one data point immediately before the test) then plan on obtaining test measurements until the LNAPL thickness has stabilized to its static thickness. This will provide the most complete insight into the LNAPL distribution in the formation and confirm the initial equilibrium fluid levels. A typical indication of LNAPL thickness stabilizing is when the LNAPL thickness reaches a plateau for approximately one quarter to one half of a log cycle. This should be documented with 3 measurements over that period (see Fig. 1).

6.1.4.17 The actual time and date of each measurement should be recorded, particularly when it may deviate from the initial schedule. If the change in LNAPL thickness between each event is less than the percentages listed above, then the frequency of measurements may be decreased. However, if the change in LNAPL thickness is greater than the percentages listed above, then measurement frequency should be increased.

NOTE 1—During the test, accurate measurements of the depths to LNAPL and water are critical. Every effort should be made to ensure that these readings are consistent and reliable. It is important to evaluate the data as it is collected and confirm any apparent erratic gauging data. Confirmation readings should be supported with comments on the field form. LNAPL thickness should ideally be increasing (or remaining the same) from one measurement to the next, not decreasing.

6.1.4.18 In some cases, fluid levels may change more rapidly than can be measured manually. Under these circumstances a LNAPL baildown test can be conducted using a pressure transducer. Conduct a baildown test with a pressure transducer with the following modifications from the procedure described above:

(1) Synchronize the transducer clock with the time piece used to collect gauging measurements. Next, set the measurement schedule to collect a minimum of 50 readings over the estimated test duration. Ensure that the pressure transducer has the appropriate battery life and is calibrated.

(2) Lower the pressure transducer to the bottom of the well and gauge the well until the fluid levels have stabilized again.

(3) Following stabilization, record and compare the gauged measurements to the reading on the pressure transducer to ensure it is working properly.

(4) Start and run the test as described above in 6.1.4 except that the LNAPL/water interface does not need to be gauged during the test. The air/LNAPL and LNAPL/water interfaces should be gauged prior to initiating the test and following completion of the test for use in calibration of the pressure transducer depth.

(5) Gauge the air/LNAPL interface as frequently as possible throughout the test.

(6) Review manufacturer specifications to understand the accuracy and precision of transducer data collected and ensure the data to be potentially used is not limited by equipment specifications.

(7) Post-Test Procedure—Conduct preliminary analysis of data before leaving the field and evaluate the test regarding the criteria given in this test method. The test data should be analogous to the trend shown in Fig. 1. The drawdown and time magnitudes are expected to vary but the overall trend on a semi-log plot should be similar.

6.1.5 *Report:*

6.1.5.1 Include the information listed below in the report of the field procedure:

(1) Well identification.

(2) Well construction (well depth, filter pack and screen interval, inner casing, screen, and borehole diameter).

(3) Date and time of initial fluid gauging data.

(4) Initial fluid levels.

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(5) Field staff.

(6) Known LNAPL characteristics (for example, LNAPL density and product type).

(7) Well Identification (ID), casing diameter and other known well information.

(8) Method of LNAPL withdrawal removal notes.

(9) Calculated well volume.

(10) Establish and record the measurement point from which all measurements of fluid levels were made.

(11) All gauging data collected prior to and during the test.

(12) Start and stop date and time of LNAPL purge event or slug withdrawal.

(13) Volume of LNAPL and water removed during purge or slug withdrawal event.

(14) If the fluid levels are measured with a pressure transducer, report the model type of the pressure transducer used, recorded pressure versus time data, and the data used to convert pressure data to fluid depth (that is, calibration fluid level data and the fluid density).

6.1.6 *Precision and Bias:*

6.1.6.1 *Precision*—It is not practical to specify the precision of this specific test method because the response of aquifer systems during testing is dependent upon ambient system stresses.

6.1.6.2 *Bias*—No statement can be made about bias because no true reference values exist.

6.2 *Manual Skimming Field Methods*—This test method describes the field procedures involved in conducting a LNAPL manual skimming test. This test consists of the removal of LNAPL from the well casing and borehole on a repeated basis, without allowing more than approximately 25 % of recharge to occur in between product removal events. The rate of removal is therefore dependent on well recharge behavior. The key criterion is that greater than 75 % of the maximum skimming drawdown must be consistently induced. Purging is completed until the recovery rate stabilizes. The LNAPL discharge or recovery rate for each LNAPL removal step is calculated. The recovery volume and gauging data, along with the volume of LNAPL removed, can be used to estimate the LNAPL transmissivity and recoverability. LNAPL transmissivity is calculated from the stabilized LNAPL discharge data. This test ranges from a few hours for wells exhibiting higher LNAPL transmissivities to in excess of weeks for wells exhibiting lower LNAPL transmissivities. The manual skimming test can be performed on most wells that contain LNAPL.

6.2.1 *Apparatus*—This section describes the types of equipment that can be used. Since there are an infinite variety of testing conditions and because similar results can be achieved with different apparatus, engineering specifications for apparatus are not discussed in this guide. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this guide.

6.2.1.1 *LNAPL Removal Equipment*—Because a variety of equipment can be used to induce a change in LNAPL head, this method will not provide engineering specifications of the exact means in which head is changed, but rather identify how common types of equipment can affect the final results.

6.2.1.2 *Fluid Level Measurement Equipment*—Typically, the air/LNAPL and LNAPL/water interfaces will be gauged using an interface probe. Currently the most precise available interface probes utilize optical and electrical resistivity technologies. Additionally, current technology allows for probes to be relatively small (⅝-in.) in diameter. The optical and electrical resistivity type interface probes increase the ability to measure fluid interfaces to typical accuracies from 0.01 to 0.02 ft (0.3 to 0.6 cm) and the small probe diameter causes little displacement to fluids in the well.

6.2.1.3 *Time Piece*—Used to record the elapsed time of the test.

6.2.1.4 *Graduated Container*—A container for water and LNAPL collection that is graduated to measure within 10 % of total estimated recovery volume between fluids removal events. For example, a container that can measure 0.1 gal intervals for an expected 1 gal of recovered product, or a container that can measure 1 gal intervals for an expected 10 gal of recovered LNAPL.

(1) Decontamination Equipment—Typically, LNAPL in a well can foul measuring devices and should be cleaned with an appropriate cleaning agent. If multiple wells are tested, equipment should be cleaned of well fluids between testing separate wells.

(2) Test Forms—Test forms should be used to record the parameters listed in 6.3.2 and 6.3.4 (that is, Conditioning and Procedure).

6.2.2 *Conditioning:*

6.2.2.1 *Pre-Test Well Information*—The following well construction information needs to be obtained prior to initiating the manual skimming tests:

(1) Borehole diameter of well to be tested.

(2) Casing and screen diameter.

(3) Top of screen relative to top of casing.

(4) Bottom of screen interval relative to top of casing.

(5) Total well depth.

(6) Verify interval that the well is screened over the formation thickness.

6.2.2.2 Manual skimming tests are used to evaluate the transmissivity of LNAPL in the formation. It is recommended that the LNAPL existing within the well and borehole be occasionally evacuated prior to the manual skimming test in order for the LNAPL to stay in communication with the formation. Prior to the test, the well being tested must be fully recharged. This will ensure the starting fluid levels surface head are all representative of equilibrium formation conditions.

6.2.2.3 *Measuring Pre-Test Fluid Levels*—Measure the fluid levels in the well before beginning the test to determine the pre-test fluid levels.

6.2.2.4 The pre-test fluid levels need to represent equilibrium conditions in order for the accurate calculation of LNAPL drawdown.

6.2.2.5 No other pre test procedures are required.

6.2.3 *Test Procedure:*

6.2.3.1 Because of the LNAPL extraction and measurement frequency needed over the first 8 h, plan to start the manual skimming portion of the test early in the work day and on a day when you will be able to return frequently to the well.

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6.2.3.2 The test consists of the following four steps:

(1) Initial gauging of fluid levels.

(2) Purging the well and borehole of the LNAPL.

(3) Periodically returning to the well to:

(a) Gauge fluid levels.

(b) Purge any recovered LNAPL.

(c) Gauge fluid levels following purging.

(4) Data analysis.

6.2.3.3 To start the test, remove LNAPL until further LNAPL removal is not possible while minimizing the groundwater recovered. Record the start and finish time of LNAPL removal. Record the total volume of LNAPL and water removed. If large volumes (over 5 gal/19 L) of LNAPL are removed or removal occurs over a long period of time (over 30 min), record several interim measurements of volume removed and time. Try not to disturb the static potentiometric surface level during LNAPL removal. Methods of LNAPL removal may include bailers, peristaltic pumps, vacuum truck removal and other skimmer pumps as long as the volumes can accurately be measured.

6.2.3.4 Remove LNAPL until the product is no longer being removed.

6.2.3.5 Begin recording the date/time and measured depths to the air/LNAPL interface and LNAPL/water interface immediately after removing the LNAPL. Once the well has recovered ¼ of the initial thickness, re-purge the LNAPL in the well. Record the start and stop time of purging and the gauging data before and after each purging event. The time elapsed between the completion of the initial purge and the start time of the following purging event will provide an estimated return time for the next event.

6.2.3.6 A best practice of the test is to gauge and purge the well before the well recovers ¼ of the original thickness. The following frequencies are provided as an initial recommendation and should be adjusted based on field observations:

(1) First hour: every 10 min (6 measurements).

(2) 2 h to 4 h: every 30 min (4 measurements).

(3) 4 h till end of first day (1 measurement).

(4) Second day: 2 to 3 times.

(5) Subsequent days: At least twice per day until the LNAPL discharge rate has stabilized.

6.2.3.7 The actual time and date of each measurement should be recorded, especially when it may deviate from the initial schedule. The calculated recharge will typically start out high and decrease until it reaches a constant value. The test should continue until the calculated recharge into the well stabilizes. At some locations this may take a week. Following the first 4 h and the first day of testing, the data should be reviewed to improve the timeline with which gauging and purging events will be conducted. If previous knowledge of the recovery behavior for a given well is available, the provided timescale can be modified based on those data.

6.2.3.8 If the well is recovering less than ¼ of its initial thickness between each measurement, the frequency of measurements may likely be decreased. However, if the LNAPL thickness recovers to more than ¼ of the initial thickness, frequency of gauging and purging should be increased.

6.2.3.9 The maximum practical measurement and purge frequency is 5 min for a single field staff due to the constraints of gauging, fluid removal activities, recovered fluid volume removal measurement and documentation. It is not necessary to increase the frequency beyond this. If the well recovers too fast for these conditions to be met then an alternate testing methodology should be employed, such as a pilot test with an automated skimming pump in conjunction with the recovery system-based field and analysis method.

6.2.3.10 The test is complete when three or four consecutive discharge rates are within 25 % of each other and no consistently decreasing trend is observed.

6.2.3.11 During the test, accurate measurements of the recovered volume and depths to air/LNAPL and LNAPL/water interfaces are critical. Every effort should be made to ensure that these readings are consistent and reliable. Re-measure and document any readings that seem anomalous and then make notes regarding the methodology taken to confirm or revise anomalous data.

6.2.3.12 Ensure that the bucket/container used for measuring recovered volume spans the volumes being recovered each period. Typically the removal volumes for each purging event will be less than ½ gal. A 5-gal bucket is not precise enough for measuring the recovered volume following the initial removal. See section 6.3.1 (Apparatus).

6.2.3.13 *Post-Test Procedure*—Make a preliminary analysis of the data before leaving the field and evaluate the test regarding the criteria given in this test method to determine if the test should be rerun.

6.2.4 *Report*—Include the information listed below in the report of the field procedure:

6.2.4.1 Well identification.

6.2.4.2 Well construction (well depth, filter pack and screen interval, inner casing, screen, and borehole diameter).

6.2.4.3 Date and time of initial fluid gauging data.

6.2.4.4 Initial fluid levels.

6.2.4.5 Field staff.

6.2.4.6 Known LNAPL characteristics (for example, LNAPL density and product type).

6.2.4.7 Casing diameter and other known well information.

6.2.4.8 Method of LNAPL withdrawal removal notes.

6.2.4.9 Calculated well volume.

6.2.4.10 Establish and record the measurement point from which all measurements of fluid levels were made.

6.2.4.11 All gauging data collected prior to the test.

6.2.4.12 Date and time of test start.

6.2.4.13 Depth to fluid levels before and after each purge event.

6.2.4.14 Start and stop date and time of each gauging and purge event.

6.2.4.15 Volume of LNAPL and water removed during each purge event.

6.2.5 *Precision and Bias:*

6.2.5.1 *Precision*—It is not practical to specify the precision of this test method because the response of aquifer systems during LNAPL manual skimming tests is dependent upon ambient system stresses.

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6.2.5.2 *Bias*—No statement can be made about bias because no true reference values exist.

6.3 *Long-term Recovery System Method*—This test method describes the field procedures involved with collecting product recovery system data for the purposes of estimating LNAPL transmissivity under steady state conditions. LNAPL transmissivity calculations for recovery systems are based on the achieved LNAPL recovery rate versus drawdown induced. Therefore, this section is focused on methods used to estimate LNAPL recovery rate for all systems and specific methods used to estimate drawdown induced by the specific technologies.

6.3.1 *Apparatus*—The equipment consists of storage containers which allow for measurement of fluid volumes recovered over time, flow meters for individual and/or total fluids and instantaneous flow measurements. In addition, equipment used to measure pneumatic and/or hydraulic head at individual well locations and/or for the system as a whole. Because there are an infinite number of recovery system designs, this guide does not specify the equipment to be used, but rather the equipment used must meet the data objectives set forth in the guide.

6.3.2 *Conditioning*—All recovery wells where LNAPL transmissivity is estimated should be properly developed in order to ensure non-linear head losses are minimized. Maintenance schedules should consist of development following well installation, as well as, periodic rehabilitation to prevent deterioration of the well performance to scaling and biofouling. One time well development is not sufficient for most active recovery systems that run longer than five years.

6.3.3 Verify interval that the well is screened over the formation thickness.

6.3.4 *Procedure*—Because the procedure for measurement is dependent on system design and equipment, it is not feasible to specify the measurement procedure for each parameter in this method. Field forms for individual technologies are provided in Annex A1 and identify the minimum field parameters, as well as, where additional measurements would provide multiple lines of evidence for LNAPL transmissivity calculations.

6.3.5 *Report*—Field forms included in Annex A1 identify the reporting requirements for individual technologies. The report consists of measured input values and justification for each parameter measured on the field forms and variables provided in Tables A2.5-A2.8.

6.3.6 *Precision and Bias:*

6.3.6.1 *Precision*—It is not practical to specify the precision of this test method because the response of aquifer systems during LNAPL recovery is dependent upon ambient system stresses.

6.3.6.2 *Bias*—No statement can be made about bias because no true reference values exist.

7. Tracer Test Field Methods

7.1 This test method describes field procedures for conducting LNAPL tracer tests.

7.2 *Apparatus*—This section describes the types of equipment that can be used. Because of the infinite variety of testing conditions, engineering specifications for apparatus are not provided. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this guide.

7.2.1 *Spectrometer/Fiber Optic Cable and Computer*—To date, a temperature regulated, visible light spectrometer has been used to measure the tracer presence and relative concentration in the LNAPL. The spectrometer consists of a light source to induce fluorescence in the tracer. The output from the spectrometer is converted to a digital signal and transmitted to a laptop computer, Program Logic Controller (PLC), or similar device to store and display the measured values.

7.2.2 The fiber optic cable used to date consists of multiple fibers. A portion of the fibers within the cable are used to transmit the excitation light source to the tracer in the LNAPL in the well, and others return the resulting fluorescence response back to the spectrometer.

7.2.3 The spectrum of excitation and measured fluorescence response is key as fiber optic cables tend will attenuate signals too rapidly to be of use if they are not appropriate for the excitation and fluorescence spectrums of intent. Typically, attenuation occurs more rapidly for shorter wavelengths (for example, less than 290 nm).

7.2.4 To date, a laptop computer equipped with software to communicate with the spectrometer has been used to control the spectrometer and display a graph of the spectrum (intensity versus wavelength) and record output.

7.2.5 *Tracer:*

7.2.5.1 The tracer used to date is BSL 715.[4] This tracer is a concentrated liquid hydrocarbon which has unique fluorescence peaks at 545 and 580 nm when excited at 470 nm. It fluoresces yellow under ultraviolet light and is used in the automotive industry to detect oil leaks. This tracer is specifically listed (Sale et. al., 2008) **(7)** because it has undergone testing to ensure that it will not decrease in concentration over time in the well based on non-flow related mechanisms such as dissolution, volatilization, or sorption. Any new tracer used to estimate LNAPL transmissivity will need to be tested to ensure that it acts as a conservative tracer.

7.2.5.2 The tracer has the following characteristics:

(1) It is detectable in LNAPL at low concentrations (less than 1 ppm in Soltrol 220, Woodlands, Texas).

(2) It is insoluble in water.

(3) It has no significant effect (at application concentrations) on the physical properties of LNAPL.

(4) It fluoresces at a wavelength where most LNAPLs have low background fluorescence.

(5) It has low toxicity relative to constituents present in most LNAPLs.

7.2.6 *In-Well Calibration Standards*—In-well calibration standards are used to correct for potential non-tracer related florescence from the LNAPL induced by the 470 nm light source. Small diameter pipes are inserted within the test well to occlude a volume of LNAPL without tracer and a volume of

[4] The sole source of supply of the apparatus known to the committee at this time is Bright Solutions Inc., Troy, Michigan. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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LNAPL with the initial tracer concentration. A small-diameter pipe is inserted into the test well, through the LNAPL before tracer is added, for Eq 5 this well is called C_0. Tracer is then added and mixed with the LNAPL. A second pipe is then inserted into the test well through the LNAPL. This well is called C_{100} in Eq 5. The two pipes, one without tracer and one with the initial tracer concentration allow for in-well spectrometer calibrations to be made with each tracer concentration measurement. Measurements of remaining tracer in the test wells at the end of each measurement period are corrected using the calibrations assuming a linear relationship between fluorescence and intensity can be calculated as:

$$\frac{C_{T_{t+\Delta t}}}{C_{T_t}} = \frac{\dfrac{I_{test_well_{t+\Delta t}} - I_{Cal_well.C_{0_{t+\Delta t}}}}{I_{Cal_well.C_{100_{t+\Delta t}}} - I_{Cal_well.C_{0_{t+\Delta t}}}}}{\dfrac{I_{test_well_t} - I_{Cal_well.C_{0_t}}}{I_{Cal_well.C_{100_t}} - I_{Cal_well.C_{0_t}}}} \quad (5)$$

where:

$C_{T_{t+\Delta t}}$ = concentration of tracer mass remaining at time of measurement (M/L^3),
C_{T_t} = concentration of initial tracer mass (M/L^3),
$I_{test_well_{t+\Delta t}}$ = fluorescence intensity in test well at time of measurement (unitless),
$I_{Cal_well.C_{0t+\Delta t}}$ = fluorescence intensity in C_0 calibration well at time of measurement (unitless),
$I_{Cal_well.C_{100t+\Delta t}}$ = fluorescence intensity in C_{100} well at time of measurement (unitless),
$I_{test_well_t}$ = initial fluorescence intensity in test well (unitless),
$I_{Cal_well.C_{0t}}$ = initial fluorescence intensity in C_0 well (unitless), and
$I_{Cal_well.C_{100t}}$ = initial fluorescence intensity in C_{100} well (unitless).

7.2.7 *Interface Probe*—An interface probe should be used to record LNAPL thickness in the test well each time tracer concentration is measured. Additionally, the interface probe is used to measure the LNAPL and hydraulic gradients occurring throughout the test duration.

7.2.8 *Pressure Transducer*—The use of a pressure transducer should be considered for sites where the fluid levels are expected to vary the LNAPL gradient over the length of the test and where site gauging events are expected to be infrequent.

7.2.9 *Decontamination Equipment*—LNAPL must be cleaned from the fiber optic cable between calibration standard measurements and test well measurements to ensure that there is no transfer of tracer dye between standards or test well. A cleaning agent such as detergent or isopropyl alcohol should be used to clean the fiber optic cable between readings. Further information on decontamination can be found in Practice D5088. Additionally, LNAPL can foul other fluid-level measurement devices. These devices should be cleaned with an appropriate cleaning agent. If multiple wells are tested, equipment should be cleaned of fluids between testing of separate wells.

7.3 *Conditioning:*

7.3.1 Collect representative LNAPL samples from monitoring wells to be used for testing prior to initiating the LNAPL tracer tests. Measure and record fluorescence of the LNAPL sample using the spectrometer. Add tracer to the LNAPL sample, thoroughly mix the sample, and measure and record fluorescence of the sample. Repeat the preceding step adding increasing amounts of tracer to evaluate the dose-response relationship between tracer concentration and fluorescence intensity. Initial tracer concentrations should be determined for each LNAPL type based on the following guidelines.

7.3.2 Review well construction logs to ensure the current LNAPL thickness is within the well screened interval.

7.3.3 Collect representative LNAPL samples from monitoring wells to be used for testing prior to initiating the LNAPL tracer tests. Measure background fluorescence and conduct titration tests to evaluate the dose-response relationship between tracer concentration and fluorescence intensity for each LNAPL type. Initial tracer concentrations should be determined for each LNAPL type based on the following guidelines.

7.3.3.1 All fluorescence measurements throughout this methodology should be made in triplicate to ensure the readings are within 1 %.

7.3.3.2 A tracer fluorescence peak that is at least twice that of the background LNAPL is desirable to ensure that the tracer fluorescence signal is not overwhelmed by background LNAPL fluorescence and remains detectable for a sufficient period of time.

7.3.3.3 Generally, a plot of tracer concentration versus fluorescence intensity will have a linear segment followed by a non-linear asymptotic segment, beyond which the relationship between tracer concentration and LNAPL flow through the well becomes difficult to quantify. It is therefore important to ensure that the initial quantity of tracer added results in a concentration that falls within the linear range for the LNAPL type in the well.

7.3.4 Large tracer concentrations may alter the physical properties of the LNAPL that govern flow, and therefore the smallest amount of tracer that can be used to conduct the test is recommended.

7.3.5 Verify interval that the well is screened over the formation thickness.

7.4 *Procedure:*

7.4.1 *Test Initiation*—Consists of the following procedures:

7.4.1.1 Measure the depth to the air/LNAPL and LNAPL/water interfaces, and LNAPL thickness in the test well. Review well construction logs to ensure that the LNAPL within the test well is in communication with the screened interval of the test well.

7.4.1.2 Conduct a baseline scan of the LNAPL within the test well using the spectrometer and down-well fiber optic cable to measure background fluorescence. Decontaminate and inspect the fiber optic cables and reflectance probe (at the tip of the fiber optic cable) prior to use to ensure there are no sources of light interference that may yield erroneous data. Decontamination and inspection will be conducted prior to each reading using the down-well fiber optic cable and spectrometer.

7.4.1.3 Insert a small diameter pipe into each well selected for testing to isolate a volume of LNAPL from the contents of the well. The pipe will be inserted to the bottom of each well to ensure that the LNAPL remains isolated during the test period. The isolated LNAPL sample, hereafter referred to as

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C_0, represents the LNAPL within the formation materials and is used throughout the duration of the LNAPL tracer test to calibrate the spectrometer against the background fluorescence of the LNAPL. The smallest diameter pipe that can accommodate a down hole fiber optic cable within its inner diameter should be used.

7.4.1.4 After isolating a volume of LNAPL within the well in the C_0 pipe, calculate the total volume of LNAPL in the well, and calculate the volume of tracer that will need to be mixed with the LNAPL in accordance with the guidelines outlined in 7.3. Carefully remove a small vial of LNAPL from the well and amend with the previously determined volume of LNAPL soluble tracer. After mixing the LNAPL and tracer thoroughly in the weighted vial, carefully lower the mixture into the well, and gently raise and lower the vial beneath the air/LNAPL interface until all of the LNAPL/tracer mixture is mixed into the LNAPL within the test well. Make sure that none of the liquid in the vial splashes onto the well casing, which could slowly drip back into the well over the duration of the test and potentially introduce error to the LNAPL transmissivity estimates.

7.4.1.5 Scan the column of LNAPL/tracer in the well using the spectrometer and down-hole fiber optic cable to ensure that the tracer is well mixed throughout the well. If the fluorescence readings vary with depth through the LNAPL column, mix the LNAPL and tracer together. A small air line should be lowered into the test well to a depth beneath the water-LNAPL interface. The air line is then used to mix the LNAPL to a "well-mixed" condition. Once adequately mixed, confirm that the fluorescence readings in the LNAPL/tracer mixture agree with the targeted fluorescence.

7.4.1.6 After mixing the desired proportions within the well, insert a second small diameter pipe to isolate a volume of the initial LNAPL/tracer mixture. The drop pipe will be inserted to the bottom of the test well to ensure that a sample representative of the initial LNAPL/tracer mixture remains isolated during the test period. This sample is referred to as C_{100} and used throughout the tracer test to calibrate the spectrometer with the initial tracer concentration introduced into the LNAPL within the test well. Each time the concentration of tracer is measured within the test well (C_{WELL}) the spectrometer is calibrated using the in-well standards (C_{100} and C_0).

7.4.1.7 Scan and record intensity readings for C_0, C_{100}, and C_{WELL}, and then repeat these measurements, making sure that consecutive readings for each of the controls (C_0 and C_{100}) and the fluorescence readings in the test well (C_{WELL}) are within 2 % of the previous readings. If the readings are not within 2 %, remix the test well and recollect the data until all of the readings are within 2 %.

7.4.2 *Routine Data Collection:*

7.4.2.1 Thoroughly mix the LNAPL/tracer mixture in the well with a down-well airline, the calibration standard pipes, or other appropriate method; mixing should be sufficient to create a 'well mixed' condition. Mixing too aggressively can push tracer out of the well resulting in erroneously high readings. Verify that the LNAPL/tracer mixture is adequately mixed by conducting a vertical scan through the LNAPL column in the well using the down-well fiber optic cable and spectrometer. Decontaminate and inspect the fiber optic cables and reflectance probe (at the tip of the fiber optic cable) prior to each use to ensure there are no sources of light interference that may yield erroneous data.

7.4.2.2 Measure and record depth to the air/LNAPL and LNAPL/water interfaces using an oil-water interface probe in the test well. Do not gauge the well with the interface probe prior to mixing, as removing small volumes of poorly mixed LNAPL or LNAPL/tracer mixture (even volumes as small as the quantity that sticks to the interface probe) could potentially introduce error to the mass-balance calculations used to estimate LNAPL flux through the well.

7.4.2.3 Measure and record LNAPL fluorescence within the in-well standard pipes (C_0 and C_{100}) and the test well (C_{WELL}). Decontaminate the fiber optic cable between readings to prevent transfer of dyed or undyed LNAPL between calibration standards and the test well. Repeat measurement of LNAPL fluorescence within the in-well standard pipes (C_0 and C_{100}) and the test well (C_{WELL}). Two percent or less variability between the first and second measurements of $C_0$0, C_{100}, and C_{WELL}, respectively, are desirable. Additional mixing of the LNAPL and additional measurement repetition may be necessary to achieve the target variability.

7.4.2.4 The test should be terminated, or re-started by adding more tracer to the test well (C_{WELL}) when the tracer concentration in the test well approaches the natural background fluorescence in C_0 due to accuracy of the spectrometer. Generally, when the tracer concentration in the test well (C_{WELL}) is less than 20 % greater than C_0, the test should be restarted or terminated.

7.5 *Report:*

7.5.1 Include the information listed below in the report of the field procedure:

7.5.1.1 Date, time, and well identification.

7.5.1.2 Volume of tracer added.

7.5.1.3 Background florescence of LNAPL in C_0.

7.5.1.4 LNAPL fluorescence in C_{100}.

7.5.1.5 All gauged LNAPL thickness measurements in test well.

7.5.1.6 All gauged depth to air/LNAPL interface measurements.

7.5.1.7 All gauged depth to LNAPL/water interface measurements.

7.5.1.8 Diameter of well.

7.5.1.9 Diameter of small diameter pipes (isolation tubes) and type of material.

7.6 *Precision and Bias:*

7.6.1 Repetition of readings increases test precision. At a minimum, duplicate readings are taken and the duplicate readings should match within two percent of previous readings. There is no known bias in the testing method. Site-to-site test precision has not yet been quantified based on variability in site conditions and instruments utilized for testing.

7.6.2 It can be envisioned that if there is no LNAPL transmissivity, tracer will never leave the well due to advective processes, but there is still connection between LNAPL in the well and the LNAPL in the formation, so tracer can still diffuse from the well. The lower detection limit of the method is

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governed by the rate if diffusion of tracer from the well into the formation. Taylor (2004) (**8**) developed a rigorous solution to calculate the lower detection limit based on the effective diffusion coefficient of the tracer.

7.6.3 The method precision will be discussed in a qualitative sense. There are issues associated with the precision of the method based on variability of collecting individual tracer concentration data points. The data that is collected in the field is fit to a non-linear analytic model, much like the other methods. Each time a fluorescence concentration is measured, a duplicate reading is collected. The goal for the duplicate readings is to achieve two percent (on a normalized basis) variability. If the LNAPL transmissivity is very low, and the readings are taken over a small time period, it can be envisioned that the two percent variability within each data point might be larger than the actual decrease in tracer concentration. This results in the inability to calculate an absolute transmissivity value; however, an upper limit transmissivity could be still be calculated generating data where LNAPL transmissivities can be reported as less than a time weighted absolute transmissivity value.

8. Data Analysis

8.1 *Calculations for General Parameters*—This section provides guidance on how to calculate standard parameters potentially applicable to any methodology.

8.1.1 *Calculating Fluid Levels from Pressure Transducers*—Setups can include the use of one, two or three pressure transducers. This section will cover how to estimate the air/LNAPL interface, LNAPL/water interface and the calculated water-table elevations.

8.1.1.1 Pressure transducers measure either the absolute pressure or gage pressure (pressure relative to atmospheric pressure). For this discussion it is assumed that absolute pressures are measured. If the air/LNAPL interface is the objective of a given transducer then the measured pressure will need to be corrected for LNAPL density for estimating LNAPL head.

8.1.1.2 To use a pressure transducer, the density of the LNAPL should be known prior to interpreting the test results.

8.1.1.3 Eq 6 assumes the transducer provides absolute pressure data. These equations, combined with calibration gauging data and LNAPL density data, will allow calculation of each fluid interface elevation whether one pressure transducer is being used in conjunction with gauging of the air/LNAPL interface or two pressure transducers are being used, one in each fluid phase.

$$Z_{CGW} = Z_{P1} + \frac{P_{P1} - P_{atm}}{\rho_w g} \tag{6}$$

where:

Z_{P1} = elevation of water phase pressure transducer (that is, pressure transducer P1) (L),
Z_{CGW} = elevation of the calculated water-table level (L),
P_{P1} = measured absolute pressure from pressure transducer P1 (M/t^2L),
P_{atm} = measured atmospheric pressure inside the well casing (M/t^2L),
ρ_w = groundwater density (M/L^3), and
g = gravitational acceleration (L/T^2).

8.1.1.4 Eq 6 combined with atmospheric pressure data and pressure transducer data is used to calculate the corrected water-table elevation.

$$Z_{AN} = Z_{P2} \mp \frac{P_{P2} - P_{atm}}{\rho_n g} \tag{7}$$

where:

Z_{P2} = elevation of LNAPL phase pressure transducer (that is, pressure transducer P2 located within the LNAPL column in the well) (L),
Z_{AN} = elevation of the air/LNAPL interface (L),
P_{P2} = measured absolute pressure from pressure transducer P2 (M/t^2L),
ρ_n = LNAPL density (M/L^3), and
g = gravitational acceleration (L/T^2).

8.1.1.5 Eq 7 combined with the atmospheric pressure data and pressure transducer data is used to calculate the elevation of the air/LNAPL interface.

$$Z_{OW} = \frac{Z_{CGW} - \rho_r Z_{AN}}{1 - \rho_r} \tag{8}$$

where:

Z_{OW} = elevation of the LNAPL/Water interface (L), and
ρ_r = the relative LNAPL to water density, that is, $\rho_r = \rho_n / \rho_w$ (unitless)

8.1.2 Eq 8 results in the LNAPL/water interface elevation. Eq 8 requires the density of LNAPL and the elevations of the calculated water-table level and the air/LNAPL interface to be known. The required fluid elevations can be measured in any combination of gauging data or pressure transducer data that provides these required input elevations. LNAPL density should be estimated based on laboratory analysis of site specific LNAPL.

8.1.3 *Calculation of LNAPL Drawdown*—The calculation of LNAPL drawdown must compare the pressure (head) existing in a given extraction well to the equilibrium pressure (head) of LNAPL within the mobile interval in the formation. For every case the top of the mobile interval of LNAPL in the formation is the reference point for drawdown. If multiple soil horizons exist then the interval estimated to exhibit the highest transmissivity would be selected at the primary interval and therefore would represent the reference point for drawdown calculations. A silt overlying a fine sand may have some mobile LNAPL but would be insignificant compared to the underlying sand. In this case, the top of the underlying sand would be selected for the reference point to calculate drawdown.

8.1.3.1 *Unconfined*—Drawdown under unconfined conditions is given by the following equation for air/LNAPL interface drawdown:

$$S_{nt} = Z_{AN^*} - Z_{AN(t)} \tag{9}$$

where:

Z_{AN^*} = the air/LNAPL interface elevation for equilibrium conditions (L),
$Z_{AN(t)}$ = the air/LNAPL interface elevation at time t (L), and

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S_{nt} = LNAPL drawdown at time t (L).

8.1.3.2 *Confined LNAPL Drawdown*—Drawdown for confined conditions is not solely based on the air/LNAPL interface elevation because as LNAPL is extracted from a well both LNAPL and water can rise above the mobile interval of LNAPL (that is, the confining layer), and drawdown calculation must consider the entire fluid column and fluid density between the mobile interval and air/LNAPL interface.

(1) Where the calculated water-table elevation is equal to equilibrium conditions, the LNAPL/water interface is above the confining contact and LNAPL is recovering from a baildown test or being removed via a skimming technology, Eq 10 can be used to estimate the LNAPL drawdown. In this scenario of a constant calculated water-table, drawdown is constant so long as the LNAPL/water interface remains above the confining contact elevation because as a given mass of LNAPL flows into the well, an equal mass of water flows out of the well. For this constant LNAPL drawdown condition the fluid pressure distribution across the mobile interval of LNAPL remains constant.

$$S_{nt} = b_{nf}\frac{1-\rho_r}{\rho_r} \quad (10)$$

where:

b_{nf} = mobile interval of LNAPL in the formation, which is not equal to the gauged LNAPL thickness (L).

(2) Once the elevation of the LNAPL/water interface has decreased below the confining contact, the LNAPL drawdown is calculated using the difference in air/LNAPL interface (that is, Eq 9).

(3) Note that the formation thickness of confined LNAPL can be estimated by taking the difference in the static LNAPL/water interface and the confining contact elevation in the formation, typically estimated based on soil boring data such as soil type and LNAPL impacts.

(4) When confined LNAPL exists, the LNAPL/water interface is above the confining contact, the calculated water-table is less than equilibrium, and LNAPL is recovering from a baildown/slug test or continuous liquid extraction, Eq 11 can be used to estimate LNAPL drawdown.

$$S_{nt} = \frac{(Z_{AN^*} - Z_{cc})\rho_n - (Z_{NW(t)} - Z_{cc})\rho_w - (Z_{AN(t)} - Z_{NW(t)})\rho_n}{\rho_n} \quad (11)$$

where:

S_{nt} = the drawdown at time t for LNAPL existing in a confined state below the confining contact elevation,

Z_{cc} = elevation of confining contact (L),

$Z_{NW(t)}$ = elevation of LNAPL/water interface at time t (L), and

Z_{AN^*} = elevation of air/LNAPL interface for equilibrium conditions (L).

(5) If well extraction has resulted in the air/LNAPL interface occurring below the confining layer then drawdown is calculated with Eq 9 (that is, same as unconfined conditions). This equation will hold until the air/LNAPL interface reaches the confining contact. During this scenario for confined LNAPL, drawdown is not constant and will decrease with time. It is possible that Eq 9-11 are all required to cover the span of a recovery event (baildown, slug or liquid extraction).

(6) Each equation covers a specific set of conditions that may or may not be present during any given test where confined LNAPL exists.

8.1.3.3 *Perched*—The drawdown for perched LNAPL conditions is the same as for unconfined except that the maximum possible drawdown for liquid only extraction is equal to the mobile interval of LNAPL in the formation. Vacuum enhanced extraction can increase this drawdown and the equations are discussed under 8.2. The mobile interval of LNAPL in the formation is equal to the difference in the equilibrium air/LNAPL interface and the perched layer contact. The contact for perched LNAPL can be estimated based on soil boring data such as soil type and LNAPL impact data.

8.1.4 *Data Analysis–Baildown Testing:*

8.1.4.1 *General Boundary Conditions:*

(1) The primary condition which needs to be met is that the relationship between LNAPL drawdown and LNAPL discharge to the well from the formation, (that is, well recharge) is a direct relationship and the data would trend such that the discharge and drawdown would reach zero simultaneously. Fig. 2 provides the ideal behavior.

(2) Baildown test that meet this criterion need not be run to completion since the data trends confirm that the fluid level used to represent equilibrium conditions is a reasonable value.

(3) Baildown test data that exhibit deviations from this ideal trend indicate that the data is not suitable for analysis or that the value used for equilibrium conditions is inaccurate. Equilibrium fluid levels should be checked and can be corrected to represent the final fluid levels if these data are more representative of equilibrium conditions based on gauging data trends obtained during the baildown test. If a correction is not reasonable then the data not exhibiting the correct trend should not be analyzed with the baildown test methods provided. Where uncertainty occurs with equilibrium fluid levels, the baildown test should be run to completion to understand the equilibrium fluid levels. The test can then be repeated or an alternate method in this guide used to estimate LNAPL transmissivity.

(4) Data that initially trends towards zero drawdown where the discharge would still be positive typically represents perched or confined LNAPL behavior (Fig. 3).

(5) Data that initially trends towards zero discharge where the drawdown would still be positive typically represents filter pack recharge and should not be analyzed (Fig. 4).

(6) Eq 12 is used to calculate the recovered thickness attributable to filter pack recharge, where all recovery up to this thickness should be considered filter pack recharge. Eq 12 is only applicable where the initial gauged thickness of LNAPL in a well exists completely within the screened interval.

$$b_r = b_n - \frac{V_r}{\pi\left(S_{yf}\left(r_b^2 - r_c^2\right) + r_c^2\right)} \quad (12)$$

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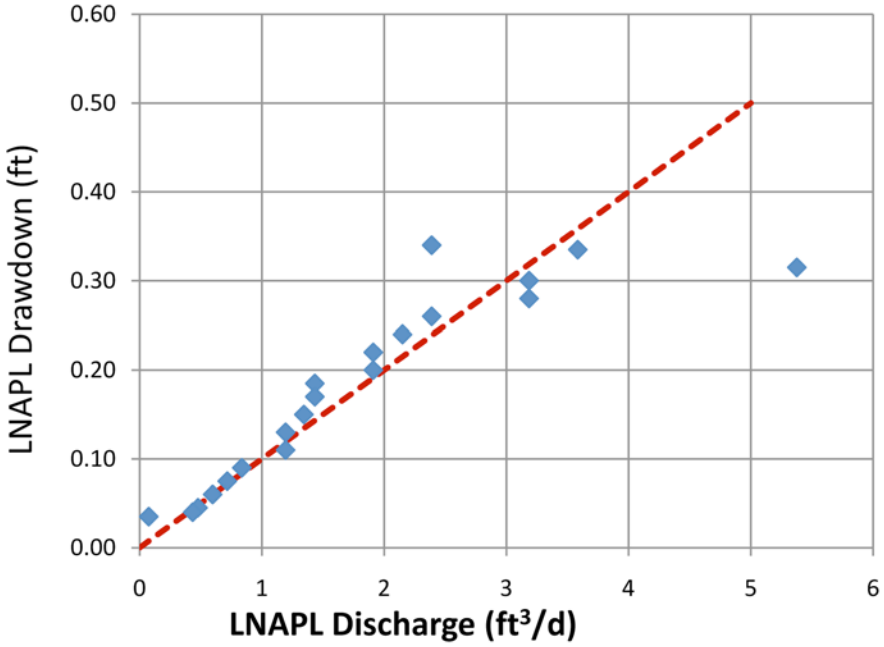


FIG. 2 Baildown Test Data Representing the Ideal Relationship between Drawdown and Discharge

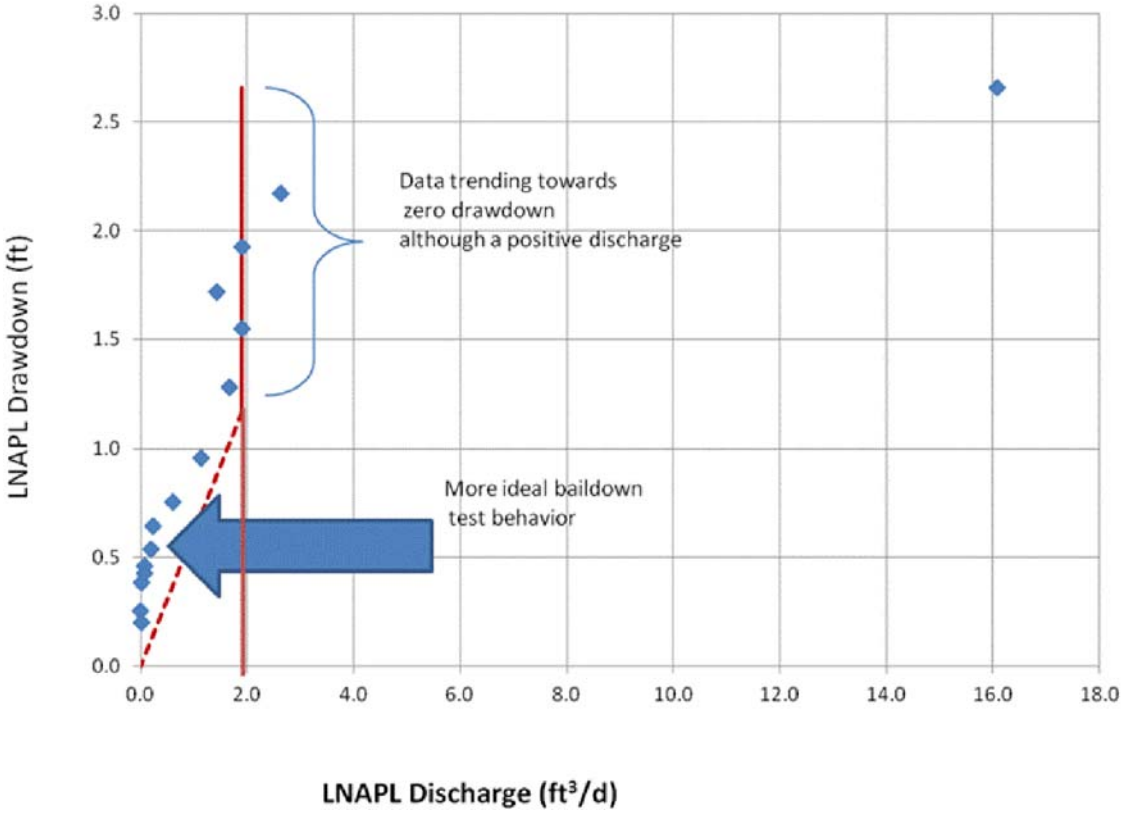


FIG. 3 Baildown Test Data Representing Confined or Perched Discharge Behavior

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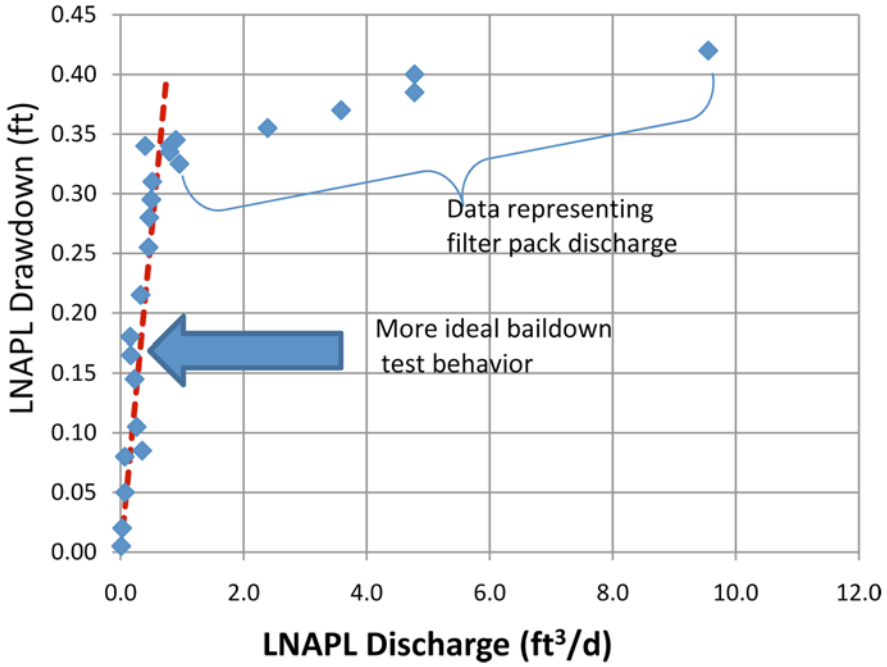


FIG. 4 Baildown Test Data Initially Representing Filter Pack Discharge Behavior and then Becomes Ideal

where:

V_r = volume of LNAPL initially recovered or displaced (L^3),

b_r = recovered LNAPL thickness due to filter pack recharge (L), and

b_n = initial gauged LNAPL thickness prior to removal (L).

(7) Data that consistently trends such that it intersects the zero discharge with remaining drawdown or zero drawdown with remaining discharge likely represents that the fluid levels being used for equilibrium conditions are inaccurate (Figs. 3 and 4).

(8) Best practices will utilize equilibrium fluid levels that are confirmed by reviewing the fluid levels at the start to the end of the test where the well was gauged until it fully recovered. However, where variables such as extended test times combined with fluctuating water-table conditions exist, an alternative method can be employed to confirm equilibrium fluid levels. Equilibrium fluid levels can also be ensured by gauging the well 10 times over a period equal to the test duration analyzed prior to the start of the test. These data will allow for an understanding of variability in water-table conditions near the time the test was conducted.

(9) Wells need to be in good communication with the formation. This consists of well being properly developed and not containing weathered LNAPL induced by stagnant well conditions. Fluid gauging data exhibiting repeatable fluid levels following LNAPL removal events for a given well is the best practice to establish equilibrium fluid levels are accurate.

(10) If the water-table varies by a magnitude greater than 20 % of the max drawdown induced over the period of analysis, then an alternative method should be used to evaluate LNAPL transmissivity.

(11) All equilibrium fluid levels need to be compared to the soil profile to identify the possibility of perched or confined LNAPL. This will enable the identification of perched or confined LNAPL conditions. These conditions affect how drawdown is calculated.

(12) The use of a storativity term in the numerical analysis of baildown/slug test data accounts for non-steady state recharge (that is, transient) conditions such as in the Jacob-Lohman Method. However, many tests are not significantly affected by transient behavior and one can use methods more representative of steady state origins such as the Bouwer-Rice method.

(13) The Bouwer-Rice solution is useful for baildown test analysis because the translation method (Butler 1998) **(9)** can be applied where the slug introduction was not instantaneous. This may happen more frequently with tests where LNAPL is more completely removed from the casing and filter pack for the purposes of minimizing filter pack recharge effects.

(14) The Jacob-Lohman based analysis is useful for cases where transient effects are observed in the recharge response and the slug or fluid withdrawal meets instantaneous conditions.

(15) Instantaneous should be relative to the test duration, the removal period should be less than 100th of the entire test duration.

(16) If the slug/fluid removal approximates instantaneous and no significant transient effects are observed, then both analysis methods can be used and should correlate well.

