FINAL

ADDITIONAL LIGHT NON-AQUEOUS PHASE LIQUID RECOVERY PARTIAL PILOT TEST SUMMARY REPORT HARTFORD PETROLEUM RELEASE SITE HARTFORD, ILLINOIS

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1.0 INTRODUCTION

Pursuant to a unilateral Administrative Order issued by the United States Environmental Protection Agency (USEPA) on July 20, 2010, Apex Oil Company, Inc. (Apex) partially completed additional light non-aqueous phase liquid (LNAPL) recovery pilot testing within Area A of the Hartford Petroleum Release Site (Hartford Site). In general, Area A includes a small portion of the Hartford Site located on North Olive Street between East Forest and East Elm Streets, and does not extend beyond the rights-of-way for the Norfolk and Western, Union Pacific, Kansas City Southern, and Norfolk Southern Railroads (Figure 1). The additional pilot testing activities involved focused groundwater pumping at a rate of 300 gallons per minute (gpm) during unconfined groundwater conditions (groundwater generally below 400 feet above mean sea level [ft-amsl] beneath Area A). Focused pumping began on March 8, 2014 and was discontinued prior to completion of the test on April 2, 2014. Prior to initiating focused pumping, new infrastructure for groundwater extraction and treatment, as well as LNAPL recovery and storage were installed within Area A. The pilot test infrastructure, as well as operation, maintenance, and monitoring activities performed during the partial test are described in the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a).

1.1 BACKGROUND

The Dual Optimal LNAPL Response (DOLR) conceptual model was developed (H2A 2006) to explain the occurrence and potential recoverability of LNAPL under various hydraulic conditions. The DOLR model applies to the LNAPL present in the Main Sand stratum, where the water table periodically transitions from unconfined to confined conditions. The DOLR model might also be applicable to shallower permeable strata such as the Rand and Main Silt, where LNAPL transitions between unconfined and confined conditions. However, as described in the *Revised LNAPL Component to the Conceptual Site Model* (Trihydro 2014), LNAPL is detected infrequently in monitoring locations screened within these strata, suggesting that the fraction of total LNAPL that is potentially mobile and recoverable is relatively low. Therefore, the DOLR model is most useful in conceptualizing LNAPL recovery within the Main Sand, where the majority of LNAPL appears to be present beneath the Hartford Site (Trihydro 2014).

LNAPL, when present, shares available