8.1.4.2 *Bouwer and Rice:*

(1) LNAPL transmissivity calculation methods for baildown testing analysis theory via the Bouwer-Rice method are provided in detail in Lundy and Zimmerman (1996) **(6)** and Huntley (2000) **(10)**, and in Bouwer and Rice (1976) **(11)** and Bouwer (1989) **(12)**.

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(2) The primary assumptions include a quasi-steady-state model for recharge to the well (the model assumes steady radial flow to the well with rate dependent on the well drawdown; no storage effects are included) and that the ratio of change in LNAPL head to LNAPL thickness (ds_n/db_n) is constant. This ratio will be referred to as the *j*-ratio.

(3) The magnitude of the *j*-ratio has been discussed in two published papers. Where the water transmissivity through the well screen is significantly lower than the LNAPL transmissivity, this ratio equals unity (1) (Lundy and Zimmerman, 1996) (**6**). An example of this behavior is shown in Figs. 5 and 6. Where the water transmissivity is significantly higher than the LNAPL transmissivity through the well screen and the potentiometric surface in consistent throughout the analyzed portion of data, this ratio equals unity minus relative density ($1 - \rho_r$) (Huntley, 2000) (**10**). For an example of this type of behavior see Figs. 7 and 8.

(4) The magnitude of *j*-ratio need not be assumed 'a priori' because every baildown or slug test provides necessary data to evaluate if a constant slope between LNAPL thickness and head exists, along with the magnitude of this ratio. By plotting the thickness on the *x*-axis versus the drawdown as calculated based on the difference in air/LNAPL interface from equilibrium on the *y*-axis the data can be reviewed for a period exhibiting a consistent slope. The value of that slope represents the ratio that should be used in the solution. This can be tested by plotting the change in the air/LNAPL interface (that is, drawdown) versus gauged LNAPL thickness.

(5) If at any point in the test a constant slope between gauged LNAPL thickness and drawdown exists and the recharge is not representative of filter pack recharge, the boundary condition is met and the Bouwer-Rice methodology can be applied to that time sequence. Butler describes a translation method for non-instantaneous slug tests initiation which can be applied to this method (Butler, 1998) (**9**).

(6) The greater the variability in *j*-ratio, the larger the error associated with the Bouwer-Rice methodology. Large variability suggests that the Jacob-Lohman methodology should be applied.

(7) According to Bouwer-Rice method, the logarithm of the drawdown varies as a linear function of time. A straight line may be fit to the drawdown-time data and the slope of this line is used to determine the LNAPL transmissivity. When the line if fit using linear regression, the variance of the slope of the line can be used to estimate the LNAPL transmissivity standard deviation.

$$T_n = r_w^2 \frac{\ln\left(\frac{s_o}{s_n}\right) \ln\left(\frac{R_{oi}}{r_w}\right)}{2jt} \tag{13}$$

where:

T = LNAPL Transmissivity (L^2/t),
s_o = maximum drawdown induced; estimated from *y*-intercept of the drawdown versus log-time plot fitted to the selected data range (L),
s_n = LNAPL drawdown at time t (L),
j = ratio of change in drawdown to change in thickness over the recovery period being analyzed,
t = elapsed time (t),
R_{oi} = radius of influence, and
r_w = effective well radius.

(8) The ratio of the radius of influence to the effective well radius may be calculated using the polynomial approximation presented by Butler (1998) (**9**). This is based on the results presented by Bouwer and Rice (1976) (**11**).

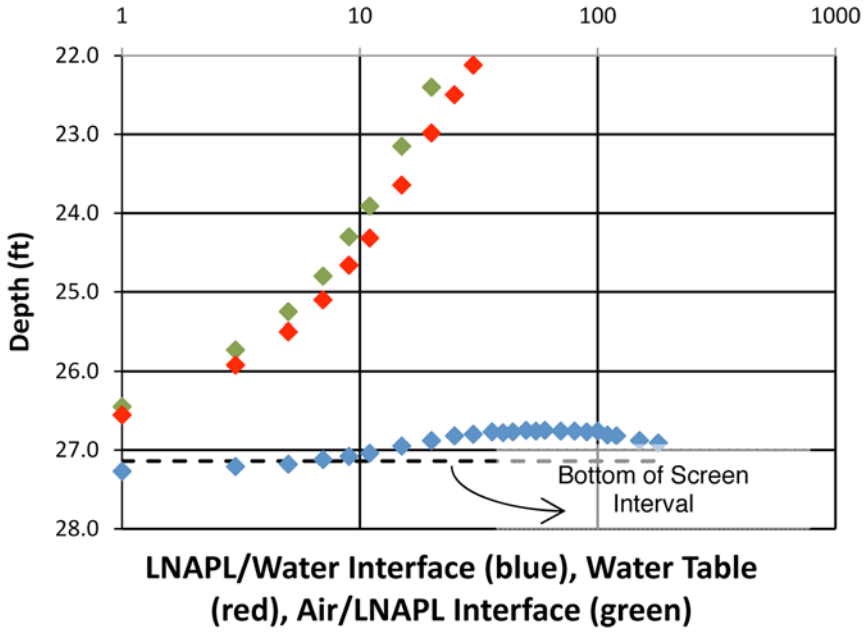


FIG. 5 Hydrograph of Baildown Test Recovery Illustrating a Constant LNAPL/Water Interface during Recovery

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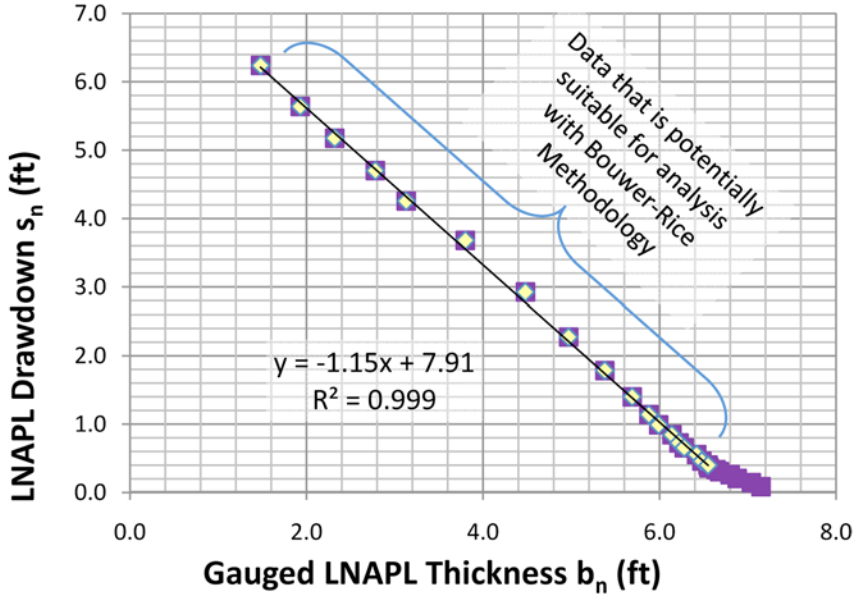


FIG. 6 Gauged LNAPL Thickness versus LNAPL Drawdown for Baildown Test Approximating a Change in Thickness to Decrease in Drawdown Ratio Value of One

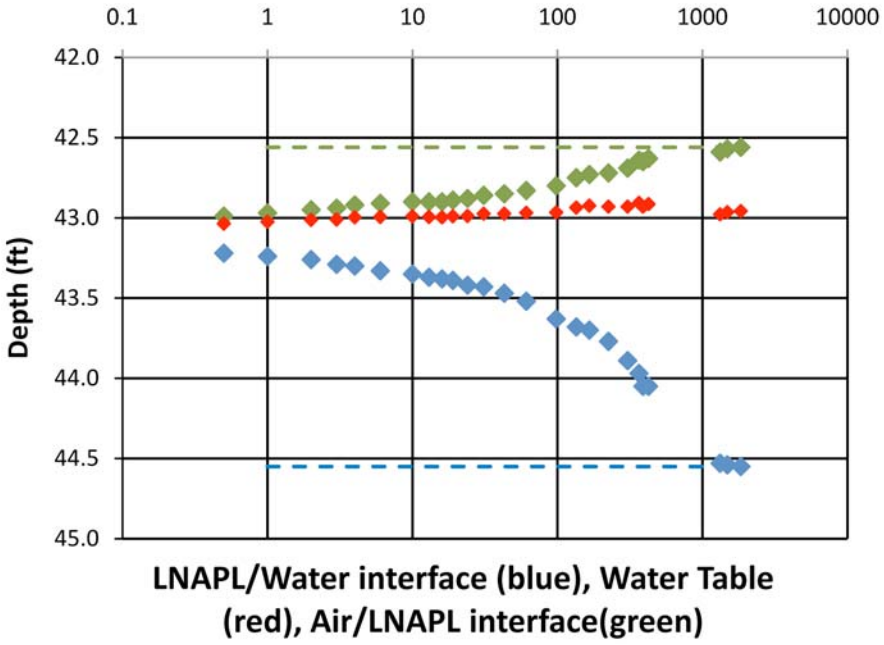


FIG. 7 Hydrograph of Baildown Test Recovery Approximating a Constant Calculated Water-table Elevation During Recovery

(9) Jacob-Lohman—The theory of baildown/slug testing analysis via Jacob-Lohman methods is provided in detail in Huntley (2000) **(10)** and Jacob and Lohman **(13)**. Although three different methods are presented by Huntley (2000) **(10)** from Jacob and Lohman's **(13)** modification of the Cooper-Jacob method for constant drawdown-variable discharge conditions of LNAPL baildown testing, only the sum of the squared residual (SSR) method has been found to consistently provide an applicable method. The other Cooper-Jacob (that is, methods 1/Q and s/Q) provided by Huntley do not consistently provide comparable or accurate results and are not recommended as part of this guide.

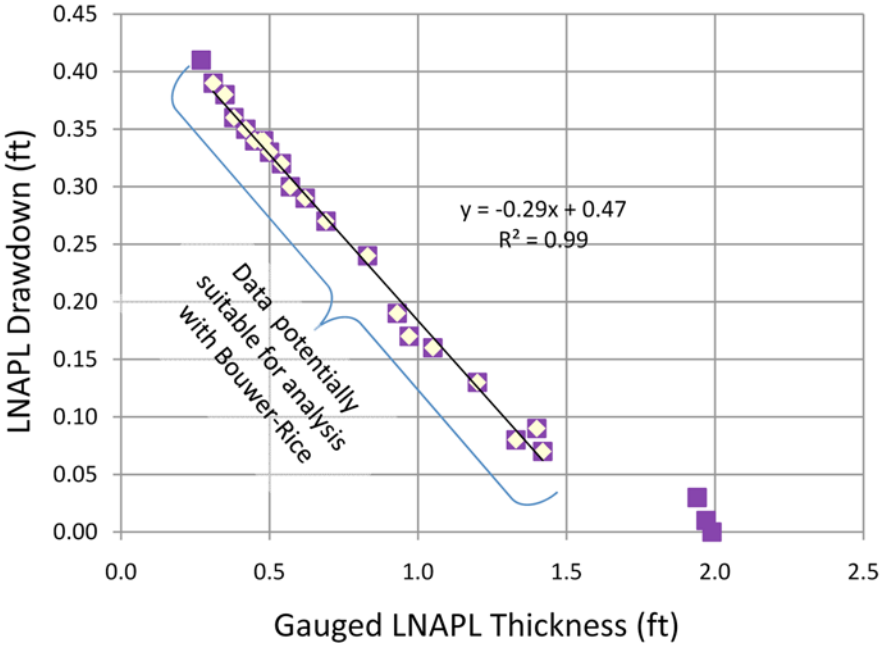
8.1.4.3 Because the recharge rate is calculated independently of drawdown, no relationship between the change in recovered gauged thickness and drawdown is required to hold.

8.1.4.4 This analysis method accounts for transient recharge conditions and storage effects.

8.1.4.5 The primary condition which needs to be met is that the relationship between drawdown and discharge to the well from the formation (that is, recharge) is a direct relationship and the trend will simultaneously intersect zero for each variable (see Fig. 2).

(1) Sum of the Squared Residual Method—The Sum of the Squared Residual (SSR) method is useful to minimize any

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Approximating a change in thickness to decrease in drawdown ratio value of the quantity relative density minus one; where the relative density is estimated to be 0.8.

FIG. 8 Gauged LNAPL Thickness versus LNAPL Drawdown for Baildown Test

scatter induced by deviations from the primary assumption of constant, known drawdown. The primary assumption is still constant, known drawdown, but the methodology allows for minimization of error introduced by the resulting scatter when the drawdown is variable (Huntley, 2000) (**10**).

(2) Although Huntley provides the recommendation to solve for both LNAPL transmissivity and storativity, experience has found that it is prudent to iteratively select a storativity value based on the LNAPL transmissivity. Guidance values are provided in Table 1. Therefore start with a value of 0.1 then solve for LNAPL transmissivity. Based on that LNAPL transmissivity reselect the storativity to match the new transmissivity. Repeat until results are within a factor less than 2.

(3) Use of Table 1 will result in reasonable estimates of LNAPL transmissivity in conjunction with the SSR Method. The error associated with varying storativity by plus or minus half an order of magnitude results in a variability of plus or minus approximately 30 %.

TABLE 1 Storativity Estimates for a Given LNAPL Transmissivity

Resulting LNAPL Transmissivity (ft^2/day)	General Estimate for LNAPL Storativity/Specific Yield (Volume/Bulk Volume)
50	0.175
20	0.1225
10	0.07
5	0.0525
1	0.035
0.1	0.008

(4) The SSR Method is completed by calculating the left side of the Eq 14 below and running a numerical solution to fit the right side of the equation by varying LNAPL transmissivity.

$$S\Delta t = \frac{Q_n \Delta t}{4\pi T_n} \ln\left(\frac{2.25T}{r_w^2 S}\right) \quad (14)$$

where:

Q = LNAPL discharge rate from the formation to the well, (that is, well recharge rate), and
S = LNAPL specific yield.

8.1.4.6 Alternatively the SSR method can be used in the following form which each side of the equation represents a more tangible value of measured recovered volume to calculated recovered volume of volume recovered in each time step.

$$Q\Delta t = \frac{4\pi sT}{\ln\left(\frac{2.25T}{r_w^2 s}\right)} \Delta t \quad (15)$$

8.2 *Data Analysis—Manual Skimming Test:*

8.2.1 To calculate LNAPL Transmissivity from manual skimming test data, use the following equation (Charbeneau, 2007) (**14**):

$$T_n = \frac{Q_n \ln\left(\frac{R_{oi}}{r_w}\right)}{2\pi s_n} \quad (16)$$

where:

T_n = LNAPL transmissivity (L^2/t),
Q_n = measured LNAPL recovery rate (L^3/t),
R_{oi} = radius of influence (L), and

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r_w = well radius (L).

NOTE 2—The value of the term $\ln(R_{oi}/r_w)$ can be assumed to equal 4.6 with the introduction of little additional error.

8.2.2 The drawdown value for a given period should be taken as the geometric mean of the starting and ending drawdown values.

8.2.3 The drawdown value can be directly measured using the fluid level gauging data and the guidance provided in 8.1.3.

8.2.4 The maximum skimming drawdown for unconfined conditions is given by Eq 15. The maximum drawdown for confined and perched conditions is given by Eq 16 and Eq 17 respectively.

8.2.5 To calculate LNAPL Transmissivity, take the stabilized LNAPL recovery rate (Q_n) and estimate the drawdown that corresponds to this discharge and calculate T_n using the manual skimming test equation, above. If you have perched or confined LNAPL then the drawdown must be adjusted as noted in 5.4.

8.2.6 The accuracy of this equation is most sensitive to the accuracy of the measured LNAPL recovery rate and drawdown. Consistent operation of the skimming system such that the induced drawdown is know and consistent will improve accuracy of calculations.

8.3 *Data Analysis—Long Term Recovery System Data:*

8.3.1 *LNAPL Skimming*—Eq 16 can be used to estimate LNAPL transmissivity, however the assumptions for LNAPL drawdown vary from those in the manual skimming test.

8.3.1.1 The drawdown value can be directly measured using the fluid level gauging data and the guidance provided in 8.1.3 or through assumptions based on equilibrium fluid levels if the system is designed to maintain close to zero gauged LNAPL thickness in the well. Routine direct measurement will provide the best accuracy.

8.3.1.2 The maximum skimming drawdown for unconfined conditions is given by Eq 17. The maximum drawdown for confined and perched conditions is given by Eq 18 and Eq 19 respectively.

$$s_{n_unconfined} = b_n(1 - \rho_r) \tag{17}$$

$$s_{n_confined} = b_{nf}\frac{1 - \rho_r}{\rho_r} \tag{18}$$

$$s_{n_perched} = b_{nf} \tag{19}$$

8.3.1.3 Unless an automatic fluid level system is being utilized, long-term continuous recovery requires estimates of drawdown that are based on point measurements representing long periods of time. The accuracy of this method is based on the ability of the recovery systems to maintain a constant LNAPL drawdown and how water-table fluctuations affect the mobile interval in the formation.

8.3.1.4 The skimming methodology when using periodic drawdown measurements provides estimates for LNAPL transmissivity that are likely within an order of magnitude of the actual LNAPL transmissivity value, however weekly or monthly measurements of drawdown can often span significant fluctuations in water-table.

8.3.1.5 The value of the term, $\ln(R_{oi}/r_w)$ can be assumed to equal 4.6 with the introduction of little additional error.

8.3.2 *Vacuum-Enhanced LNAPL Only Liquid Recovery (Vacuum-Enhanced Skimming)*—LNAPL transmissivity may be determined from a vacuum-enhanced recovery system using air and LNAPL discharge data, assumed formation air permeability and air-water viscosity ratio, and formation hydraulic conductivity across the screened interval above the LNAPL. For vacuum-enhanced skimming, transmissivity can be calculated using the following equation (Charbeneau, 2007) **(14)** :

$$T_n = \frac{Q_n k_{ra} K_w b_a \rho_r}{\mu_{ar} Q_a} \tag{20}$$

where:

Q_a = air discharge rate in terms of standard air pressure and temperature (L^3/t),

k_{ra} = relative permeability of open screen length in the vadose zone to air (unit less),

K_w = saturated hydraulic conductivity value for corresponding to the soil type existing in the vadose zone immediately above the mobile LNAPL interval (L/t),

b_a = screen length open to the portion of the vadose zone representative of the saturated hydraulic conductivity value used (L), and

μ_{ar} = relative viscosity of air to water (unitless).

NOTE 3—The value for relative viscosity, μ_{ar}, is assumed to be 0.018 and relative permeability to air, k_{ra}, is assumed to be 0.9. Use of site-specific data for these parameters is also acceptable.

8.3.2.1 Additionally, if the air discharge rate is unknown Eq 16 can be used where the LNAPL drawdown due to vacuum enhanced skimming and ratio of radius of influence to well radius are known. The LNAPL drawdown term in this equation will be equal to the sum of the vacuum applied to the formation and the LNAPL skimming drawdown.

8.3.2.2 Where the LNAPL skimming drawdown is one tenth or less of the applied vacuum to the formation it does not have to be considered and only the applied vacuum needs to be measured.

8.3.2.3 The applied vacuum to the formation must account for head losses in the system and filter pack. Well head vacuums ahead of any supplemental air release valves are applicable but step pilot test data provide the best calibration to additional losses through the casing and filter pack. The air flow based calculation is typically more accurate relative to using applied vacuum because no estimation of head loss is required.

8.3.3 *Water-Enhanced LNAPL Recovery (Total Fluids Pumping, Single or Dual Pump)*—LNAPL transmissivity may be determined using water and LNAPL discharge data from a water-enhanced recovery system, provided the recovery system is operated at a sufficiently low pumping rate to ensure small drawdown at the recovery well to prevent significant smearing (Charbeneau, 2007) **(14)**. Eq 21 uses the water discharge rate, the LNAPL discharge rate and the hydraulic transmissivity to estimate LNAPL transmissivity. However this assumes that the drawdown induced with water extraction is much larger than the drawdown that is achievable via skimming. If the water induced drawdown is 10 times or greater than the skimming drawdown then Eq 21 (Charbeneau, 2007) **(14)** can be used. Cases where the skimming drawdown is

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greater than one-tenth of the water extraction induced drawdown then Eq 22 is more appropriate.

$$T_n = \frac{Q_o T_w \rho_r}{Q_w} \quad (21)$$

where:

Q_w = water discharge rate in terms of standard air pressure and temperature (L^3/t), and
T_w = aquifer transmissivity (L^2/t).

8.3.3.1 Eq 21 is useful especially for systems with variability in water extraction rates and even frequent periods of down time. Only the LNAPL and water volumes for a given period need to be measured. If the system down time was unknown, LNAPL transmissivity can still be accurately calculated because the time period cancels out of the equation for the LNAPL and water discharge terms. The discharge terms could also be converted in to volumes of oil and water recovered. The transmissivity calculated will be representative of the average LNAPL transmissivity for the period those volumes were recovered over.

$$T_n = \frac{Q_n T_w}{Q_w} \frac{1}{\left(\frac{1}{\rho_r} + \frac{S_{skim}}{S_w}\right)} \quad (22)$$

where:

S_{skim} = the maximum skimming drawdown (see 8.3.1.2).

8.3.3.2 Eq 22 approaches Eq 21 as the skimming drawdown becomes small relative to the water extraction induced drawdown.

8.3.4 *Water and Vacuum-Enhanced LNAPL Recovery*—Multiphase extraction being conducted as total fluids (that is, single stinger extraction) or dual phase extraction (that is, stinger combined with one or more liquid pumps) can also provide data to estimate LNAPL transmissivity.

8.3.4.1 Estimates of LNAPL transmissivity for multi-phase extraction are based on the summation of the total LNAPL production based on the drawdown induce from each phase. Eq 23 provides the LNAPL transmissivity estimate using the ratio of water and air flows to LNAPL flow from a well (Kirkman 2009) (**15**).

$$T_n = \frac{Q_n \rho_r}{\frac{\mu_{ar} Q_a}{k_{ra} K_w b_a} + \frac{Q_w}{T_w}} \quad (23)$$

8.3.4.2 The equation to estimate of LNAPL transmissivity for multi-phase extraction using the applied vacuum to the formation and the LNAL and water production rates is provided as Eq 24 (Hawthorne 2010) (**16**).

$$T_n = \frac{Q_n \rho_r}{\frac{2\pi s_n}{\ln\left(\frac{R_{oi}}{r_w}\right)} + \frac{Q_w}{T_w}} \quad (24)$$

8.3.4.3 The difference in equipment application between total fluids and dual-phase extraction will not affect the resulting LNAPL recovery performance beyond the head losses induced via the equipment. As discussed in 8.1 head losses associated with applied vacuum must be accounted for such that the applied vacuum value used to estimate LNAPL drawdown in Eq 24 represents applied vacuum to the formation. Step tests and an understanding of well screen length versus water-table and vacuum conditions are required.

8.4 *Data Analysis—Tracer Testing*—The tracer test has the following assumptions:

8.4.1 Flow under natural gradients is at steady state.

8.4.2 Fluid levels are constant throughout the duration of the test.

8.4.3 The LNAPL in the well is in hydraulic connection with the LNAPL in the formation.

8.4.4 The tracer is initially well mixed at time zero for the test.

8.4.5 The tracer is well mixed again prior to each measurement.

8.4.6 Relationship between tracer mass and fluorescence is assumed to be linear or known a priori.

8.4.7 Diffusive transport of tracer from the well is small and can be neglected.

8.4.8 Cross-sectional flow on the up and down gradient side of the well are equal.

8.4.9 If any of the above assumptions are violated, the practitioner should be determine the effects on the data reduction and calculated transmissivity by violating the assumptions.

8.4.10 The following is an implicit analytical solution for estimating the LNAPL Transmissivity as a function of changes in tracer concentrations in LNAPL in a well between intermittent mixing events. Also presented is an analysis of the limits on time between mixing-measurement events.

$$\frac{C_{T_{t_o+\Delta t}}}{C_{T_{t_o}}} = \frac{2a\cos\left(\frac{T_n i_{LNAPL} \alpha \Delta t}{2 r_w b_{wL}}\right) - \sin\left[2a\cos\left(\frac{T_n i_{LNAPL} \alpha \Delta t}{2 r_w b_{wL}}\right)\right]}{\pi} \quad (25)$$

$$\text{for} \quad \frac{T_n i_{LNAPL} \alpha \Delta t}{2 r_w b_{wL}} < 1$$

where:

$C_{T_{t+\Delta t}}$ = the tracer concentrations after mixing (M/L^3),
C_{T_t} = the initial tracer concentrations (M/L^3),
Δt = the time between mixing events (T),
T_n = the LNAPL transmissivity (L^2 /T),
i_{LNAPL} = the LNAPL gradient (unitless),
r_w = the radius of monitoring well (L),
b_{wL} = the thickness of LNAPL in the monitoring well (L), and
α = the flux convergence factor, often assumed to be equal to a value between 0.5 and 2 or a mean of 1.7 (unitless).

8.4.10.1 A full derivation is presented in Smith (**17**).

8.4.11 *Limit on Maximum Elapsed Time Between Mixing Events*—LNAPL transmissivity through the well and adjacent geologic formation includes vertical variations in LNAPL saturations and correspondingly relative permeability to LNAPL (Farr (**18**)). Given the assumptions of a uniform

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porous media, the following advances a maximum time between mixing without violating any of the assumptions from 7.6.1 is defined as:

$$\Delta t_{max} = \frac{2r_w}{q_{wL_{ave}}} \frac{k_{r_{ave}}}{k_{r_{max}}} \quad (26)$$

where:

Δt_{max} = the maximum time allowed between intermittent mixing events (T),

$q_{wL_{ave}}$ = the vertical LNAPL flux in the well (L/T),

$k_{r_{ave}}$ = the vertical averaged relative permeability (unitless), and

$k_{r_{max}}$ = the maximum relative permeability (unitless).

8.4.11.1 Further analysis of limits on Δt_{max} and full derivation is provided in Smith (**17**).

ANNEXES

(Mandatory Information)

A1. FIELD FORMS

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Well_____ Site_____

Manual Skimming Test Field Form

Project #:		**Site Name:**	
Well:		**Samplers:**	
Evacuation Method:		**Weather:**	

Borehole Diameter (INCHES):
Filter Pack Specific Yield (LNAPL)
0.175

Well Information		**LNAPL Information**	
Casing Diameter:		**Fluid Type:**	
Total Depth :		**Volume Removed:**	
Depth to Top of Screen:		**Evacuation Method:**	
Screen Length:		**LNAPL Well Volume:**	

Effective Well Radius (FT)

Length and volumetric units need to be specified

Length Units: **Volume Units:**

	LNAPL Well Volume
ft^3	
gal	
ml	

Pump	Date	Time Hour	Time Minute	Elapsed Time (min)	LNAPL Volume Removed	Water Volume Removed	Depth to LNAPL	Depth to Water	Comments
Static			:						
Pump On			:						Test Start
Pump Off			:						
			:						
			:						
			:						
			:						
			:						
			:						
			:						
			:						
			:						

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Well_____ Site_____

Pump	Date	Time Hour	Time Minute	Elapsed Time (min)	LNAPL Volume Removed	Water Volume Removed	Depth to LNAPL	Depth to Water	Comments
		:							
		:							
		:							
		:							
		:							
		:							
		:							
		:							
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Well_____ Site_____

Baildown/Slug Test Field Form

Project #:		**Site Name:**	
Well:		**Samplers:**	
Evacuation Method:		**Weather:**	

Borehole Diameter (INCHES):
Filter Pack Specific Yield (LNAPL)
0.175

Well Information		**LNAPL Information**	
Casing Diameter (INCHES):		**Fluid Type:**	
Total Depth (FT):		**Volume Removed:**	
Depth to Top of Screen (FT):		**Evacuation Method:**	
Screen Length (FT):		**LNAPL Well Volume:**	

Length and volumetric units need to be specified

Length Units: **Volume Units:**

Effective Well Radius (FT)	
	LNAPL Well Volume
ft^3	
gal	
ml	

Period	Date	Time HH:MM	Elapsed Time (min)	DTP (feet)	DTW (feet)	Comments
Initial						
Removal Start						Test Start
Removal Stop						LNAPL/Slug Volume Removed (gal): Water Volume Removed (gal):

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Site

Well

Period	Date	Time HH:MM	Elapsed Time (min)	DTP (feet)	DTW (feet)	Comments

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Well_____ Site_____

Skimming Recovery Field Form

Project #:		**Site Name:**	
Well:		**Field Staff:**	
		Weather:	

Well Information		**Recovery System Information**	
Casing Diameter:		**Pump Type:**	
Total Well Depth:		**Recovered Volume Measurement Method:**	
Depth to Top of Screen:		**(Tank Volume, Totalizer, Instantaneous)**	
Screen Length:			

Length and volumetric units need to be specified

Length Units: **Volume Units:**

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Depth to LNAPL	Depth to Water	Pump Depth	Comments

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Well_____ Site_____

Water Enhanced Recovery Field Form

Project #:		Site Name:	
Well:		Field Staff:	
		Weather:	

Well Information		Recovery System Information	
Casing Diameter:		Pump Type:	
Total Well Depth:		Recovered Volume Measurement Method: (Tank Volume, Totalizer, Instantaneous)	
Depth to Top of Screen:			
Screen Length:			

Length and volumetric units need to be specified

Length Units: **Volume Units:** **Vacuum Units:** **Air Flow Units:**

Note:Either measure the Recovered LNAPL and water volumes separately (i.e.,dual pump) or measure the total fluids recovered and oil/water ratio (i.e., total fluids pump)

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Total Fluids Recovered	Oil/Water Ratio	Depth to LNAPL	Depth to Water	Pump Depth	Comments

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Well_____ Site_____

Vacuum Enhanced Recovery Field Form

Project #:			Site Name:	
Well:			Field Staff:	
			Weather:	

Well Information			Recovery System Information	
Casing Diameter:			Pump Type:	
Total Well Depth:			Recovered Volume Measurement Method: (Tank Volume, Totalizer, Instantaneous)	
Depth to Top of Screen:				
Screen Length:				

Length, volumetric, vaccum, and air flow units need to be specified

Length Units: **Volume Units:** **Vacuum Units:** **Air Flow Units:**

Note: Recovered volumes, airflow and well vacuum required

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Airflow	Well Vacuum	Depth to LNAPL	Depth to Water	Pump/ Stinger Depth	Comments

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Well_____ Site_____

Multiphase Recovery Field Form

Project #:		**Site Name:**	
Well:		**Field Staff:**	
		Weather:	

Well Information		**Recovery System Information**	
Casing Diameter:		**Pump Type:**	
Total Well Depth:		**Recovered Volume Measurement Method:**	
Depth to Top of Screen:		**(Tank Volume, Totalizer, Instantaneous)**	
Screen Length:			

Length, volumetric, vaccum, and air flow units need to be specified

Length Units: **Volume Units:** **Vacuum Units:** **Air Flow Units:**

Note: Either measure the Recovered LNAPL and water volumes separately (i.e.,dual pump) or measure the total fluids recovered and oil/water ratio (i.e., total fluids pump); Air flow and vacuum required.

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Total Fluids Recovered	Oil/water ratio	Airflow	Well Vacuum	Depth to LNAPL	Depth to Water	Pump/ Stinger Depth	Comments

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A2. TABLES

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TABLE A2.1 Method Selection Table—Part One

NOTE 1—All of these methods may be used for confined, unconfined or perched aquifer scenarios; however, the use of recovery system data must be limited to data from technologies applicable for the given hydrogeologic scenario.

Methods	Detection Limit	Test Duration	Area Represented	Frequency of Method Transmissivity Values	Key Data List
Baildown/Slug Test	Typically 0.005 ft^2/day is reasonably achievable with minor water-table changes over length of test. No theoretical limit exists, therefore lower detections are feasible given reasonable test conditions. However, fluctuating water-tables may inhibit analysis of long-term data required for lower detection limits. (See thickness limitations)	Minutes to months–Actual duration is dependent on the recharge rate. However, this method is applicable when time is limited. Partial recovery can be analyzed if starting levels represent equilibrium.	"Point" Value, limited to the radius of influence for the test which is a few feet beyond borehole	Singular event period	-Well Construction -Equilibrium fluid levels -Soil profile across mobile LNAPL interval -LNAPL density -Volume of LNAPL removed/slug -Gauging data prior to test and over recovery period
Manual Skimming	Typically 0.001 ft^2/day is reasonably achievable. No theoretical limit exists, therefore lower detections are feasible given reasonable test conditions. However, fluctuating water-tables may inhibit analysis of long-term data required for lower detection limits.	Hours to weeks–Lower transmissivity wells will require more time, however this method is applicable when time is limited.	″Point″ Value, limited to the radius of influence for the test which is a few feet beyond borehole.	Singular event period	-Well Construction -Equilibrium fluid levels -Soil profile across mobile LNAPL interval -LNAPL density -Recovered volume over time -Gauging data prior to test and over recovery period
Recovery System Data	Detection limits based on combination of the recovery equation input parameter detection limits and/or values. Theoretical limit exists for water enhanced recovery calculations based on accuracy of LNAPL/water ratio measurement and the magnitude of aquifer transmissivities (for example, Aquifer transmissivity of 5,000 ft^2/day and an oil/water ratio detection limit of 0.001 for a gasoline will result in a detection limit of 3.75 ft^2/day).	Because recovery is representative of a relatively large area, steady state conditions need to be reached and maintained. Ongoing estimates are easily obtained based on the frequency of data collection.	"Area" Value, limited by the operational parameters of system and length of continual operation time which result in a given radius of capture. In general, representative of a larger area than other methods.	Continual time series representation	-Well Construction -Equilibrium fluid levels -Soil profile across mobile LNAPL interval -LNAPL density -Recovered LNAPL volume over time -Air/water flow rates -Well vacuum -Gauging data during recovery
Tracer Testing	Field trials have shown 1 ft^2/day is readily achievable with some tests achieving 0.2 ft^2/day. These values are based on a limited number of field trials completed to date. There is no theoretical limitation to the lower bound for transmissivity measurement. However, a simplifying assumption in the analysis is that diffusive dye loss is negligible as compared to loss due to LNAPL movement in the formation. This simplifying assumption may not be valid for measurement of ultra low transmissivity values.	Typical test duration is 3 to 6 months. A long test duration is recommended because the method is based on the natural gradient and a longer duration provides better averaging of individual measurement variability.	"Point" Value, The flux measurement is representative of a few feet outside the borehole. The gradient is representative of the well network density. This method is more applicable to a uniform LNAPL flow field. Uniform LNAPL flow fields occur in homogenous conditions and are often induced by active recovery.	Time-averaged over duration of test	-Well construction -Fluid levels -Hydraulic gradient of air/oil interface -Gauging data prior to test and after test

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TABLE A2.2 Method Selection Table—Part Two

Methods	Influenced by Non-Ideal Conditions	LNAPL Type	In-Well Gauged LNAPL Thickness	Capital Cost	Data Analysis Cost	Startup/Shutdown Metric
Baildown Test	Long-term tests likely affected by background changes in water-table. This includes areas affected by fluctuating rivers, changing pumping conditions and tidal environments	No Limitations have been identified	<0.5 ft - not recommended <0.2 ft - not acceptable	**Low to Medium** Higher costs incurred when tests require excessive time (that is, weeks) to complete at remote sites	**Moderate** Boundary conditions must be check for data set being analyzed	Startup and Shutdown
Manual Skimming	Long-term tests likely affected by background changes in water-table. However, the variability can be better averaged across representative site conditions. Additionally, LNAPL drawdown can be kept at a maximum versus baildown and slug testing where the continually reducing drawdown becomes more susceptible to changes in the water-table	No limitations have been identified	No constraints	**Low** Typically results can be obtained within 1 to 3 days.	**Low to Medium**	Startup and Shutdown
Recovery System Data	Although recovery system data is affected by changes in water-table, the continual time series nature of the data collection can allow for periods of constant water-table elevations to be isolated and analyzed.	No limitations have been identified	No constraints	**Medium** System design needs to include contingencies for accurate parameter measurements. Redundancy for performance parameters is also recommended. Method is more cost effective for time-weighted averaging than baildown or manual skimming tests conducted at same frequency.	**Moderate** Quality assurance is required to confirm system operational efficiency, pump/stinger depth settings and collection of performance data.	Shutdown only
Tracer Testing	LNAPL flux measurements can be affected by changes in the water-table. Negative flux values have been observed under dynamic water table conditions. However, long test duration provides time-weighted averages that mitigates measurement-to-measurement variability. Fluid level fluctuations may complicate LNAPL gradient measurement.	High viscosity LNAPLs can be problematic. In-well LNAPL calibration standards for viscous LNAPLs may be depleted through repeated measurements that coat the measurement tools with LNAPL.	>0.2 ft	**Medium to High** Specialized field equipment is required and data is collected routinely over a period of weeks to months. Method is more cost effective for time-weighted averaging than baildown or manual skimming tests conducted at same frequency.	**Low**	Startup and Shutdown (representativeness may improve after recovery homogenizes LNAPL distribution).

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TABLE A2.3 LNAPL Baildown/Slug Test

Measurement Parameter	Equation Symbol	Apparatus/Method
Equilibrium Fluid Interface Depth: Air-NAPL interface depths	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface depths	Z_{NW^*}	Optical/electrical resistivity interface probe Second pressure transducer w/ LNAPL & water density correction
LNAPL Volume: LNAPL removal measurement	V	Peristaltic pump; submersible pump; bailer, solid slug
LNAPL/H_2O Volume: LNAPL/water removal measurement		Graduated container measurable to 0.1 gal
Fluid Density: LNAPL density	ρ_n	ASTM Test D1298, ASTM Test D1217 ASTM Test D1480, ASTM Test D1481 ASTM Test D4052, ASTM Test D5002
Groundwater density, specific gravity	ρ_w	ASTM Test D1429
Time: Elapsed test time	t	Timepiece measurable to 1 second
Fluid Interface Elevation: Air-LNAPL interface elevation	Z_{AN}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface	Z_{NW}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.4 Manual LNAPL Skimming Test

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL Discharge: Stabilized LNAPL recovery rate	Q_n	Graduated container measurable to 0.1 gal Timepiece measurable to 1 second
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Often assumed equal to 4.6
Fluid Interface Elevation: Air-LNAPL interface elevation at equilibrium	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Air-LNAPL interface	Z_{NW^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log
LNAPL Skimming Drawdown: Unconfined LNAPL at equilibrium	s_n	$Z_{AN^*} - Z_{AN(t)}$
Maximum Skimming Drawdown confined LNAPL	s_n	$Z_{CC} - Z_{NW^*}$
Maximum Skimming Drawdown perched LNAPL	s	$Z_{AN^*} - Z_{CC}$
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Totalizer records (normalized for all system downtime)
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Often assumed equal to 4.6
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.5 LNAPL Skimming Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL Discharge: Stabilized LNAPL recovery rate	Q_n	Graduated container measurable to 0.1 gal Timepiece measurable to 1 second
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Often assumed equal to 4.6
Fluid Interface Elevation: Air-LNAPL interface elevation at equilibrium	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Air-LNAPL interface	Z_{NW^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log
LNAPL Skimming Drawdown: Unconfined LNAPL at equilibrium	s_n	$Z_{AN^*} - Z_{AN(t)}$
Maximum Skimming Drawdown unconfined LNAPL	s_n	$Z_{AN^*} - Z_{CGW}$
Maximum Skimming Drawdown confined LNAPL	s_n	$Z_{CC} - Z_{NW^*}$
Maximum Skimming Drawdown perched LNAPL	$s_n s_n$	$Z_{AN^*} - Z_{CC}$
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Totalizer records (normalized for all system downtime)
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.6 Vacuum-Enhanced LNAPL Skimming Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL-Only Discharge: Stabilized LNAPL recovery rate (L^3/t)	Q_n	Flow meter and totalizer records (normalized for all system downtime)
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Only required if using drawdown based equations Airflow based equations do not require this parameter
Open Screen Length: Screened interval open to vadose zone air flow (L)	b_a	Well Construction data and Soil Boring Log (ASTM E2531)
Air-Phase Relative Permeability: Formation pneumatic permeability	k_{ra}	Generally assumed = 0.9
Hydraulic Conductivity: Formation water saturated hydraulic conductivity (L/t)	K_w	ASTM D4043
Air-Water Viscosity Ratio: Viscosity ratio	μ_{ar}	Usually = 0.018
Air Discharge Rate: Air discharge rate from vacuum system (L^3/t)	Q_a	Airflow meter (normalized for all system downtime)
Vacuum Head: Head reduction in well induced by vacuum system (L)	s_a	Wellhead vacuum gauge Only required if using drawdown based equations Airflow based equations do not require this parameter
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.7 Water-Enhanced LNAPL Recovery Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Flow meter and totalizer records
LNAPL-Water Density Ratio: Density ratio	ρ_r	ρ_{oil}/ρ_{water}
Groundwater Discharge: Groundwater system recovery rate	Q_w	Flow meter and totalizer records
Groundwater Transmissivity: Formation hydraulic conductivity multiplied by saturated thickness in well screen	T_w	ASTM D4043
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Only required if using drawdown based equations Oil/water ratio based equation does not require this parameter
Groundwater Drawdown: Groundwater drawdown in recovery well	S_{water}	Estimated by gauging data or via Thiem equation (see Bouwer and Rice, 1976) **(11)** Drawdown will need to be converted into LNAPL head Only required if using drawdown based equations
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.8 Water- and Vacuum-Enhanced LNAPL Recovery Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Flow meter and totalizer records (normalized for all system downtime)
LNAPL-Water Density Ratio: Density ratio	ρ_r	ρ_{oil}/ρ_{water}
Groundwater Discharge: Groundwater system recovery rate	Q_w	Flow meter and totalizer records (normalized for all system downtime)
Groundwater Transmissivity: Formation hydraulic conductivity multiplied by saturated thickness in well screen	T_w	ASTM D4043
Air-Water Viscosity Ratio: Viscosity ratio	μ_{ar}	Usually = 0.018
Hydraulic Conductivity: Formation water saturated hydraulic conductivity	K_w	ASTM D4043
Air-Phase Relative Permeability: Formation pneumatic permeability	k_{ra}	Generally assumed = 0.9
Air Discharge Rate: Air discharge rate from vacuum system (SCFM)	Q_a	Airflow meter
Open Screen Length: Screened interval above LNAPL level	b_a	
Well vacuum head Water head	s_{aw}	Wellhead vacuum gauge Only required if using vacuum head based equations Airflow based equations do not require this parameter
Pneumatic radius of influence Effective radius of influence of formation air pressure drop	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Only required if using vacuum head based equations Airflow based equations do not require this parameter
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.9 LNAPL Tracer Test

Measurement Parameter	Equation Symbol	Apparatus/Method
Equilibrium Fluid Interface Depth: Air-LNAPL interface depths	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface depths	Z_{NW^*}	Optical/electrical resistivity interface probe Second pressure transducer w/ LNAPL & water density correction
Fluid Density: LNAPL density	ρ_n	ASTM Test D1298, ASTM Test D1217 ASTM Test D1480, ASTM Test D1481 ASTM Test D4052, ASTM Test D5002
Groundwater density, specific gravity	ρ_w	ASTM Test D1429
Time: Elapsed test time	t	Timepiece measurable to 1 second
Initial Tracer Concentration	C_i	Measured via Spectrometer prior to test
Tracer Concentration after mixing	$C_{i+\Delta}$	Measured via Spectrometer prior to test
LNAPL Gradient	i_{LNAPL}	Measured via site gauging data
Flux Convergence Factor	α	Alpha is often assumed to be equal to a value of 1.7
Fluid Interface Elevation: Air-LNAPL interface elevation	Z_{AN}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface	Z_{NW}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log

APPENDIXES

(Nonmandatory Information)

X1. APPLICATION OF LNAPL TRANSMISSIVITY METHODS IN TIDALLY INFLUENCED ENVIRONMENTS

X1.1 *Introduction* —Special precautions needs to be taken when measuring LNAPL transmissivity using the methods discussed in this guide under tidal conditions.

X1.1.1 In tidally influenced environments, formation and in-well LNAPL thicknesses (and by extension formation saturations) continuously change with the tide.

X1.1.2 Hence both the variability in the instantaneous LNAPL transmissivity and the effective LNAPL transmissivity average over several tidal cycles may both be of importance.

X1.1.3 The tidal stress will confound the result of a LNAPL transmissivity test at least on the time scale of the tidal cycle or less.

X1.1.4 Adjustments have to be made to the data collection procedure or the timing of the test to account for this effect.

X1.1.5 In some instances, a particular method's utility may be limited due to the time scale for test completion relative to the tidal cycle.

X1.1.6 Also, even in cases where a method may be applicable, the normal accuracy of a test may be compromised under tidal conditions.

X1.1.7 However, useful transmissivity information can still be obtained to improve site understanding, to aid CSM development and guide decision making.

X1.1.8 The magnitude of tidal cycles varies over lunar cycles and should be accounted for in any field test design.

X1.2 *Scope*—The following appendix provides more specific comment for the LNAPL transmissivity methods as applied to tidally influenced environments.

X1.3 *Short-Term Aquifer Testing Methods*:

X1.3.1 These LNAPL transmissivity measurement methods (LNAPL baildown, slug, and manual LNAPL skimming test) are most affected by tides because of the instantaneous nature of the applied stress relative to the tidal cycles.

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X1.3.2 In low LNAPL transmissivity formations where the time to recovery is long relative to the tidal cycle, the results of these short-term methods will be severely impacted by the tides and it is recommended that one the long-term test methods (that is, recovery data-based or tracer methods) or a modification of the recovery data-based method used to estimate an average LNAPL transmissivity for the tidal cycle.

X1.3.3 If the recovery period is short relative to the tidal cycle, the short-term test can be used as outlined below; however, the accuracy of the test will be lower than under non-tidal conditions.

X1.3.4 *LNAPL Baildown Test/Manual Skimming Test:*

X1.3.4.1 If the recovery period of these test are short relative to a tidal cycle (4 h), then these short-term test can be done as outlined in this document, however, the test will be less accurate.

X1.3.4.2 Also, it is recommended that these tests be done covering periods of high tides and low tide to provide a bound on the LNAPL transmissivity value at the tested location.

X1.3.4.3 Data from the pilot test can be analyzed by appropriate method proposed in this document to provide bounds on LNAPL transmissivity.

X1.3.4.4 If the recovery period is long relative to a tidal cycle and the discharge versus drawdown relationship identified in Section 6 cannot be met, then baildown and slug test methods cannot be employed and a long-term method should be employed.

X1.3.4.5 Additionally, if a manual skimming test is used and requires a longer time frame relative to a tidal cycle, the a long-term method should be employed.

X1.4 *Long-Term Aquifer Testing Methods*:

X1.4.1 *Considerations:*

X1.4.1.1 Because of the long-term nature of the applied stress for LNAPL for recovery data-based and tracer methods relative to the time scale of a tidal cycle, these methods can be used as outlined in the standard to estimate LNAPL transmissivity under tidal conditions.

X1.4.1.2 LNAPL recovery systems operate from months to years and the leaching process for tracer tests takes weeks to months.

X1.4.1.3 To determine the LNAPL transmissivity from a tracer test, an estimate of the LNAPL gradient is needed and the shifting gradient induced by the tides will have to be taken into account.

X1.4.1.4 To provide an estimate of the net gradient, a pressure transducer tidal study could be done over several tidal cycles.

X1.4.1.5 A tidal filtering algorithm should be applied to remove tidal effects, and the effective gradient estimated from the unfiltered data for methods relying on absolute drawdown values and/or gradients (that is, skimming and tracer testing).

X1.4.1.6 Data from the pilot test can be analyzed by appropriate method proposed in this document to provide LNAPL transmissivity estimates.

X1.4.1.7 The LNAPL transmissivity determined from these long term tests will averaged over the tidal cycles and effective over the capture/leaching zones of the LNAPL recovery system/tracer test for the time scales measured.

X1.5 *Short-Term Pilot Tests*—If an LNAPL recovery system is not in place or it's impractical to conduct a LNAPL tracer test, a modification of the recovery data-based method can be used; that is, a water enhanced pilot test can be done to provide estimates of LNAPL transmissivity.

X1.5.1 However, it is recommended that either a minimum of two of these tests be done (one covering each extreme of the tidal cycle) or the test be run continuously across a minimum of two tidal cycles.

X1.5.2 Ideally, the pilot test should be run over several tidal cycles.

X1.5.3 The LNAPL transmissivity in the formation may change over the test due to changes within the water level in the formation and mobile LNAPL saturation, however this test would be able to provide both a bound on the range in variability and an average value if designed to collect data at a frequency higher than the tidal cycles (that is, data collection every 1 to 2 h).

X1.5.4 If the data frequency is greater than tidal cycles then only an average value will be obtained.

X1.5.5 Data from the short-term pilot test can be analyzed by the appropriate method proposed in this guide to provide bounds on the LNAPL transmissivity over the capture zone of the test at the time scale of the test.

X1.5.6 The resulting LNAPL transmissivity will be averaged over tidal cycles and effective over the capture zone and time scale of the test.

X1.5.7 Water-enhanced pilot tests are a reasonable method because the analysis relies on the oil/water ratio produced, LNAPL relative density and aquifer transmissivity; the variation in equilibrium fluid levels induced by tidal cycles will not affect the analysis.

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X2. BAILDOWN TEST EXAMPLES

X2.1 Figs. X2.1-X2.23

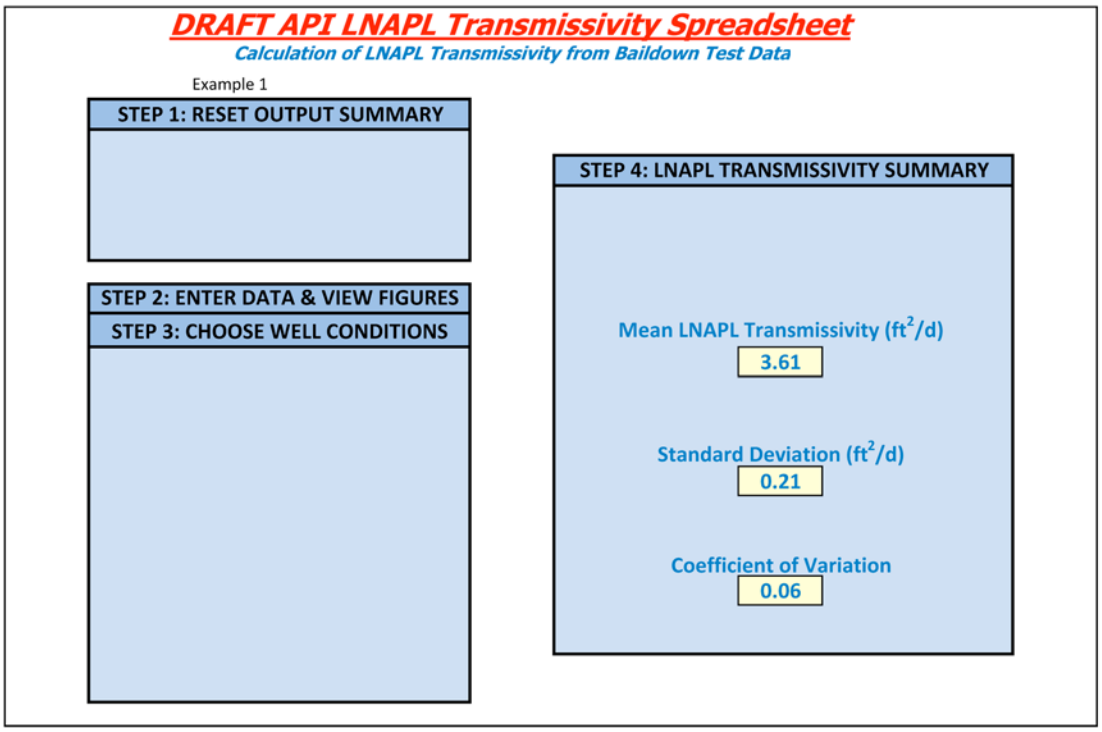


FIG. X2.1 Results Page—Constant Potentiometric Surface

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Example 1
Well Designation: Ideal Unconfined Case
Date:

Ground Surface Elev (ft msl)	0.0	Enter These Data	**Drawdown Adjustment (ft)**
Top of Casing Elev (ft msl)	0.0		
Well Casing Radius, r_c (ft):	0.083	r_{e1}	0
Well Radius, r_w (ft):	0.343333333		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.75		
Top of Screen (ft bgs):	0.0		
Bottom of Screen (ft bgs):	0.0		
LNAPL Baildown Vol. (gal.):	0.0		
Effective Radius, r_{e3} (ft):	0.162	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.147		
Initial Casing LNAPL Vol. (gal.):	0.28		
Initial Filter LNAPL Vol. (gal.):	0.78		

	Enter Data Here			
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)
Initial Fluid Levels:	0	41.14	42.86	41.14	42.86
Test Starts:	0.5	41.46	41.81	41.46	41.81
	1.0	41.45	41.87	41.45	41.87
	2.0	41.45	41.89	41.45	41.89
	3.0	41.44	41.91	41.44	41.91
	4.0	41.43	41.89	41.43	41.89
	6.0	41.42	41.97	41.42	41.97
	9.0	41.40	42.03	41.40	42.03
	12.0	41.38	42.09	41.38	42.09
	15.0	41.36	42.13	41.36	42.13
	20.0	41.34	42.20	41.34	42.20
	25.0	41.32	42.26	41.32	42.26
	30.0	41.30	42.32	41.30	42.32
	35.0	41.29	42.37	41.29	42.37
	40.0	41.27	42.41	41.27	42.41
	48.0	41.25	42.48	41.25	42.48
	55.0	41.23	42.53	41.23	42.53
	65.0	41.21	42.61	41.21	42.61
	75.0	41.19	42.66	41.19	42.66
	85.0	41.18	42.71	41.18	42.71
	95.0	41.16	42.74	41.16	42.74
	105.0	41.15	42.77	41.15	42.77
	127.0	41.15	42.85	41.15	42.85
	154.0	41.15	42.83	41.15	42.83
	179.0	41.14	42.85	41.14	42.85
	218.0	41.14	42.86	41.14	42.86
	1125.0	41.20	42.93	41.20	42.93
	1625.0	41.18	42.93	41.18	42.93
	2615.00	41.18	42.94		
	3087.00	41.15	42.91		

FIG. X2.2 Data Page 1—Constant Potentiometric Surface

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Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Index	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
41.57	0.43					1.72	
41.55	0.32	1.0					
41.56	0.31	2.0	0.7	16.694	0.32	0.42	0.162
41.56	0.31	3.0	1.5	2.385	0.31	0.44	0.162
41.56	0.30	4.0	2.5	3.577	0.31	0.47	0.162
41.55	0.29	5.0	3.5	-1.192	0.29	0.46	0.162
41.56	0.28	6.0	5.0	5.366	0.29	0.55	0.162
41.56	0.26	7.0	7.5	3.180	0.27	0.63	0.162
41.56	0.24	8.0	10.5	3.180	0.25	0.71	0.162
41.55	0.22	9.0	13.5	2.385	0.23	0.77	0.162
41.56	0.20	10.0	17.5	2.146	0.21	0.86	0.162
41.56	0.18	11.0	22.5	1.908	0.19	0.94	0.162
41.56	0.16	12.0	27.5	1.908	0.17	1.02	0.162
41.56	0.15	13.0	32.5	1.431	0.15	1.08	0.162
41.56	0.13	14.0	37.5	1.431	0.14	1.14	0.162
41.56	0.11	15.0	44.0	1.341	0.12	1.23	0.162
41.56	0.09	16.0	51.5	1.192	0.10	1.30	0.162
41.56	0.07	17.0	60.0	1.192	0.08	1.40	0.162
41.56	0.05	18.0	70.0	0.835	0.06	1.47	0.162
41.56	0.04	19.0	80.0	0.715	0.04	1.53	0.162
41.56	0.02	20.0	90.0	0.596	0.03	1.58	0.162
41.56	0.01	21.0	100.0	0.477	0.01	1.62	0.162
41.58	0.01	22.0	116.0	0.434	0.01	1.70	0.162
41.57	0.01	23.0	140.5	-0.088	0.01	1.68	0.162
41.57	0.00	24.0	166.5	0.143	0.00	1.71	0.162
41.57	0.00	25.0	198.5	0.031	0.00	1.72	0.162
41.63	0.06	26.0	671.5	0.001	0.03	1.73	0.162
41.62	0.04	27.0	1375.0	0.005	0.05	1.75	0.162

FIG. X2.3 Data Page 2—Constant Potentiometric Surface

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DTP (ft bgs)	DTW (ft bgs)	LNAPL Volume (gallons)	
		0	
41.46	41.84	0.04	
41.45	41.88	0.06	0
41.45	41.90	0.07	-0.2
41.44	41.90	0.07	-1
41.43	41.93	0.12	-0.25
41.41	42.00	0.17	-0.1765
41.39	42.06	0.22	-0.25
41.37	42.11	0.26	-0.2857
41.35	42.17	0.32	-0.2667
41.33	42.23	0.37	-0.2353
41.31	42.29	0.41	-0.25
41.30	42.35	0.45	-0.2143
41.28	42.39	0.49	-0.25
41.26	42.45	0.55	-0.2667
41.24	42.51	0.59	-0.25
41.22	42.57	0.65	-0.2353
41.20	42.64	0.69	-0.2353
41.19	42.69	0.73	-0.2308
41.17	42.73	0.76	-0.2727
41.16	42.76	0.79	-0.3333
41.15	42.81	0.84	-0.0833
41.15	42.84	0.82	0
41.15	42.84	0.84	-1
41.14	42.86	0.85	-0.25
41.17	42.90	0.85	3
41.19	42.93	0.87	1.33333

FIG. X2.4 Data Page 3—Constant Potentiometric Surface

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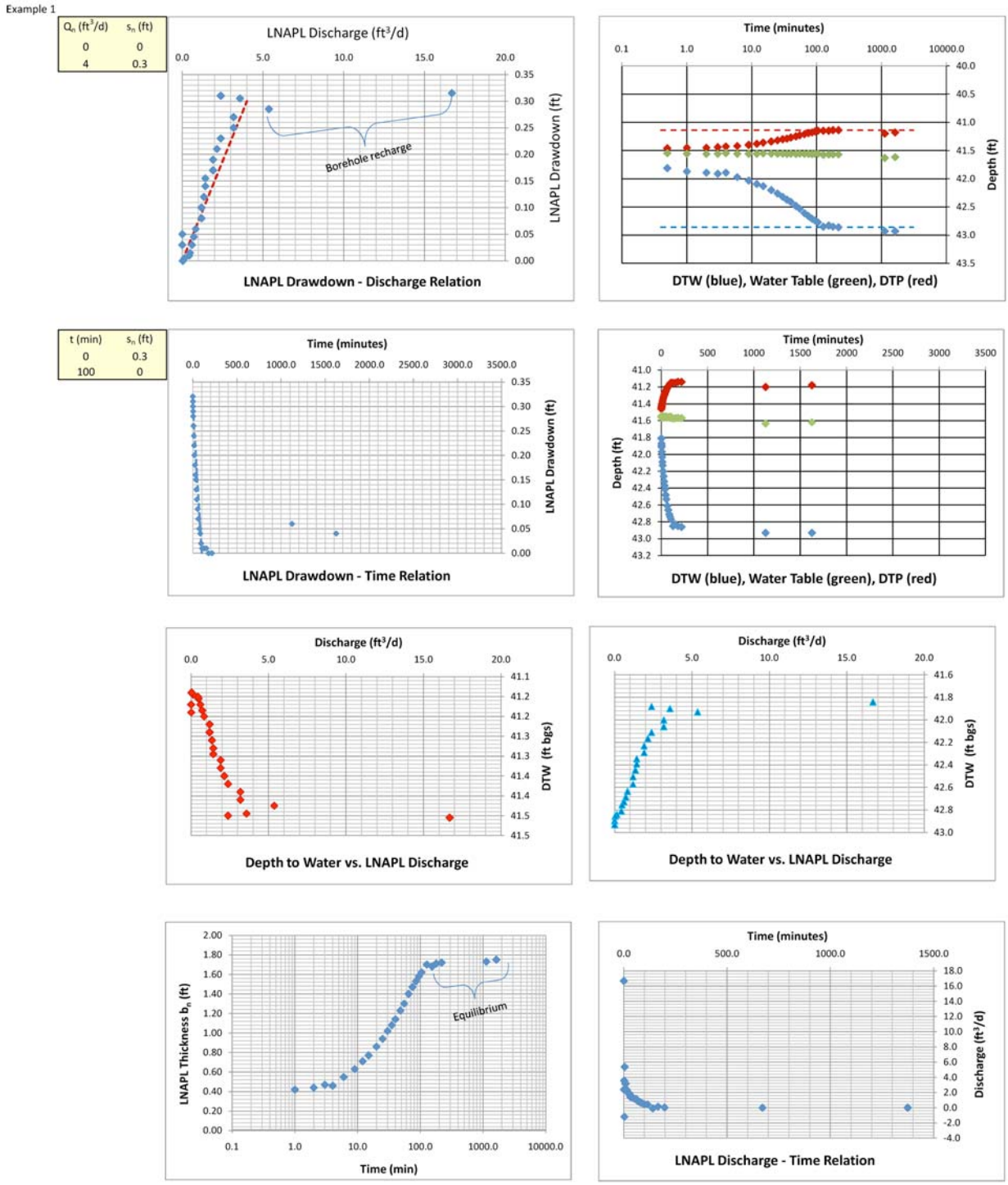


FIG. X2.5 Figures Page 1—Constant Potentiometric Surface

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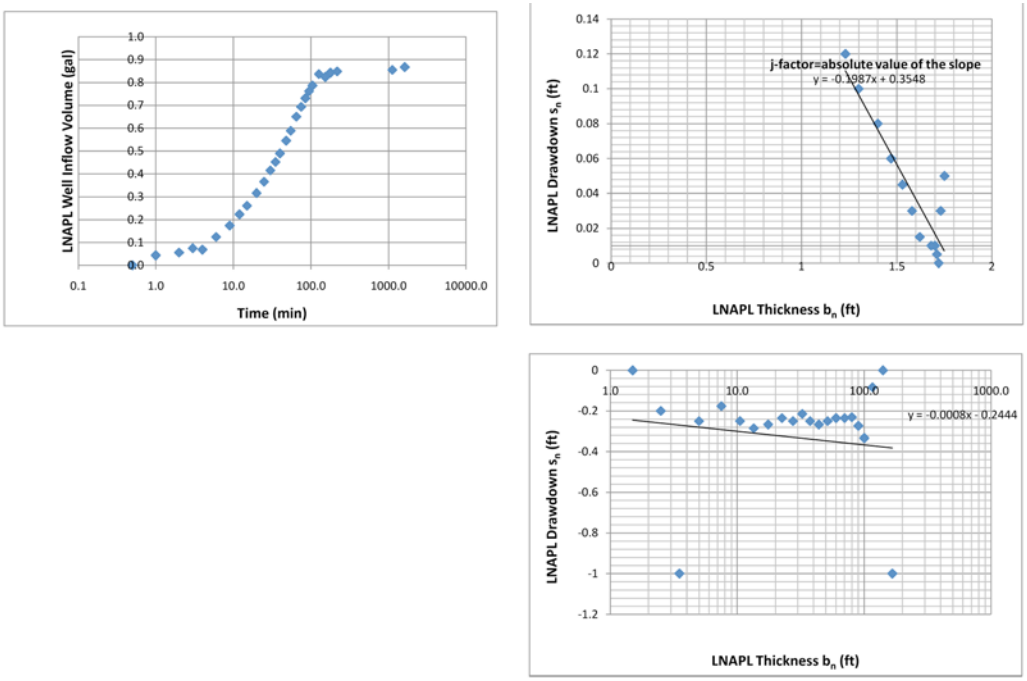


FIG. X2.5 Figures Page 2—Constant Potentiometric Surface *(continued)*

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X_i	Y_i	X^2	XY	$(y-A-Bx)^2$	ε	count	s/s_0
							#N/A
0.00	-1.17	0.00	0.00	0.00	0.00	1	#N/A
1.00	-1.20	1.00	-1.20	0.00	-0.01	1	1.00
2.00	-1.24	4.00	-2.48	0.00	-0.02	1	0.96
4.00	-1.27	16.00	-5.09	0.01	-0.01	1	0.93
7.00	-1.35	49.00	-9.43	0.02	-0.01	1	0.90
10.00	-1.43	100.00	-14.27	0.06	-0.02	1	0.84
13.00	-1.51	169.00	-19.68	0.10	-0.03	1	0.77
18.00	-1.61	324.00	-28.97	0.18	-0.01	1	0.71
23.00	-1.71	529.00	-39.44	0.27	0.01	1	0.64
28.00	-1.83	784.00	-51.31	0.41	0.01	1	0.58
33.00	-1.90	1089.00	-62.60	0.50	0.07	1	0.51
38.00	-2.04	1444.00	-77.53	0.72	0.04	1	0.48
46.00	-2.21	2116.00	-101.53	1.03	0.07	1	0.42
53.00	-2.41	2809.00	-127.62	1.48	0.04	1	0.35
63.00	-2.66	3969.00	-167.53	2.16	0.03	1	0.29
73.00	-3.00	5329.00	-218.69	3.26	-0.07	1	0.22
83.00	-3.22	6889.00	-267.17	4.11	-0.05	1	0.16
							0.13

FIG. X2.6 Bouwer-Rice Worksheet—Constant Potentiometric Surface

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Cooper and Jacob (1946)

Example 1

$$V_n(t_i) = \sum_j^i \frac{4\pi T s_j}{\ln\left(\frac{2.25 T t_j}{r_e^2 S}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Trial S:	0.040	<-- Change S value can be manual
Root-Mean-Square Error:	0.104	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	3.585	<-- By changing T_n (and S)
		Add constraint T_n > 0.00001
Model Result:	T_n (ft^2/d) = 3.58	

Index	t_i	Vi (meas)	Vi (calc)	SE
1	0.7	0.043357	2.67E-02	0.000278813
2	1.5	0.055745	6.16E-02	3.43739E-05
3	2.5	0.074326	8.92E-02	0.000221257
4	3.5	0.068132	1.13E-01	0.001996732
5	5.0	0.123877	1.53E-01	0.000876678
6	7.5	0.173428	2.05E-01	0.00099169
7	10.5	0.222978	2.49E-01	0.000654283
8	13.5	0.260141	2.86E-01	0.000686546
9	17.5	0.315886	3.41E-01	0.000608393
10	22.5	0.365437	3.87E-01	0.000465855
11	27.5	0.414988	4.27E-01	0.000142476
12	32.5	0.452151	4.62E-01	9.95184E-05
13	37.5	0.489314	4.93E-01	1.40577E-05
14	44.0	0.545058	5.34E-01	0.000116887
15	51.5	0.588415	5.63E-01	0.000624037
16	60.0	0.650354	5.96E-01	0.002964359

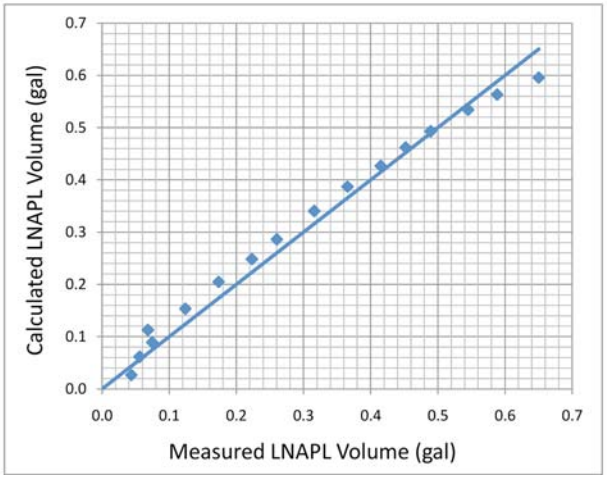


FIG. X2.7 Cooper and Jacob Worksheet—Constant Potentiometric Surface

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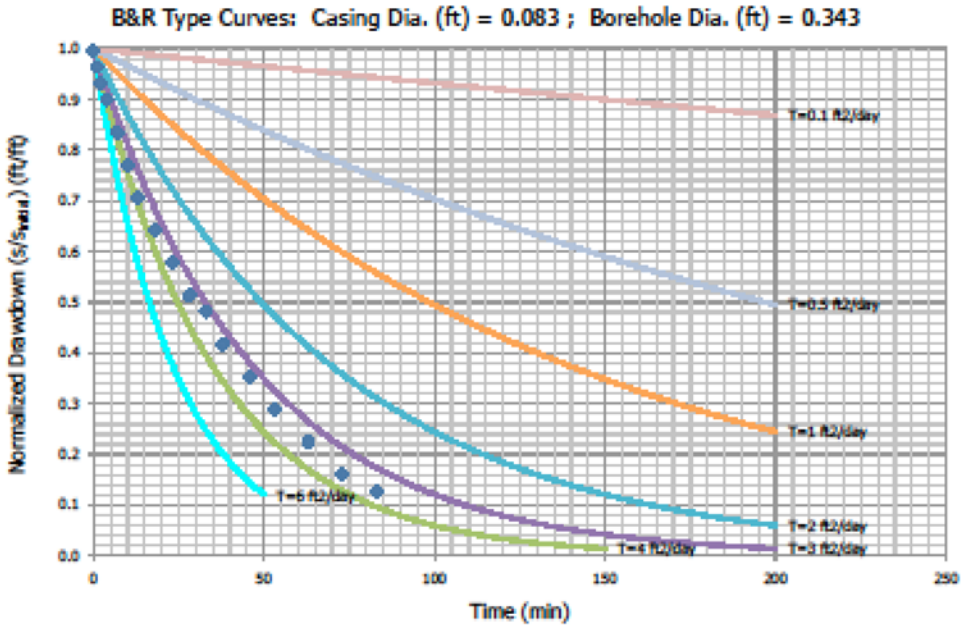
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Dia. (ft) = 0.083 ; Borehole Dia. (ft) = 0.343

Example 1

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=6 ft2/day		50	6
2	T=4 ft2/day		150	4
3	T=3 ft2/day		200	3
4	T=2 ft2/day		200	2
5	T=1 ft2/day		200	1
6	T=0.5 ft2/day		200	0.5
7	T=0.1 ft2/day		200	0.1



Field Data

Record Data in Fields Below						Calculate and Plot Fields Below		
Well ID		Well Dia. (ft)		Total Depth (ft)				
Notes	Date	Time	Elapsed Time (min)	Depth To Product (TOC)	Depth to Water (TOC)	Product Thickness (ft)	Drawdown (s) DTP-DTP(Initial) (ft)	Normalized Drawdown ($s/s_{initial}$)
Initial Measurement								
Stopped Bailing/Start Gauging			0					
Well Starts recovering								

FIG. X2.8 Bouwer-Rice Type Curve Worksheet—Constant Potentiometric Surface

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Cooper, Bredehoeft and Papadopulos (1967)

Example 1

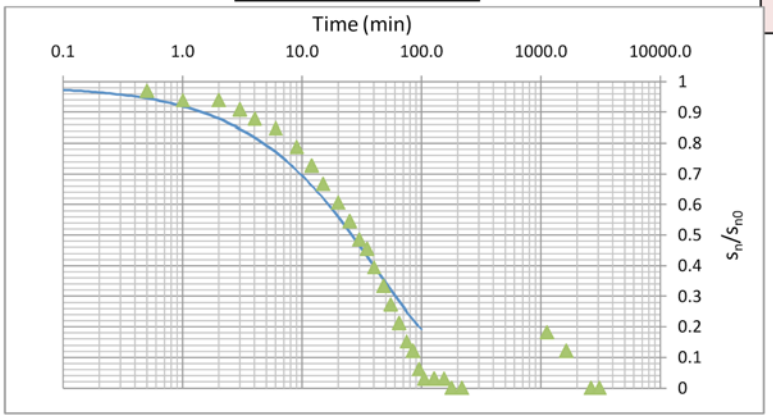
Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Initial Drawdown s_n (ft):	0.33	
Trial S:	0.036	<-- Adjust manually or through "Solver"
Root-Mean-Square Error:	0.432	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	3.830	<-- By changing T_n through "Solver" (and S)

Add constraint Tn > 0.00001

Model Result: T_n (ft^2/d) = 3.83 0.06786

T_{min}	0.1
T_{max}	100



Count	Time (min)	H/H_o	G (a,b,e)	SE
1	0.500	0.969697	0.94551064	0.000584979
1	1.000	0.939394	0.91967573	0.000388808
1	2.000	0.939394	0.87954636	0.003581732
1	3.000	0.909091	0.8471282	0.003839377
1	4.000	0.878788	0.81909598	0.003563123
1	6.000	0.848485	0.7712209	0.005969717
1	9.000	0.787879	0.71217583	0.005730937
1	12.000	0.727273	0.66291707	0.004141651
1	15.000	0.666667	0.62043647	0.002137231
1	20.000	0.606061	0.56045422	0.002079942
1	25.000	0.545455	0.51039042	0.001229493
1	30.000	0.484848	0.46769623	0.0002942
1	35.000	0.454545	0.43073951	0.000566723
1	40.000	0.393939	0.39839078	1.98148E-05
1	48.000	0.333333	0.35423876	0.000437037
1	55.000	0.272727	0.3216953	0.002397867
1	65.000	0.212121	0.28279424	0.004994676
1	75.000	0.151515	0.25081234	0.009859932
1	85.000	0.121212	0.22415878	0.010598015
1	95.000	0.060606	0.2016938	0.019905751
1	105.000	0.030303	0.1825761	0.023187087
1	127.000	0.030303	0.14938045	0.014179431
1	154.000	0.030303	0.12021381	0.008083949
1	179.000	0	0.10063937	0.010128282
1	218.000	0	0.07907575	0.006252975
1	1125.000	0.181818	0.01087427	0.02922182
1	1625.000	0.121212	0.00726318	0.012984362
1	2615.000	0	0.0043724	1.91179E-05
1	3087.000	0	0.0036735	1.34946E-05
0	0.000	0	0	0
0	0.000	0	0	0
0	0.000	0	0	0

FIG. X2.9 Cooper, Bredehoeft and Papadopulos Worksheet—Constant Potentiometric Surface

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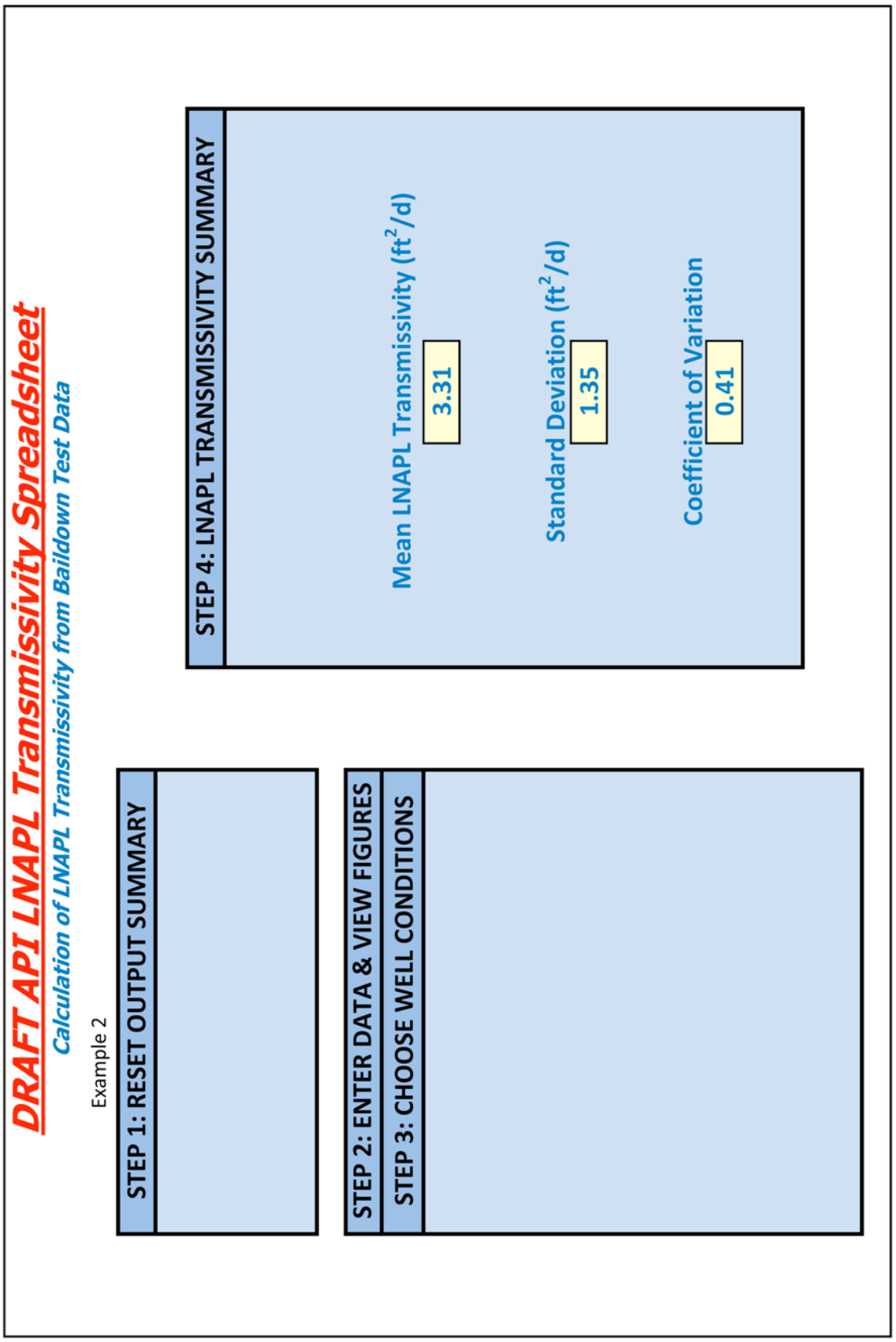


FIG. X2.10 Results Page—Constant LNAPL/water Interface

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Example 2
Well Designation: Relatively constant O-W interface
Date:

Ground Surface Elev (ft msl)	20.1	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	20.1		
Well Casing Radius, r_c (ft):	0.167	r_{e1}	0
Well Radius, r_w (ft):	0.5000		
LNAPL Specific Yield, S_y:	0.105		
LNAPL Density Ratio, ρ_r:	0.87		
Top of Screen (ft bgs):	8.0		
Bottom of Screen (ft bgs):	28.0		
LNAPL Baildown Vol. (gal.):	8.0		
Effective Radius, r_{e3} (ft):	0.226	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.219		
Initial Casing LNAPL Vol. (gal.):	4.76		
Initial Filter LNAPL Vol. (gal.):	4.00		

	Enter Data Here											
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Index	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	19.85	27.14	19.85	27.14	20.80	0.95					7.29	
Test Starts:	1.0	26.45	27.27	26.45	27.27	26.56	6.60	1.0					
	3.0	25.73	27.21	25.73	27.21	25.92	5.88	2.0	2.0	76.303	6.24	1.48	0.226
	5.0	25.25	27.18	25.25	27.18	25.50	5.40	3.0	4.0	52.025	5.64	1.93	0.226
	7.0	24.80	27.12	24.80	27.12	25.10	4.95	4.0	6.0	45.088	5.18	2.32	0.226
	9.0	24.30	27.08	24.30	27.08	24.66	4.45	5.0	8.0	53.181	4.70	2.78	0.226
	11.0	23.91	27.04	23.91	27.04	24.32	4.06	6.0	10.0	40.464	4.26	3.13	0.226
	15.0	23.15	26.95	23.15	26.95	23.64	3.30	7.0	13.0	38.730	3.68	3.80	0.226
	20.0	22.40	26.88	22.40	26.88	22.98	2.55	8.0	17.5	31.446	2.93	4.48	0.226
	25.0	21.85	26.82	21.85	26.82	22.50	2.00	9.0	22.5	22.660	2.28	4.97	0.226
	30.0	21.42	26.80	21.42	26.80	22.12	1.57	10.0	27.5	18.960	1.79	5.38	0.226
	36.0	21.08	26.77	21.08	26.77	21.82	1.23	11.0	33.0	11.946	1.40	5.69	0.226
	40.0	20.90	26.78	20.90	26.78	21.66	1.05	12.0	38.0	10.983	1.14	5.88	0.226
	44.0	20.78	26.77	20.78	26.77	21.56	0.93	13.0	42.0	6.359	0.99	5.99	0.226
	50.0	20.61	26.75	20.61	26.75	21.41	0.76	14.0	47.0	5.781	0.85	6.14	0.226
	55.0	20.54	26.76	20.54	26.76	21.35	0.69	15.0	52.5	3.700	0.73	6.22	0.226
	60.0	20.47	26.75	20.47	26.75	21.29	0.62	16.0	57.5	2.775	0.66	6.28	0.226
	70.0	20.34	26.76	20.34	26.76	21.17	0.49	17.0	65.0	3.237	0.56	6.42	0.226
	80.0	20.28	26.76	20.28	26.76	21.12	0.43	18.0	75.0	1.387	0.46	6.48	0.226
	90.0	20.22	26.77	20.22	26.77	21.07	0.37	19.0	85.0	1.619	0.40	6.55	0.226
	100.0	20.20	26.76	20.20	26.76	21.05	0.35	20.0	95.0	0.231	0.36	6.56	0.226
	110.0	20.17	26.81	20.17	26.81	21.03	0.32	21.0	105.0	1.850	0.34	6.64	0.226
	120.0	20.14	26.82	20.14	26.82	21.01	0.29	22.0	115.0	0.925	0.31	6.68	0.226
	150.0	20.08	26.88	20.08	26.88	20.96	0.23	23.0	135.0	0.925	0.26	6.80	0.226
	180.0	20.03	26.91	20.03	26.91	20.92	0.18	24.0	165.0	0.617	0.21	6.88	0.226
	240.0	19.96	27.00	19.96	27.00	20.88	0.11	25.0	210.0	0.617	0.15	7.04	0.226
	300.0	19.91	27.06	19.91	27.06	20.84	0.06	26.0	270.0	0.424	0.09	7.15	0.226

FIG. X2.11 Data Page—Constant LNAPL/water Interface

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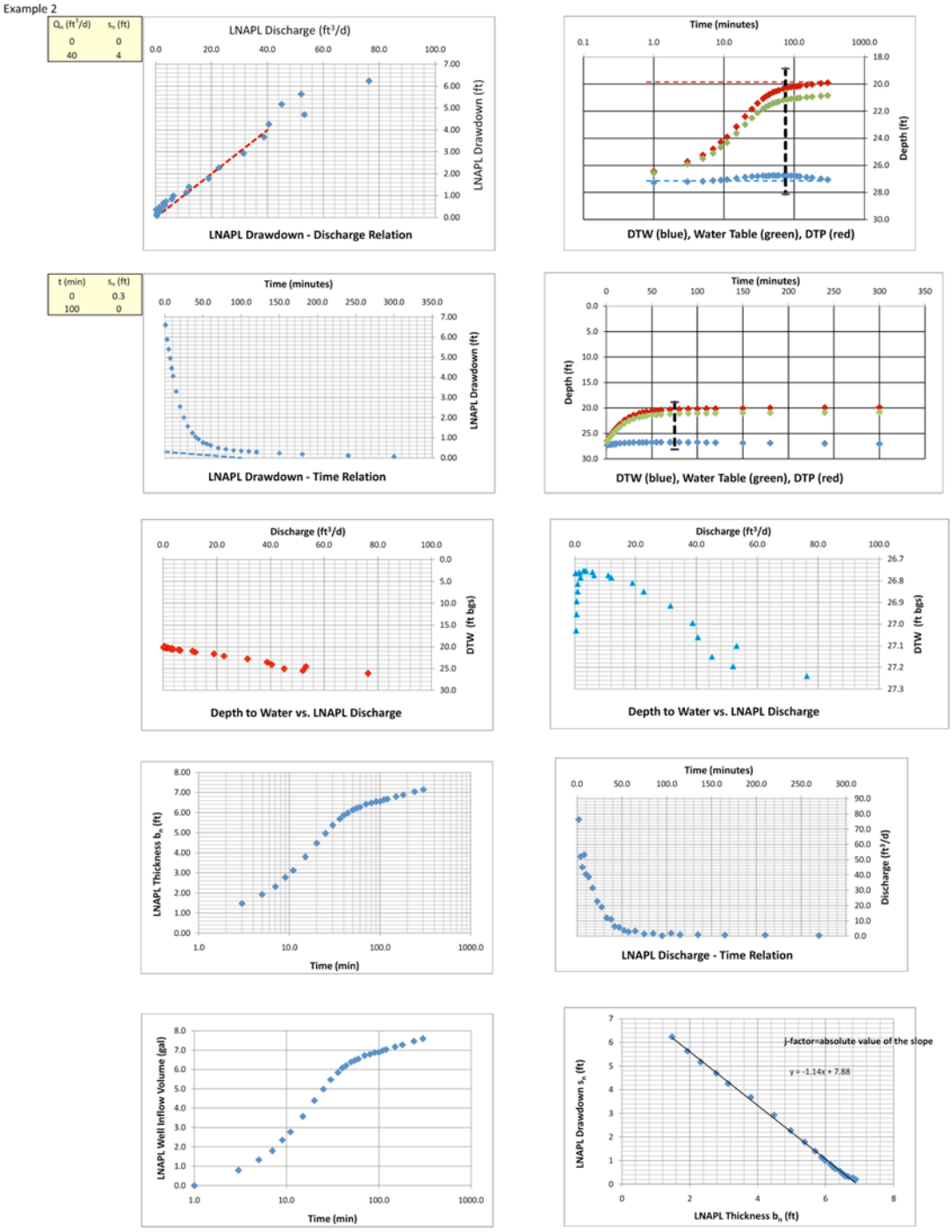


FIG. X2.12 Figures Page—Constant LNAPL/water Interface

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X_i	Y_i	X^2	XY	$(y-A-Bx)^2$	ε	count	s/s_0
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
1.00	1.77	1.00	1.77	0.00	0.04	1	1.00
3.00	1.69	9.00	5.06	0.00	0.04	1	0.92
5.00	1.60	25.00	8.00	0.02	0.04	1	0.84
7.00	1.49	49.00	10.45	0.05	0.02	1	0.76
9.00	1.40	81.00	12.61	0.11	0.02	1	0.69
13.00	1.19	169.00	15.52	0.28	-0.01	1	0.56
18.00	0.94	324.00	16.85	0.62	-0.04	1	0.43
23.00	0.69	529.00	15.94	1.07	-0.06	1	0.34
28.00	0.45	784.00	12.63	1.62	-0.08	1	0.27
34.00	0.21	1156.00	7.04	2.31	-0.06	1	0.21
38.00	0.05	1444.00	1.85	2.81	-0.05	1	0.18
42.00	-0.07	1764.00	-3.05	3.23	-0.01	1	0.16
48.00	-0.27	2304.00	-13.17	4.00	0.03	1	0.13
53.00	-0.37	2809.00	-19.67	4.39	0.13	1	0.12

FIG. X2.13 Bouwer-Rice Worksheet—Constant LNAPL/water Interface

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Cooper and Jacob (1946)

Example 2

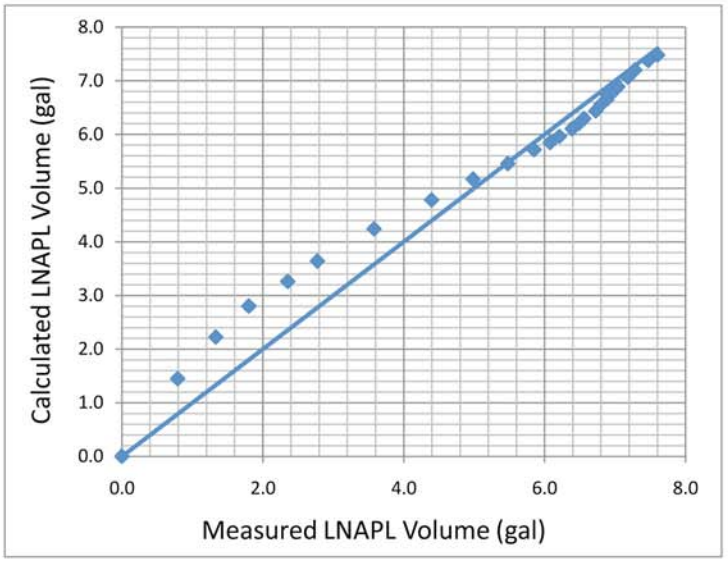
$$V_n(t_i) = \sum_j^i \frac{4\pi T s_j}{\ln\left(\frac{2.25 T t_j}{r_e^2 S}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Trial S:	0.040	<-- Change S value can be manual
Root-Mean-Square Error:	2.252	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	1.798	<-- By changing T_n (and S)

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **1.80**



Index	t_i	Vi (meas)	Vi (calc)	SE
1	2.0	0.79270341	1.45E+00	0.43047
2	4.0	1.33318301	2.23E+00	0.79663
3	6.0	1.80159867	2.80E+00	0.999976
4	8.0	2.35408892	3.26E+00	0.824001
5	10.0	2.77446195	3.64E+00	0.754402
6	13.0	3.57917602	4.24E+00	0.439837
7	17.5	4.39590075	4.78E+00	0.149229
8	22.5	4.98442298	5.17E+00	0.034929
9	27.5	5.47685995	5.46E+00	0.000293
10	33.0	5.84919034	5.72E+00	0.017145
11	38.0	6.07739284	5.85E+00	0.050096
12	42.0	6.20951007	5.97E+00	0.058237
13	47.0	6.38966994	6.11E+00	0.077673
14	52.5	6.4857552	6.21E+00	0.07581
15	57.5	6.55781915	6.30E+00	0.067301
16	65.0	6.72596836	6.44E+00	0.079837
17	75.0	6.7980323	6.56E+00	0.056707
18	85.0	6.88210691	6.66E+00	0.049987
19	95.0	6.89411757	6.75E+00	0.022156
20	105.0	6.99020283	6.82E+00	0.027504
21	115.0	7.03824546	6.90E+00	0.020498
22	135.0	7.18237335	7.07E+00	0.012545
23	165.0	7.27845861	7.20E+00	0.005624
24	210.0	7.47062914	7.38E+00	0.00755
25	270.0	7.60274638	7.48E+00	0.013882
26	0.0	0	0.00E+00	0
27	0.0	0	0.00E+00	0
28	0.0	0	0.00E+00	0
29	0.0	0	0.00E+00	0
30	0.0	0	0.00E+00	0
31	0.0	0	0.00E+00	0
32	0.0	0	0.00E+00	0
33	0.0	0	0.00E+00	0

FIG. X2.14 Cooper and Jacob Worksheet—Constant LNAPL/water Interface

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Cooper, Bredehoeft and Papadopulos (1967)

Example 2

Enter early time cut-off for least-squares model fit

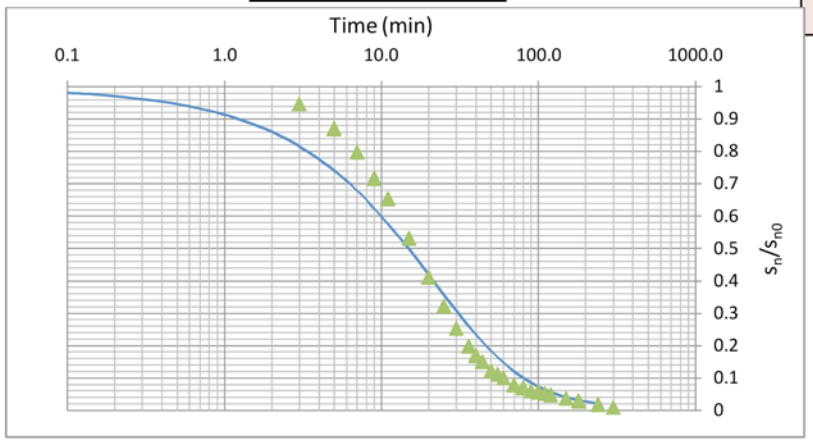
$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Initial Drawdown s_n (ft):	6.2	

Trial S:	0.005	<-- Adjust manually or through "Solver"
Root-Mean-Square Error:	0.341	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	4.393	<-- By changing T_n through "Solver" (and S)

Add constraint Tn > 0.00001

Model Result: T_n (ft^2/d) = 4.39 0.077842

T_{min}	0.1
T_{max}	250



Count	Time (min)	H/H_o	G (a,b,e)	SE
1	1.000	1.064516	0.9138387	0.022704
1	3.000	0.948387	0.81586235	0.017563
1	5.000	0.870968	0.74060068	0.016996
1	7.000	0.798387	0.67784769	0.01453
1	9.000	0.717742	0.62384676	0.008816
1	11.000	0.654839	0.57655128	0.006129
1	15.000	0.532258	0.49720815	0.001228
1	20.000	0.41129	0.41898496	5.92E-05
1	25.000	0.322581	0.35736551	0.00121
1	30.000	0.253226	0.30787019	0.002986
1	36.000	0.198387	0.26036763	0.003842
1	40.000	0.169355	0.23426983	0.004214
1	44.000	0.15	0.21172819	0.00381
1	50.000	0.122581	0.18332371	0.00369
1	55.000	0.11129	0.16365351	0.002742
1	60.000	0.1	0.14690143	0.0022
1	70.000	0.079032	0.1201752	0.001693
1	80.000	0.069355	0.10012386	0.000947
1	90.000	0.059677	0.08478382	0.00063
1	100.000	0.056452	0.07284058	0.000269
1	110.000	0.051613	0.06339255	0.000139
1	120.000	0.046774	0.0558084	8.16E-05
1	150.000	0.037097	0.0403192	1.04E-05
1	180.000	0.029032	0.03111429	4.33E-06
1	240.000	0.017742	0.02106869	1.11E-05
1	300.000	0.009677	0.01584122	3.8E-05
0	0.000	0	0	0
0	0.000	0	0	0

FIG. X2.15 Cooper, Bredehoeft and Papadopulos Worksheet—Constant LNAPL/water Interface

Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Dia. (ft) = 0.167 ; Borehole Dia. (ft) = 0.5

Example 2

			Enter these values	
Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=6 ft2/day		50	6
2	T=4 ft2/day		150	4
3	T=3 ft2/day		200	3
4	T=2 ft2/day		200	2
5	T=1 ft2/day		200	1
6	T=0.5 ft2/day		200	0.5
7	T=0.1 ft2/day		200	0.1

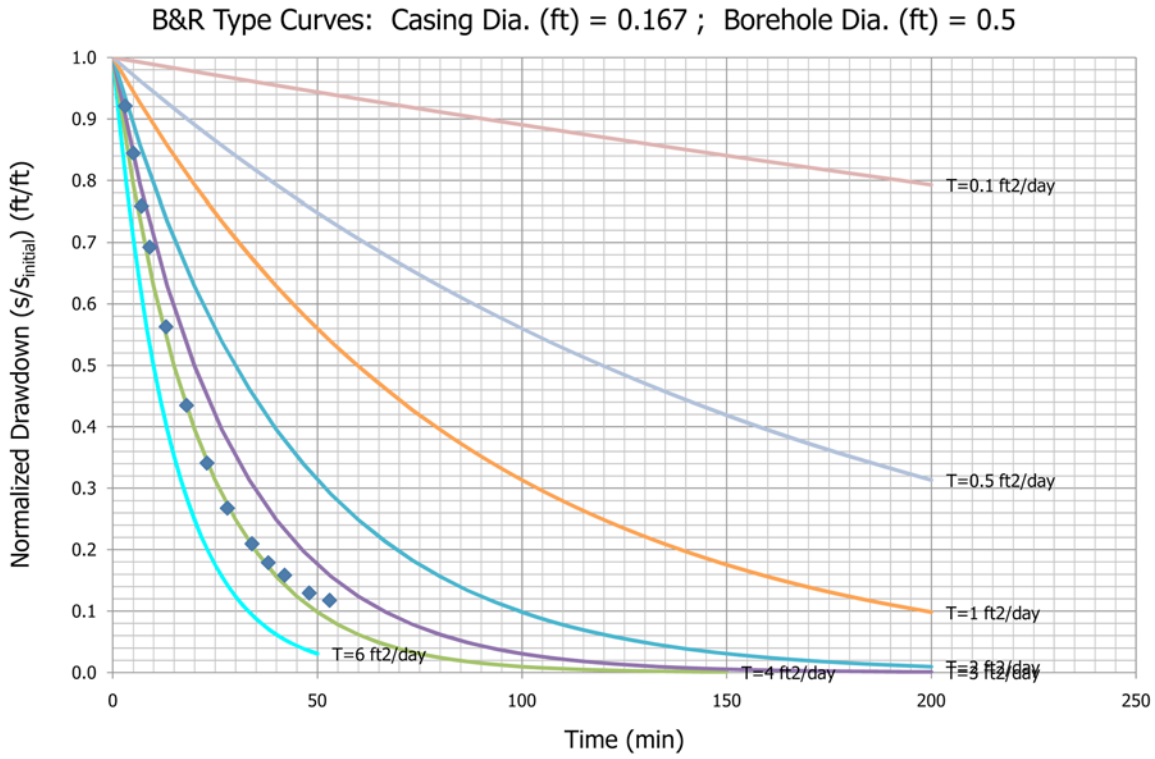


FIG. X2.16 Bouwer-Rice Type Curve Worksheet—Constant LNAPL/water Interface

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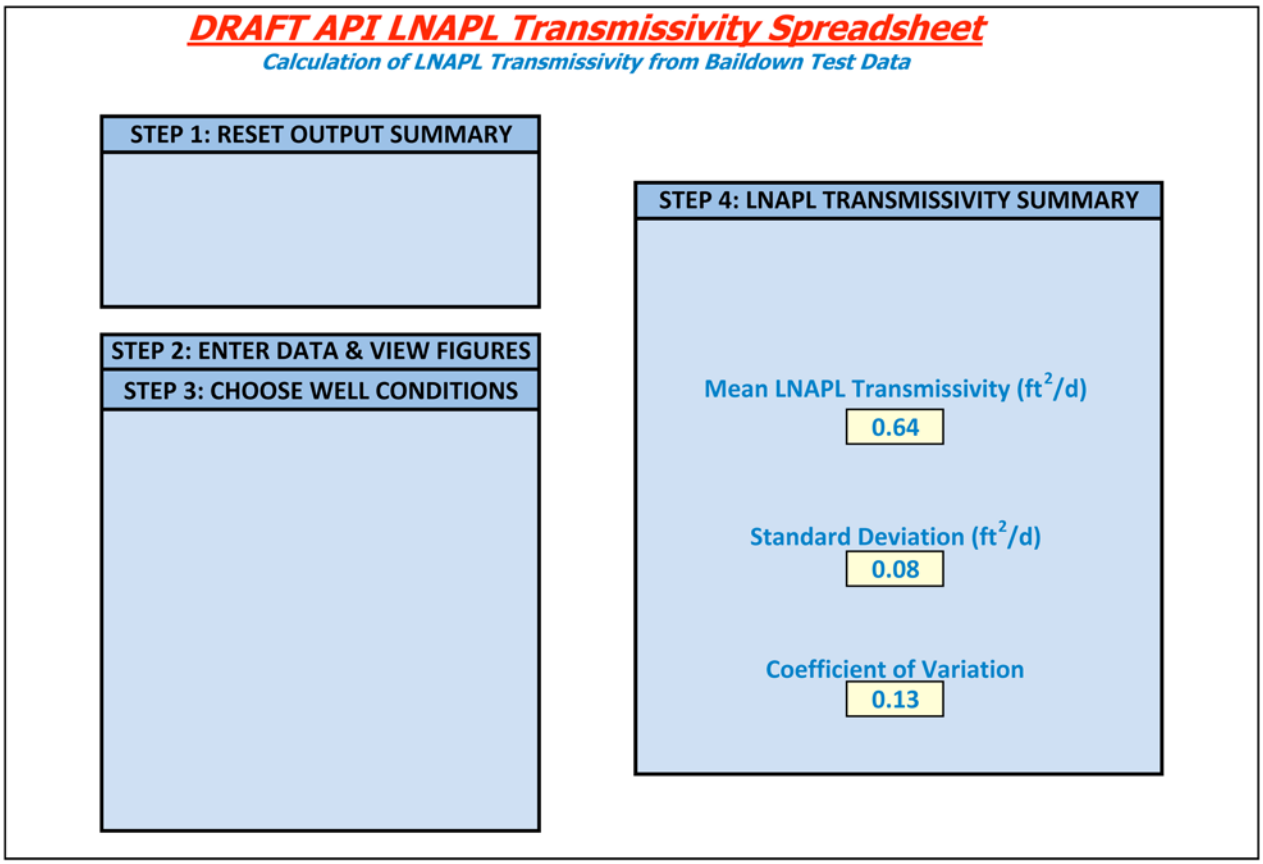


FIG. X2.17 Results Page—Variable LNAPL/Water Interface

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Well Designation: Example 3: Variable Water-table and Oil/water interface
Date:

Ground Surface Elev (ft msl)	0.0	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	0.0		
Well Casing Radius, r_c (ft):	0.167	r_{e1}	0
Well Radius, r_w (ft):	0.4167		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.79		
Top of Screen (ft bgs):	0.0		
Bottom of Screen (ft bgs):	0.0		
LNAPL Baildown Vol. (gal.):	0.0	Calculated Parameters	
Effective Radius, r_{e3} (ft):	0.231		
Effective Radius, r_{e2} (ft):	0.219		
Initial Casing LNAPL Vol. (gal.):	6.19		
Initial Filter LNAPL Vol. (gal.):	5.69		

Initial Fluid Levels:

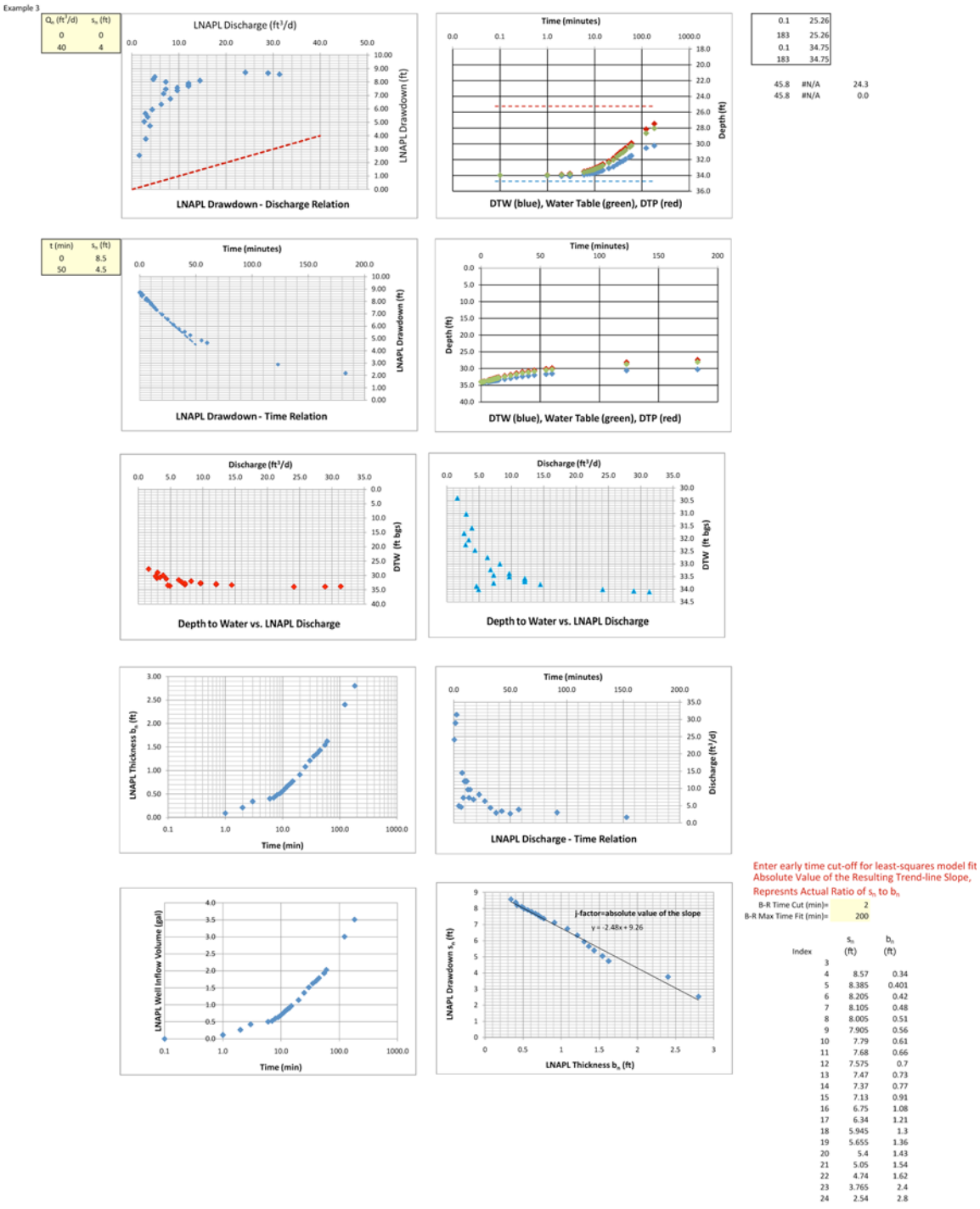
Test Starts:

Enter Data Here					Water Table	LNAPL		LNAPL								
Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Depth (ft)	Drawdown s_n (ft)	Index	Average Time (min)	Discharge Q_n (ft²/d)	s_n (ft)	b_n (ft)	r_e (ft)	DTP (ft bgs)	DTW (ft bgs)	LNAPL Volume (gallons)	
0	25.26	34.75	25.26	34.75	27.25	1.99					9.49					
0.1	33.98	33.98	33.98	33.98	33.98	8.72	1.0									
1.0	33.96	34.05	33.96	34.05	33.98	8.70	2.0	0.6	24.112	8.71	0.09	0.231	33.97	34.02	0.11	-0.6667
2.0	33.88	34.09	33.88	34.09	33.92	8.62	3.0	1.5	28.934	8.66	0.21	0.231	33.92	34.07	0.26	-0.72
3.0	33.78	34.12	33.78	34.12	33.85	8.52	4.0	2.5	31.345	8.57	0.34	0.231	33.83	34.11	0.43	-1.9372
6.0	33.51	33.91	33.51	33.91	33.59	8.25	5.0	4.5	4.903	8.39	0.40	0.231	33.65	34.02	0.50	-4.5
7.0	33.42	33.84	33.42	33.84	33.51	8.16	6.0	6.5	4.581	8.21	0.42	0.231	33.47	33.88	0.53	-2.5316
8.0	33.31	33.79	33.31	33.79	33.41	8.05	7.0	7.5	14.467	8.11	0.48	0.231	33.37	33.82	0.60	-2.2222
9.0	33.22	33.73	33.22	33.73	33.33	7.96	8.0	8.5	7.234	8.01	0.51	0.231	33.27	33.76	0.64	-2.5
10.0	33.11	33.67	33.11	33.67	33.23	7.85	9.0	9.5	12.056	7.91	0.56	0.231	33.17	33.70	0.70	-2.3
11.0	32.99	33.60	32.99	33.60	33.12	7.73	10.0	10.5	12.056	7.79	0.61	0.231	33.05	33.64	0.76	-2.2
12.0	32.89	33.55	32.89	33.55	33.03	7.63	11.0	11.5	12.056	7.68	0.66	0.231	32.94	33.58	0.83	-2.3333
13.0	32.78	33.48	32.78	33.48	32.93	7.52	12.0	12.5	9.645	7.58	0.70	0.231	32.84	33.52	0.88	-3
14.0	32.68	33.41	32.68	33.41	32.83	7.42	13.0	13.5	7.234	7.47	0.73	0.231	32.73	33.45	0.91	-2.8571
15.0	32.58	33.35	32.58	33.35	32.74	7.32	14.0	14.5	9.645	7.37	0.77	0.231	32.63	33.38	0.96	-2.6667
20.0	32.20	33.11	32.20	33.11	32.39	6.94	15.0	17.5	6.751	7.13	0.91	0.231	32.39	33.23	1.14	-2.4516
25.0	31.82	32.90	31.82	32.90	32.05	6.56	16.0	22.5	8.198	6.75	1.08	0.231	32.01	33.01	1.35	-2.7333
30.0	31.38	32.59	31.38	32.59	31.63	6.12	17.0	27.5	6.269	6.34	1.21	0.231	31.60	32.75	1.52	-3.5909
35.0	31.03	32.33	31.03	32.33	31.30	5.77	18.0	32.5	4.340	5.95	1.30	0.231	31.21	32.46	1.63	-3.8667
40.0	30.80	32.16	30.80	32.16	31.09	5.54	19.0	37.5	2.893	5.66	1.36	0.231	30.92	32.25	1.70	-3.9231
45.0	30.52	31.95	30.52	31.95	30.82	5.26	20.0	42.5	3.376	5.40	1.43	0.231	30.66	32.06	1.79	-3.8889
55.0	30.10	31.64	30.10	31.64	30.42	4.84	21.0	50.0	2.652	5.05	1.54	0.231	30.31	31.80	1.93	-3.2632
60.0	29.90	31.52	29.90	31.52	30.24	4.64	22.0	57.5	3.858	4.74	1.62	0.231	30.00	31.58	2.03	-2.2674
123.0	28.15	30.55	28.15	30.55	28.65	2.89	23.0	91.5	2.985	3.77	2.40	0.231	29.03	31.04	3.01	-2.0763
183.0	27.45	30.25	27.45	30.25	28.04	2.19	24.0	153.0	1.607	2.54	2.80	0.231	27.80	30.40	3.51	

FIG. X2.18 Data Page—Variable LNAPL/Water Interface

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Index	s_n (ft)	b_n (ft)
3		
4	8.57	0.34
5	8.385	0.401
6	8.205	0.42
7	8.105	0.48
8	8.005	0.51
9	7.905	0.56
10	7.79	0.61
11	7.68	0.66
12	7.575	0.7
13	7.47	0.73
14	7.37	0.77
15	7.13	0.91
16	6.75	1.08
17	6.34	1.21
18	5.945	1.3
19	5.655	1.36
20	5.4	1.43
21	5.05	1.54
22	4.74	1.62
23	3.765	2.4
24	2.54	2.8

FIG. X2.19 Figure Page—Variable LNAPL/Water Interface

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Bouwer and Rice (1976)

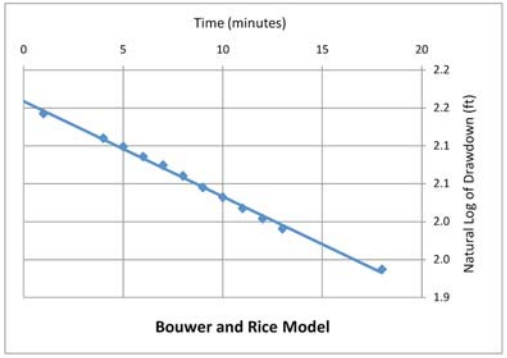
Example 3

$$T_n = \frac{r_c^2 \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(1-\rho_r)(t-t_1)}$$

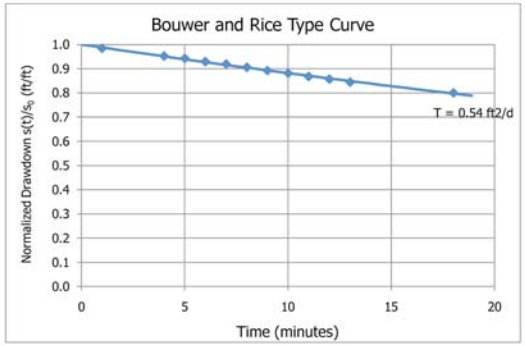
Go To 'Figures' Cell V78, prior to analysis

$Time_{cut}$	2	<- From Figures, Cell V78
Ratio of s_n to b_n	2.5	<- Use $(1-\rho_r)$ or field value from 'Figures' tab

Model Results: T_n (ft^2/d) = 0.54 +/- 0.35 ft^2/d



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



L_e/r_e	41.1
C	2.44
R/r_e	16.69
Coef. Of Variation	0.64

X_i	Y_i	X^2	XY	$(y-A-Bx)^2$	ε	count	s/s_0
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
1.00	2.14	1.00	2.14	0.00	-0.03	1	0.98
4.00	2.11	16.00	8.44	0.00	0.01	1	0.95
5.00	2.10	25.00	10.50	0.00	0.03	1	0.94
6.00	2.09	36.00	12.51	0.00	0.02	1	0.93
7.00	2.07	49.00	14.52	0.01	0.03	1	0.92
8.00	2.06	64.00	16.48	0.01	0.02	1	0.91
9.00	2.05	81.00	18.41	0.01	-0.01	1	0.89
10.00	2.03	100.00	20.32	0.01	-0.01	1	0.88
11.00	2.02	121.00	22.19	0.02	-0.02	1	0.87
12.00	2.00	144.00	24.05	0.02	-0.03	1	0.86
13.00	1.99	169.00	25.88	0.02	-0.04	1	0.85
18.00	1.94	324.00	34.87	0.04	0.04	1	0.80

y = A + B x

ΣX	104.00
ΣY	24.60
ΣX^2	1130
ΣXY	210.3
N	12
Δ	2744
A	2.16
B	-0.013
σ_y^2	0.015
σ_B^2	6.47E-05

Plot Model Line

0	2.159
18	1.933
factor	0.030
s_0 (ft)	8.66

B&R Type Curve t (min)	s/s0
0	1.000
0.63	0.992
1.26	0.984
1.89	0.977
2.52	0.969
3.15	0.961
3.78	0.954
4.41	0.946
5.04	0.939
5.67	0.931
6.30	0.924
6.93	0.917
7.56	0.909
8.19	0.902
8.82	0.895
9.45	0.888
10.08	0.881
10.71	0.874
11.34	0.867
11.97	0.860
12.60	0.853
13.23	0.847
13.86	0.840
14.49	0.833
15.12	0.827
15.75	0.820
16.38	0.814
17.01	0.807
17.64	0.801
18.27	0.795
18.90	0.788

0.54
0.54
T = 0.54 ft2/d

FIG. X2.20 Bouwer-Rice Worksheet—Variable LNAPL/Water Interface

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Cooper and Jacob (1946)

Example 3

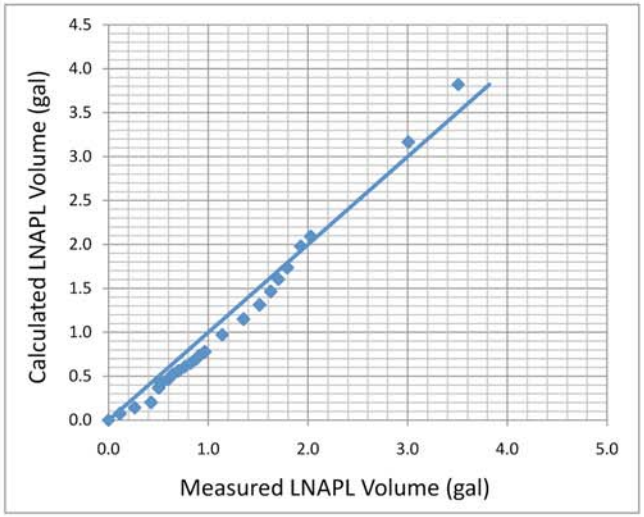
$$V_n(t_i) = \sum_j^i \frac{4\pi T s_j}{\ln\left(\frac{2.25 T t_j}{r_e^2 S}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Trial S:	0.0001	<-- Change S value can be manual
Root-Mean-Square Error:	0.766	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.680	<-- By changing T_n (and S)

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.68**



Index	t_i	Vi (meas)	Vi (calc)	SE
1	0.6	0.112722	7.41E-02	0.001494
2	1.5	0.263019	1.42E-01	0.014765
3	2.5	0.42584	2.03E-01	0.049769
4	4.5	0.502241	3.67E-01	0.018298
5	6.5	0.526037	4.18E-01	0.011718
6	7.5	0.601186	4.67E-01	0.018005
7	8.5	0.63876	5.15E-01	0.015368
8	9.5	0.701383	5.61E-01	0.019626
9	10.5	0.764007	6.07E-01	0.024805
10	11.5	0.82663	6.51E-01	0.030998
11	12.5	0.876729	6.94E-01	0.033551
12	13.5	0.914303	7.36E-01	0.031955
13	14.5	0.964402	7.77E-01	0.035272
14	17.5	1.139748	9.71E-01	0.028618
15	22.5	1.352668	1.15E+00	0.041587
16	27.5	1.515489	1.31E+00	0.041336
17	32.5	1.628211	1.46E+00	0.027455
18	37.5	1.703359	1.60E+00	0.010027
19	42.5	1.791032	1.74E+00	0.003058
20	50.0	1.928804	1.98E+00	0.002539
21	57.5	2.029002	2.09E+00	0.003936
22	91.5	3.005928	3.16E+00	0.025247
23	153.0	3.506916	3.82E+00	0.097995
24	0.0	0	0.00E+00	0
25	0.0	0	0.00E+00	0
26	0.0	0	0.00E+00	0
27	0.0	0	0.00E+00	0
28	0.0	0	0.00E+00	0
29	0.0	0	0.00E+00	0
30	0.0	0	0.00E+00	0
31	0.0	0	0.00E+00	0
32	0.0	0	0.00E+00	0
33	0.0	0	0.00E+00	0
34	0.0	0	0.00E+00	0
35	0.0	0	0.00E+00	0
36	0.0	0	0.00E+00	0

FIG. X2.21 Cooper and Jacob Worksheet—Variable LNAPL/Water Interface

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			e	0.000001		
	Count	Time (min)	H/H$_o$	G (a,b,e)	SE	
	1	0.100	1.025882	0.997288	0.000818	
	1	1.000	1.023529	0.98334	0.001615	
	1	2.000	1.014118	0.970525	0.0019	
	1	3.000	1.002353	0.958749	0.001901	
	1	6.000	0.970588	0.926704	0.001926	
	1	7.000	0.96	0.916758	0.00187	
	1	8.000	0.947059	0.907092	0.001597	
	1	9.000	0.936471	0.897675	0.001505	
	1	10.000	0.923529	0.888481	0.001228	
	1	11.000	0.909412	0.879493	0.000895	
	1	12.000	0.897647	0.870694	0.000726	
	1	13.000	0.884706	0.862072	0.000512	
	1	14.000	0.872941	0.853616	0.000373	
	1	15.000	0.861176	0.845315	0.000252	
	1	20.000	0.816471	0.805898	0.000112	
	1	25.000	0.771765	0.769465	5.29E-06	
	1	30.000	0.72	0.735546	0.000242	
	1	35.000	0.678824	0.703812	0.000624	
	1	40.000	0.651765	0.674015	0.000495	
	1	45.000	0.618824	0.64596	0.000736	
	1	55.000	0.569412	0.59446	0.000627	
	1	60.000	0.545882	0.570766	0.000619	
	1	123.000	0.34	0.3549	0.000222	
	1	183.000	0.257647	0.237138	0.000421	

FIG. X2.22 Cooper, Bredehoeft and Papadopulos—Worksheet Variable LNAPL/Water Interface

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Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Dia. (ft) = 0.167 ; Borehole Dia. (ft) = 0.417

Example 3

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=6 ft2/day		10	6
2	T=4 ft2/day		20	4
3	T=3 ft2/day		40	3
4	T=2 ft2/day		50	2
5	T=1 ft2/day		50	1
6	T=0.5 ft2/day		50	0.5
7	T=0.1 ft2/day		50	0.1

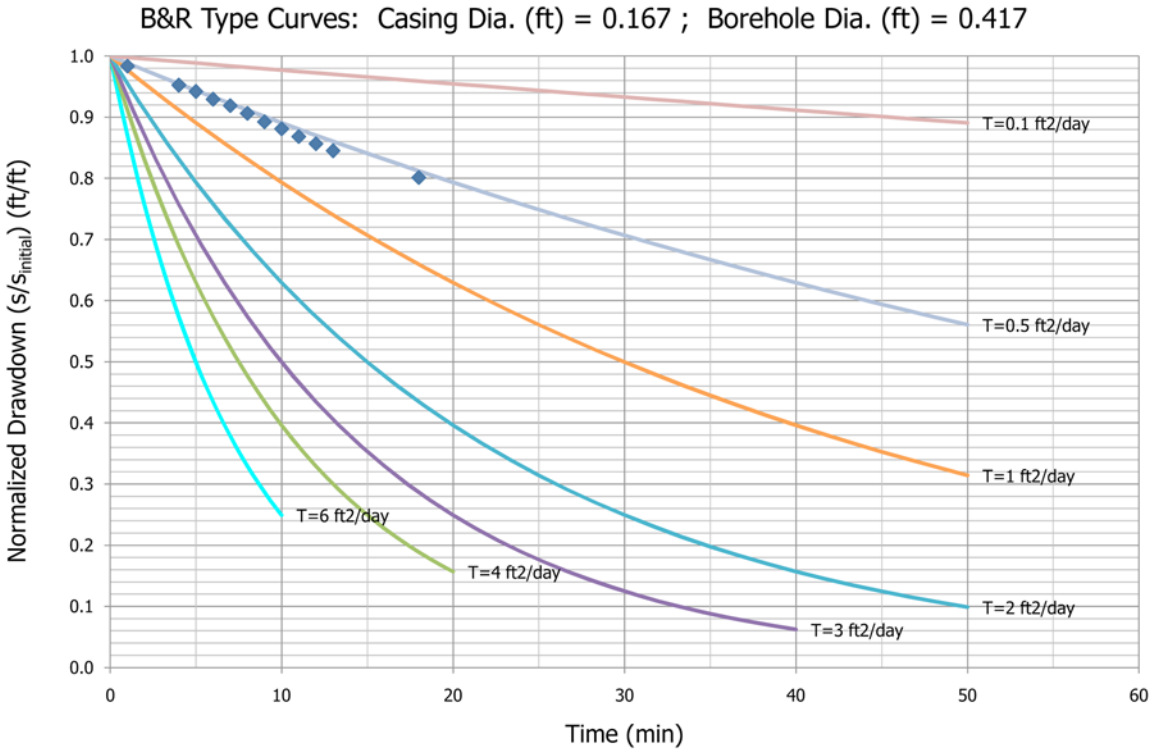


FIG. X2.23 Bouwer-Rice Type Curve Worksheet—Variable LNAPL/Water Interface

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Designation: E2856 – 13

Standard Guide for Estimation of LNAPL Transmissivity[1]

This standard is issued under the fixed designation E2856; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides field data collection and calculation methodologies for the estimation of light non-aqueous phase liquid (LNAPL) transmissivity in unconsolidated porous sediments. The methodologies presented herein may, or may not be, applicable to other hydrogeologic regimes (for example, karst, fracture flow). LNAPL transmissivity represents the volume of LNAPL (L^3) through a unit width (L) of aquifer per unit time (t) per unit drawdown (L) with units of (L^2/T). LNAPL transmissivity is a directly proportional metric for LNAPL recoverability whereas other metrics such as apparent LNAPL thickness gauged in wells do not exhibit a consistent relationship to recoverability. The recoverability for a given gauged LNAPL thickness in a well will vary between different soil types, LNAPL types or hydrogeologic conditions. LNAPL transmissivity accounts for those parameters and conditions. LNAPL transmissivity values can be used in the following five ways: *(1)* Estimate LNAPL recovery rate for multiple technologies; *(2)* Identify trends in recoverability via mapping; *(3)* Applied as a leading (startup) indicator for recovery; *(4)* Applied as a lagging (shutdown) indicator for LNAPL recovery; and *(5)* Applied as a robust calibration metric for multiphase models (Hawthorne and Kirkman, 2011 (**1**)[2] and ITRC ((**2**)). The methodologies for LNAPL transmissivity estimation provided in this document include short-term aquifer testing methods (LNAPL baildown/slug testing and manual LNAPL skimming testing), and long-term methods (that is, LNAPL recovery system performance analysis, and LNAPL tracer testing). The magnitude of transmissivity of any fluid in the subsurface is controlled by the same variables (that is, fluid pore space saturation, soil permeability, fluid density, fluid viscosity, the interval that LNAPL flows over in the formation and the gravitational acceleration constant). A direct mathematical relationship exists between the transmissivity of a fluid and the discharge of that fluid for a given induced drawdown. The methodologies are generally aimed at measuring the relationship of discharge versus drawdown for the occurrence of LNAPL in a well, which can be used to estimate the transmissivity of LNAPL in the formation. The focus, therefore, is to provide standard methodology on how to obtain accurate measurements of these two parameters (that is, discharge and drawdown) for multi-phase occurrences to estimate LNAPL transmissivity.

1.2 *Organization of this Guide:*

1.2.1 Section 2 presents documents referenced.

1.2.2 Section 3 presents terminology used.

1.2.3 Section 4 presents significance and use.

1.2.4 Section 5 presents general information on four methods for data collection related to LNAPL transmissivity calculation. This section compares and contrasts the methods in a way that will allow a user of this guide to assess which method most closely aligns with the site conditions and available data collection opportunities.

1.2.5 Sections 6 and 7 presents the test methods for each of the four data collection options. After reviewing Section 5 and selecting a test method, a user of this guide shall then proceed to the applicable portion of Sections 6 and 7 which describes the detailed test methodology for the selected method.

1.2.6 Section 8 presents data evaluation methods. After reviewing Section 5 and the pertinent test method section(s) of Sections 6 and 7, the user of this guide shall then proceed to the applicable portion(s) of Section 8 to understand the methodologies for evaluation of the data which will be collected. It is highly recommended that the test methods and data evaluation procedures be understood prior to initiating data collection.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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

1.5 *This document is applicable to wells exhibiting LNAPL consistently (that is, LNAPL transmissivity values above zero). This methodology does not substantiate zero LNAPL transmissivity; rather the lack of detection of LNAPL within the well*

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

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

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combined with proper well development and purging procedures are required to confirm zero LNAPL transmissivity.

1.6 *This document cannot replace education or experience and should be used in conjunction with professional competence in the hydrogeology field and expertise in the behavior of LNAPL in the subsurface.*

1.7 *This document cannot be assumed to be a substitute for or replace any laws or regulations whether federal, state, tribal or local.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D5088 Practice for Decontamination of Field Equipment Used at Waste Sites

D5521 Guide for Development of Groundwater Monitoring Wells in Granular Aquifers

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

3. Terminology

3.1 *Definitions:*

3.1.1 *air/LNAPL interface (Z_{an})*—The surface shared by air and LNAPL in a control well. (L)

3.1.2 *calculated water-table elevation (Z_{CGW})*—the theoretical location of the air/water surface based on a density correction if LNAPL were not present in a well. (L)

3.1.3 *confined LNAPL*—LNAPL trapped in an aquifer beneath a layer that exhibits a pore entry pressure greater than the capillary LNAPL head, thereby impeding the upward migration of LNAPL limits the upward movement of the LNAPL. The term confined LNAPL is used because the mobile LNAPL is under pressure greater than gauge pressure against the underside of the LNAPL confining layer.

3.1.4 *control well*—well by which the aquifer is stressed or tested.

3.1.5 *discharge*—the flow of a fluid into or out of a well. (L^3/t)

3.1.6 *drawdown*—a pressure differential in terms of fluid head. (L)

3.1.7 *effective well radius*—the radius that represents the area of the well casing and the interconnected porosity of the filter pack. (L)

3.1.8 *equilibrium fluid levels*—gauged fluid levels that represent the oil head and the water head or the calculated water-table elevation of the formation. Under equilibrium fluid levels no net oil or water flow occurs between the formation and the well.

3.1.9 *fluid level*—the level of a fluid interface (either air/oil, LNAPL/water, or potentiometric surface).

3.1.10 *formation thickness (b_{nf})*—the interval that LNAPL flows over in the formation. For unconfined conditions this is approximately equal to the gauged LNAPL thickness. Confined and perched conditions the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

3.1.11 *gauged LNAPL thickness (b_n)*—The difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)

3.1.12 *hydraulic conductivity (derived via field aquifer tests)*—the volume of water at the existing kinematic viscosity that will move in a unit time, under a unit hydraulic gradient, through a unit area, measured at right angles to the direction of flow. (L/t)

3.1.13 *LNAPL*—Light Non Aqueous Phase Liquid.

3.1.14 *LNAPL baildown test*—a procedure which includes the act of removing a measured LNAPL volume from a well and filter pack to induce a head differential and the follow-up gauging of fluid levels in the well.

3.1.15 *LNAPL borehole volume*—the volume of LNAPL existing within the casing and the drainable volume existing within the filter pack of a well. Based on effective radius and gauged thickness of LNAPL. (L^3)

3.1.16 *LNAPL slug test*—a procedure which includes the act of removing or displacing a known volume of LNAPL from a well to induce a head differential and the follow-up gauging of fluid levels in the well.

3.1.17 *LNAPL specific yield (S_{yn})*—the volume of LNAPL an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in LNAPL head for gravity drainage conditions. (unitless)

3.1.18 *LNAPL specific yield filter pack (S_{yf})* —the volume of LNAPL released or takes into storage per unit surface area of the filter pack per unit change in LNAPL head for gravity drainage conditions. (unitless)

3.1.19 *LNAPL storage coefficient (S_n)* —the volume of LNAPL an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in LNAPL head. For a confined aquifer, it is based on the volume of fluid released due to decompression. For an unconfined aquifer, the storage coefficient is approximately equal to the LNAPL specific yield. (unitless)

3.1.20 *LNAPL transmissivity (T_n)*—the volume of LNAPL at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer. (L^2/t)

3.1.21 *observation well*—a well screened across all or part of an aquifer.

3.1.22 *oil/water interface (Z_{nw})*—The surface shared by LNAPL and water in a control well. (L)

3.1.23 *perched LNAPL*—mobile LNAPL that accumulates in the vadose zone of a site for some time period above a layer that exhibits a pore entry pressure greater than the capillary LNAPL head, thereby impeding the downward migration of LNAPL.

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

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3.1.24 *potentiometric surface*—see *calculated water-table elevation*.

3.1.25 *radius of influence*—the distance from a well that the pumping induced head differential from non-pumping conditions is zero, head differentials due to background gradients may still exist at this radius. (L)

3.1.26 *slug*—a volume of water or solid object used to induce a sudden change of head in a well.

3.1.27 *test well*—a well by which the aquifer is stressed, for example, by pumping, injection, or change of head.

3.2 For definitions of other terms used in this test method refer to Terminology, Guide D653.

4. Significance and Use

4.1 *Application:*

4.1.1 LNAPL transmissivity is an accurate metric for understanding LNAPL recovery, is directly proportional to LNAPL recoverability and tracking remediation progress towards residual LNAPL saturation.

4.1.2 LNAPL transmissivity can be used to estimate the rate of recovery for a given drawdown from various technologies.

4.1.3 LNAPL transmissivity is not an intrinsic aquifer property but rather a summary metric based on the aquifer properties, LNAPL physical properties, and the magnitude of LNAPL saturation over a given interval of aquifer.

4.1.4 LNAPL transmissivity will vary over time with changing conditions such as, seasonal fluctuations in water table, changing hydrogeologic conditions and with variability in LNAPL impacts (that is, interval that LNAPL flows over in the formation and LNAPL pore space saturation) within the formation.

4.1.5 Any observed temporal or spatial variability in values derived from consistent data collection and analysis methods of LNAPL transmissivity is not erroneous, rather is indicative of the actual variability in subsurface conditions related to the parameters encompassed by LNAPL transmissivity (that is, fluid pore space saturation, soil permeability, fluid density, fluid viscosity, and the interval that LNAPL flows over in the formation).

4.1.6 LNAPL transmissivity is a more accurate metric for evaluating recoverability and mobile LNAPL than gauged LNAPL thickness. Gauged LNAPL thickness does not account for soil permeability, magnitude of LNAPL saturation above residual saturation, or physical fluid properties of LNAPL (that is, density, interfacial tension, and viscosity).

4.1.7 The accurate calculation of LNAPL transmissivity requires certain aspects of the LNAPL Conceptual Site Model (LCSM) to be completely understood and defined in order to calculate LNAPL drawdown correctly. The methodologies for development of the LCSM are provided in Guide E2531. The general conceptual site model aspects applicable to this guide include:

4.1.7.1 Equilibrium fluid levels (for example, air/LNAPL and LNAPL/water).

4.1.7.2 Soil profile over which LNAPL is mobile.

4.1.7.3 LNAPL hydrogeologic scenario (for example, unconfined, confined, perched, macro pores, and so forth).

4.1.7.4 LNAPL density.

4.1.7.5 Hydraulic conductivity for each soil type within the well screen interval.

4.1.7.6 Well screen interval in the vadose and saturated zones.

4.1.8 Incorporation of LNAPL transmissivity can further LCSMs by providing a single comparable metric that quantifies LNAPL recoverability at individual locations across a site.

4.1.9 Each of the methods provided in this document is applicable to LNAPL in confined, unconfined, and perched conditions. Any differences in evaluation are discussed in Section 5.

4.2 *Purpose*—The methods used to calculate LNAPL transmissivity have been published over the past 20 years; however little effort has been focused on providing quality assurance for individual tests or refinement of field procedures. In addition to summarizing the existing methods to calculate LNAPL transmissivity, this document will provide guidance on refined field procedures for data collection and minimum requirements for data sets before they are used to calculate LNAPL transmissivity.

4.2.1 *Considerations*—The following section provides a brief review of considerations associated with LNAPL transmissivity testing.

4.2.1.1 *Aquifer Conditions (confined, unconfined, perched)*—In general, each testing type is applicable to confined, unconfined, and perched conditions; however, consideration should be given to how LNAPL drawdown is calculated from well gauging data relative to formation conditions. Calculation of LNAPL transmissivity for confined and perched conditions is possible; however, the soil profile needs to be considered in combination with the fluid levels to accurately calculate drawdown. Drawdown values for perched and confined conditions can easily be overestimated without proper consideration. This results in LNAPL transmissivity being underestimated. The calculations of drawdown under perched and confined conditions are discussed within this document. Tidal influences or a vertical gradient on the water table also affect measurements and could distort the transmissivity results. Tidal influences are discussed in more detail in Appendix X1.

4.2.1.2 *Well Construction*—Any well being tested should be screened over the entire mobile interval of LNAPL. For locations where multiple discrete mobile intervals exist, it may be preferable to screen individual wells across each mobile interval. This will simplify the calculation of drawdown and derivation of LNAPL transmissivity. The interval of mobile LNAPL does not always correspond to the elevation of the air/LNAPL interface (for example, the mobile interval can be beneath the base of a confining layer under confined conditions). Appropriately screened wells can be substantiated based on vertical delineation of the entire LNAPL impacted interval (see Guide E2531).

4.2.1.3 *LNAPL Type*—No limitations have been identified for LNAPL type. However, the specific gravity of the LNAPL must contrast with that of the water to be measurable with an interface probe.

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4.2.1.4 *Well Development*—In order to derive the most accurate LNAPL transmissivity value, appropriate well development should be conducted to ensure connectivity between LNAPL in the formation and the well (Hampton 2003) (**3**). Industry experience has observed that LNAPL can require up to several months following well installation to saturate the filter pack and establish connectivity within the well. Well development can help to reduce this time frame and should be completed in accordance with Guide D5521.

4.2.2 *Analysis Method*—An understanding of the analysis method and theory is necessary prior to the field testing to ensure that all appropriate dimensions and measurements are properly recorded.

4.3 *Precision and Bias*—At this time this document aims to provide methodologies for data collection and analysis to yield an accuracy of LNAPL transmissivity values within a factor of two (compared with the unknown actual value). This modest accuracy is reasonable based on the overall industry experience in implementing these procedures and the lack of comparison studies. The objectives initiated through development of this document are to provide improved guidance for more consistent data collection and analysis methodology, which in turn will provide a larger and more accurate data set on which to base future methodology revisions and improvements.

5. Method Selection

5.1 The following section describes each of four test methods for the user to evaluate which methodology best fits their data objectives, site setting, and hydrogeologic conditions. An overview of this section is provided in Table A2.1 and Table A2.2. A review of the required parameters to be measured is provided in Tables A2.3-A2.9.

5.2 *Baildown/Slug Testing:*

5.2.1 *Overview*—The LNAPL baildown/slug test consists of either removing the entire LNAPL from the well casing and filter pack or the displacement of a partial volume to induce a head differential, respectively. Following the induction of the head differential, fluid levels are gauged during recovery.

5.2.2 *Data Analysis*—The LNAPL baildown/slug test field procedure is used in conjunction with LNAPL slug test analytical procedures to provide estimates of LNAPL transmissivity at any well exhibiting sufficient LNAPL thickness (that is, at least 0.5 ft/15.2 cm).

5.2.3 *Waste Disposal*—The baildown/slug test provides an advantage over other tests in that it does not typically require the disposal of large quantities of LNAPL or water that may be produced, nor does it require specialized equipment.

5.2.4 *Aquifer Extent Represented*—LNAPL baildown/slug tests reflect conditions near the well, and therefore represent a limited radius of influence. LNAPL transmissivity values from baildown/slug tests may not compare well with transmissivity values estimated using recovery system-based data (5.3) because of the differences in scale of evaluation between the two methods. However, increasing or decreasing trends in transmissivity will be seen in both recovery system-based data and baildown testing-based data.

5.2.5 *Capital Cost*—The capital cost for this method is low because it can be implemented on existing wells exhibiting LNAPL, does not require the construction of a recovery system nor does it require specialized equipment above and beyond other methods.

5.2.6 *Test Duration*—The test length timeframe is inversely related to the transmissivity of LNAPL and directly related to the effective well radius. LNAPL baildown/slug tests may require minutes to months to completely recover as LNAPL transmissivity may vary by several orders of magnitude across sites. However, in cases of slow recovery (that is, greater than a month) and where high confidence exists that the initial fluid levels represent equilibrium conditions, it is not necessary to allow the well to fully recover. A data set representing partial recovery combined with substantiated equilibrium fluid levels can be used to estimate an LNAPL transmissivity or at a minimum place an upper bound on recoverability.

5.2.7 *Special Considerations:*

5.2.7.1 Existence of a vertical gradient or tidal influences on the water table may limit the accuracy of the slug and/or baildown test, because the initial thickness in the well may be exaggerated (downward hydraulic gradient) or thin (upward hydraulic gradient), compared with static conditions. The relationships between LNAPL thickness, vertical gradient, and LNAPL recovery (recharge) rate may be complex and distort test data and the interpretation and are beyond the scope of this guide.

5.2.7.2 Periodic LNAPL removal events from wells have historically resulted in wells in a continual state of non-equilibrium and result in inaccurate equilibrium fluid levels. Equilibrium fluid level data is required for accurate drawdown calculations. LNAPL drawdown has historically been one of the primary variables inducing significant error to LNAPL baildown/slug tests.

5.2.7.3 The baildown test methodology provided minimizes filter pack recharge effects and is applicable where formation storativity effects are not significant in test results. Slug tests will exhibit larger borehole storage effects at a given well because the slug represents a relatively small percentage of the LNAPL volume in the well and filter pack. However, slug tests are more ideal for an instantaneous removal event, which is needed where steady state conditions are not well approximated due to formation storage effects. The advantage of baildown test methods with their larger removal volumes and stresses is the minimization of borehole storage induced errors. The advantage of slug test methods with their smaller, faster removal is the minimization of non-instantaneous effects. The quantified magnitude of these individual differences has not been widely studied.

5.2.7.4 The error associated with the recharge rate calculations is directly related to the error in gauged LNAPL thickness measurement. Smaller equilibrium thicknesses either result in fewer data points being collected or data points representing smaller changes in well recovery. Based on the accuracy of estimating the LNAPL/water and air/water interface with available interface probes, it is possible but generally not recommended to complete baildown tests at wells with a gauged LNAPL thickness of less than 0.5 ft (for 2-in. or 4-in. wells). Baildown/slug testing should not be attempted at wells with a measured thickness of LNAPL less than 0.2 ft.

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5.3 *Manual LNAPL Skimming Tests:*

5.3.1 *Overview*—The manual LNAPL skimming test is conducted by removing LNAPL at a rate that maintains drawdown in the well until a consistent LNAPL recovery rate is achieved.

5.3.2 *Data Analysis*—This manual LNAPL skimming test field procedure is used in conjunction with a skimming test analytical method, to derive estimates of LNAPL transmissivity.

5.3.3 *Waste Disposal*—The manual LNAPL skimming test typically generates more waste than baildown/slug or tracer tests and less than recovery system methods.

5.3.4 *Aquifer Extent Represented*—The manual LNAPL skimming test provides an advantage over other tests in that; the longer period of time the test is performed, the larger the area of the formation it represents and the accuracy of recovery volume estimates increase, which are used in the calculation of LNAPL transmissivity.

5.3.5 *Capital Cost*—The capital cost of this method is relatively low as it can be completed at existing wells with LNAPL and typically requires similar equipment to baildown tests. If LNAPL transmissivity is sufficiently high then the use of a pump could incur additional costs. This method requires less capital cost than recovery system-based or tracer tests.

5.3.6 *Test Duration*—The length of the manual skimming tests is inversely related to the LNAPL transmissivity and directly related to the well diameter and LNAPL storativity in the formation. The manual skimming test duration is similar or longer in time frame compared with baildown/slug tests and a shorter timeframe than tracer tests.

5.3.7 LNAPL skimming tests may be completed at any well exhibiting a gauged LNAPL thickness. This test is especially useful for wells exhibiting a gauged thickness less than 0.5 ft because it allows the measurement of LNAPL volume above-ground. In addition, the error associated with estimating the recharged LNAPL volume at this initial gauged thickness can be more accurately estimated above-ground than in-situ.

5.3.8 Recovery system based-data transmissivity values may not compare identically with “instantaneous” and “point” transmissivity method results (for example, manual skimming test results) because of the differences in scale of evaluation between the two methods. However, increasing or decreasing trends in transmissivity will be seen in both recovery system-based data and manual skimming testing-based data.

5.3.9 Manual LNAPL skimming tests may be conducted in all types of aquifer materials.

5.3.10 Manual LNAPL skimming tests do not provide data to graphically estimate equilibrium fluid levels. Therefore, a good understanding of fluid level behavior (for example, hydrograph) is required to ensure initial fluid levels represent equilibrium conditions for accurate calculation of LNAPL drawdown.

5.4 *Recovery Data-Based Methods:*

5.4.1 This guide provides general procedures for deriving LNAPL transmissivities using data obtained from continuous operation of LNAPL skimmer pumps and/or other types of product recovery systems where aquifer conditions approach steady-state conditions. These recovery systems are designed to extract LNAPL, groundwater and/or formation air/vapor from a recovery well.

5.4.2 Because LNAPL transmissivity is being continually reduced through product recovery, steady-state conditions can be approached but not reached. Steady-state conditions are approximated when the maximum radius of influence (ROI) is reached for the current drawdown induced via the given technology.

5.4.3 The derivation of LNAPL transmissivity using recovery system data is based on the theory of radial fluid flow. Subsurface barriers (for example, building foundations) or significant heterogeneities can result in an under-estimation of LNAPL transmissivity when calculation methods involve the use of the radius of influence parameter. The equation for radial fluid flow will provide an average LNAPL transmissivity for all directions. However, it will under estimate LNAPL transmissivity in directions away from a subsurface barrier. Changes in soil type or lithologic properties affecting the hydraulic or pneumatic permeability of the formation and occurring within the recovery system radius of influence can affect the accuracy of the LNAPL transmissivity results. This effect is not significant when the fluid production ratio equations are used and the changes in subsurface conditions affect all extracted fluids and phases similarly. Accounting for such variability via site characterization data and accurate site conceptual models is necessary to achieve the most accurate results.

5.4.4 If the recovery system is operating consistently and the LCSM is well developed and understood, this method can provide high accuracy and repeatability of transmissivity calculations. However, use of recovery system-based data for estimation of LNAPL transmissivity requires a well-defined LCSM and frequent monitoring of recovery system operational parameters. LNAPL transmissivity values estimated from recovery data are representative of a region within an area of mobile LNAPL that is proportional to drawdown induced, recovery well spacing, and operational time. In other words, the area represented by an LNAPL transmissivity value is proportional to the drawdown induced, length of time run and distance between recovery well locations. As a result, recovery data transmissivity values may differ significantly from those obtained using “instantaneous” and “point” transmissivity method results (for example, baildown/slug test results) because of the differences in scale of evaluation between the methods. However, increasing or decreasing trends in transmissivity will be seen in both recovery system-based data and baildown testing-based data.

5.4.5 LNAPL transmissivity measurement by long-term operation of a skimming device or other LNAPL recovery system assumes continuous operation over the temporal interval of interest. Complete knowledge and maintenance of the system operation representing optimal conditions (for example, pump depth corresponds to the interval of mobile LNAPL or ensuring sufficient storage tank capacity) is necessary to obtaining representative LNAPL transmissivity values.

5.4.6 The LNAPL transmissivity values derived by recovery system data are based on fluid flow through a porous media and not karst environments or fractured rock. Attempts to apply this

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document to estimate LNAPL transmissivities in fractured rock, karst environments or other non-porous media may result in inaccurate LNAPL transmissivity values.

5.4.7 Fluctuations of water table elevation during the LNAPL recovery data collection period that significantly change the relationship between the groundwater/LNAPL interface (or the air/LNAPL interface) relative to the location of the recovery pump(s) can result in inaccurate transmissivity determinations. In addition, both horizontal and vertical pneumatic formation permeability must be determined when estimating the air radius of influence for determining transmissivity using LNAPL systems that incorporate vacuum-enhanced recovery.

5.4.8 The relative depths of the recovery well screen intervals, the groundwater/LNAPL interface, the air/LNAPL interface, and the depth of pump(s) intake(s) must be known. In addition, the configuration of the well construction, interfaces, and pump(s) intake(s) must be appropriate for the specific recovery system used to derive LNAPL transmissivity.

5.4.9 This guide provides analytical equations to calculate LNAPL transmissivity (T_n) using recovery system-based data from four types of remediation technologies:

5.4.9.1 LNAPL only liquid removal (skimming).

5.4.9.2 Vacuum-enhanced LNAPL only liquid removal (vacuum-enhanced skimming).

5.4.9.3 Water-enhanced LNAPL removal (total fluids pumping, single or dual pump).

5.4.9.4 Water and vacuum-enhanced LNAPL removal (multi-phase fluid extraction [MPE]).

5.5 *Tracer Test-Based Methods:*

5.5.1 *Overview*—This tracer test field procedure shall be utilized in conjunction with a tracer test analytical procedure to derive LNAPL flux and estimates of LNAPL transmissivity at any properly screened well exhibiting LNAPL thickness greater than 0.2 ft.

5.5.2 Tracer tests can be conducted under conditions of a natural or imposed gradient. Imposed gradient test can be conducted about active recovery wells. Natural gradient tests do not require fluid extraction.

5.5.3 *Test Duration*—Natural gradient tests are conducted over several weeks or months and, therefore, provide temporally-averaged and vertically-averaged transmissivity values. Imposed gradient tests can be conducted in period of hours to days.

5.5.4 *Waste Disposal*—LNAPL or water disposal is not required since the testing method does not generate water or LNAPL.

5.5.5 *Data Analysis*—Data reduction methods assume steady-state conditions, which can occur under natural or ambient conditions, or during steady-state recovery.

5.5.6 The LNAPL flux measurement is representative of a few feet outside the borehole. The LNAPL gradient is representative of the LNAPL surface within the well network density.

5.5.7 Although the flux measurement does not require a uniform flow field, it is combined with the LNAPL gradient to calculate an LNAPL transmissivity value. The LNAPL gradient estimates assume a uniform flow field between wells. Therefore, this method is more applicable to a uniform LNAPL flow field. Uniform LNAPL flow fields occur in homogenous conditions and can be induced by active recovery.

5.5.8 LNAPL tracer tests may be conducted in unconfined, perched and confined aquifer materials where the fluid levels are in equilibrium with the formation.

5.5.9 Inputs for data analysis (analytical procedure) should be known prior to the field testing to ensure that all appropriate dimensions and measurements are properly recorded.

5.5.10 *Specialized Equipment Needed*—A hydrophobic fluorescent tracer and a UV/VIS spectrometer with a down hole fiber optic cable are needed to make measurements of tracer concentration through time.

5.5.11 *Screening Factors for Test Method Selection:*

5.5.11.1 Using hydrophobic tracers to determine LNAPL transmissivity is a relatively new method, and it is expected that this method will become more refined in the future. The following methods have been proven at a laboratory scale (Smith et al, 2011) (**4**) and at seven field sites (Mahler et al, 2011) (**5**).

5.5.11.2 *Measurement of LNAPL Gradient*—The local LNAPL gradient must be measured or estimated as an input to the equation for LNAPL transmissivity using tracer tests.

TEST METHODS

6. Short-Term Aquifer Testing-Based Methods

6.1 *Baildown/Slug Testing Field Methods*—This test method describes the field procedures involved in conducting an instantaneous LNAPL baildown/slug test. The LNAPL baildown/slug test method involves causing a sudden change in LNAPL head in a control well and measuring the fluid level response within that control well. Head change is induced by removing a known and measurable LNAPL volume from the control well.

6.1.1 *Apparatus*—This test method describes the types of equipment that can be used. Since there can be an infinite variety of testing conditions and because similar results can be achieved with different apparatus, engineering specifications for testing equipment are not discussed in this document. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this guide.

6.1.1.1 *LNAPL Displacement Equipment*—Because a variety of equipment can be used to induce a change in LNAPL head, this method will not provide engineering specifications of the exact means in which head is changed, but will rather identify how common types of equipment can affect the final results. Single slug displacement or removal methods such as solid slugs or bailers, respectively, will provide a more instantaneous change in LNAPL head. This is useful at well locations exhibiting higher LNAPL transmissivities. The use of solid slugs is acceptable since their volume can easily be measured. However use of equipment such as peristaltic pumps to remove the entire volume of LNAPL in the well casing and borehole will result in minimizing filter pack recharge effects. It is strongly recommended to use equipment that can remove LNAPL from the well and allow the use of graduated containers to measure the total volume within 10 %. Vacuum trucks at best have a detection limit of 5 gal and an accuracy of 1 gal

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above 5 gal (19 L). Down-hole non-intrinsically safe electrical pumps need to remain submerged below the air/LNAPL interface to prevent explosions; therefore down-hole electrical pumps used to evacuate LNAPL to zero thickness, for example, are not acceptable practices.

6.1.1.2 In some cases the LNAPL removal equipment available will not be able to remove LNAPL at a high enough rate to completely purge the control well. If this occurs during the test, a slug test or any of the other LNAPL transmissivity test methods discussed in this document can be applied.

6.1.1.3 *Fluid Level Measurement Equipment*—Typically, the air/LNAPL and LNAPL/water interfaces will be gauged using an interface probe. Currently the most precise available interface probes utilize optical and electrical resistivity technologies. Additionally, current technology allows for probes to be relatively small (⅝-in.) in diameter. The optical and electrical resistivity type interface probes increase the ability to measure fluid interfaces to typical accuracies from 0.01 to 0.02 ft (0.3 to 0.6 cm). The small probe diameter causes less displacement to fluids in the well. When the recovery of LNAPL occurs rapidly (that is, less than 1 h), tests can be conducted with an intrinsically safe pressure transducer, where the pressure transducer is set near the bottom of the well (in the water phase). Then the field staff only will be required to measure the depth to the air/LNAPL interface following removal of LNAPL. By only measuring the air/LNAPL interface less disturbance will be introduced to the well during recovery since the probe does not need to penetrate the fluid column to measure the LNAPL/water interface. Two pressure transducers can still be used, where one transducer is placed in the water phase and a second within the LNAPL phase; however, they are not necessary.

6.1.1.4 *Time Piece*—Used to record the elapsed time of the test.

6.1.1.5 *Graduated Container*—A container for water and LNAPL collection that is graduated to measure within 10 % of total estimated recovery volume (unit conversion: 1 gallon = 3.825 litres = 3,825 millilitres (mL) = 0.134 cubic feet). For example, a container that can measure 0.1 gal (~400 mL) intervals for an expected 1 gal (~4000 mL) of recovered product, or a container that can measure 1 gal (~4000 mL) intervals for an expected 10 gal (40 000 mL) of recovered LNAPL.

6.1.1.6 *Decontamination Equipment*—Typically, LNAPL in a well can foul measuring devices and should be cleaned with an appropriate cleaning agent. If multiple wells are tested, equipment should be cleaned of well fluids between testing separate wells.

6.1.1.7 *Test Forms*—Test forms should be used to record the parameters listed in 6.1.2 and 6.1.3 (that is, Conditioning & Procedure). Semi-log graph paper should be used to plot data during the test in order to understand when equilibrium is reached and the test is completed. Fig. 1 provides an example of LNAPL thickness reaching equilibrium during a test.

6.1.2 *Conditioning:*

6.1.2.1 *Pre-Test Well Information*—The following well construction information needs to be obtained prior to initiating the baildown tests:

(1) Borehole diameter of well to be tested (feet).

(2) Casing and screen diameter (inches).

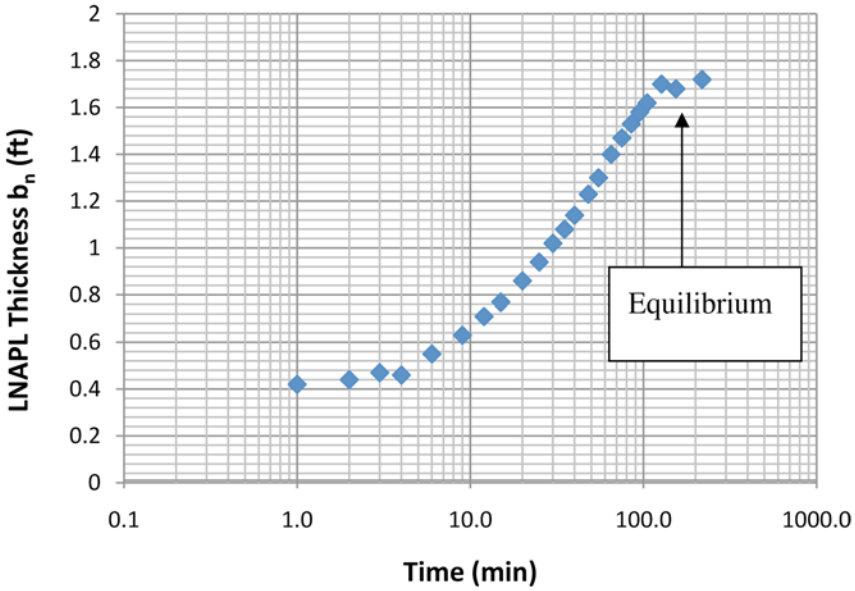
(3) Top of screen relative to top of casing (feet).

(4) Bottom of screen interval relative to top of casing (feet).

(5) Total well depth (feet).

(6) Verify interval that the well is screened over the formation thickness.

6.1.2.2 Baildown/slug tests are used to evaluate the transmissivity of LNAPL in the aquifer. It is recommended that the



Graph illustrating how the frequency of gauging data should be based on consistent changes in LNAPL thickness rather than time, and demonstrating the attainment of recharge equilibrium conditions.

FIG. 1 Gauging Data Graph

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LNAPL existing within the well and borehole need to be occasionally evacuated prior to the baildown test in order for the LNAPL to stay in communication with the formation. The maximum lag time between removal events is two years.

6.1.2.3 Prior to the test, the well being tested should be fully recharged; this will ensure the starting LNAPL thickness, LNAPL head, and potentiometric surface head are all representative of equilibrium formation conditions.

6.1.3 *Pre-Test Procedure:*

6.1.3.1 *Measuring Pre-Test Fluid Levels*—Measure the fluid levels in the well before the test for a period longer than the time it will take the well to recover in order to ensure equilibrium fluid levels are known and to calculate the effective well volume. This should be established during the initial evacuation of LNAPL from the well prior to the test (see 6.1.2.2).

6.1.3.2 Errors associated with erroneously assumed equilibrium fluid levels will reduce test accuracy and may invalidate the test.

6.1.3.3 Plan on gauging the well until complete equilibration occurs (Fig. 1) for wells where recovery behavior is not well understood or the pretest gauging data is realized not to represent equilibrium conditions.

6.1.3.4 The scope of work should plan for gauging to potentially be conducted over days or even weeks.

6.1.3.5 For unconfined conditions, the filter pack typically holds the majority of the stored LNAPL volume within the effective well radius. Partial displacement or removal of the LNAPL will result in the test being dominated by filter pack recharge.

6.1.3.6 Filter pack effects can be reduced through larger displacement volumes for slug tests or the complete removal of LNAPL in the filter pack and casing during baildown tests. The following equations can be used to approximate the volume of LNAPL within the well casing and borehole.

$$V_b = S_{yf} b_b \pi (r_b^2 - r_c^2) \quad (1)$$

$$V_c = b_n \pi r_c^2 \quad (2)$$

$$V_t = V_c + V_b \quad (3)$$

where:

V_t = total effective borehole LNAPL volume (L^3),
V_b = volume of LNAPL in the borehole (L^3),
V_c = volume of LNAPL in the casing (L^3),
b_b = LNAPL thickness existing within borehole (L),
b_n = gauged LNAPL thickness (L),
r_c = well casing radius (L),
r_b = well borehole radius (L), and
S_{yf} = specific yield or storage coefficient of well filter pack.

6.1.3.7 To account for borehole porosity and LNAPL saturation, a storage coefficient needs to be estimated. Empirical data suggest that 0.175 to 0.190 is a good value for this parameter at any site. If viscosity of the LNAPL is known, an alternate method of estimating storage coefficient that has been tested between viscosities of 0.7 and 2 centipoises can be derived by using Eq 4 (Lundy, 2005) (**6**). Using Eq 2 combined with viscosities of 0.5 cp and 5 cp results in a range in storativity of 0.23 to 0.13 where the geometric mean is 0.175. The empirical data and Eq 4 suggest an average value of 0.175 and the range should not vary by more than a factor of 50 %.

$$S_{yf} = -0.0418 ln(\mu_n) + 0.2007 \quad (4)$$

where:

S_{yf} = filter pack LNAPL specific yield, and
μ_n = dynamic viscosity of LNAPL (M/Lt).

6.1.3.8 Well construction data will need to be reviewed to evaluate if the filter pack exists over the entire gauged interval of LNAPL. If the well screen and filter pack do not exist across the entire gauged thickness, then the filter pack thickness, used in Eq 1 will have to be reduced from the gauged thickness value.

6.1.4 *Test Procedure:*

6.1.4.1 Where the LNAPL transmissivity or recharge behavior is not well known, plan to start the baildown portion of the test early in the work day and on a day when you will be able to return frequently to the well. This will ensure that sufficient measurement frequency can be obtained within the first 8 h of the test.

6.1.4.2 Remove the known LNAPL volume up to a maximum as calculated using Eq 3. Smaller removal volumes will exhibit larger filter pack recharge effects and be more instantaneous. Larger removal volumes will minimize filter pack recharge effects although may not be instantaneous relative to the test duration.

6.1.4.3 Baildown/slug test LNAPL head change rate must be induced in a time that is $1/100^{th}$ or less of the total test duration, in order to approximate instantaneous head change. If full removal of LNAPL from filter pack and well casing requires longer time and an analysis method that relies on instantaneous withdrawal is being used (for example, Cooper-Jacob), then a slug method or alternative method should be used.

6.1.4.4 Instantaneous removal or slug introduction is relative to total length of test. For example 15 min of purging can be considered instantaneous if the length of the test is 1 day or more. Non-instantaneous removals can potentially be corrected in conjunction with steady state based slug test solutions (that is, Bouwer-Rice), which is discussed in Section 8. However, efforts should be made to complete the slug/fluid removal in as short of a timeframe as is practical so that removal approximates an 'instantaneous' head change.

6.1.4.5 Record the start and finish time of LNAPL removal. Record the total volume of LNAPL and water removed or slug length and volume. If large volumes (over 5 gal/ 19 L) of LNAPL are removed or removal occurs for a relatively long period of time (over 30 min), record several interim measurements of volume removed and time.

6.1.4.6 Baildown tests conducted in wells containing low viscosity LNAPL (that is, <1 centipoise) generally require 30 min or less for purging, while higher viscosity LNAPL (that is, >2 centipoises) can require a few hours. This is acceptable if the baildown test takes days to complete, the time for removal in this case would approximate instantaneous head change relative to the test duration.

6.1.4.7 Following LNAPL removal, begin recording the time and measuring the depth to the air/LNAPL and LNAPL/

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water interfaces. Depth to the air/LNAPL interface should be decreasing (or remaining the same). The gauged LNAPL thickness should be increasing. Re-measure and report any readings that do not match these trends. Record notes regarding the methodology taken to confirm or revise anomalous data.

6.1.4.8 The depth to the air/LNAPL interface could decrease if the overall groundwater elevation at the site is dropping. To verify whether the water-table elevation is dropping, a nearby control well can be measured prior to and during testing.

6.1.4.9 The best practice for gauging fluid levels during the baildown test is to collect a measurement at a maximum frequency of every 0.05 to 0.1 ft (1.5 cm) change in LNAPL thickness from static. A minimum change in thickness that is reasonable for use in data analysis is 0.05 to 0.1 ft (1.5 cm) of change in thickness.

6.1.4.10 The best practice also consists of gauging fluid levels at a minimum frequency corresponding to a change in thickness that represents 5 % of the equilibrium gauged LNAPL thickness or 0.05 ft (that is, 1.5 cm), whichever is less. This methodology is conducted for the first 100 min of recovery. The remainder of the test can be completed by gauging measurements on a frequency corresponding to a change of 5 to 10 % of the equilibrium thickness. This methodology will result in data being collected on a logarithmic timescale which is appropriate for data analysis. Because the recovery rate will drop as the well recovers, measurements can be collected on a logarithmic time scale (that is, at some point, the well may only have to be gauged weekly or monthly).

6.1.4.11 The minimum practical time for measuring fluid levels with a single interface probe is at 1-minute intervals since two interfaces need to be gauged.

6.1.4.12 After the first 100 min of a test, the data should be reviewed and a schedule should be prepared by the field staff based on the collected data set.

6.1.4.13 Plotting the recovered LNAPL thickness versus the log of time will help to forecast future events and help to provide data to support the conclusion of the test (see Fig. 1).

6.1.4.14 The time point representing the next change in thickness of 5 to 10 % of the static thickness or 0.05 ft (1.5 cm), whichever is less, can then be forecast based on the graph. For example, if over the initial 100 min the well has recovered less than 5 % of its initial thickness, the next measurement would be at least an additional 100 min from the current time.

6.1.4.15 In order to ensure that equilibrium fluid levels are understood and can be used to calculate LNAPL drawdown, gauging data representing consistent equilibrium fluid levels must exist for a period that is equal to the length of a completed test. This data can represent fluid levels prior to start of test or following test.

6.1.4.16 If the initial gauging data is insufficient to ensure equilibrium fluid levels (for example, one data point immediately before the test) then plan on obtaining test measurements until the LNAPL thickness has stabilized to its static thickness. This will provide the most complete insight into the LNAPL distribution in the formation and confirm the initial equilibrium fluid levels. A typical indication of LNAPL thickness stabilizing is when the LNAPL thickness reaches a plateau for approximately one quarter to one half of a log cycle. This should be documented with 3 measurements over that period (see Fig. 1).

6.1.4.17 The actual time and date of each measurement should be recorded, particularly when it may deviate from the initial schedule. If the change in LNAPL thickness between each event is less than the percentages listed above, then the frequency of measurements may be decreased. However, if the change in LNAPL thickness is greater than the percentages listed above, then measurement frequency should be increased.

NOTE 1—During the test, accurate measurements of the depths to LNAPL and water are critical. Every effort should be made to ensure that these readings are consistent and reliable. It is important to evaluate the data as it is collected and confirm any apparent erratic gauging data. Confirmation readings should be supported with comments on the field form. LNAPL thickness should ideally be increasing (or remaining the same) from one measurement to the next, not decreasing.

6.1.4.18 In some cases, fluid levels may change more rapidly than can be measured manually. Under these circumstances a LNAPL baildown test can be conducted using a pressure transducer. Conduct a baildown test with a pressure transducer with the following modifications from the procedure described above:

(1) Synchronize the transducer clock with the time piece used to collect gauging measurements. Next, set the measurement schedule to collect a minimum of 50 readings over the estimated test duration. Ensure that the pressure transducer has the appropriate battery life and is calibrated.

(2) Lower the pressure transducer to the bottom of the well and gauge the well until the fluid levels have stabilized again.

(3) Following stabilization, record and compare the gauged measurements to the reading on the pressure transducer to ensure it is working properly.

(4) Start and run the test as described above in 6.1.4 except that the LNAPL/water interface does not need to be gauged during the test. The air/LNAPL and LNAPL/water interfaces should be gauged prior to initiating the test and following completion of the test for use in calibration of the pressure transducer depth.

(5) Gauge the air/LNAPL interface as frequently as possible throughout the test.

(6) Review manufacturer specifications to understand the accuracy and precision of transducer data collected and ensure the data to be potentially used is not limited by equipment specifications.

(7) Post-Test Procedure—Conduct preliminary analysis of data before leaving the field and evaluate the test regarding the criteria given in this test method. The test data should be analogous to the trend shown in Fig. 1. The drawdown and time magnitudes are expected to vary but the overall trend on a semi-log plot should be similar.

6.1.5 *Report:*

6.1.5.1 Include the information listed below in the report of the field procedure:

(1) Well identification.

(2) Well construction (well depth, filter pack and screen interval, inner casing, screen, and borehole diameter).

(3) Date and time of initial fluid gauging data.

(4) Initial fluid levels.

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(5) Field staff.

(6) Known LNAPL characteristics (for example, LNAPL density and product type).

(7) Well Identification (ID), casing diameter and other known well information.

(8) Method of LNAPL withdrawal removal notes.

(9) Calculated well volume.

(10) Establish and record the measurement point from which all measurements of fluid levels were made.

(11) All gauging data collected prior to and during the test.

(12) Start and stop date and time of LNAPL purge event or slug withdrawal.

(13) Volume of LNAPL and water removed during purge or slug withdrawal event.

(14) If the fluid levels are measured with a pressure transducer, report the model type of the pressure transducer used, recorded pressure versus time data, and the data used to convert pressure data to fluid depth (that is, calibration fluid level data and the fluid density).

6.1.6 *Precision and Bias:*

6.1.6.1 *Precision*—It is not practical to specify the precision of this specific test method because the response of aquifer systems during testing is dependent upon ambient system stresses.

6.1.6.2 *Bias*—No statement can be made about bias because no true reference values exist.

6.2 *Manual Skimming Field Methods*—This test method describes the field procedures involved in conducting a LNAPL manual skimming test. This test consists of the removal of LNAPL from the well casing and borehole on a repeated basis, without allowing more than approximately 25 % of recharge to occur in between product removal events. The rate of removal is therefore dependent on well recharge behavior. The key criterion is that greater than 75 % of the maximum skimming drawdown must be consistently induced. Purging is completed until the recovery rate stabilizes. The LNAPL discharge or recovery rate for each LNAPL removal step is calculated. The recovery volume and gauging data, along with the volume of LNAPL removed, can be used to estimate the LNAPL transmissivity and recoverability. LNAPL transmissivity is calculated from the stabilized LNAPL discharge data. This test ranges from a few hours for wells exhibiting higher LNAPL transmissivities to in excess of weeks for wells exhibiting lower LNAPL transmissivities. The manual skimming test can be performed on most wells that contain LNAPL.

6.2.1 *Apparatus*—This section describes the types of equipment that can be used. Since there are an infinite variety of testing conditions and because similar results can be achieved with different apparatus, engineering specifications for apparatus are not discussed in this guide. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this guide.

6.2.1.1 *LNAPL Removal Equipment*—Because a variety of equipment can be used to induce a change in LNAPL head, this method will not provide engineering specifications of the exact means in which head is changed, but rather identify how common types of equipment can affect the final results.

6.2.1.2 *Fluid Level Measurement Equipment*—Typically, the air/LNAPL and LNAPL/water interfaces will be gauged using an interface probe. Currently the most precise available interface probes utilize optical and electrical resistivity technologies. Additionally, current technology allows for probes to be relatively small (⅝-in.) in diameter. The optical and electrical resistivity type interface probes increase the ability to measure fluid interfaces to typical accuracies from 0.01 to 0.02 ft (0.3 to 0.6 cm) and the small probe diameter causes little displacement to fluids in the well.

6.2.1.3 *Time Piece*—Used to record the elapsed time of the test.

6.2.1.4 *Graduated Container*—A container for water and LNAPL collection that is graduated to measure within 10 % of total estimated recovery volume between fluids removal events. For example, a container that can measure 0.1 gal intervals for an expected 1 gal of recovered product, or a container that can measure 1 gal intervals for an expected 10 gal of recovered LNAPL.

(1) Decontamination Equipment—Typically, LNAPL in a well can foul measuring devices and should be cleaned with an appropriate cleaning agent. If multiple wells are tested, equipment should be cleaned of well fluids between testing separate wells.

(2) Test Forms—Test forms should be used to record the parameters listed in 6.3.2 and 6.3.4 (that is, Conditioning and Procedure).

6.2.2 *Conditioning:*

6.2.2.1 *Pre-Test Well Information*—The following well construction information needs to be obtained prior to initiating the manual skimming tests:

(1) Borehole diameter of well to be tested.

(2) Casing and screen diameter.

(3) Top of screen relative to top of casing.

(4) Bottom of screen interval relative to top of casing.

(5) Total well depth.

(6) Verify interval that the well is screened over the formation thickness.

6.2.2.2 Manual skimming tests are used to evaluate the transmissivity of LNAPL in the formation. It is recommended that the LNAPL existing within the well and borehole be occasionally evacuated prior to the manual skimming test in order for the LNAPL to stay in communication with the formation. Prior to the test, the well being tested must be fully recharged. This will ensure the starting fluid levels surface head are all representative of equilibrium formation conditions.

6.2.2.3 *Measuring Pre-Test Fluid Levels*—Measure the fluid levels in the well before beginning the test to determine the pre-test fluid levels.

6.2.2.4 The pre-test fluid levels need to represent equilibrium conditions in order for the accurate calculation of LNAPL drawdown.

6.2.2.5 No other pre test procedures are required.

6.2.3 *Test Procedure:*

6.2.3.1 Because of the LNAPL extraction and measurement frequency needed over the first 8 h, plan to start the manual skimming portion of the test early in the work day and on a day when you will be able to return frequently to the well.

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6.2.3.2 The test consists of the following four steps:

(1) Initial gauging of fluid levels.

(2) Purging the well and borehole of the LNAPL.

(3) Periodically returning to the well to:

(a) Gauge fluid levels.

(b) Purge any recovered LNAPL.

(c) Gauge fluid levels following purging.

(4) Data analysis.

6.2.3.3 To start the test, remove LNAPL until further LNAPL removal is not possible while minimizing the groundwater recovered. Record the start and finish time of LNAPL removal. Record the total volume of LNAPL and water removed. If large volumes (over 5 gal/19 L) of LNAPL are removed or removal occurs over a long period of time (over 30 min), record several interim measurements of volume removed and time. Try not to disturb the static potentiometric surface level during LNAPL removal. Methods of LNAPL removal may include bailers, peristaltic pumps, vacuum truck removal and other skimmer pumps as long as the volumes can accurately be measured.

6.2.3.4 Remove LNAPL until the product is no longer being removed.

6.2.3.5 Begin recording the date/time and measured depths to the air/LNAPL interface and LNAPL/water interface immediately after removing the LNAPL. Once the well has recovered ¼ of the initial thickness, re-purge the LNAPL in the well. Record the start and stop time of purging and the gauging data before and after each purging event. The time elapsed between the completion of the initial purge and the start time of the following purging event will provide an estimated return time for the next event.

6.2.3.6 A best practice of the test is to gauge and purge the well before the well recovers ¼ of the original thickness. The following frequencies are provided as an initial recommendation and should be adjusted based on field observations:

(1) First hour: every 10 min (6 measurements).

(2) 2 h to 4 h: every 30 min (4 measurements).

(3) 4 h till end of first day (1 measurement).

(4) Second day: 2 to 3 times.

(5) Subsequent days: At least twice per day until the LNAPL discharge rate has stabilized.

6.2.3.7 The actual time and date of each measurement should be recorded, especially when it may deviate from the initial schedule. The calculated recharge will typically start out high and decrease until it reaches a constant value. The test should continue until the calculated recharge into the well stabilizes. At some locations this may take a week. Following the first 4 h and the first day of testing, the data should be reviewed to improve the timeline with which gauging and purging events will be conducted. If previous knowledge of the recovery behavior for a given well is available, the provided timescale can be modified based on those data.

6.2.3.8 If the well is recovering less than ¼ of its initial thickness between each measurement, the frequency of measurements may likely be decreased. However, if the LNAPL thickness recovers to more than ¼ of the initial thickness, frequency of gauging and purging should be increased.

6.2.3.9 The maximum practical measurement and purge frequency is 5 min for a single field staff due to the constraints of gauging, fluid removal activities, recovered fluid volume removal measurement and documentation. It is not necessary to increase the frequency beyond this. If the well recovers too fast for these conditions to be met then an alternate testing methodology should be employed, such as a pilot test with an automated skimming pump in conjunction with the recovery system-based field and analysis method.

6.2.3.10 The test is complete when three or four consecutive discharge rates are within 25 % of each other and no consistently decreasing trend is observed.

6.2.3.11 During the test, accurate measurements of the recovered volume and depths to air/LNAPL and LNAPL/water interfaces are critical. Every effort should be made to ensure that these readings are consistent and reliable. Re-measure and document any readings that seem anomalous and then make notes regarding the methodology taken to confirm or revise anomalous data.

6.2.3.12 Ensure that the bucket/container used for measuring recovered volume spans the volumes being recovered each period. Typically the removal volumes for each purging event will be less than ½ gal. A 5-gal bucket is not precise enough for measuring the recovered volume following the initial removal. See section 6.3.1 (Apparatus).

6.2.3.13 *Post-Test Procedure*—Make a preliminary analysis of the data before leaving the field and evaluate the test regarding the criteria given in this test method to determine if the test should be rerun.

6.2.4 *Report*—Include the information listed below in the report of the field procedure:

6.2.4.1 Well identification.

6.2.4.2 Well construction (well depth, filter pack and screen interval, inner casing, screen, and borehole diameter).

6.2.4.3 Date and time of initial fluid gauging data.

6.2.4.4 Initial fluid levels.

6.2.4.5 Field staff.

6.2.4.6 Known LNAPL characteristics (for example, LNAPL density and product type).

6.2.4.7 Casing diameter and other known well information.

6.2.4.8 Method of LNAPL withdrawal removal notes.

6.2.4.9 Calculated well volume.

6.2.4.10 Establish and record the measurement point from which all measurements of fluid levels were made.

6.2.4.11 All gauging data collected prior to the test.

6.2.4.12 Date and time of test start.

6.2.4.13 Depth to fluid levels before and after each purge event.

6.2.4.14 Start and stop date and time of each gauging and purge event.

6.2.4.15 Volume of LNAPL and water removed during each purge event.

6.2.5 *Precision and Bias:*

6.2.5.1 *Precision*—It is not practical to specify the precision of this test method because the response of aquifer systems during LNAPL manual skimming tests is dependent upon ambient system stresses.

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6.2.5.2 *Bias*—No statement can be made about bias because no true reference values exist.

6.3 *Long-term Recovery System Method*—This test method describes the field procedures involved with collecting product recovery system data for the purposes of estimating LNAPL transmissivity under steady state conditions. LNAPL transmissivity calculations for recovery systems are based on the achieved LNAPL recovery rate versus drawdown induced. Therefore, this section is focused on methods used to estimate LNAPL recovery rate for all systems and specific methods used to estimate drawdown induced by the specific technologies.

6.3.1 *Apparatus*—The equipment consists of storage containers which allow for measurement of fluid volumes recovered over time, flow meters for individual and/or total fluids and instantaneous flow measurements. In addition, equipment used to measure pneumatic and/or hydraulic head at individual well locations and/or for the system as a whole. Because there are an infinite number of recovery system designs, this guide does not specify the equipment to be used, but rather the equipment used must meet the data objectives set forth in the guide.

6.3.2 *Conditioning*—All recovery wells where LNAPL transmissivity is estimated should be properly developed in order to ensure non-linear head losses are minimized. Maintenance schedules should consist of development following well installation, as well as, periodic rehabilitation to prevent deterioration of the well performance to scaling and biofouling. One time well development is not sufficient for most active recovery systems that run longer than five years.

6.3.3 Verify interval that the well is screened over the formation thickness.

6.3.4 *Procedure*—Because the procedure for measurement is dependent on system design and equipment, it is not feasible to specify the measurement procedure for each parameter in this method. Field forms for individual technologies are provided in Annex A1 and identify the minimum field parameters, as well as, where additional measurements would provide multiple lines of evidence for LNAPL transmissivity calculations.

6.3.5 *Report*—Field forms included in Annex A1 identify the reporting requirements for individual technologies. The report consists of measured input values and justification for each parameter measured on the field forms and variables provided in Tables A2.5-A2.8.

6.3.6 *Precision and Bias:*

6.3.6.1 *Precision*—It is not practical to specify the precision of this test method because the response of aquifer systems during LNAPL recovery is dependent upon ambient system stresses.

6.3.6.2 *Bias*—No statement can be made about bias because no true reference values exist.

7. Tracer Test Field Methods

7.1 This test method describes field procedures for conducting LNAPL tracer tests.

7.2 *Apparatus*—This section describes the types of equipment that can be used. Because of the infinite variety of testing conditions, engineering specifications for apparatus are not provided. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this guide.

7.2.1 *Spectrometer/Fiber Optic Cable and Computer*—To date, a temperature regulated, visible light spectrometer has been used to measure the tracer presence and relative concentration in the LNAPL. The spectrometer consists of a light source to induce fluorescence in the tracer. The output from the spectrometer is converted to a digital signal and transmitted to a laptop computer, Program Logic Controller (PLC), or similar device to store and display the measured values.

7.2.2 The fiber optic cable used to date consists of multiple fibers. A portion of the fibers within the cable are used to transmit the excitation light source to the tracer in the LNAPL in the well, and others return the resulting fluorescence response back to the spectrometer.

7.2.3 The spectrum of excitation and measured fluorescence response is key as fiber optic cables tend will attenuate signals too rapidly to be of use if they are not appropriate for the excitation and fluorescence spectrums of intent. Typically, attenuation occurs more rapidly for shorter wavelengths (for example, less than 290 nm).

7.2.4 To date, a laptop computer equipped with software to communicate with the spectrometer has been used to control the spectrometer and display a graph of the spectrum (intensity versus wavelength) and record output.

7.2.5 *Tracer:*

7.2.5.1 The tracer used to date is BSL 715.[4] This tracer is a concentrated liquid hydrocarbon which has unique fluorescence peaks at 545 and 580 nm when excited at 470 nm. It fluoresces yellow under ultraviolet light and is used in the automotive industry to detect oil leaks. This tracer is specifically listed (Sale et. al., 2008) **(7)** because it has undergone testing to ensure that it will not decrease in concentration over time in the well based on non-flow related mechanisms such as dissolution, volatilization, or sorption. Any new tracer used to estimate LNAPL transmissivity will need to be tested to ensure that it acts as a conservative tracer.

7.2.5.2 The tracer has the following characteristics:

(1) It is detectable in LNAPL at low concentrations (less than 1 ppm in Soltrol 220, Woodlands, Texas).

(2) It is insoluble in water.

(3) It has no significant effect (at application concentrations) on the physical properties of LNAPL.

(4) It fluoresces at a wavelength where most LNAPLs have low background fluorescence.

(5) It has low toxicity relative to constituents present in most LNAPLs.

7.2.6 *In-Well Calibration Standards*—In-well calibration standards are used to correct for potential non-tracer related florescence from the LNAPL induced by the 470 nm light source. Small diameter pipes are inserted within the test well to occlude a volume of LNAPL without tracer and a volume of

[4] The sole source of supply of the apparatus known to the committee at this time is Bright Solutions Inc., Troy, Michigan. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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LNAPL with the initial tracer concentration. A small-diameter pipe is inserted into the test well, through the LNAPL before tracer is added, for Eq 5 this well is called C_0. Tracer is then added and mixed with the LNAPL. A second pipe is then inserted into the test well through the LNAPL. This well is called C_{100} in Eq 5. The two pipes, one without tracer and one with the initial tracer concentration allow for in-well spectrometer calibrations to be made with each tracer concentration measurement. Measurements of remaining tracer in the test wells at the end of each measurement period are corrected using the calibrations assuming a linear relationship between fluorescence and intensity can be calculated as:

$$\frac{C_{T_{t+\Delta t}}}{C_{T_t}} = \frac{\dfrac{I_{test_well_{t+\Delta t}} - I_{Cal_well.C_{0_{t+\Delta t}}}}{I_{Cal_well.C_{100_{t+\Delta t}}} - I_{Cal_well.C_{0_{t+\Delta t}}}}}{\dfrac{I_{test_well_t} - I_{Cal_well.C_{0_t}}}{I_{Cal_well.C_{100_t}} - I_{Cal_well.C_{0_t}}}} \quad (5)$$

where:

$C_{T_{t+\Delta t}}$ = concentration of tracer mass remaining at time of measurement (M/L^3),
C_{T_t} = concentration of initial tracer mass (M/L^3),
$I_{test_well_{t+\Delta t}}$ = fluorescence intensity in test well at time of measurement (unitless),
$I_{Cal_well.C_{0t+\Delta t}}$ = fluorescence intensity in C_0 calibration well at time of measurement (unitless),
$I_{Cal_well.C_{100t+\Delta t}}$ = fluorescence intensity in C_{100} well at time of measurement (unitless),
$I_{test_well_t}$ = initial fluorescence intensity in test well (unitless),
$I_{Cal_well.C_{0t}}$ = initial fluorescence intensity in C_0 well (unitless), and
$I_{Cal_well.C_{100t}}$ = initial fluorescence intensity in C_{100} well (unitless).

7.2.7 *Interface Probe*—An interface probe should be used to record LNAPL thickness in the test well each time tracer concentration is measured. Additionally, the interface probe is used to measure the LNAPL and hydraulic gradients occurring throughout the test duration.

7.2.8 *Pressure Transducer*—The use of a pressure transducer should be considered for sites where the fluid levels are expected to vary the LNAPL gradient over the length of the test and where site gauging events are expected to be infrequent.

7.2.9 *Decontamination Equipment*—LNAPL must be cleaned from the fiber optic cable between calibration standard measurements and test well measurements to ensure that there is no transfer of tracer dye between standards or test well. A cleaning agent such as detergent or isopropyl alcohol should be used to clean the fiber optic cable between readings. Further information on decontamination can be found in Practice D5088. Additionally, LNAPL can foul other fluid-level measurement devices. These devices should be cleaned with an appropriate cleaning agent. If multiple wells are tested, equipment should be cleaned of fluids between testing of separate wells.

7.3 *Conditioning:*

7.3.1 Collect representative LNAPL samples from monitoring wells to be used for testing prior to initiating the LNAPL tracer tests. Measure and record fluorescence of the LNAPL sample using the spectrometer. Add tracer to the LNAPL sample, thoroughly mix the sample, and measure and record fluorescence of the sample. Repeat the preceding step adding increasing amounts of tracer to evaluate the dose-response relationship between tracer concentration and fluorescence intensity. Initial tracer concentrations should be determined for each LNAPL type based on the following guidelines.

7.3.2 Review well construction logs to ensure the current LNAPL thickness is within the well screened interval.

7.3.3 Collect representative LNAPL samples from monitoring wells to be used for testing prior to initiating the LNAPL tracer tests. Measure background fluorescence and conduct titration tests to evaluate the dose-response relationship between tracer concentration and fluorescence intensity for each LNAPL type. Initial tracer concentrations should be determined for each LNAPL type based on the following guidelines.

7.3.3.1 All fluorescence measurements throughout this methodology should be made in triplicate to ensure the readings are within 1 %.

7.3.3.2 A tracer fluorescence peak that is at least twice that of the background LNAPL is desirable to ensure that the tracer fluorescence signal is not overwhelmed by background LNAPL fluorescence and remains detectable for a sufficient period of time.

7.3.3.3 Generally, a plot of tracer concentration versus fluorescence intensity will have a linear segment followed by a non-linear asymptotic segment, beyond which the relationship between tracer concentration and LNAPL flow through the well becomes difficult to quantify. It is therefore important to ensure that the initial quantity of tracer added results in a concentration that falls within the linear range for the LNAPL type in the well.

7.3.4 Large tracer concentrations may alter the physical properties of the LNAPL that govern flow, and therefore the smallest amount of tracer that can be used to conduct the test is recommended.

7.3.5 Verify interval that the well is screened over the formation thickness.

7.4 *Procedure:*

7.4.1 *Test Initiation*—Consists of the following procedures:

7.4.1.1 Measure the depth to the air/LNAPL and LNAPL/water interfaces, and LNAPL thickness in the test well. Review well construction logs to ensure that the LNAPL within the test well is in communication with the screened interval of the test well.

7.4.1.2 Conduct a baseline scan of the LNAPL within the test well using the spectrometer and down-well fiber optic cable to measure background fluorescence. Decontaminate and inspect the fiber optic cables and reflectance probe (at the tip of the fiber optic cable) prior to use to ensure there are no sources of light interference that may yield erroneous data. Decontamination and inspection will be conducted prior to each reading using the down-well fiber optic cable and spectrometer.

7.4.1.3 Insert a small diameter pipe into each well selected for testing to isolate a volume of LNAPL from the contents of the well. The pipe will be inserted to the bottom of each well to ensure that the LNAPL remains isolated during the test period. The isolated LNAPL sample, hereafter referred to as

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C_0, represents the LNAPL within the formation materials and is used throughout the duration of the LNAPL tracer test to calibrate the spectrometer against the background fluorescence of the LNAPL. The smallest diameter pipe that can accommodate a down hole fiber optic cable within its inner diameter should be used.

7.4.1.4 After isolating a volume of LNAPL within the well in the C_0 pipe, calculate the total volume of LNAPL in the well, and calculate the volume of tracer that will need to be mixed with the LNAPL in accordance with the guidelines outlined in 7.3. Carefully remove a small vial of LNAPL from the well and amend with the previously determined volume of LNAPL soluble tracer. After mixing the LNAPL and tracer thoroughly in the weighted vial, carefully lower the mixture into the well, and gently raise and lower the vial beneath the air/LNAPL interface until all of the LNAPL/tracer mixture is mixed into the LNAPL within the test well. Make sure that none of the liquid in the vial splashes onto the well casing, which could slowly drip back into the well over the duration of the test and potentially introduce error to the LNAPL transmissivity estimates.

7.4.1.5 Scan the column of LNAPL/tracer in the well using the spectrometer and down-hole fiber optic cable to ensure that the tracer is well mixed throughout the well. If the fluorescence readings vary with depth through the LNAPL column, mix the LNAPL and tracer together. A small air line should be lowered into the test well to a depth beneath the water-LNAPL interface. The air line is then used to mix the LNAPL to a "well-mixed" condition. Once adequately mixed, confirm that the fluorescence readings in the LNAPL/tracer mixture agree with the targeted fluorescence.

7.4.1.6 After mixing the desired proportions within the well, insert a second small diameter pipe to isolate a volume of the initial LNAPL/tracer mixture. The drop pipe will be inserted to the bottom of the test well to ensure that a sample representative of the initial LNAPL/tracer mixture remains isolated during the test period. This sample is referred to as C_{100} and used throughout the tracer test to calibrate the spectrometer with the initial tracer concentration introduced into the LNAPL within the test well. Each time the concentration of tracer is measured within the test well (C_{WELL}) the spectrometer is calibrated using the in-well standards (C_{100} and C_0).

7.4.1.7 Scan and record intensity readings for C_0, C_{100}, and C_{WELL}, and then repeat these measurements, making sure that consecutive readings for each of the controls (C_0 and C_{100}) and the fluorescence readings in the test well (C_{WELL}) are within 2 % of the previous readings. If the readings are not within 2 %, remix the test well and recollect the data until all of the readings are within 2 %.

7.4.2 *Routine Data Collection:*

7.4.2.1 Thoroughly mix the LNAPL/tracer mixture in the well with a down-well airline, the calibration standard pipes, or other appropriate method; mixing should be sufficient to create a 'well mixed' condition. Mixing too aggressively can push tracer out of the well resulting in erroneously high readings. Verify that the LNAPL/tracer mixture is adequately mixed by conducting a vertical scan through the LNAPL column in the well using the down-well fiber optic cable and spectrometer. Decontaminate and inspect the fiber optic cables and reflectance probe (at the tip of the fiber optic cable) prior to each use to ensure there are no sources of light interference that may yield erroneous data.

7.4.2.2 Measure and record depth to the air/LNAPL and LNAPL/water interfaces using an oil-water interface probe in the test well. Do not gauge the well with the interface probe prior to mixing, as removing small volumes of poorly mixed LNAPL or LNAPL/tracer mixture (even volumes as small as the quantity that sticks to the interface probe) could potentially introduce error to the mass-balance calculations used to estimate LNAPL flux through the well.

7.4.2.3 Measure and record LNAPL fluorescence within the in-well standard pipes (C_0 and C_{100}) and the test well (C_{WELL}). Decontaminate the fiber optic cable between readings to prevent transfer of dyed or undyed LNAPL between calibration standards and the test well. Repeat measurement of LNAPL fluorescence within the in-well standard pipes (C_0 and C_{100}) and the test well (C_{WELL}). Two percent or less variability between the first and second measurements of $C_0$0, C_{100}, and C_{WELL}, respectively, are desirable. Additional mixing of the LNAPL and additional measurement repetition may be necessary to achieve the target variability.

7.4.2.4 The test should be terminated, or re-started by adding more tracer to the test well (C_{WELL}) when the tracer concentration in the test well approaches the natural background fluorescence in C_0 due to accuracy of the spectrometer. Generally, when the tracer concentration in the test well (C_{WELL}) is less than 20 % greater than C_0, the test should be restarted or terminated.

7.5 *Report:*

7.5.1 Include the information listed below in the report of the field procedure:

7.5.1.1 Date, time, and well identification.

7.5.1.2 Volume of tracer added.

7.5.1.3 Background florescence of LNAPL in C_0.

7.5.1.4 LNAPL fluorescence in C_{100}.

7.5.1.5 All gauged LNAPL thickness measurements in test well.

7.5.1.6 All gauged depth to air/LNAPL interface measurements.

7.5.1.7 All gauged depth to LNAPL/water interface measurements.

7.5.1.8 Diameter of well.

7.5.1.9 Diameter of small diameter pipes (isolation tubes) and type of material.

7.6 *Precision and Bias:*

7.6.1 Repetition of readings increases test precision. At a minimum, duplicate readings are taken and the duplicate readings should match within two percent of previous readings. There is no known bias in the testing method. Site-to-site test precision has not yet been quantified based on variability in site conditions and instruments utilized for testing.

7.6.2 It can be envisioned that if there is no LNAPL transmissivity, tracer will never leave the well due to advective processes, but there is still connection between LNAPL in the well and the LNAPL in the formation, so tracer can still diffuse from the well. The lower detection limit of the method is

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governed by the rate if diffusion of tracer from the well into the formation. Taylor (2004) (**8**) developed a rigorous solution to calculate the lower detection limit based on the effective diffusion coefficient of the tracer.

7.6.3 The method precision will be discussed in a qualitative sense. There are issues associated with the precision of the method based on variability of collecting individual tracer concentration data points. The data that is collected in the field is fit to a non-linear analytic model, much like the other methods. Each time a fluorescence concentration is measured, a duplicate reading is collected. The goal for the duplicate readings is to achieve two percent (on a normalized basis) variability. If the LNAPL transmissivity is very low, and the readings are taken over a small time period, it can be envisioned that the two percent variability within each data point might be larger than the actual decrease in tracer concentration. This results in the inability to calculate an absolute transmissivity value; however, an upper limit transmissivity could be still be calculated generating data where LNAPL transmissivities can be reported as less than a time weighted absolute transmissivity value.

8. Data Analysis

8.1 *Calculations for General Parameters*—This section provides guidance on how to calculate standard parameters potentially applicable to any methodology.

8.1.1 *Calculating Fluid Levels from Pressure Transducers*—Setups can include the use of one, two or three pressure transducers. This section will cover how to estimate the air/LNAPL interface, LNAPL/water interface and the calculated water-table elevations.

8.1.1.1 Pressure transducers measure either the absolute pressure or gage pressure (pressure relative to atmospheric pressure). For this discussion it is assumed that absolute pressures are measured. If the air/LNAPL interface is the objective of a given transducer then the measured pressure will need to be corrected for LNAPL density for estimating LNAPL head.

8.1.1.2 To use a pressure transducer, the density of the LNAPL should be known prior to interpreting the test results.

8.1.1.3 Eq 6 assumes the transducer provides absolute pressure data. These equations, combined with calibration gauging data and LNAPL density data, will allow calculation of each fluid interface elevation whether one pressure transducer is being used in conjunction with gauging of the air/LNAPL interface or two pressure transducers are being used, one in each fluid phase.

$$Z_{CGW} = Z_{P1} + \frac{P_{P1} - P_{atm}}{\rho_w g} \tag{6}$$

where:

Z_{P1} = elevation of water phase pressure transducer (that is, pressure transducer P1) (L),
Z_{CGW} = elevation of the calculated water-table level (L),
P_{P1} = measured absolute pressure from pressure transducer P1 (M/t^2L),
P_{atm} = measured atmospheric pressure inside the well casing (M/t^2L),
ρ_w = groundwater density (M/L^3), and
g = gravitational acceleration (L/T^2).

8.1.1.4 Eq 6 combined with atmospheric pressure data and pressure transducer data is used to calculate the corrected water-table elevation.

$$Z_{AN} = Z_{P2} \mp \frac{P_{P2} - P_{atm}}{\rho_n g} \tag{7}$$

where:

Z_{P2} = elevation of LNAPL phase pressure transducer (that is, pressure transducer P2 located within the LNAPL column in the well) (L),
Z_{AN} = elevation of the air/LNAPL interface (L),
P_{P2} = measured absolute pressure from pressure transducer P2 (M/t^2L),
ρ_n = LNAPL density (M/L^3), and
g = gravitational acceleration (L/T^2).

8.1.1.5 Eq 7 combined with the atmospheric pressure data and pressure transducer data is used to calculate the elevation of the air/LNAPL interface.

$$Z_{OW} = \frac{Z_{CGW} - \rho_r Z_{AN}}{1 - \rho_r} \tag{8}$$

where:

Z_{OW} = elevation of the LNAPL/Water interface (L), and
ρ_r = the relative LNAPL to water density, that is, $\rho_r = \rho_n / \rho_w$ (unitless)

8.1.2 Eq 8 results in the LNAPL/water interface elevation. Eq 8 requires the density of LNAPL and the elevations of the calculated water-table level and the air/LNAPL interface to be known. The required fluid elevations can be measured in any combination of gauging data or pressure transducer data that provides these required input elevations. LNAPL density should be estimated based on laboratory analysis of site specific LNAPL.

8.1.3 *Calculation of LNAPL Drawdown*—The calculation of LNAPL drawdown must compare the pressure (head) existing in a given extraction well to the equilibrium pressure (head) of LNAPL within the mobile interval in the formation. For every case the top of the mobile interval of LNAPL in the formation is the reference point for drawdown. If multiple soil horizons exist then the interval estimated to exhibit the highest transmissivity would be selected at the primary interval and therefore would represent the reference point for drawdown calculations. A silt overlying a fine sand may have some mobile LNAPL but would be insignificant compared to the underlying sand. In this case, the top of the underlying sand would be selected for the reference point to calculate drawdown.

8.1.3.1 *Unconfined*—Drawdown under unconfined conditions is given by the following equation for air/LNAPL interface drawdown:

$$S_{nt} = Z_{AN^*} - Z_{AN(t)} \tag{9}$$

where:

Z_{AN^*} = the air/LNAPL interface elevation for equilibrium conditions (L),
$Z_{AN(t)}$ = the air/LNAPL interface elevation at time t (L), and

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S_{nt} = LNAPL drawdown at time t (L).

8.1.3.2 *Confined LNAPL Drawdown*—Drawdown for confined conditions is not solely based on the air/LNAPL interface elevation because as LNAPL is extracted from a well both LNAPL and water can rise above the mobile interval of LNAPL (that is, the confining layer), and drawdown calculation must consider the entire fluid column and fluid density between the mobile interval and air/LNAPL interface.

(1) Where the calculated water-table elevation is equal to equilibrium conditions, the LNAPL/water interface is above the confining contact and LNAPL is recovering from a baildown test or being removed via a skimming technology, Eq 10 can be used to estimate the LNAPL drawdown. In this scenario of a constant calculated water-table, drawdown is constant so long as the LNAPL/water interface remains above the confining contact elevation because as a given mass of LNAPL flows into the well, an equal mass of water flows out of the well. For this constant LNAPL drawdown condition the fluid pressure distribution across the mobile interval of LNAPL remains constant.

$$S_{nt} = b_{nf}\frac{1-\rho_r}{\rho_r} \quad (10)$$

where:

b_{nf} = mobile interval of LNAPL in the formation, which is not equal to the gauged LNAPL thickness (L).

(2) Once the elevation of the LNAPL/water interface has decreased below the confining contact, the LNAPL drawdown is calculated using the difference in air/LNAPL interface (that is, Eq 9).

(3) Note that the formation thickness of confined LNAPL can be estimated by taking the difference in the static LNAPL/water interface and the confining contact elevation in the formation, typically estimated based on soil boring data such as soil type and LNAPL impacts.

(4) When confined LNAPL exists, the LNAPL/water interface is above the confining contact, the calculated water-table is less than equilibrium, and LNAPL is recovering from a baildown/slug test or continuous liquid extraction, Eq 11 can be used to estimate LNAPL drawdown.

$$S_{nt} = \frac{(Z_{AN^*} - Z_{cc})\rho_n - (Z_{NW(t)} - Z_{cc})\rho_w - (Z_{AN(t)} - Z_{NW(t)})\rho_n}{\rho_n} \quad (11)$$

where:

S_{nt} = the drawdown at time t for LNAPL existing in a confined state below the confining contact elevation,

Z_{cc} = elevation of confining contact (L),

$Z_{NW(t)}$ = elevation of LNAPL/water interface at time t (L), and

Z_{AN^*} = elevation of air/LNAPL interface for equilibrium conditions (L).

(5) If well extraction has resulted in the air/LNAPL interface occurring below the confining layer then drawdown is calculated with Eq 9 (that is, same as unconfined conditions). This equation will hold until the air/LNAPL interface reaches the confining contact. During this scenario for confined LNAPL, drawdown is not constant and will decrease with time. It is possible that Eq 9-11 are all required to cover the span of a recovery event (baildown, slug or liquid extraction).

(6) Each equation covers a specific set of conditions that may or may not be present during any given test where confined LNAPL exists.

8.1.3.3 *Perched*—The drawdown for perched LNAPL conditions is the same as for unconfined except that the maximum possible drawdown for liquid only extraction is equal to the mobile interval of LNAPL in the formation. Vacuum enhanced extraction can increase this drawdown and the equations are discussed under 8.2. The mobile interval of LNAPL in the formation is equal to the difference in the equilibrium air/LNAPL interface and the perched layer contact. The contact for perched LNAPL can be estimated based on soil boring data such as soil type and LNAPL impact data.

8.1.4 *Data Analysis–Baildown Testing:*

8.1.4.1 *General Boundary Conditions:*

(1) The primary condition which needs to be met is that the relationship between LNAPL drawdown and LNAPL discharge to the well from the formation, (that is, well recharge) is a direct relationship and the data would trend such that the discharge and drawdown would reach zero simultaneously. Fig. 2 provides the ideal behavior.

(2) Baildown test that meet this criterion need not be run to completion since the data trends confirm that the fluid level used to represent equilibrium conditions is a reasonable value.

(3) Baildown test data that exhibit deviations from this ideal trend indicate that the data is not suitable for analysis or that the value used for equilibrium conditions is inaccurate. Equilibrium fluid levels should be checked and can be corrected to represent the final fluid levels if these data are more representative of equilibrium conditions based on gauging data trends obtained during the baildown test. If a correction is not reasonable then the data not exhibiting the correct trend should not be analyzed with the baildown test methods provided. Where uncertainty occurs with equilibrium fluid levels, the baildown test should be run to completion to understand the equilibrium fluid levels. The test can then be repeated or an alternate method in this guide used to estimate LNAPL transmissivity.

(4) Data that initially trends towards zero drawdown where the discharge would still be positive typically represents perched or confined LNAPL behavior (Fig. 3).

(5) Data that initially trends towards zero discharge where the drawdown would still be positive typically represents filter pack recharge and should not be analyzed (Fig. 4).

(6) Eq 12 is used to calculate the recovered thickness attributable to filter pack recharge, where all recovery up to this thickness should be considered filter pack recharge. Eq 12 is only applicable where the initial gauged thickness of LNAPL in a well exists completely within the screened interval.

$$b_r = b_n - \frac{V_r}{\pi\left(S_{yf}\left(r_b^2 - r_c^2\right) + r_c^2\right)} \quad (12)$$

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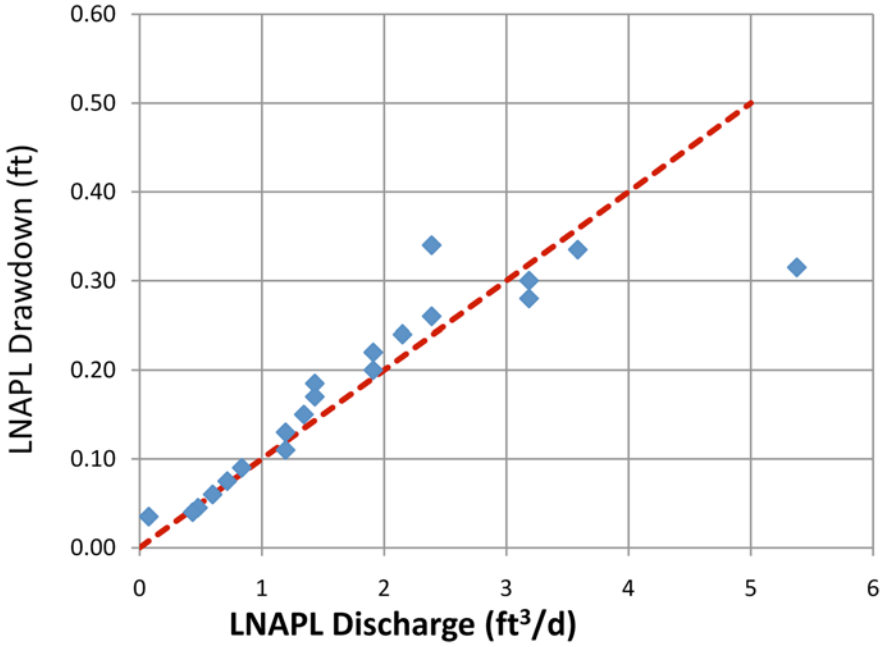


FIG. 2 Baildown Test Data Representing the Ideal Relationship between Drawdown and Discharge

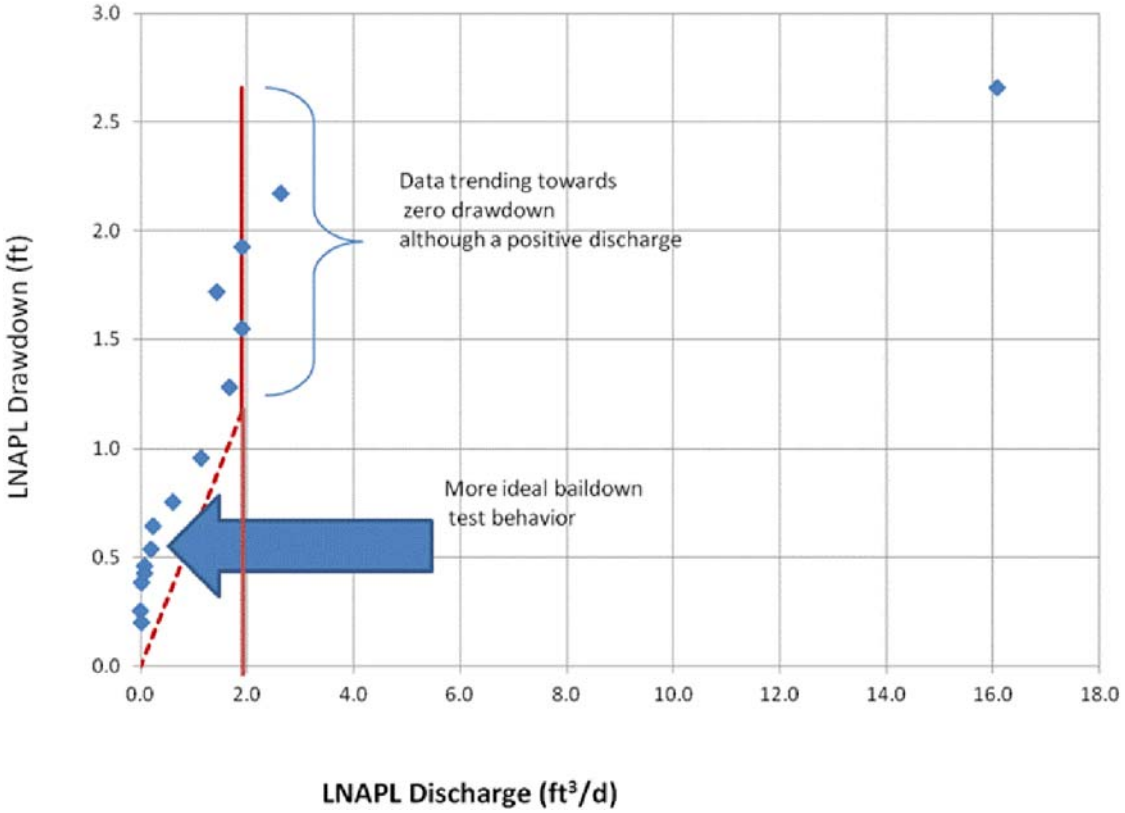


FIG. 3 Baildown Test Data Representing Confined or Perched Discharge Behavior

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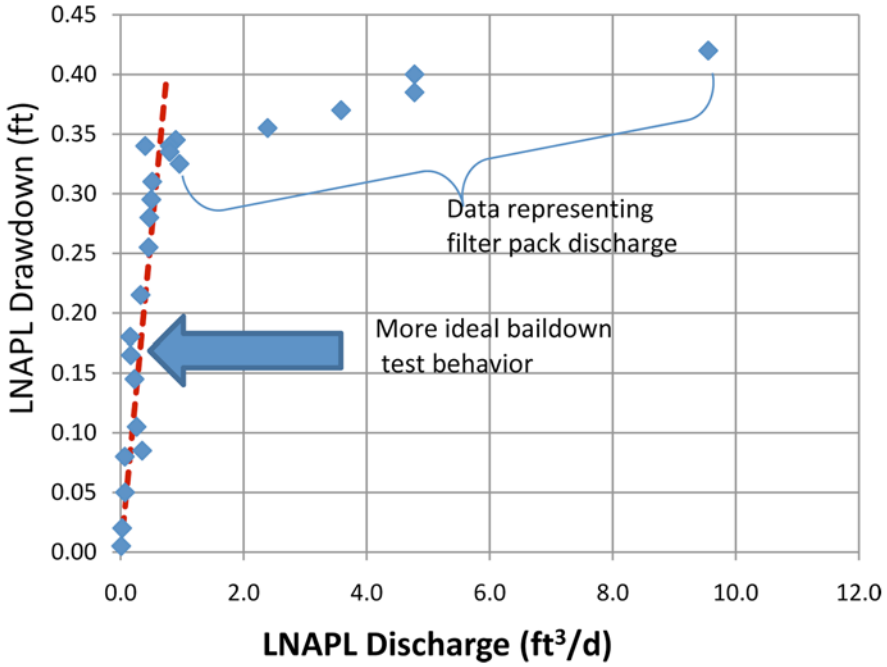


FIG. 4 Baildown Test Data Initially Representing Filter Pack Discharge Behavior and then Becomes Ideal

where:

V_r = volume of LNAPL initially recovered or displaced (L^3),

b_r = recovered LNAPL thickness due to filter pack recharge (L), and

b_n = initial gauged LNAPL thickness prior to removal (L).

(7) Data that consistently trends such that it intersects the zero discharge with remaining drawdown or zero drawdown with remaining discharge likely represents that the fluid levels being used for equilibrium conditions are inaccurate (Figs. 3 and 4).

(8) Best practices will utilize equilibrium fluid levels that are confirmed by reviewing the fluid levels at the start to the end of the test where the well was gauged until it fully recovered. However, where variables such as extended test times combined with fluctuating water-table conditions exist, an alternative method can be employed to confirm equilibrium fluid levels. Equilibrium fluid levels can also be ensured by gauging the well 10 times over a period equal to the test duration analyzed prior to the start of the test. These data will allow for an understanding of variability in water-table conditions near the time the test was conducted.

(9) Wells need to be in good communication with the formation. This consists of well being properly developed and not containing weathered LNAPL induced by stagnant well conditions. Fluid gauging data exhibiting repeatable fluid levels following LNAPL removal events for a given well is the best practice to establish equilibrium fluid levels are accurate.

(10) If the water-table varies by a magnitude greater than 20 % of the max drawdown induced over the period of analysis, then an alternative method should be used to evaluate LNAPL transmissivity.

(11) All equilibrium fluid levels need to be compared to the soil profile to identify the possibility of perched or confined LNAPL. This will enable the identification of perched or confined LNAPL conditions. These conditions affect how drawdown is calculated.

(12) The use of a storativity term in the numerical analysis of baildown/slug test data accounts for non-steady state recharge (that is, transient) conditions such as in the Jacob-Lohman Method. However, many tests are not significantly affected by transient behavior and one can use methods more representative of steady state origins such as the Bouwer-Rice method.

(13) The Bouwer-Rice solution is useful for baildown test analysis because the translation method (Butler 1998) **(9)** can be applied where the slug introduction was not instantaneous. This may happen more frequently with tests where LNAPL is more completely removed from the casing and filter pack for the purposes of minimizing filter pack recharge effects.

(14) The Jacob-Lohman based analysis is useful for cases where transient effects are observed in the recharge response and the slug or fluid withdrawal meets instantaneous conditions.

(15) Instantaneous should be relative to the test duration, the removal period should be less than 100th of the entire test duration.

(16) If the slug/fluid removal approximates instantaneous and no significant transient effects are observed, then both analysis methods can be used and should correlate well.

8.1.4.2 *Bouwer and Rice:*

(1) LNAPL transmissivity calculation methods for baildown testing analysis theory via the Bouwer-Rice method are provided in detail in Lundy and Zimmerman (1996) **(6)** and Huntley (2000) **(10)**, and in Bouwer and Rice (1976) **(11)** and Bouwer (1989) **(12)**.

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(2) The primary assumptions include a quasi-steady-state model for recharge to the well (the model assumes steady radial flow to the well with rate dependent on the well drawdown; no storage effects are included) and that the ratio of change in LNAPL head to LNAPL thickness (ds_n/db_n) is constant. This ratio will be referred to as the *j*-ratio.

(3) The magnitude of the *j*-ratio has been discussed in two published papers. Where the water transmissivity through the well screen is significantly lower than the LNAPL transmissivity, this ratio equals unity (1) (Lundy and Zimmerman, 1996) (**6**). An example of this behavior is shown in Figs. 5 and 6. Where the water transmissivity is significantly higher than the LNAPL transmissivity through the well screen and the potentiometric surface in consistent throughout the analyzed portion of data, this ratio equals unity minus relative density ($1 - \rho_r$) (Huntley, 2000) (**10**). For an example of this type of behavior see Figs. 7 and 8.

(4) The magnitude of *j*-ratio need not be assumed 'a priori' because every baildown or slug test provides necessary data to evaluate if a constant slope between LNAPL thickness and head exists, along with the magnitude of this ratio. By plotting the thickness on the *x*-axis versus the drawdown as calculated based on the difference in air/LNAPL interface from equilibrium on the *y*-axis the data can be reviewed for a period exhibiting a consistent slope. The value of that slope represents the ratio that should be used in the solution. This can be tested by plotting the change in the air/LNAPL interface (that is, drawdown) versus gauged LNAPL thickness.

(5) If at any point in the test a constant slope between gauged LNAPL thickness and drawdown exists and the recharge is not representative of filter pack recharge, the boundary condition is met and the Bouwer-Rice methodology can be applied to that time sequence. Butler describes a translation method for non-instantaneous slug tests initiation which can be applied to this method (Butler, 1998) (**9**).

(6) The greater the variability in *j*-ratio, the larger the error associated with the Bouwer-Rice methodology. Large variability suggests that the Jacob-Lohman methodology should be applied.

(7) According to Bouwer-Rice method, the logarithm of the drawdown varies as a linear function of time. A straight line may be fit to the drawdown-time data and the slope of this line is used to determine the LNAPL transmissivity. When the line if fit using linear regression, the variance of the slope of the line can be used to estimate the LNAPL transmissivity standard deviation.

$$T_n = r_w^2 \frac{\ln\left(\frac{s_o}{s_n}\right) \ln\left(\frac{R_{oi}}{r_w}\right)}{2jt} \tag{13}$$

where:

T = LNAPL Transmissivity (L^2/t),
s_o = maximum drawdown induced; estimated from *y*-intercept of the drawdown versus log-time plot fitted to the selected data range (L),
s_n = LNAPL drawdown at time t (L),
j = ratio of change in drawdown to change in thickness over the recovery period being analyzed,
t = elapsed time (t),
R_{oi} = radius of influence, and
r_w = effective well radius.

(8) The ratio of the radius of influence to the effective well radius may be calculated using the polynomial approximation presented by Butler (1998) (**9**). This is based on the results presented by Bouwer and Rice (1976) (**11**).

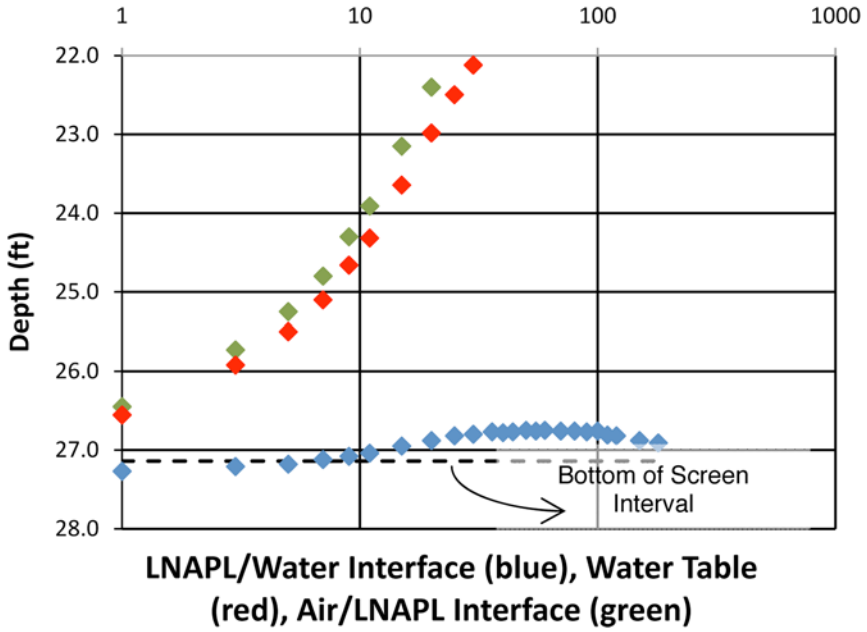


FIG. 5 Hydrograph of Baildown Test Recovery Illustrating a Constant LNAPL/Water Interface during Recovery

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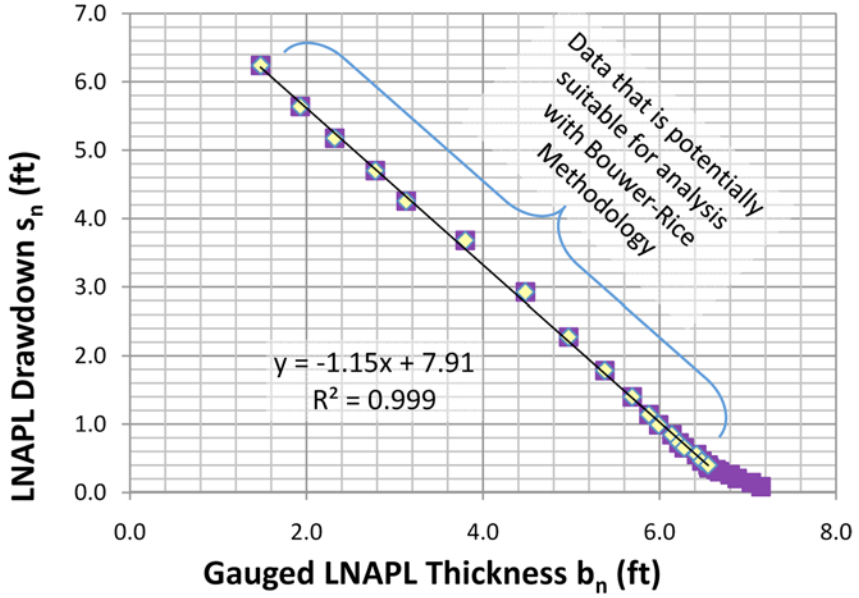


FIG. 6 Gauged LNAPL Thickness versus LNAPL Drawdown for Baildown Test Approximating a Change in Thickness to Decrease in Drawdown Ratio Value of One

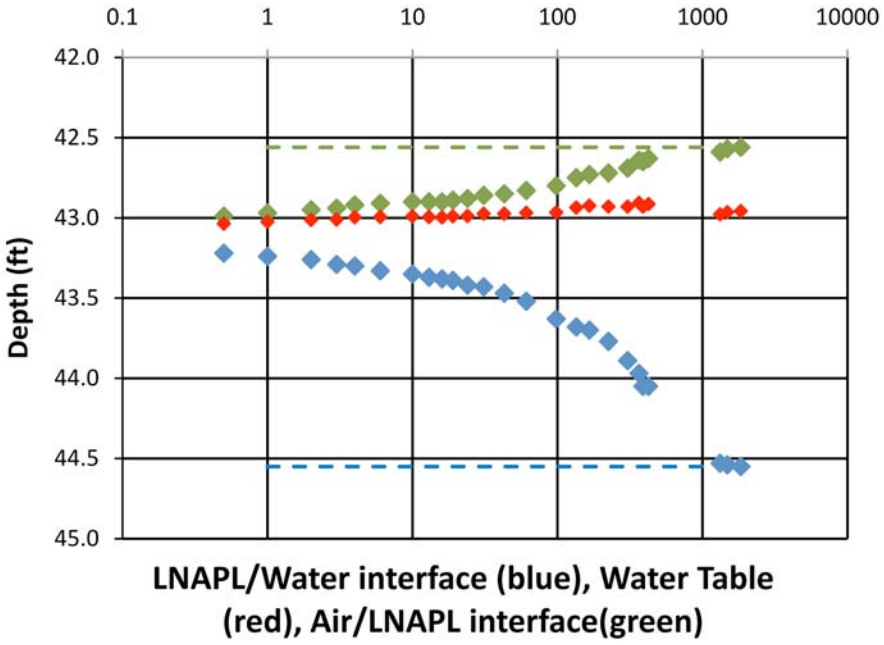


FIG. 7 Hydrograph of Baildown Test Recovery Approximating a Constant Calculated Water-table Elevation During Recovery

(9) Jacob-Lohman—The theory of baildown/slug testing analysis via Jacob-Lohman methods is provided in detail in Huntley (2000) **(10)** and Jacob and Lohman **(13)**. Although three different methods are presented by Huntley (2000) **(10)** from Jacob and Lohman's **(13)** modification of the Cooper-Jacob method for constant drawdown-variable discharge conditions of LNAPL baildown testing, only the sum of the squared residual (SSR) method has been found to consistently provide an applicable method. The other Cooper-Jacob (that is, methods 1/Q and s/Q) provided by Huntley do not consistently provide comparable or accurate results and are not recommended as part of this guide.

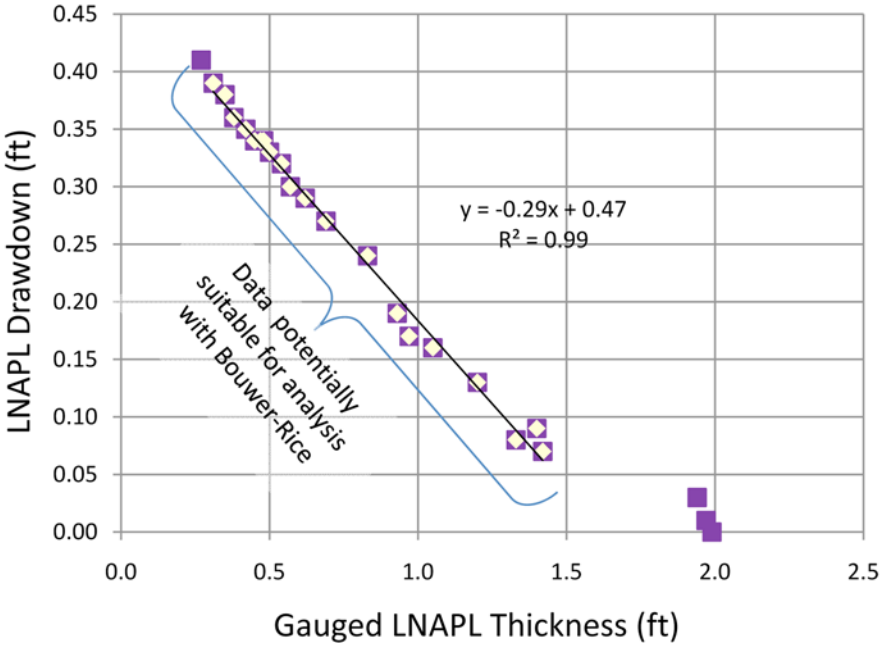
8.1.4.3 Because the recharge rate is calculated independently of drawdown, no relationship between the change in recovered gauged thickness and drawdown is required to hold.

8.1.4.4 This analysis method accounts for transient recharge conditions and storage effects.

8.1.4.5 The primary condition which needs to be met is that the relationship between drawdown and discharge to the well from the formation (that is, recharge) is a direct relationship and the trend will simultaneously intersect zero for each variable (see Fig. 2).

(1) Sum of the Squared Residual Method—The Sum of the Squared Residual (SSR) method is useful to minimize any

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Approximating a change in thickness to decrease in drawdown ratio value of the quantity relative density minus one; where the relative density is estimated to be 0.8.

FIG. 8 Gauged LNAPL Thickness versus LNAPL Drawdown for Baildown Test

scatter induced by deviations from the primary assumption of constant, known drawdown. The primary assumption is still constant, known drawdown, but the methodology allows for minimization of error introduced by the resulting scatter when the drawdown is variable (Huntley, 2000) (**10**).

(2) Although Huntley provides the recommendation to solve for both LNAPL transmissivity and storativity, experience has found that it is prudent to iteratively select a storativity value based on the LNAPL transmissivity. Guidance values are provided in Table 1. Therefore start with a value of 0.1 then solve for LNAPL transmissivity. Based on that LNAPL transmissivity reselect the storativity to match the new transmissivity. Repeat until results are within a factor less than 2.

(3) Use of Table 1 will result in reasonable estimates of LNAPL transmissivity in conjunction with the SSR Method. The error associated with varying storativity by plus or minus half an order of magnitude results in a variability of plus or minus approximately 30 %.

TABLE 1 Storativity Estimates for a Given LNAPL Transmissivity

Resulting LNAPL Transmissivity (ft^2/day)	General Estimate for LNAPL Storativity/Specific Yield (Volume/Bulk Volume)
50	0.175
20	0.1225
10	0.07
5	0.0525
1	0.035
0.1	0.008

(4) The SSR Method is completed by calculating the left side of the Eq 14 below and running a numerical solution to fit the right side of the equation by varying LNAPL transmissivity.

$$S\Delta t = \frac{Q_n \Delta t}{4\pi T_n} \ln\left(\frac{2.25T}{r_w^2 S}\right) \quad (14)$$

where:

Q = LNAPL discharge rate from the formation to the well, (that is, well recharge rate), and
S = LNAPL specific yield.

8.1.4.6 Alternatively the SSR method can be used in the following form which each side of the equation represents a more tangible value of measured recovered volume to calculated recovered volume of volume recovered in each time step.

$$Q\Delta t = \frac{4\pi sT}{\ln\left(\frac{2.25T}{r_w^2 s}\right)} \Delta t \quad (15)$$

8.2 *Data Analysis—Manual Skimming Test:*

8.2.1 To calculate LNAPL Transmissivity from manual skimming test data, use the following equation (Charbeneau, 2007) (**14**):

$$T_n = \frac{Q_n \ln\left(\frac{R_{oi}}{r_w}\right)}{2\pi s_n} \quad (16)$$

where:

T_n = LNAPL transmissivity (L^2/t),
Q_n = measured LNAPL recovery rate (L^3/t),
R_{oi} = radius of influence (L), and

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r_w = well radius (L).

NOTE 2—The value of the term $\ln(R_{oi}/r_w)$ can be assumed to equal 4.6 with the introduction of little additional error.

8.2.2 The drawdown value for a given period should be taken as the geometric mean of the starting and ending drawdown values.

8.2.3 The drawdown value can be directly measured using the fluid level gauging data and the guidance provided in 8.1.3.

8.2.4 The maximum skimming drawdown for unconfined conditions is given by Eq 15. The maximum drawdown for confined and perched conditions is given by Eq 16 and Eq 17 respectively.

8.2.5 To calculate LNAPL Transmissivity, take the stabilized LNAPL recovery rate (Q_n) and estimate the drawdown that corresponds to this discharge and calculate T_n using the manual skimming test equation, above. If you have perched or confined LNAPL then the drawdown must be adjusted as noted in 5.4.

8.2.6 The accuracy of this equation is most sensitive to the accuracy of the measured LNAPL recovery rate and drawdown. Consistent operation of the skimming system such that the induced drawdown is know and consistent will improve accuracy of calculations.

8.3 *Data Analysis—Long Term Recovery System Data:*

8.3.1 *LNAPL Skimming*—Eq 16 can be used to estimate LNAPL transmissivity, however the assumptions for LNAPL drawdown vary from those in the manual skimming test.

8.3.1.1 The drawdown value can be directly measured using the fluid level gauging data and the guidance provided in 8.1.3 or through assumptions based on equilibrium fluid levels if the system is designed to maintain close to zero gauged LNAPL thickness in the well. Routine direct measurement will provide the best accuracy.

8.3.1.2 The maximum skimming drawdown for unconfined conditions is given by Eq 17. The maximum drawdown for confined and perched conditions is given by Eq 18 and Eq 19 respectively.

$$s_{n_unconfined} = b_n(1 - \rho_r) \tag{17}$$

$$s_{n_confined} = b_{nf}\frac{1 - \rho_r}{\rho_r} \tag{18}$$

$$s_{n_perched} = b_{nf} \tag{19}$$

8.3.1.3 Unless an automatic fluid level system is being utilized, long-term continuous recovery requires estimates of drawdown that are based on point measurements representing long periods of time. The accuracy of this method is based on the ability of the recovery systems to maintain a constant LNAPL drawdown and how water-table fluctuations affect the mobile interval in the formation.

8.3.1.4 The skimming methodology when using periodic drawdown measurements provides estimates for LNAPL transmissivity that are likely within an order of magnitude of the actual LNAPL transmissivity value, however weekly or monthly measurements of drawdown can often span significant fluctuations in water-table.

8.3.1.5 The value of the term, $\ln(R_{oi}/r_w)$ can be assumed to equal 4.6 with the introduction of little additional error.

8.3.2 *Vacuum-Enhanced LNAPL Only Liquid Recovery (Vacuum-Enhanced Skimming)*—LNAPL transmissivity may be determined from a vacuum-enhanced recovery system using air and LNAPL discharge data, assumed formation air permeability and air-water viscosity ratio, and formation hydraulic conductivity across the screened interval above the LNAPL. For vacuum-enhanced skimming, transmissivity can be calculated using the following equation (Charbeneau, 2007) **(14)** :

$$T_n = \frac{Q_n k_{ra} K_w b_a \rho_r}{\mu_{ar} Q_a} \tag{20}$$

where:

Q_a = air discharge rate in terms of standard air pressure and temperature (L^3/t),

k_{ra} = relative permeability of open screen length in the vadose zone to air (unit less),

K_w = saturated hydraulic conductivity value for corresponding to the soil type existing in the vadose zone immediately above the mobile LNAPL interval (L/t),

b_a = screen length open to the portion of the vadose zone representative of the saturated hydraulic conductivity value used (L), and

μ_{ar} = relative viscosity of air to water (unitless).

NOTE 3—The value for relative viscosity, μ_{ar}, is assumed to be 0.018 and relative permeability to air, k_{ra}, is assumed to be 0.9. Use of site-specific data for these parameters is also acceptable.

8.3.2.1 Additionally, if the air discharge rate is unknown Eq 16 can be used where the LNAPL drawdown due to vacuum enhanced skimming and ratio of radius of influence to well radius are known. The LNAPL drawdown term in this equation will be equal to the sum of the vacuum applied to the formation and the LNAPL skimming drawdown.

8.3.2.2 Where the LNAPL skimming drawdown is one tenth or less of the applied vacuum to the formation it does not have to be considered and only the applied vacuum needs to be measured.

8.3.2.3 The applied vacuum to the formation must account for head losses in the system and filter pack. Well head vacuums ahead of any supplemental air release valves are applicable but step pilot test data provide the best calibration to additional losses through the casing and filter pack. The air flow based calculation is typically more accurate relative to using applied vacuum because no estimation of head loss is required.

8.3.3 *Water-Enhanced LNAPL Recovery (Total Fluids Pumping, Single or Dual Pump)*—LNAPL transmissivity may be determined using water and LNAPL discharge data from a water-enhanced recovery system, provided the recovery system is operated at a sufficiently low pumping rate to ensure small drawdown at the recovery well to prevent significant smearing (Charbeneau, 2007) **(14)**. Eq 21 uses the water discharge rate, the LNAPL discharge rate and the hydraulic transmissivity to estimate LNAPL transmissivity. However this assumes that the drawdown induced with water extraction is much larger than the drawdown that is achievable via skimming. If the water induced drawdown is 10 times or greater than the skimming drawdown then Eq 21 (Charbeneau, 2007) **(14)** can be used. Cases where the skimming drawdown is

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greater than one-tenth of the water extraction induced drawdown then Eq 22 is more appropriate.

$$T_n = \frac{Q_o T_w \rho_r}{Q_w} \quad (21)$$

where:

Q_w = water discharge rate in terms of standard air pressure and temperature (L^3/t), and
T_w = aquifer transmissivity (L^2/t).

8.3.3.1 Eq 21 is useful especially for systems with variability in water extraction rates and even frequent periods of down time. Only the LNAPL and water volumes for a given period need to be measured. If the system down time was unknown, LNAPL transmissivity can still be accurately calculated because the time period cancels out of the equation for the LNAPL and water discharge terms. The discharge terms could also be converted in to volumes of oil and water recovered. The transmissivity calculated will be representative of the average LNAPL transmissivity for the period those volumes were recovered over.

$$T_n = \frac{Q_n T_w}{Q_w} \frac{1}{\left(\frac{1}{\rho_r} + \frac{S_{skim}}{S_w}\right)} \quad (22)$$

where:

S_{skim} = the maximum skimming drawdown (see 8.3.1.2).

8.3.3.2 Eq 22 approaches Eq 21 as the skimming drawdown becomes small relative to the water extraction induced drawdown.

8.3.4 *Water and Vacuum-Enhanced LNAPL Recovery*—Multiphase extraction being conducted as total fluids (that is, single stinger extraction) or dual phase extraction (that is, stinger combined with one or more liquid pumps) can also provide data to estimate LNAPL transmissivity.

8.3.4.1 Estimates of LNAPL transmissivity for multi-phase extraction are based on the summation of the total LNAPL production based on the drawdown induce from each phase. Eq 23 provides the LNAPL transmissivity estimate using the ratio of water and air flows to LNAPL flow from a well (Kirkman 2009) (**15**).

$$T_n = \frac{Q_n \rho_r}{\frac{\mu_{ar} Q_a}{k_{ra} K_w b_a} + \frac{Q_w}{T_w}} \quad (23)$$

8.3.4.2 The equation to estimate of LNAPL transmissivity for multi-phase extraction using the applied vacuum to the formation and the LNAL and water production rates is provided as Eq 24 (Hawthorne 2010) (**16**).

$$T_n = \frac{Q_n \rho_r}{\frac{2\pi s_n}{\ln\left(\frac{R_{oi}}{r_w}\right)} + \frac{Q_w}{T_w}} \quad (24)$$

8.3.4.3 The difference in equipment application between total fluids and dual-phase extraction will not affect the resulting LNAPL recovery performance beyond the head losses induced via the equipment. As discussed in 8.1 head losses associated with applied vacuum must be accounted for such that the applied vacuum value used to estimate LNAPL drawdown in Eq 24 represents applied vacuum to the formation. Step tests and an understanding of well screen length versus water-table and vacuum conditions are required.

8.4 *Data Analysis—Tracer Testing*—The tracer test has the following assumptions:

8.4.1 Flow under natural gradients is at steady state.

8.4.2 Fluid levels are constant throughout the duration of the test.

8.4.3 The LNAPL in the well is in hydraulic connection with the LNAPL in the formation.

8.4.4 The tracer is initially well mixed at time zero for the test.

8.4.5 The tracer is well mixed again prior to each measurement.

8.4.6 Relationship between tracer mass and fluorescence is assumed to be linear or known a priori.

8.4.7 Diffusive transport of tracer from the well is small and can be neglected.

8.4.8 Cross-sectional flow on the up and down gradient side of the well are equal.

8.4.9 If any of the above assumptions are violated, the practitioner should be determine the effects on the data reduction and calculated transmissivity by violating the assumptions.

8.4.10 The following is an implicit analytical solution for estimating the LNAPL Transmissivity as a function of changes in tracer concentrations in LNAPL in a well between intermittent mixing events. Also presented is an analysis of the limits on time between mixing-measurement events.

$$\frac{C_{T_{t_o+\Delta t}}}{C_{T_{t_o}}} = \frac{2a\cos\left(\frac{T_n i_{LNAPL} \alpha \Delta t}{2 r_w b_{wL}}\right) - \sin\left[2a\cos\left(\frac{T_n i_{LNAPL} \alpha \Delta t}{2 r_w b_{wL}}\right)\right]}{\pi} \quad (25)$$

$$\text{for} \quad \frac{T_n i_{LNAPL} \alpha \Delta t}{2 r_w b_{wL}} < 1$$

where:

$C_{T_{t+\Delta t}}$ = the tracer concentrations after mixing (M/L^3),
C_{T_t} = the initial tracer concentrations (M/L^3),
Δt = the time between mixing events (T),
T_n = the LNAPL transmissivity (L^2 /T),
i_{LNAPL} = the LNAPL gradient (unitless),
r_w = the radius of monitoring well (L),
b_{wL} = the thickness of LNAPL in the monitoring well (L), and
α = the flux convergence factor, often assumed to be equal to a value between 0.5 and 2 or a mean of 1.7 (unitless).

8.4.10.1 A full derivation is presented in Smith (**17**).

8.4.11 *Limit on Maximum Elapsed Time Between Mixing Events*—LNAPL transmissivity through the well and adjacent geologic formation includes vertical variations in LNAPL saturations and correspondingly relative permeability to LNAPL (Farr (**18**)). Given the assumptions of a uniform

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porous media, the following advances a maximum time between mixing without violating any of the assumptions from 7.6.1 is defined as:

$$\Delta t_{max} = \frac{2r_w}{q_{wL_{ave}}} \frac{k_{r_{ave}}}{k_{r_{max}}} \quad (26)$$

where:

Δt_{max} = the maximum time allowed between intermittent mixing events (T),

$q_{wL_{ave}}$ = the vertical LNAPL flux in the well (L/T),

$k_{r_{ave}}$ = the vertical averaged relative permeability (unitless), and

$k_{r_{max}}$ = the maximum relative permeability (unitless).

8.4.11.1 Further analysis of limits on Δt_{max} and full derivation is provided in Smith (**17**).

ANNEXES

(Mandatory Information)

A1. FIELD FORMS

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Well_____ Site_____

Manual Skimming Test Field Form

Project #:		**Site Name:**	
Well:		**Samplers:**	
Evacuation Method:		**Weather:**	

Borehole Diameter (INCHES):
Filter Pack Specific Yield (LNAPL)
0.175

Well Information		**LNAPL Information**	
Casing Diameter:		**Fluid Type:**	
Total Depth :		**Volume Removed:**	
Depth to Top of Screen:		**Evacuation Method:**	
Screen Length:		**LNAPL Well Volume:**	

Effective Well Radius (FT)

Length and volumetric units need to be specified

Length Units: **Volume Units:**

	LNAPL Well Volume
ft^3	
gal	
ml	

Pump	Date	Time Hour	Time Minute	Elapsed Time (min)	LNAPL Volume Removed	Water Volume Removed	Depth to LNAPL	Depth to Water	Comments
Static			:						
Pump On			:						Test Start
Pump Off			:						
			:						
			:						
			:						
			:						
			:						
			:						
			:						
			:						
			:						

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Well_____ Site_____

Pump	Date	Time Hour	Time Minute	Elapsed Time (min)	LNAPL Volume Removed	Water Volume Removed	Depth to LNAPL	Depth to Water	Comments
		:							
		:							
		:							
		:							
		:							
		:							
		:							
		:							
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Well_____ Site_____

Baildown/Slug Test Field Form

Project #:		**Site Name:**	
Well:		**Samplers:**	
Evacuation Method:		**Weather:**	

Borehole Diameter (INCHES):
Filter Pack Specific Yield (LNAPL)
0.175

Well Information		**LNAPL Information**	
Casing Diameter (INCHES):		**Fluid Type:**	
Total Depth (FT):		**Volume Removed:**	
Depth to Top of Screen (FT):		**Evacuation Method:**	
Screen Length (FT):		**LNAPL Well Volume:**	

Length and volumetric units need to be specified

Length Units: **Volume Units:**

Effective Well Radius (FT)	
	LNAPL Well Volume
ft^3	
gal	
ml	

Period	Date	Time HH:MM	Elapsed Time (min)	DTP (feet)	DTW (feet)	Comments
Initial						
Removal Start						Test Start
Removal Stop						LNAPL/Slug Volume Removed (gal): Water Volume Removed (gal):

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Site

Well

Period	Date	Time HH:MM	Elapsed Time (min)	DTP (feet)	DTW (feet)	Comments

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Well_____ Site_____

Skimming Recovery Field Form

Project #:		**Site Name:**	
Well:		**Field Staff:**	
		Weather:	

Well Information		**Recovery System Information**	
Casing Diameter:		**Pump Type:**	
Total Well Depth:		**Recovered Volume Measurement Method:**	
Depth to Top of Screen:		**(Tank Volume, Totalizer, Instantaneous)**	
Screen Length:			

Length and volumetric units need to be specified

Length Units: **Volume Units:**

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Depth to LNAPL	Depth to Water	Pump Depth	Comments

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Well_____ Site_____

Water Enhanced Recovery Field Form

Project #:		Site Name:	
Well:		Field Staff:	
		Weather:	

Well Information		Recovery System Information	
Casing Diameter:		Pump Type:	
Total Well Depth:		Recovered Volume Measurement Method: (Tank Volume, Totalizer, Instantaneous)	
Depth to Top of Screen:			
Screen Length:			

Length and volumetric units need to be specified

Length Units: **Volume Units:** **Vacuum Units:** **Air Flow Units:**

Note:Either measure the Recovered LNAPL and water volumes separately (i.e.,dual pump) or measure the total fluids recovered and oil/water ratio (i.e., total fluids pump)

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Total Fluids Recovered	Oil/Water Ratio	Depth to LNAPL	Depth to Water	Pump Depth	Comments

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Well_____ Site_____

Vacuum Enhanced Recovery Field Form

Project #:			Site Name:	
Well:			Field Staff:	
			Weather:	

Well Information			Recovery System Information	
Casing Diameter:			Pump Type:	
Total Well Depth:			Recovered Volume Measurement Method: (Tank Volume, Totalizer, Instantaneous)	
Depth to Top of Screen:				
Screen Length:				

Length, volumetric, vaccum, and air flow units need to be specified

Length Units: **Volume Units:** **Vacuum Units:** **Air Flow Units:**

Note: Recovered volumes, airflow and well vacuum required

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Airflow	Well Vacuum	Depth to LNAPL	Depth to Water	Pump/ Stinger Depth	Comments

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Well_____ Site_____

Multiphase Recovery Field Form

Project #:		**Site Name:**	
Well:		**Field Staff:**	
		Weather:	

Well Information		**Recovery System Information**	
Casing Diameter:		**Pump Type:**	
Total Well Depth:		**Recovered Volume Measurement Method:**	
Depth to Top of Screen:		**(Tank Volume, Totalizer, Instantaneous)**	
Screen Length:			

Length, volumetric, vaccum, and air flow units need to be specified

Length Units: **Volume Units:** **Vacuum Units:** **Air Flow Units:**

Note: Either measure the Recovered LNAPL and water volumes separately (i.e.,dual pump) or measure the total fluids recovered and oil/water ratio (i.e., total fluids pump); Air flow and vacuum required.

Operational (Y/N)	Date	Time HH:MM	LNAPL Volume Recovered	Water Volume Recovered	Total Fluids Recovered	Oil/water ratio	Airflow	Well Vacuum	Depth to LNAPL	Depth to Water	Pump/ Stinger Depth	Comments

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A2. TABLES

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TABLE A2.1 Method Selection Table—Part One

NOTE 1—All of these methods may be used for confined, unconfined or perched aquifer scenarios; however, the use of recovery system data must be limited to data from technologies applicable for the given hydrogeologic scenario.

Methods	Detection Limit	Test Duration	Area Represented	Frequency of Method Transmissivity Values	Key Data List
Baildown/Slug Test	Typically 0.005 ft^2/day is reasonably achievable with minor water-table changes over length of test. No theoretical limit exists, therefore lower detections are feasible given reasonable test conditions. However, fluctuating water-tables may inhibit analysis of long-term data required for lower detection limits. (See thickness limitations)	Minutes to months–Actual duration is dependent on the recharge rate. However, this method is applicable when time is limited. Partial recovery can be analyzed if starting levels represent equilibrium.	"Point" Value, limited to the radius of influence for the test which is a few feet beyond borehole	Singular event period	-Well Construction -Equilibrium fluid levels -Soil profile across mobile LNAPL interval -LNAPL density -Volume of LNAPL removed/slug -Gauging data prior to test and over recovery period
Manual Skimming	Typically 0.001 ft^2/day is reasonably achievable. No theoretical limit exists, therefore lower detections are feasible given reasonable test conditions. However, fluctuating water-tables may inhibit analysis of long-term data required for lower detection limits.	Hours to weeks–Lower transmissivity wells will require more time, however this method is applicable when time is limited.	″Point″ Value, limited to the radius of influence for the test which is a few feet beyond borehole.	Singular event period	-Well Construction -Equilibrium fluid levels -Soil profile across mobile LNAPL interval -LNAPL density -Recovered volume over time -Gauging data prior to test and over recovery period
Recovery System Data	Detection limits based on combination of the recovery equation input parameter detection limits and/or values. Theoretical limit exists for water enhanced recovery calculations based on accuracy of LNAPL/water ratio measurement and the magnitude of aquifer transmissivities (for example, Aquifer transmissivity of 5,000 ft^2/day and an oil/water ratio detection limit of 0.001 for a gasoline will result in a detection limit of 3.75 ft^2/day).	Because recovery is representative of a relatively large area, steady state conditions need to be reached and maintained. Ongoing estimates are easily obtained based on the frequency of data collection.	"Area" Value, limited by the operational parameters of system and length of continual operation time which result in a given radius of capture. In general, representative of a larger area than other methods.	Continual time series representation	-Well Construction -Equilibrium fluid levels -Soil profile across mobile LNAPL interval -LNAPL density -Recovered LNAPL volume over time -Air/water flow rates -Well vacuum -Gauging data during recovery
Tracer Testing	Field trials have shown 1 ft^2/day is readily achievable with some tests achieving 0.2 ft^2/day. These values are based on a limited number of field trials completed to date. There is no theoretical limitation to the lower bound for transmissivity measurement. However, a simplifying assumption in the analysis is that diffusive dye loss is negligible as compared to loss due to LNAPL movement in the formation. This simplifying assumption may not be valid for measurement of ultra low transmissivity values.	Typical test duration is 3 to 6 months. A long test duration is recommended because the method is based on the natural gradient and a longer duration provides better averaging of individual measurement variability.	"Point" Value, The flux measurement is representative of a few feet outside the borehole. The gradient is representative of the well network density. This method is more applicable to a uniform LNAPL flow field. Uniform LNAPL flow fields occur in homogenous conditions and are often induced by active recovery.	Time-averaged over duration of test	-Well construction -Fluid levels -Hydraulic gradient of air/oil interface -Gauging data prior to test and after test

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TABLE A2.2 Method Selection Table—Part Two

Methods	Influenced by Non-Ideal Conditions	LNAPL Type	In-Well Gauged LNAPL Thickness	Capital Cost	Data Analysis Cost	Startup/Shutdown Metric
Baildown Test	Long-term tests likely affected by background changes in water-table. This includes areas affected by fluctuating rivers, changing pumping conditions and tidal environments	No Limitations have been identified	<0.5 ft - not recommended <0.2 ft - not acceptable	**Low to Medium** Higher costs incurred when tests require excessive time (that is, weeks) to complete at remote sites	**Moderate** Boundary conditions must be check for data set being analyzed	Startup and Shutdown
Manual Skimming	Long-term tests likely affected by background changes in water-table. However, the variability can be better averaged across representative site conditions. Additionally, LNAPL drawdown can be kept at a maximum versus baildown and slug testing where the continually reducing drawdown becomes more susceptible to changes in the water-table	No limitations have been identified	No constraints	**Low** Typically results can be obtained within 1 to 3 days.	**Low to Medium**	Startup and Shutdown
Recovery System Data	Although recovery system data is affected by changes in water-table, the continual time series nature of the data collection can allow for periods of constant water-table elevations to be isolated and analyzed.	No limitations have been identified	No constraints	**Medium** System design needs to include contingencies for accurate parameter measurements. Redundancy for performance parameters is also recommended. Method is more cost effective for time-weighted averaging than baildown or manual skimming tests conducted at same frequency.	**Moderate** Quality assurance is required to confirm system operational efficiency, pump/stinger depth settings and collection of performance data.	Shutdown only
Tracer Testing	LNAPL flux measurements can be affected by changes in the water-table. Negative flux values have been observed under dynamic water table conditions. However, long test duration provides time-weighted averages that mitigates measurement-to-measurement variability. Fluid level fluctuations may complicate LNAPL gradient measurement.	High viscosity LNAPLs can be problematic. In-well LNAPL calibration standards for viscous LNAPLs may be depleted through repeated measurements that coat the measurement tools with LNAPL.	>0.2 ft	**Medium to High** Specialized field equipment is required and data is collected routinely over a period of weeks to months. Method is more cost effective for time-weighted averaging than baildown or manual skimming tests conducted at same frequency.	**Low**	Startup and Shutdown (representativeness may improve after recovery homogenizes LNAPL distribution).

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TABLE A2.3 LNAPL Baildown/Slug Test

Measurement Parameter	Equation Symbol	Apparatus/Method
Equilibrium Fluid Interface Depth: Air-NAPL interface depths	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface depths	Z_{NW^*}	Optical/electrical resistivity interface probe Second pressure transducer w/ LNAPL & water density correction
LNAPL Volume: LNAPL removal measurement	V	Peristaltic pump; submersible pump; bailer, solid slug
LNAPL/H_2O Volume: LNAPL/water removal measurement		Graduated container measurable to 0.1 gal
Fluid Density: LNAPL density	ρ_n	ASTM Test D1298, ASTM Test D1217 ASTM Test D1480, ASTM Test D1481 ASTM Test D4052, ASTM Test D5002
Groundwater density, specific gravity	ρ_w	ASTM Test D1429
Time: Elapsed test time	t	Timepiece measurable to 1 second
Fluid Interface Elevation: Air-LNAPL interface elevation	Z_{AN}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface	Z_{NW}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.4 Manual LNAPL Skimming Test

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL Discharge: Stabilized LNAPL recovery rate	Q_n	Graduated container measurable to 0.1 gal Timepiece measurable to 1 second
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Often assumed equal to 4.6
Fluid Interface Elevation: Air-LNAPL interface elevation at equilibrium	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Air-LNAPL interface	Z_{NW^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log
LNAPL Skimming Drawdown: Unconfined LNAPL at equilibrium	s_n	$Z_{AN^*} - Z_{AN(t)}$
Maximum Skimming Drawdown confined LNAPL	s_n	$Z_{CC} - Z_{NW^*}$
Maximum Skimming Drawdown perched LNAPL	s	$Z_{AN^*} - Z_{CC}$
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Totalizer records (normalized for all system downtime)
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Often assumed equal to 4.6
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.5 LNAPL Skimming Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL Discharge: Stabilized LNAPL recovery rate	Q_n	Graduated container measurable to 0.1 gal Timepiece measurable to 1 second
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Often assumed equal to 4.6
Fluid Interface Elevation: Air-LNAPL interface elevation at equilibrium	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Air-LNAPL interface	Z_{NW^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log
LNAPL Skimming Drawdown: Unconfined LNAPL at equilibrium	s_n	$Z_{AN^*} - Z_{AN(t)}$
Maximum Skimming Drawdown unconfined LNAPL	s_n	$Z_{AN^*} - Z_{CGW}$
Maximum Skimming Drawdown confined LNAPL	s_n	$Z_{CC} - Z_{NW^*}$
Maximum Skimming Drawdown perched LNAPL	$s_n s_n$	$Z_{AN^*} - Z_{CC}$
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Totalizer records (normalized for all system downtime)
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.6 Vacuum-Enhanced LNAPL Skimming Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL-Only Discharge: Stabilized LNAPL recovery rate (L^3/t)	Q_n	Flow meter and totalizer records (normalized for all system downtime)
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Only required if using drawdown based equations Airflow based equations do not require this parameter
Open Screen Length: Screened interval open to vadose zone air flow (L)	b_a	Well Construction data and Soil Boring Log (ASTM E2531)
Air-Phase Relative Permeability: Formation pneumatic permeability	k_{ra}	Generally assumed = 0.9
Hydraulic Conductivity: Formation water saturated hydraulic conductivity (L/t)	K_w	ASTM D4043
Air-Water Viscosity Ratio: Viscosity ratio	μ_{ar}	Usually = 0.018
Air Discharge Rate: Air discharge rate from vacuum system (L^3/t)	Q_a	Airflow meter (normalized for all system downtime)
Vacuum Head: Head reduction in well induced by vacuum system (L)	s_a	Wellhead vacuum gauge Only required if using drawdown based equations Airflow based equations do not require this parameter
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.7 Water-Enhanced LNAPL Recovery Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Flow meter and totalizer records
LNAPL-Water Density Ratio: Density ratio	ρ_r	ρ_{oil}/ρ_{water}
Groundwater Discharge: Groundwater system recovery rate	Q_w	Flow meter and totalizer records
Groundwater Transmissivity: Formation hydraulic conductivity multiplied by saturated thickness in well screen	T_w	ASTM D4043
Effective Radius / Borehole Radius: Dimensionless ratio of effective radius of formation influence to borehole (well) radius	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Only required if using drawdown based equations Oil/water ratio based equation does not require this parameter
Groundwater Drawdown: Groundwater drawdown in recovery well	S_{water}	Estimated by gauging data or via Thiem equation (see Bouwer and Rice, 1976) **(11)** Drawdown will need to be converted into LNAPL head Only required if using drawdown based equations
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.8 Water- and Vacuum-Enhanced LNAPL Recovery Data

Measurement Parameter	Equation Symbol	Apparatus/Method
LNAPL-Only Discharge: Stabilized LNAPL recovery rate	Q_n	Flow meter and totalizer records (normalized for all system downtime)
LNAPL-Water Density Ratio: Density ratio	ρ_r	ρ_{oil}/ρ_{water}
Groundwater Discharge: Groundwater system recovery rate	Q_w	Flow meter and totalizer records (normalized for all system downtime)
Groundwater Transmissivity: Formation hydraulic conductivity multiplied by saturated thickness in well screen	T_w	ASTM D4043
Air-Water Viscosity Ratio: Viscosity ratio	μ_{ar}	Usually = 0.018
Hydraulic Conductivity: Formation water saturated hydraulic conductivity	K_w	ASTM D4043
Air-Phase Relative Permeability: Formation pneumatic permeability	k_{ra}	Generally assumed = 0.9
Air Discharge Rate: Air discharge rate from vacuum system (SCFM)	Q_a	Airflow meter
Open Screen Length: Screened interval above LNAPL level	b_a	
Well vacuum head Water head	s_{aw}	Wellhead vacuum gauge Only required if using vacuum head based equations Airflow based equations do not require this parameter
Pneumatic radius of influence Effective radius of influence of formation air pressure drop	$\ln(R_o/r_w)$	Estimated based on pilot test or calibration of equation to a set of known conditions Only required if using vacuum head based equations Airflow based equations do not require this parameter
Gauged LNAPL thickness	b_n	Difference between the gauged air/LNAPL interface and the water/LNAPL interface in a well. (L)
Formation thickness	b_{nf}	Interval that LNAPL flows over in the formation. For unconfined conditions, this is approximately equal to the gauged LNAPL thickness. Under confined and perched conditions, the gauged LNAPL thickness under equilibrium conditions is not equal to the formation thickness. (L)

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TABLE A2.9 LNAPL Tracer Test

Measurement Parameter	Equation Symbol	Apparatus/Method
Equilibrium Fluid Interface Depth: Air-LNAPL interface depths	Z_{AN^*}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface depths	Z_{NW^*}	Optical/electrical resistivity interface probe Second pressure transducer w/ LNAPL & water density correction
Fluid Density: LNAPL density	ρ_n	ASTM Test D1298, ASTM Test D1217 ASTM Test D1480, ASTM Test D1481 ASTM Test D4052, ASTM Test D5002
Groundwater density, specific gravity	ρ_w	ASTM Test D1429
Time: Elapsed test time	t	Timepiece measurable to 1 second
Initial Tracer Concentration	C_i	Measured via Spectrometer prior to test
Tracer Concentration after mixing	$C_{i+\Delta}$	Measured via Spectrometer prior to test
LNAPL Gradient	i_{LNAPL}	Measured via site gauging data
Flux Convergence Factor	α	Alpha is often assumed to be equal to a value of 1.7
Fluid Interface Elevation: Air-LNAPL interface elevation	Z_{AN}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
LNAPL-water interface	Z_{NW}	Optical/electrical resistivity interface probe Pressure transducer w/ LNAPL density correction
Soil profile across mobile LNAPL interval		Soil boring log from visual or other soil characterization tool (ASTM E2531)
Well Construction Data: Casing radius	r_c	Well Construction Log
Borehole radius	r_b	Well Construction Log
Screen Interval		Well Construction Log

APPENDIXES

(Nonmandatory Information)

X1. APPLICATION OF LNAPL TRANSMISSIVITY METHODS IN TIDALLY INFLUENCED ENVIRONMENTS

X1.1 *Introduction* —Special precautions needs to be taken when measuring LNAPL transmissivity using the methods discussed in this guide under tidal conditions.

X1.1.1 In tidally influenced environments, formation and in-well LNAPL thicknesses (and by extension formation saturations) continuously change with the tide.

X1.1.2 Hence both the variability in the instantaneous LNAPL transmissivity and the effective LNAPL transmissivity average over several tidal cycles may both be of importance.

X1.1.3 The tidal stress will confound the result of a LNAPL transmissivity test at least on the time scale of the tidal cycle or less.

X1.1.4 Adjustments have to be made to the data collection procedure or the timing of the test to account for this effect.

X1.1.5 In some instances, a particular method's utility may be limited due to the time scale for test completion relative to the tidal cycle.

X1.1.6 Also, even in cases where a method may be applicable, the normal accuracy of a test may be compromised under tidal conditions.

X1.1.7 However, useful transmissivity information can still be obtained to improve site understanding, to aid CSM development and guide decision making.

X1.1.8 The magnitude of tidal cycles varies over lunar cycles and should be accounted for in any field test design.

X1.2 *Scope*—The following appendix provides more specific comment for the LNAPL transmissivity methods as applied to tidally influenced environments.

X1.3 *Short-Term Aquifer Testing Methods*:

X1.3.1 These LNAPL transmissivity measurement methods (LNAPL baildown, slug, and manual LNAPL skimming test) are most affected by tides because of the instantaneous nature of the applied stress relative to the tidal cycles.

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X1.3.2 In low LNAPL transmissivity formations where the time to recovery is long relative to the tidal cycle, the results of these short-term methods will be severely impacted by the tides and it is recommended that one the long-term test methods (that is, recovery data-based or tracer methods) or a modification of the recovery data-based method used to estimate an average LNAPL transmissivity for the tidal cycle.

X1.3.3 If the recovery period is short relative to the tidal cycle, the short-term test can be used as outlined below; however, the accuracy of the test will be lower than under non-tidal conditions.

X1.3.4 *LNAPL Baildown Test/Manual Skimming Test:*

X1.3.4.1 If the recovery period of these test are short relative to a tidal cycle (4 h), then these short-term test can be done as outlined in this document, however, the test will be less accurate.

X1.3.4.2 Also, it is recommended that these tests be done covering periods of high tides and low tide to provide a bound on the LNAPL transmissivity value at the tested location.

X1.3.4.3 Data from the pilot test can be analyzed by appropriate method proposed in this document to provide bounds on LNAPL transmissivity.

X1.3.4.4 If the recovery period is long relative to a tidal cycle and the discharge versus drawdown relationship identified in Section 6 cannot be met, then baildown and slug test methods cannot be employed and a long-term method should be employed.

X1.3.4.5 Additionally, if a manual skimming test is used and requires a longer time frame relative to a tidal cycle, the a long-term method should be employed.

X1.4 *Long-Term Aquifer Testing Methods*:

X1.4.1 *Considerations:*

X1.4.1.1 Because of the long-term nature of the applied stress for LNAPL for recovery data-based and tracer methods relative to the time scale of a tidal cycle, these methods can be used as outlined in the standard to estimate LNAPL transmissivity under tidal conditions.

X1.4.1.2 LNAPL recovery systems operate from months to years and the leaching process for tracer tests takes weeks to months.

X1.4.1.3 To determine the LNAPL transmissivity from a tracer test, an estimate of the LNAPL gradient is needed and the shifting gradient induced by the tides will have to be taken into account.

X1.4.1.4 To provide an estimate of the net gradient, a pressure transducer tidal study could be done over several tidal cycles.

X1.4.1.5 A tidal filtering algorithm should be applied to remove tidal effects, and the effective gradient estimated from the unfiltered data for methods relying on absolute drawdown values and/or gradients (that is, skimming and tracer testing).

X1.4.1.6 Data from the pilot test can be analyzed by appropriate method proposed in this document to provide LNAPL transmissivity estimates.

X1.4.1.7 The LNAPL transmissivity determined from these long term tests will averaged over the tidal cycles and effective over the capture/leaching zones of the LNAPL recovery system/tracer test for the time scales measured.

X1.5 *Short-Term Pilot Tests*—If an LNAPL recovery system is not in place or it's impractical to conduct a LNAPL tracer test, a modification of the recovery data-based method can be used; that is, a water enhanced pilot test can be done to provide estimates of LNAPL transmissivity.

X1.5.1 However, it is recommended that either a minimum of two of these tests be done (one covering each extreme of the tidal cycle) or the test be run continuously across a minimum of two tidal cycles.

X1.5.2 Ideally, the pilot test should be run over several tidal cycles.

X1.5.3 The LNAPL transmissivity in the formation may change over the test due to changes within the water level in the formation and mobile LNAPL saturation, however this test would be able to provide both a bound on the range in variability and an average value if designed to collect data at a frequency higher than the tidal cycles (that is, data collection every 1 to 2 h).

X1.5.4 If the data frequency is greater than tidal cycles then only an average value will be obtained.

X1.5.5 Data from the short-term pilot test can be analyzed by the appropriate method proposed in this guide to provide bounds on the LNAPL transmissivity over the capture zone of the test at the time scale of the test.

X1.5.6 The resulting LNAPL transmissivity will be averaged over tidal cycles and effective over the capture zone and time scale of the test.

X1.5.7 Water-enhanced pilot tests are a reasonable method because the analysis relies on the oil/water ratio produced, LNAPL relative density and aquifer transmissivity; the variation in equilibrium fluid levels induced by tidal cycles will not affect the analysis.

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X2. BAILDOWN TEST EXAMPLES

X2.1 Figs. X2.1-X2.23

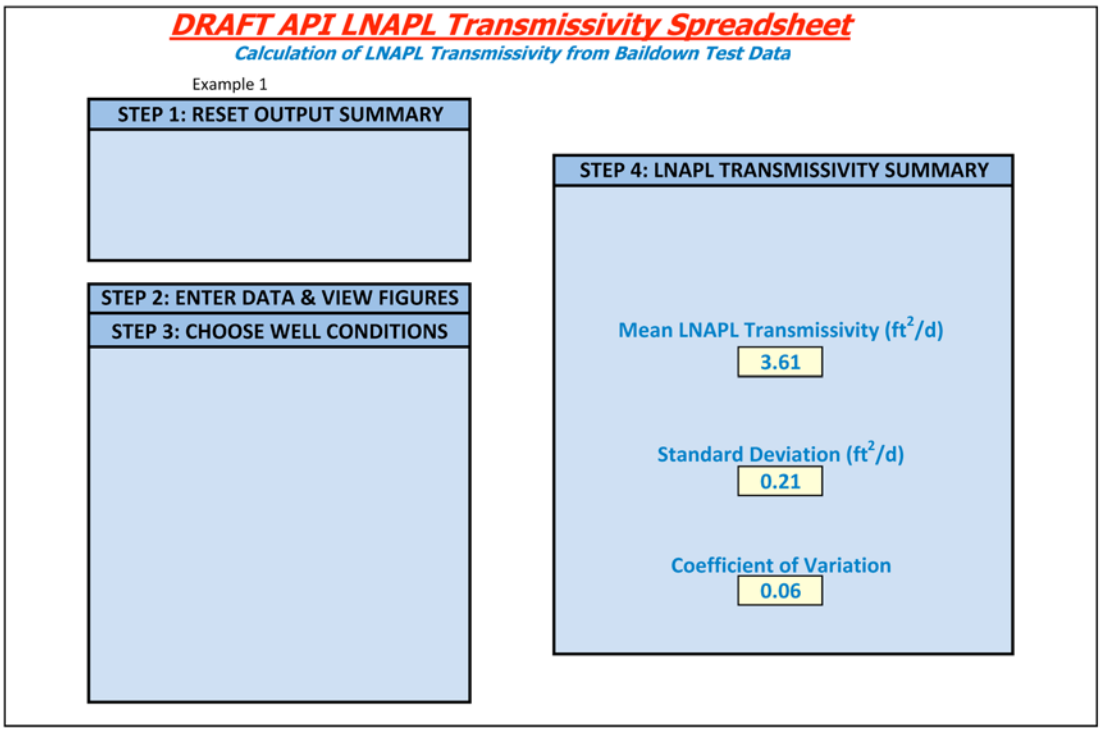


FIG. X2.1 Results Page—Constant Potentiometric Surface

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Example 1
Well Designation: Ideal Unconfined Case
Date:

Ground Surface Elev (ft msl)	0.0	Enter These Data	**Drawdown Adjustment (ft)**
Top of Casing Elev (ft msl)	0.0		
Well Casing Radius, r_c (ft):	0.083	r_{e1}	0
Well Radius, r_w (ft):	0.343333333		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.75		
Top of Screen (ft bgs):	0.0		
Bottom of Screen (ft bgs):	0.0		
LNAPL Baildown Vol. (gal.):	0.0		
Effective Radius, r_{e3} (ft):	0.162	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.147		
Initial Casing LNAPL Vol. (gal.):	0.28		
Initial Filter LNAPL Vol. (gal.):	0.78		

	Enter Data Here			
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)
Initial Fluid Levels:	0	41.14	42.86	41.14	42.86
Test Starts:	0.5	41.46	41.81	41.46	41.81
	1.0	41.45	41.87	41.45	41.87
	2.0	41.45	41.89	41.45	41.89
	3.0	41.44	41.91	41.44	41.91
	4.0	41.43	41.89	41.43	41.89
	6.0	41.42	41.97	41.42	41.97
	9.0	41.40	42.03	41.40	42.03
	12.0	41.38	42.09	41.38	42.09
	15.0	41.36	42.13	41.36	42.13
	20.0	41.34	42.20	41.34	42.20
	25.0	41.32	42.26	41.32	42.26
	30.0	41.30	42.32	41.30	42.32
	35.0	41.29	42.37	41.29	42.37
	40.0	41.27	42.41	41.27	42.41
	48.0	41.25	42.48	41.25	42.48
	55.0	41.23	42.53	41.23	42.53
	65.0	41.21	42.61	41.21	42.61
	75.0	41.19	42.66	41.19	42.66
	85.0	41.18	42.71	41.18	42.71
	95.0	41.16	42.74	41.16	42.74
	105.0	41.15	42.77	41.15	42.77
	127.0	41.15	42.85	41.15	42.85
	154.0	41.15	42.83	41.15	42.83
	179.0	41.14	42.85	41.14	42.85
	218.0	41.14	42.86	41.14	42.86
	1125.0	41.20	42.93	41.20	42.93
	1625.0	41.18	42.93	41.18	42.93
	2615.00	41.18	42.94		
	3087.00	41.15	42.91		

FIG. X2.2 Data Page 1—Constant Potentiometric Surface

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Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Index	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
41.57	0.43					1.72	
41.55	0.32	1.0					
41.56	0.31	2.0	0.7	16.694	0.32	0.42	0.162
41.56	0.31	3.0	1.5	2.385	0.31	0.44	0.162
41.56	0.30	4.0	2.5	3.577	0.31	0.47	0.162
41.55	0.29	5.0	3.5	-1.192	0.29	0.46	0.162
41.56	0.28	6.0	5.0	5.366	0.29	0.55	0.162
41.56	0.26	7.0	7.5	3.180	0.27	0.63	0.162
41.56	0.24	8.0	10.5	3.180	0.25	0.71	0.162
41.55	0.22	9.0	13.5	2.385	0.23	0.77	0.162
41.56	0.20	10.0	17.5	2.146	0.21	0.86	0.162
41.56	0.18	11.0	22.5	1.908	0.19	0.94	0.162
41.56	0.16	12.0	27.5	1.908	0.17	1.02	0.162
41.56	0.15	13.0	32.5	1.431	0.15	1.08	0.162
41.56	0.13	14.0	37.5	1.431	0.14	1.14	0.162
41.56	0.11	15.0	44.0	1.341	0.12	1.23	0.162
41.56	0.09	16.0	51.5	1.192	0.10	1.30	0.162
41.56	0.07	17.0	60.0	1.192	0.08	1.40	0.162
41.56	0.05	18.0	70.0	0.835	0.06	1.47	0.162
41.56	0.04	19.0	80.0	0.715	0.04	1.53	0.162
41.56	0.02	20.0	90.0	0.596	0.03	1.58	0.162
41.56	0.01	21.0	100.0	0.477	0.01	1.62	0.162
41.58	0.01	22.0	116.0	0.434	0.01	1.70	0.162
41.57	0.01	23.0	140.5	-0.088	0.01	1.68	0.162
41.57	0.00	24.0	166.5	0.143	0.00	1.71	0.162
41.57	0.00	25.0	198.5	0.031	0.00	1.72	0.162
41.63	0.06	26.0	671.5	0.001	0.03	1.73	0.162
41.62	0.04	27.0	1375.0	0.005	0.05	1.75	0.162

FIG. X2.3 Data Page 2—Constant Potentiometric Surface

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DTP (ft bgs)	DTW (ft bgs)	LNAPL Volume (gallons)	
		0	
41.46	41.84	0.04	
41.45	41.88	0.06	0
41.45	41.90	0.07	-0.2
41.44	41.90	0.07	-1
41.43	41.93	0.12	-0.25
41.41	42.00	0.17	-0.1765
41.39	42.06	0.22	-0.25
41.37	42.11	0.26	-0.2857
41.35	42.17	0.32	-0.2667
41.33	42.23	0.37	-0.2353
41.31	42.29	0.41	-0.25
41.30	42.35	0.45	-0.2143
41.28	42.39	0.49	-0.25
41.26	42.45	0.55	-0.2667
41.24	42.51	0.59	-0.25
41.22	42.57	0.65	-0.2353
41.20	42.64	0.69	-0.2353
41.19	42.69	0.73	-0.2308
41.17	42.73	0.76	-0.2727
41.16	42.76	0.79	-0.3333
41.15	42.81	0.84	-0.0833
41.15	42.84	0.82	0
41.15	42.84	0.84	-1
41.14	42.86	0.85	-0.25
41.17	42.90	0.85	3
41.19	42.93	0.87	1.33333

FIG. X2.4 Data Page 3—Constant Potentiometric Surface

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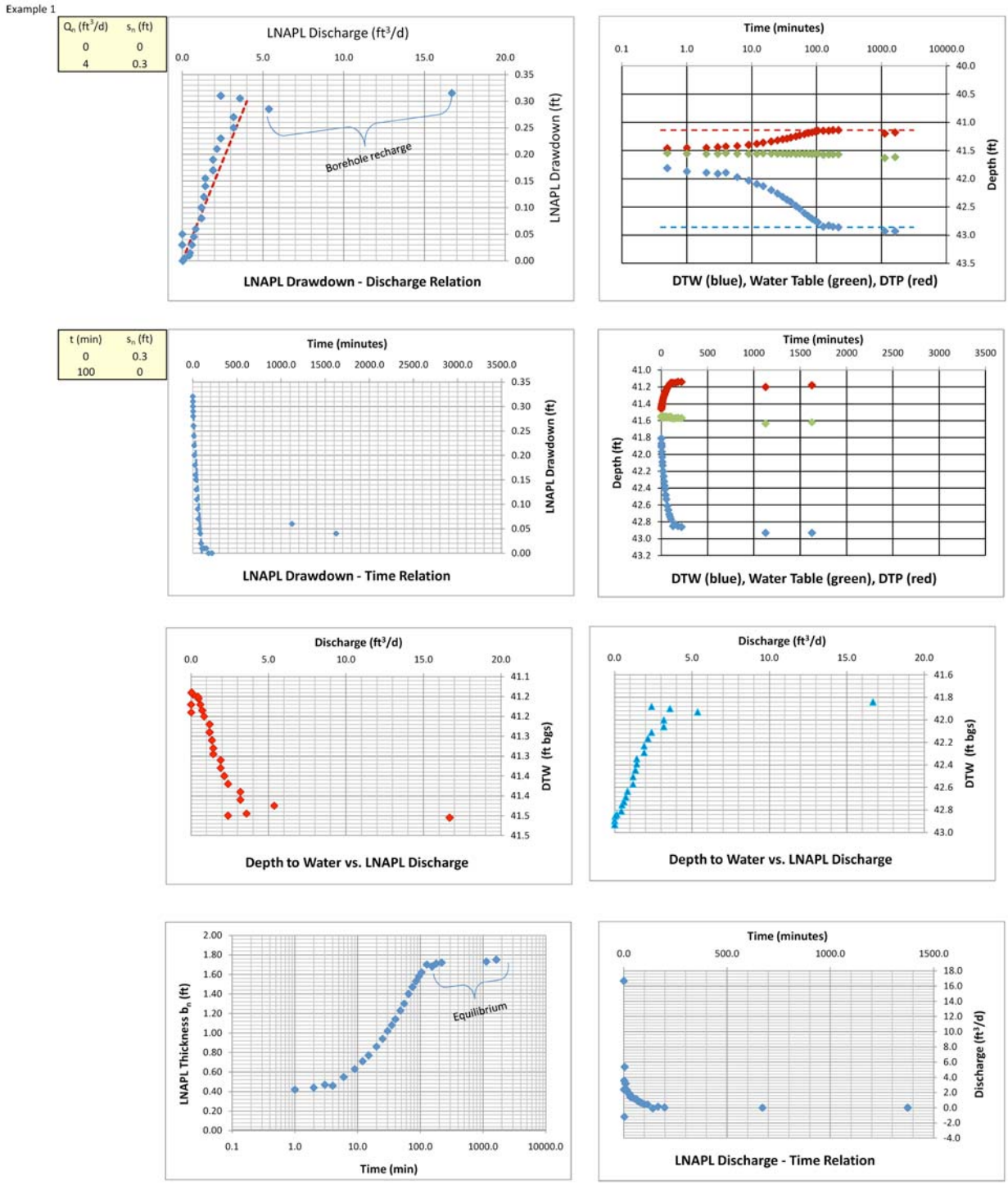


FIG. X2.5 Figures Page 1—Constant Potentiometric Surface

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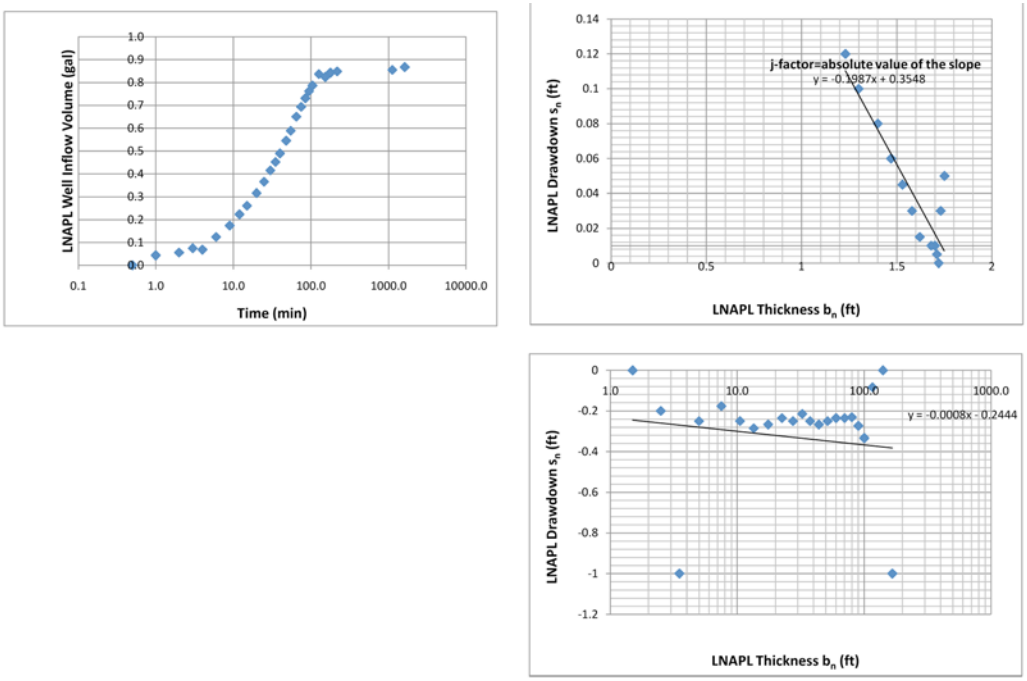


FIG. X2.5 Figures Page 2—Constant Potentiometric Surface *(continued)*

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X_i	Y_i	X^2	XY	$(y-A-Bx)^2$	ε	count	s/s_0
							#N/A
0.00	-1.17	0.00	0.00	0.00	0.00	1	#N/A
1.00	-1.20	1.00	-1.20	0.00	-0.01	1	1.00
2.00	-1.24	4.00	-2.48	0.00	-0.02	1	0.96
4.00	-1.27	16.00	-5.09	0.01	-0.01	1	0.93
7.00	-1.35	49.00	-9.43	0.02	-0.01	1	0.90
10.00	-1.43	100.00	-14.27	0.06	-0.02	1	0.84
13.00	-1.51	169.00	-19.68	0.10	-0.03	1	0.77
18.00	-1.61	324.00	-28.97	0.18	-0.01	1	0.71
23.00	-1.71	529.00	-39.44	0.27	0.01	1	0.64
28.00	-1.83	784.00	-51.31	0.41	0.01	1	0.58
33.00	-1.90	1089.00	-62.60	0.50	0.07	1	0.51
38.00	-2.04	1444.00	-77.53	0.72	0.04	1	0.48
46.00	-2.21	2116.00	-101.53	1.03	0.07	1	0.42
53.00	-2.41	2809.00	-127.62	1.48	0.04	1	0.35
63.00	-2.66	3969.00	-167.53	2.16	0.03	1	0.29
73.00	-3.00	5329.00	-218.69	3.26	-0.07	1	0.22
83.00	-3.22	6889.00	-267.17	4.11	-0.05	1	0.16
							0.13

FIG. X2.6 Bouwer-Rice Worksheet—Constant Potentiometric Surface

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Cooper and Jacob (1946)

Example 1

$$V_n(t_i) = \sum_j^i \frac{4\pi T s_j}{\ln\left(\frac{2.25 T t_j}{r_e^2 S}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Trial S:	0.040	<-- Change S value can be manual
Root-Mean-Square Error:	0.104	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	3.585	<-- By changing T_n (and S)
		Add constraint T_n > 0.00001
Model Result:	T_n (ft^2/d) = 3.58	

Index	t_i	Vi (meas)	Vi (calc)	SE
1	0.7	0.043357	2.67E-02	0.000278813
2	1.5	0.055745	6.16E-02	3.43739E-05
3	2.5	0.074326	8.92E-02	0.000221257
4	3.5	0.068132	1.13E-01	0.001996732
5	5.0	0.123877	1.53E-01	0.000876678
6	7.5	0.173428	2.05E-01	0.00099169
7	10.5	0.222978	2.49E-01	0.000654283
8	13.5	0.260141	2.86E-01	0.000686546
9	17.5	0.315886	3.41E-01	0.000608393
10	22.5	0.365437	3.87E-01	0.000465855
11	27.5	0.414988	4.27E-01	0.000142476
12	32.5	0.452151	4.62E-01	9.95184E-05
13	37.5	0.489314	4.93E-01	1.40577E-05
14	44.0	0.545058	5.34E-01	0.000116887
15	51.5	0.588415	5.63E-01	0.000624037
16	60.0	0.650354	5.96E-01	0.002964359

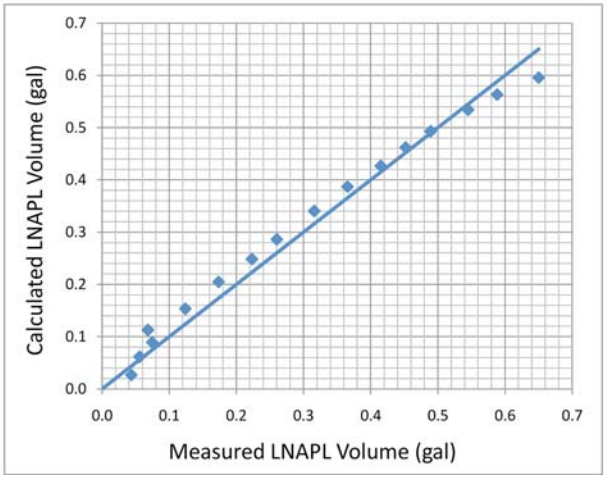


FIG. X2.7 Cooper and Jacob Worksheet—Constant Potentiometric Surface

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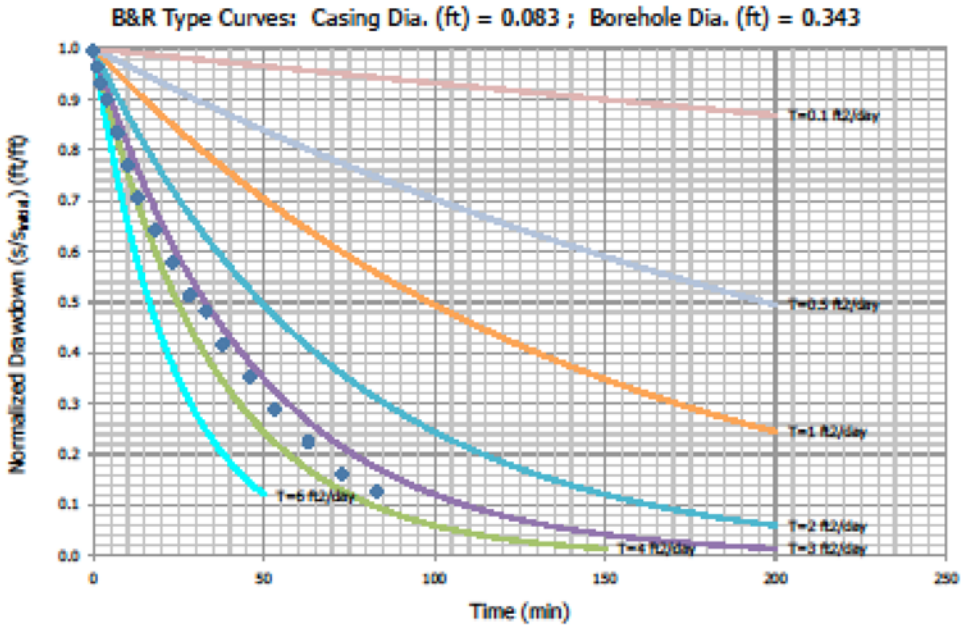
Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Dia. (ft) = 0.083 ; Borehole Dia. (ft) = 0.343

Example 1

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=6 ft2/day		50	6
2	T=4 ft2/day		150	4
3	T=3 ft2/day		200	3
4	T=2 ft2/day		200	2
5	T=1 ft2/day		200	1
6	T=0.5 ft2/day		200	0.5
7	T=0.1 ft2/day		200	0.1



Field Data

Record Data in Fields Below						Calculate and Plot Fields Below		
Well ID		Well Dia. (ft)		Total Depth (ft)				
Notes	Date	Time	Elapsed Time (min)	Depth To Product (TOC)	Depth to Water (TOC)	Product Thickness (ft)	Drawdown (s) DTP-DTP(Initial) (ft)	Normalized Drawdown ($s/s_{initial}$)
Initial Measurement								
Stopped Bailing/Start Gauging			0					
Well Starts recovering								

FIG. X2.8 Bouwer-Rice Type Curve Worksheet—Constant Potentiometric Surface

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Cooper, Bredehoeft and Papadopulos (1967)

Example 1

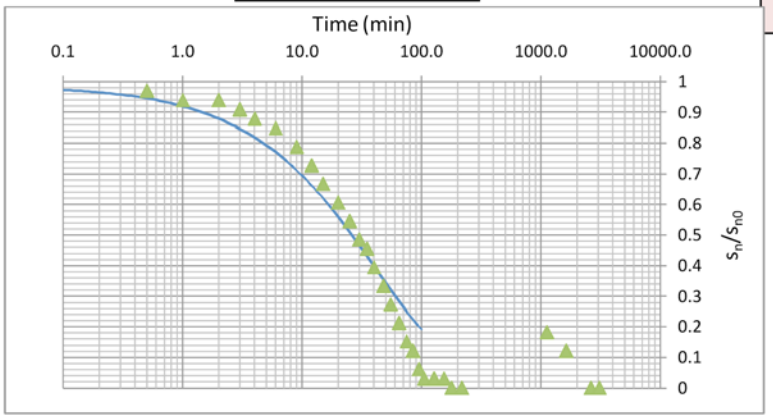
Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Initial Drawdown s_n (ft):	0.33	
Trial S:	0.036	<-- Adjust manually or through "Solver"
Root-Mean-Square Error:	0.432	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	3.830	<-- By changing T_n through "Solver" (and S)

Add constraint Tn > 0.00001

Model Result: T_n (ft^2/d) = 3.83 0.06786

T_{min}	0.1
T_{max}	100



Count	Time (min)	H/H_o	G (a,b,e)	SE
1	0.500	0.969697	0.94551064	0.000584979
1	1.000	0.939394	0.91967573	0.000388808
1	2.000	0.939394	0.87954636	0.003581732
1	3.000	0.909091	0.8471282	0.003839377
1	4.000	0.878788	0.81909598	0.003563123
1	6.000	0.848485	0.7712209	0.005969717
1	9.000	0.787879	0.71217583	0.005730937
1	12.000	0.727273	0.66291707	0.004141651
1	15.000	0.666667	0.62043647	0.002137231
1	20.000	0.606061	0.56045422	0.002079942
1	25.000	0.545455	0.51039042	0.001229493
1	30.000	0.484848	0.46769623	0.0002942
1	35.000	0.454545	0.43073951	0.000566723
1	40.000	0.393939	0.39839078	1.98148E-05
1	48.000	0.333333	0.35423876	0.000437037
1	55.000	0.272727	0.3216953	0.002397867
1	65.000	0.212121	0.28279424	0.004994676
1	75.000	0.151515	0.25081234	0.009859932
1	85.000	0.121212	0.22415878	0.010598015
1	95.000	0.060606	0.2016938	0.019905751
1	105.000	0.030303	0.1825761	0.023187087
1	127.000	0.030303	0.14938045	0.014179431
1	154.000	0.030303	0.12021381	0.008083949
1	179.000	0	0.10063937	0.010128282
1	218.000	0	0.07907575	0.006252975
1	1125.000	0.181818	0.01087427	0.02922182
1	1625.000	0.121212	0.00726318	0.012984362
1	2615.000	0	0.0043724	1.91179E-05
1	3087.000	0	0.0036735	1.34946E-05
0	0.000	0	0	0
0	0.000	0	0	0
0	0.000	0	0	0

FIG. X2.9 Cooper, Bredehoeft and Papadopulos Worksheet—Constant Potentiometric Surface

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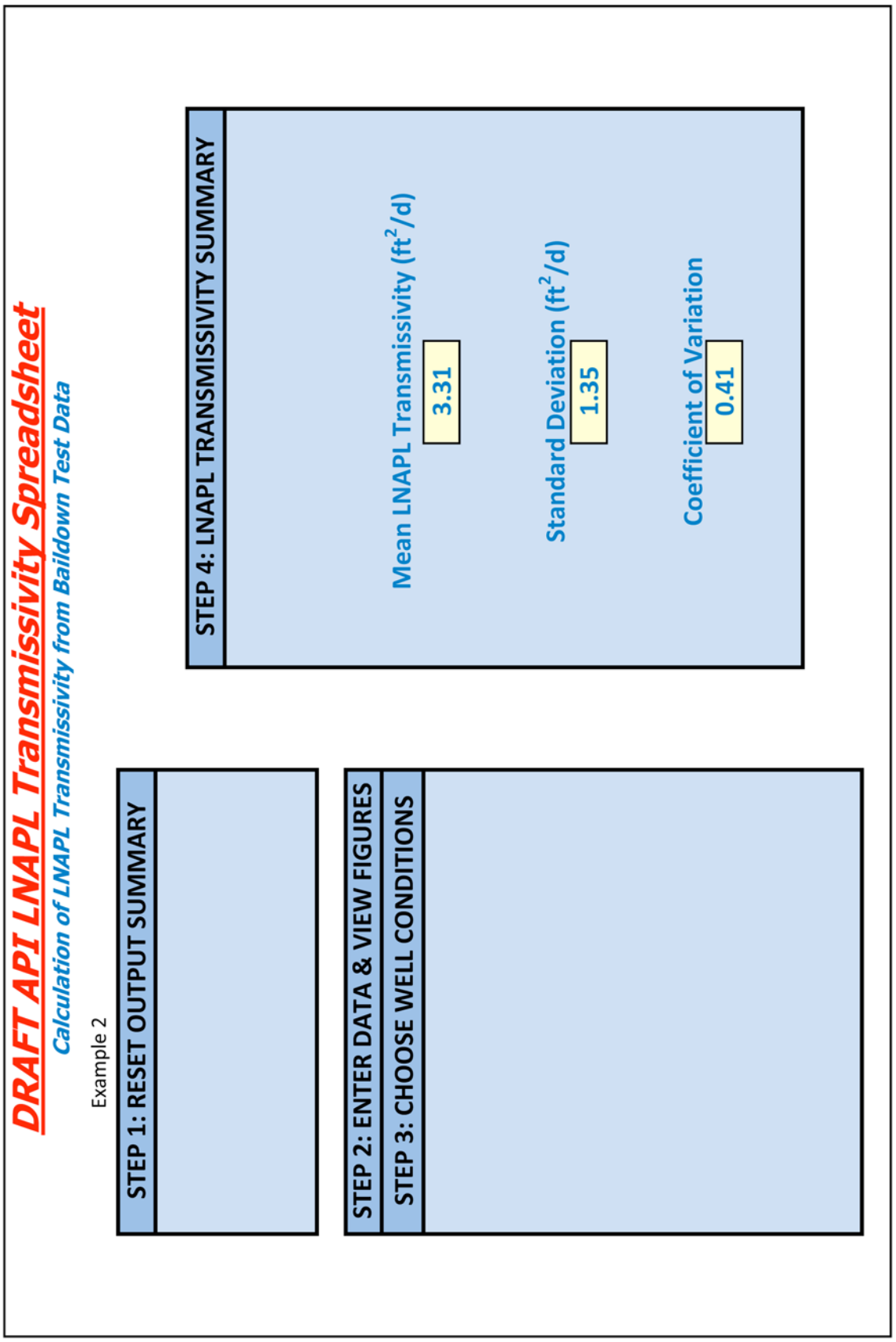


FIG. X2.10 Results Page—Constant LNAPL/water Interface

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Example 2
Well Designation: Relatively constant O-W interface
Date:

Ground Surface Elev (ft msl)	20.1	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	20.1		
Well Casing Radius, r_c (ft):	0.167	r_{e1}	0
Well Radius, r_w (ft):	0.5000		
LNAPL Specific Yield, S_y:	0.105		
LNAPL Density Ratio, ρ_r:	0.87		
Top of Screen (ft bgs):	8.0		
Bottom of Screen (ft bgs):	28.0		
LNAPL Baildown Vol. (gal.):	8.0		
Effective Radius, r_{e3} (ft):	0.226	Calculated Parameters	
Effective Radius, r_{e2} (ft):	0.219		
Initial Casing LNAPL Vol. (gal.):	4.76		
Initial Filter LNAPL Vol. (gal.):	4.00		

	Enter Data Here											
	Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Water Table Depth (ft)	LNAPL Drawdown s_n (ft)	Index	Average Time (min)	LNAPL Discharge Q_n (ft^3/d)	s_n (ft)	b_n (ft)	r_e (ft)
Initial Fluid Levels:	0	19.85	27.14	19.85	27.14	20.80	0.95					7.29	
Test Starts:	1.0	26.45	27.27	26.45	27.27	26.56	6.60	1.0					
	3.0	25.73	27.21	25.73	27.21	25.92	5.88	2.0	2.0	76.303	6.24	1.48	0.226
	5.0	25.25	27.18	25.25	27.18	25.50	5.40	3.0	4.0	52.025	5.64	1.93	0.226
	7.0	24.80	27.12	24.80	27.12	25.10	4.95	4.0	6.0	45.088	5.18	2.32	0.226
	9.0	24.30	27.08	24.30	27.08	24.66	4.45	5.0	8.0	53.181	4.70	2.78	0.226
	11.0	23.91	27.04	23.91	27.04	24.32	4.06	6.0	10.0	40.464	4.26	3.13	0.226
	15.0	23.15	26.95	23.15	26.95	23.64	3.30	7.0	13.0	38.730	3.68	3.80	0.226
	20.0	22.40	26.88	22.40	26.88	22.98	2.55	8.0	17.5	31.446	2.93	4.48	0.226
	25.0	21.85	26.82	21.85	26.82	22.50	2.00	9.0	22.5	22.660	2.28	4.97	0.226
	30.0	21.42	26.80	21.42	26.80	22.12	1.57	10.0	27.5	18.960	1.79	5.38	0.226
	36.0	21.08	26.77	21.08	26.77	21.82	1.23	11.0	33.0	11.946	1.40	5.69	0.226
	40.0	20.90	26.78	20.90	26.78	21.66	1.05	12.0	38.0	10.983	1.14	5.88	0.226
	44.0	20.78	26.77	20.78	26.77	21.56	0.93	13.0	42.0	6.359	0.99	5.99	0.226
	50.0	20.61	26.75	20.61	26.75	21.41	0.76	14.0	47.0	5.781	0.85	6.14	0.226
	55.0	20.54	26.76	20.54	26.76	21.35	0.69	15.0	52.5	3.700	0.73	6.22	0.226
	60.0	20.47	26.75	20.47	26.75	21.29	0.62	16.0	57.5	2.775	0.66	6.28	0.226
	70.0	20.34	26.76	20.34	26.76	21.17	0.49	17.0	65.0	3.237	0.56	6.42	0.226
	80.0	20.28	26.76	20.28	26.76	21.12	0.43	18.0	75.0	1.387	0.46	6.48	0.226
	90.0	20.22	26.77	20.22	26.77	21.07	0.37	19.0	85.0	1.619	0.40	6.55	0.226
	100.0	20.20	26.76	20.20	26.76	21.05	0.35	20.0	95.0	0.231	0.36	6.56	0.226
	110.0	20.17	26.81	20.17	26.81	21.03	0.32	21.0	105.0	1.850	0.34	6.64	0.226
	120.0	20.14	26.82	20.14	26.82	21.01	0.29	22.0	115.0	0.925	0.31	6.68	0.226
	150.0	20.08	26.88	20.08	26.88	20.96	0.23	23.0	135.0	0.925	0.26	6.80	0.226
	180.0	20.03	26.91	20.03	26.91	20.92	0.18	24.0	165.0	0.617	0.21	6.88	0.226
	240.0	19.96	27.00	19.96	27.00	20.88	0.11	25.0	210.0	0.617	0.15	7.04	0.226
	300.0	19.91	27.06	19.91	27.06	20.84	0.06	26.0	270.0	0.424	0.09	7.15	0.226

FIG. X2.11 Data Page—Constant LNAPL/water Interface

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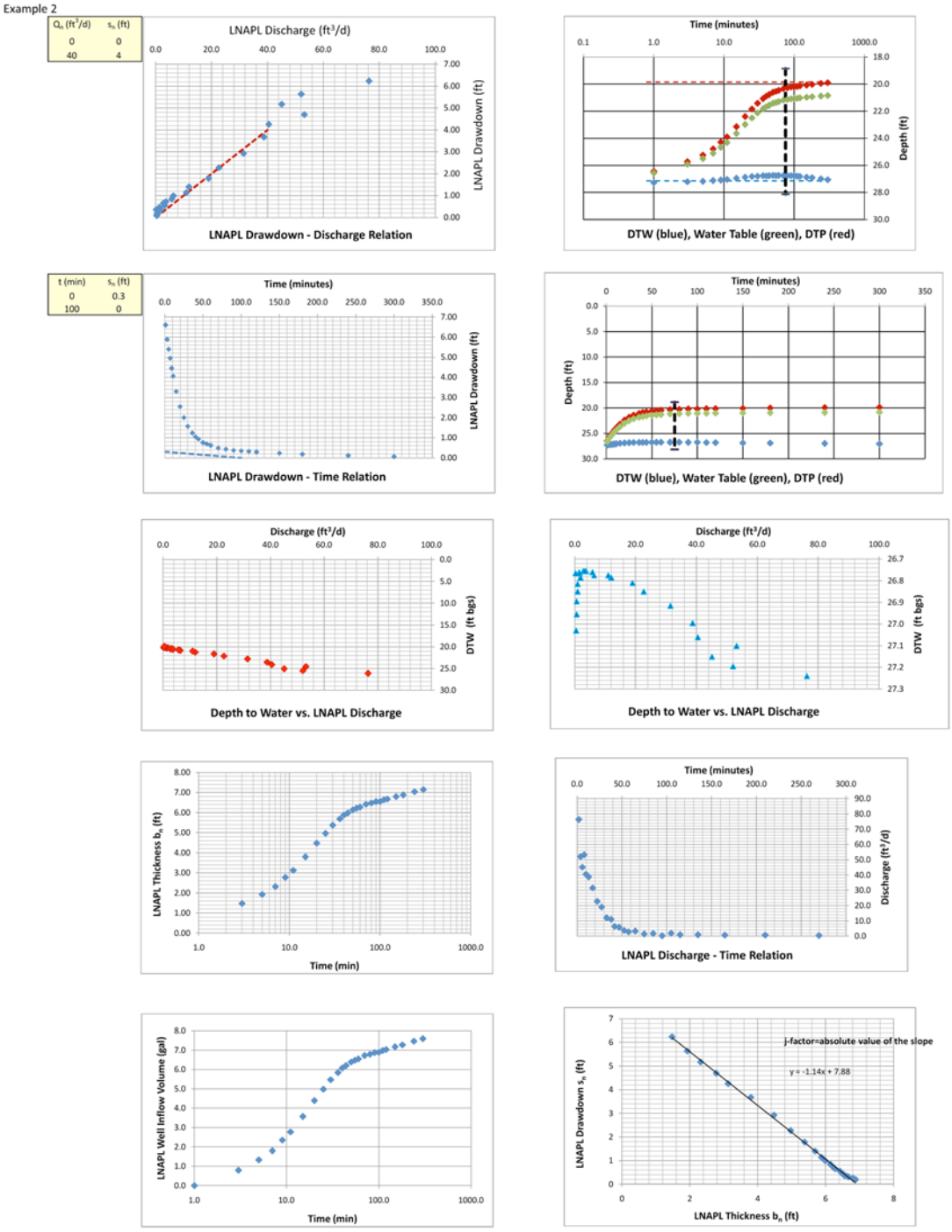


FIG. X2.12 Figures Page—Constant LNAPL/water Interface

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X_i	Y_i	X^2	XY	$(y-A-Bx)^2$	ε	count	s/s_0
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
1.00	1.77	1.00	1.77	0.00	0.04	1	1.00
3.00	1.69	9.00	5.06	0.00	0.04	1	0.92
5.00	1.60	25.00	8.00	0.02	0.04	1	0.84
7.00	1.49	49.00	10.45	0.05	0.02	1	0.76
9.00	1.40	81.00	12.61	0.11	0.02	1	0.69
13.00	1.19	169.00	15.52	0.28	-0.01	1	0.56
18.00	0.94	324.00	16.85	0.62	-0.04	1	0.43
23.00	0.69	529.00	15.94	1.07	-0.06	1	0.34
28.00	0.45	784.00	12.63	1.62	-0.08	1	0.27
34.00	0.21	1156.00	7.04	2.31	-0.06	1	0.21
38.00	0.05	1444.00	1.85	2.81	-0.05	1	0.18
42.00	-0.07	1764.00	-3.05	3.23	-0.01	1	0.16
48.00	-0.27	2304.00	-13.17	4.00	0.03	1	0.13
53.00	-0.37	2809.00	-19.67	4.39	0.13	1	0.12

FIG. X2.13 Bouwer-Rice Worksheet—Constant LNAPL/water Interface

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Cooper and Jacob (1946)

Example 2

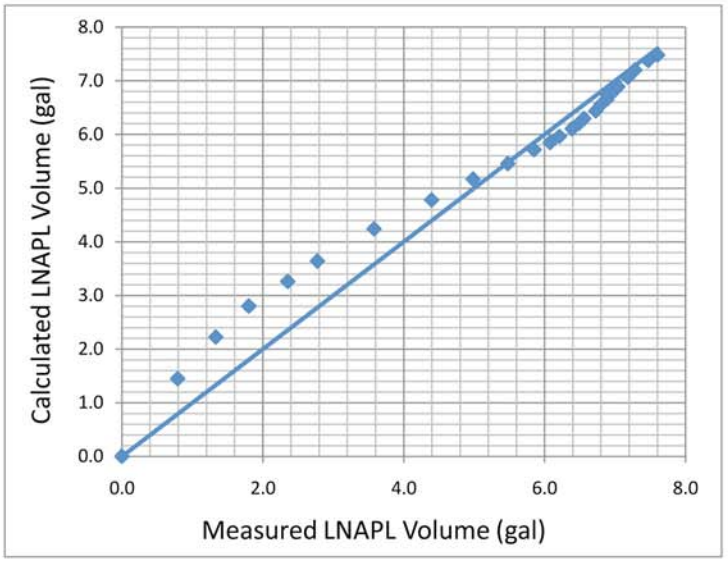
$$V_n(t_i) = \sum_j^i \frac{4\pi T s_j}{\ln\left(\frac{2.25 T t_j}{r_e^2 S}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Trial S:	0.040	<-- Change S value can be manual
Root-Mean-Square Error:	2.252	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	1.798	<-- By changing T_n (and S)

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **1.80**



Index	t_i	Vi (meas)	Vi (calc)	SE
1	2.0	0.79270341	1.45E+00	0.43047
2	4.0	1.33318301	2.23E+00	0.79663
3	6.0	1.80159867	2.80E+00	0.999976
4	8.0	2.35408892	3.26E+00	0.824001
5	10.0	2.77446195	3.64E+00	0.754402
6	13.0	3.57917602	4.24E+00	0.439837
7	17.5	4.39590075	4.78E+00	0.149229
8	22.5	4.98442298	5.17E+00	0.034929
9	27.5	5.47685995	5.46E+00	0.000293
10	33.0	5.84919034	5.72E+00	0.017145
11	38.0	6.07739284	5.85E+00	0.050096
12	42.0	6.20951007	5.97E+00	0.058237
13	47.0	6.38966994	6.11E+00	0.077673
14	52.5	6.4857552	6.21E+00	0.07581
15	57.5	6.55781915	6.30E+00	0.067301
16	65.0	6.72596836	6.44E+00	0.079837
17	75.0	6.7980323	6.56E+00	0.056707
18	85.0	6.88210691	6.66E+00	0.049987
19	95.0	6.89411757	6.75E+00	0.022156
20	105.0	6.99020283	6.82E+00	0.027504
21	115.0	7.03824546	6.90E+00	0.020498
22	135.0	7.18237335	7.07E+00	0.012545
23	165.0	7.27845861	7.20E+00	0.005624
24	210.0	7.47062914	7.38E+00	0.00755
25	270.0	7.60274638	7.48E+00	0.013882
26	0.0	0	0.00E+00	0
27	0.0	0	0.00E+00	0
28	0.0	0	0.00E+00	0
29	0.0	0	0.00E+00	0
30	0.0	0	0.00E+00	0
31	0.0	0	0.00E+00	0
32	0.0	0	0.00E+00	0
33	0.0	0	0.00E+00	0

FIG. X2.14 Cooper and Jacob Worksheet—Constant LNAPL/water Interface

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Cooper, Bredehoeft and Papadopulos (1967)

Example 2

Enter early time cut-off for least-squares model fit

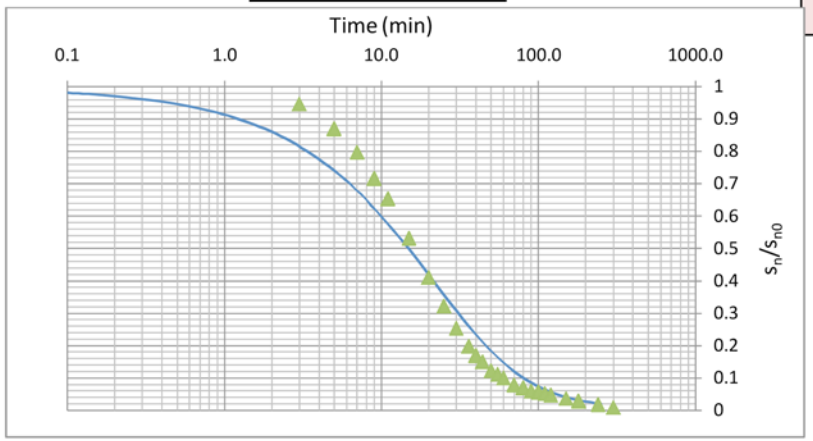
$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Initial Drawdown s_n (ft):	6.2	

Trial S:	0.005	<-- Adjust manually or through "Solver"
Root-Mean-Square Error:	0.341	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	4.393	<-- By changing T_n through "Solver" (and S)

Add constraint Tn > 0.00001

Model Result: T_n (ft^2/d) = 4.39 0.077842

T_{min}	0.1
T_{max}	250



Count	Time (min)	H/H_o	G (a,b,e)	SE
1	1.000	1.064516	0.9138387	0.022704
1	3.000	0.948387	0.81586235	0.017563
1	5.000	0.870968	0.74060068	0.016996
1	7.000	0.798387	0.67784769	0.01453
1	9.000	0.717742	0.62384676	0.008816
1	11.000	0.654839	0.57655128	0.006129
1	15.000	0.532258	0.49720815	0.001228
1	20.000	0.41129	0.41898496	5.92E-05
1	25.000	0.322581	0.35736551	0.00121
1	30.000	0.253226	0.30787019	0.002986
1	36.000	0.198387	0.26036763	0.003842
1	40.000	0.169355	0.23426983	0.004214
1	44.000	0.15	0.21172819	0.00381
1	50.000	0.122581	0.18332371	0.00369
1	55.000	0.11129	0.16365351	0.002742
1	60.000	0.1	0.14690143	0.0022
1	70.000	0.079032	0.1201752	0.001693
1	80.000	0.069355	0.10012386	0.000947
1	90.000	0.059677	0.08478382	0.00063
1	100.000	0.056452	0.07284058	0.000269
1	110.000	0.051613	0.06339255	0.000139
1	120.000	0.046774	0.0558084	8.16E-05
1	150.000	0.037097	0.0403192	1.04E-05
1	180.000	0.029032	0.03111429	4.33E-06
1	240.000	0.017742	0.02106869	1.11E-05
1	300.000	0.009677	0.01584122	3.8E-05
0	0.000	0	0	0
0	0.000	0	0	0

FIG. X2.15 Cooper, Bredehoeft and Papadopulos Worksheet—Constant LNAPL/water Interface

Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Dia. (ft) = 0.167 ; Borehole Dia. (ft) = 0.5

Example 2

			Enter these values	
Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=6 ft2/day		50	6
2	T=4 ft2/day		150	4
3	T=3 ft2/day		200	3
4	T=2 ft2/day		200	2
5	T=1 ft2/day		200	1
6	T=0.5 ft2/day		200	0.5
7	T=0.1 ft2/day		200	0.1

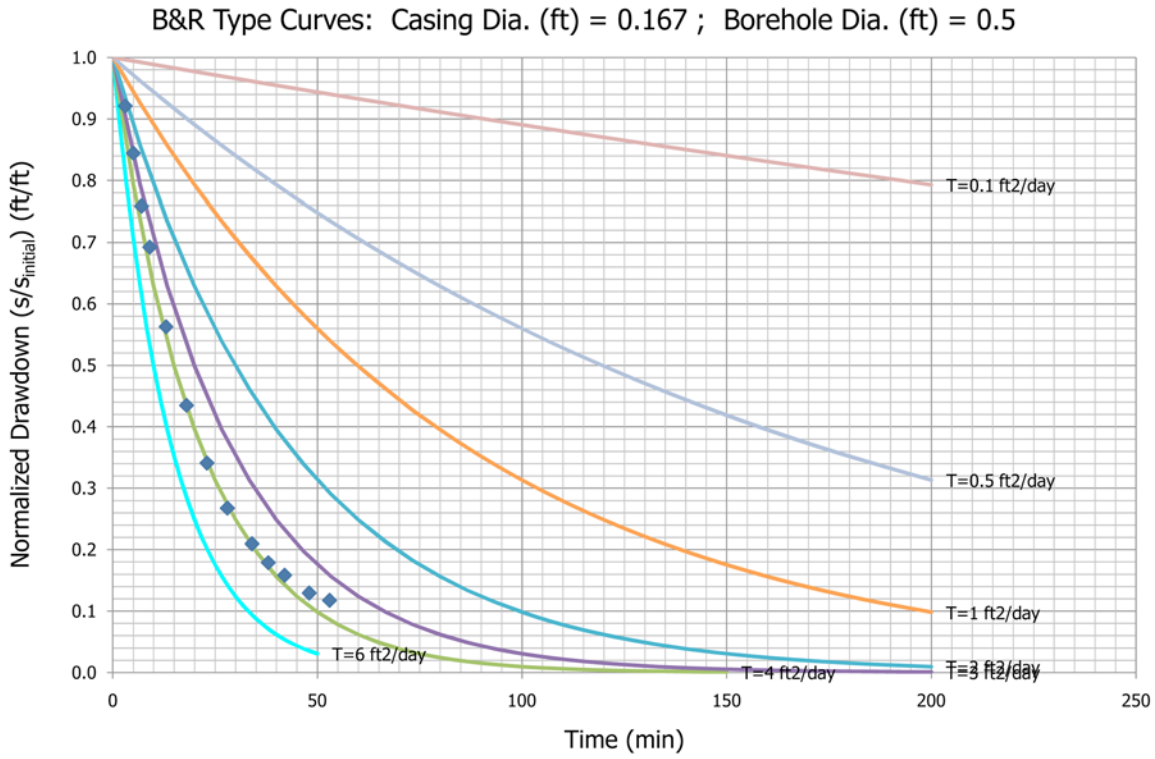


FIG. X2.16 Bouwer-Rice Type Curve Worksheet—Constant LNAPL/water Interface

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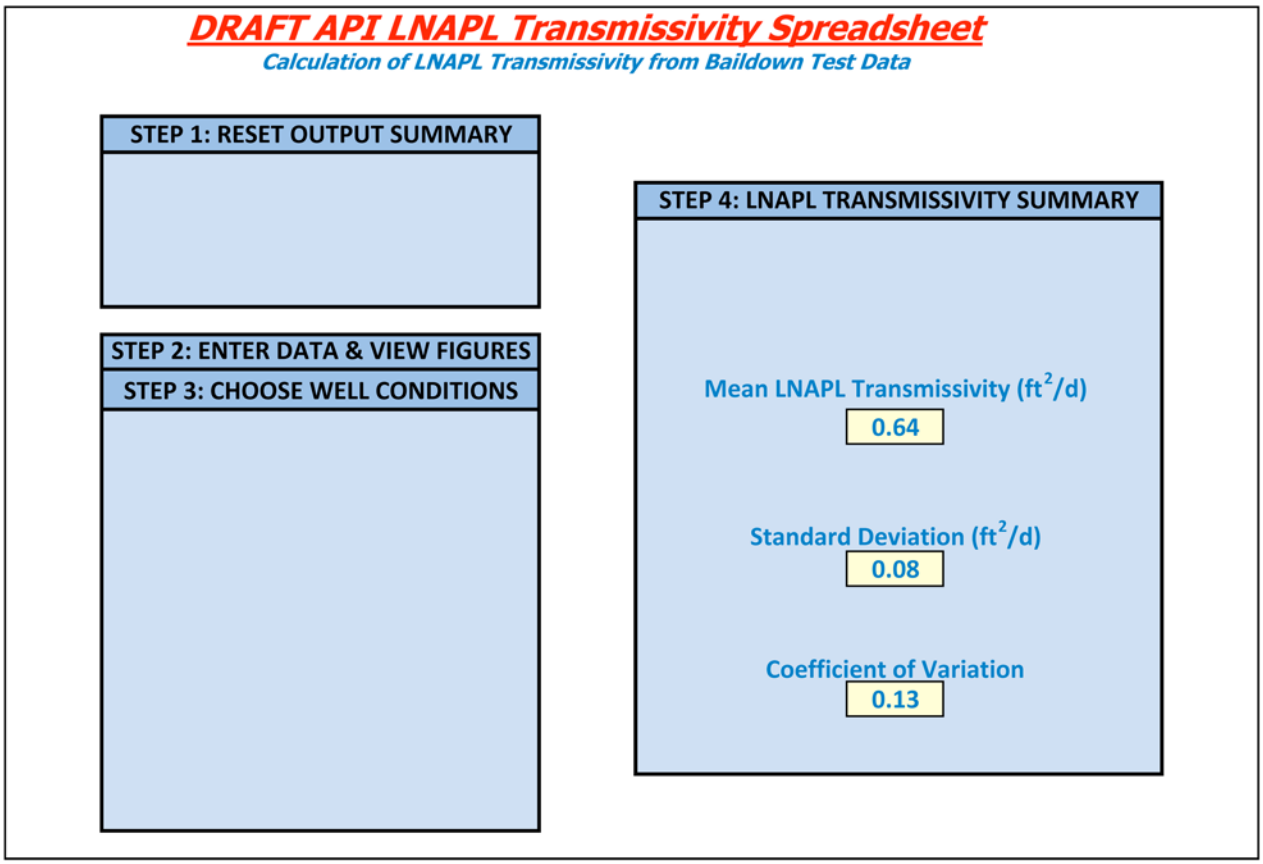


FIG. X2.17 Results Page—Variable LNAPL/Water Interface

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Well Designation: Example 3: Variable Water-table and Oil/water interface
Date:

Ground Surface Elev (ft msl)	0.0	Enter These Data	Drawdown Adjustment (ft)
Top of Casing Elev (ft msl)	0.0		
Well Casing Radius, r_c (ft):	0.167	r_{e1}	0
Well Radius, r_w (ft):	0.4167		
LNAPL Specific Yield, S_y:	0.175		
LNAPL Density Ratio, ρ_r:	0.79		
Top of Screen (ft bgs):	0.0		
Bottom of Screen (ft bgs):	0.0		
LNAPL Baildown Vol. (gal.):	0.0	Calculated Parameters	
Effective Radius, r_{e3} (ft):	0.231		
Effective Radius, r_{e2} (ft):	0.219		
Initial Casing LNAPL Vol. (gal.):	6.19		
Initial Filter LNAPL Vol. (gal.):	5.69		

Initial Fluid Levels:

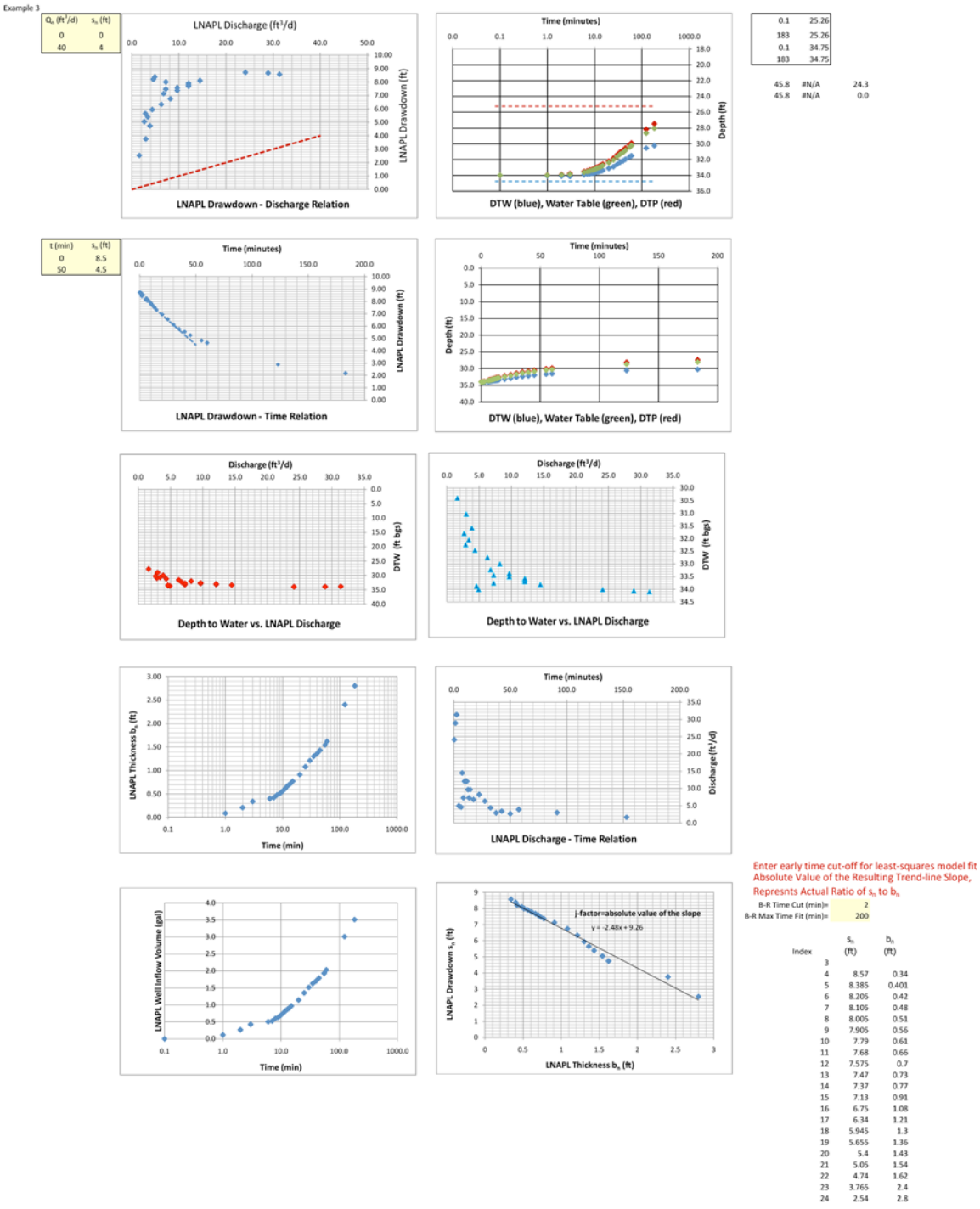
Test Starts:

Enter Data Here					Water Table	LNAPL		LNAPL								
Time (min)	DTP (ft btoc)	DTW (ft btoc)	DTP (ft bgs)	DTW (ft bgs)	Depth (ft)	Drawdown s_n (ft)	Index	Average Time (min)	Discharge Q_n (ft²/d)	s_n (ft)	b_n (ft)	r_e (ft)	DTP (ft bgs)	DTW (ft bgs)	LNAPL Volume (gallons)	
0	25.26	34.75	25.26	34.75	27.25	1.99					9.49					
0.1	33.98	33.98	33.98	33.98	33.98	8.72	1.0									
1.0	33.96	34.05	33.96	34.05	33.98	8.70	2.0	0.6	24.112	8.71	0.09	0.231	33.97	34.02	0.11	-0.6667
2.0	33.88	34.09	33.88	34.09	33.92	8.62	3.0	1.5	28.934	8.66	0.21	0.231	33.92	34.07	0.26	-0.72
3.0	33.78	34.12	33.78	34.12	33.85	8.52	4.0	2.5	31.345	8.57	0.34	0.231	33.83	34.11	0.43	-1.9372
6.0	33.51	33.91	33.51	33.91	33.59	8.25	5.0	4.5	4.903	8.39	0.40	0.231	33.65	34.02	0.50	-4.5
7.0	33.42	33.84	33.42	33.84	33.51	8.16	6.0	6.5	4.581	8.21	0.42	0.231	33.47	33.88	0.53	-2.5316
8.0	33.31	33.79	33.31	33.79	33.41	8.05	7.0	7.5	14.467	8.11	0.48	0.231	33.37	33.82	0.60	-2.2222
9.0	33.22	33.73	33.22	33.73	33.33	7.96	8.0	8.5	7.234	8.01	0.51	0.231	33.27	33.76	0.64	-2.5
10.0	33.11	33.67	33.11	33.67	33.23	7.85	9.0	9.5	12.056	7.91	0.56	0.231	33.17	33.70	0.70	-2.3
11.0	32.99	33.60	32.99	33.60	33.12	7.73	10.0	10.5	12.056	7.79	0.61	0.231	33.05	33.64	0.76	-2.2
12.0	32.89	33.55	32.89	33.55	33.03	7.63	11.0	11.5	12.056	7.68	0.66	0.231	32.94	33.58	0.83	-2.3333
13.0	32.78	33.48	32.78	33.48	32.93	7.52	12.0	12.5	9.645	7.58	0.70	0.231	32.84	33.52	0.88	-3
14.0	32.68	33.41	32.68	33.41	32.83	7.42	13.0	13.5	7.234	7.47	0.73	0.231	32.73	33.45	0.91	-2.8571
15.0	32.58	33.35	32.58	33.35	32.74	7.32	14.0	14.5	9.645	7.37	0.77	0.231	32.63	33.38	0.96	-2.6667
20.0	32.20	33.11	32.20	33.11	32.39	6.94	15.0	17.5	6.751	7.13	0.91	0.231	32.39	33.23	1.14	-2.4516
25.0	31.82	32.90	31.82	32.90	32.05	6.56	16.0	22.5	8.198	6.75	1.08	0.231	32.01	33.01	1.35	-2.7333
30.0	31.38	32.59	31.38	32.59	31.63	6.12	17.0	27.5	6.269	6.34	1.21	0.231	31.60	32.75	1.52	-3.5909
35.0	31.03	32.33	31.03	32.33	31.30	5.77	18.0	32.5	4.340	5.95	1.30	0.231	31.21	32.46	1.63	-3.8667
40.0	30.80	32.16	30.80	32.16	31.09	5.54	19.0	37.5	2.893	5.66	1.36	0.231	30.92	32.25	1.70	-3.9231
45.0	30.52	31.95	30.52	31.95	30.82	5.26	20.0	42.5	3.376	5.40	1.43	0.231	30.66	32.06	1.79	-3.8889
55.0	30.10	31.64	30.10	31.64	30.42	4.84	21.0	50.0	2.652	5.05	1.54	0.231	30.31	31.80	1.93	-3.2632
60.0	29.90	31.52	29.90	31.52	30.24	4.64	22.0	57.5	3.858	4.74	1.62	0.231	30.00	31.58	2.03	-2.2674
123.0	28.15	30.55	28.15	30.55	28.65	2.89	23.0	91.5	2.985	3.77	2.40	0.231	29.03	31.04	3.01	-2.0763
183.0	27.45	30.25	27.45	30.25	28.04	2.19	24.0	153.0	1.607	2.54	2.80	0.231	27.80	30.40	3.51	

FIG. X2.18 Data Page—Variable LNAPL/Water Interface

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Index	s_n (ft)	b_n (ft)
3		
4	8.57	0.34
5	8.385	0.401
6	8.205	0.42
7	8.105	0.48
8	8.005	0.51
9	7.905	0.56
10	7.79	0.61
11	7.68	0.66
12	7.575	0.7
13	7.47	0.73
14	7.37	0.77
15	7.13	0.91
16	6.75	1.08
17	6.34	1.21
18	5.945	1.3
19	5.655	1.36
20	5.4	1.43
21	5.05	1.54
22	4.74	1.62
23	3.765	2.4
24	2.54	2.8

FIG. X2.19 Figure Page—Variable LNAPL/Water Interface

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Bouwer and Rice (1976)

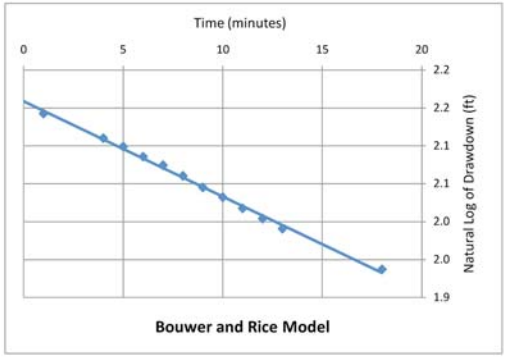
Example 3

$$T_n = \frac{r_c^2 \ln(R/r_e) \ln(s_n(t_1)/s_n(t))}{2(1-\rho_r)(t-t_1)}$$

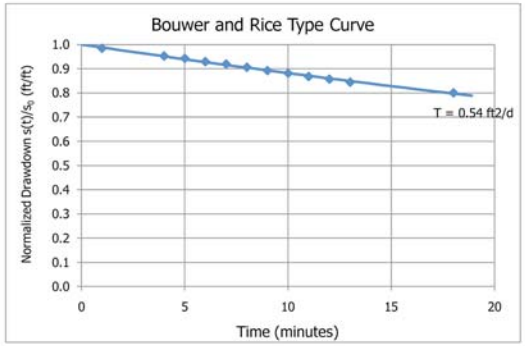
Go To 'Figures' Cell V78, prior to analysis

$Time_{cut}$	2	<- From Figures, Cell V78
Ratio of s_n to b_n	2.5	<- Use $(1-\rho_r)$ or field value from 'Figures' tab

Model Results: T_n (ft^2/d) = 0.54 +/- 0.35 ft^2/d



C coefficient calculated from Eq. 6.5(c) of Butler, The Design, Performance, and Analysis of Slug Tests, CRC Press, 2000.



L_e/r_e	41.1
C	2.44
R/r_e	16.69
Coef. Of Variation	0.64

X_i	Y_i	X^2	XY	$(y-A-Bx)^2$	ε	count	s/s_0
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
0.00	0.00	0.00	0.00	0.00	0.00	0	#N/A
1.00	2.14	1.00	2.14	0.00	-0.03	1	0.98
4.00	2.11	16.00	8.44	0.00	0.01	1	0.95
5.00	2.10	25.00	10.50	0.00	0.03	1	0.94
6.00	2.09	36.00	12.51	0.00	0.02	1	0.93
7.00	2.07	49.00	14.52	0.01	0.03	1	0.92
8.00	2.06	64.00	16.48	0.01	0.02	1	0.91
9.00	2.05	81.00	18.41	0.01	-0.01	1	0.89
10.00	2.03	100.00	20.32	0.01	-0.01	1	0.88
11.00	2.02	121.00	22.19	0.02	-0.02	1	0.87
12.00	2.00	144.00	24.05	0.02	-0.03	1	0.86
13.00	1.99	169.00	25.88	0.02	-0.04	1	0.85
18.00	1.94	324.00	34.87	0.04	0.04	1	0.80

y = A + B x

ΣX	104.00
ΣY	24.60
ΣX^2	1130
ΣXY	210.3
N	12
Δ	2744
A	2.16
B	-0.013
σ_y^2	0.015
σ_B^2	6.47E-05

Plot Model Line

0	2.159
18	1.933
factor	0.030
s_0 (ft)	8.66

B&R Type Curve t (min)	s/s0
0	1.000
0.63	0.992
1.26	0.984
1.89	0.977
2.52	0.969
3.15	0.961
3.78	0.954
4.41	0.946
5.04	0.939
5.67	0.931
6.30	0.924
6.93	0.917
7.56	0.909
8.19	0.902
8.82	0.895
9.45	0.888
10.08	0.881
10.71	0.874
11.34	0.867
11.97	0.860
12.60	0.853
13.23	0.847
13.86	0.840
14.49	0.833
15.12	0.827
15.75	0.820
16.38	0.814
17.01	0.807
17.64	0.801
18.27	0.795
18.90	0.788

0.54
0.54
T = 0.54 ft2/d

FIG. X2.20 Bouwer-Rice Worksheet—Variable LNAPL/Water Interface

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Cooper and Jacob (1946)

Example 3

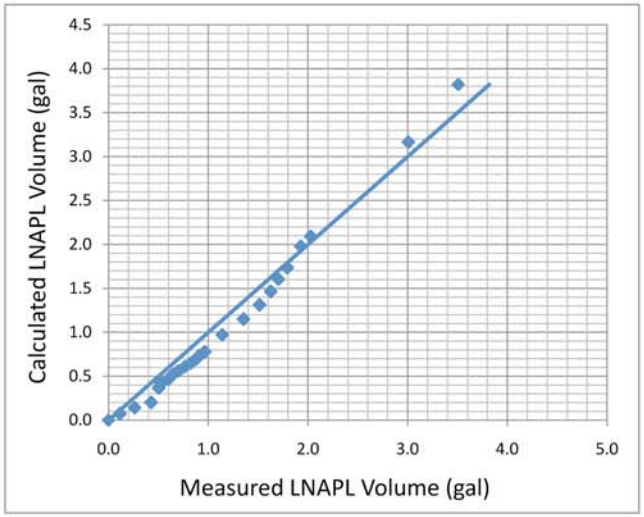
$$V_n(t_i) = \sum_j^i \frac{4\pi T s_j}{\ln\left(\frac{2.25 T t_j}{r_e^2 S}\right)} \Delta t_j$$

Enter early time cut-off for least-squares model fit

$Time_{cut}$ (min):	0	<- Enter or change values here
Time Adjustment (min):	0	
Trial S:	0.0001	<-- Change S value can be manual
Root-Mean-Square Error:	0.766	<-- Minimize this using "Solver"
Trial T_n (ft^2/d):	0.680	<-- By changing T_n (and S)

Add constraint T_n > 0.00001

Model Result: T_n (ft^2/d) = **0.68**



Index	t_i	Vi (meas)	Vi (calc)	SE
1	0.6	0.112722	7.41E-02	0.001494
2	1.5	0.263019	1.42E-01	0.014765
3	2.5	0.42584	2.03E-01	0.049769
4	4.5	0.502241	3.67E-01	0.018298
5	6.5	0.526037	4.18E-01	0.011718
6	7.5	0.601186	4.67E-01	0.018005
7	8.5	0.63876	5.15E-01	0.015368
8	9.5	0.701383	5.61E-01	0.019626
9	10.5	0.764007	6.07E-01	0.024805
10	11.5	0.82663	6.51E-01	0.030998
11	12.5	0.876729	6.94E-01	0.033551
12	13.5	0.914303	7.36E-01	0.031955
13	14.5	0.964402	7.77E-01	0.035272
14	17.5	1.139748	9.71E-01	0.028618
15	22.5	1.352668	1.15E+00	0.041587
16	27.5	1.515489	1.31E+00	0.041336
17	32.5	1.628211	1.46E+00	0.027455
18	37.5	1.703359	1.60E+00	0.010027
19	42.5	1.791032	1.74E+00	0.003058
20	50.0	1.928804	1.98E+00	0.002539
21	57.5	2.029002	2.09E+00	0.003936
22	91.5	3.005928	3.16E+00	0.025247
23	153.0	3.506916	3.82E+00	0.097995
24	0.0	0	0.00E+00	0
25	0.0	0	0.00E+00	0
26	0.0	0	0.00E+00	0
27	0.0	0	0.00E+00	0
28	0.0	0	0.00E+00	0
29	0.0	0	0.00E+00	0
30	0.0	0	0.00E+00	0
31	0.0	0	0.00E+00	0
32	0.0	0	0.00E+00	0
33	0.0	0	0.00E+00	0
34	0.0	0	0.00E+00	0
35	0.0	0	0.00E+00	0
36	0.0	0	0.00E+00	0

FIG. X2.21 Cooper and Jacob Worksheet—Variable LNAPL/Water Interface

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			e	0.000001		
	Count	Time (min)	H/H$_o$	G (a,b,e)	SE	
	1	0.100	1.025882	0.997288	0.000818	
	1	1.000	1.023529	0.98334	0.001615	
	1	2.000	1.014118	0.970525	0.0019	
	1	3.000	1.002353	0.958749	0.001901	
	1	6.000	0.970588	0.926704	0.001926	
	1	7.000	0.96	0.916758	0.00187	
	1	8.000	0.947059	0.907092	0.001597	
	1	9.000	0.936471	0.897675	0.001505	
	1	10.000	0.923529	0.888481	0.001228	
	1	11.000	0.909412	0.879493	0.000895	
	1	12.000	0.897647	0.870694	0.000726	
	1	13.000	0.884706	0.862072	0.000512	
	1	14.000	0.872941	0.853616	0.000373	
	1	15.000	0.861176	0.845315	0.000252	
	1	20.000	0.816471	0.805898	0.000112	
	1	25.000	0.771765	0.769465	5.29E-06	
	1	30.000	0.72	0.735546	0.000242	
	1	35.000	0.678824	0.703812	0.000624	
	1	40.000	0.651765	0.674015	0.000495	
	1	45.000	0.618824	0.64596	0.000736	
	1	55.000	0.569412	0.59446	0.000627	
	1	60.000	0.545882	0.570766	0.000619	
	1	123.000	0.34	0.3549	0.000222	
	1	183.000	0.257647	0.237138	0.000421	

FIG. X2.22 Cooper, Bredehoeft and Papadopulos—Worksheet Variable LNAPL/Water Interface

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Bouwer and Rice Short Term LNAPL Mobility Test Type Curves

B&R Type Curves: Casing Dia. (ft) = 0.167 ; Borehole Dia. (ft) = 0.417

Example 3

Enter these values

Type Curve ID	Type Curve Name	Notes	Max Time (min)	Transmissivity (ft^2/day)
1	T=6 ft2/day		10	6
2	T=4 ft2/day		20	4
3	T=3 ft2/day		40	3
4	T=2 ft2/day		50	2
5	T=1 ft2/day		50	1
6	T=0.5 ft2/day		50	0.5
7	T=0.1 ft2/day		50	0.1

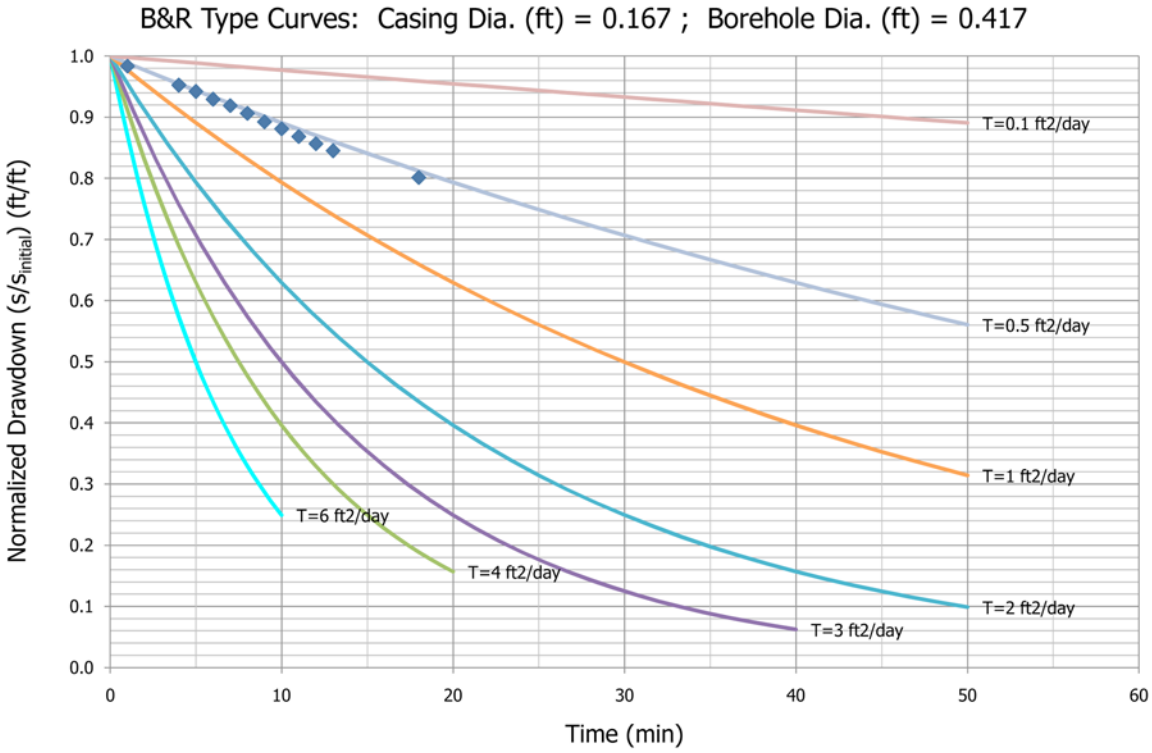


FIG. X2.23 Bouwer-Rice Type Curve Worksheet—Variable LNAPL/Water Interface

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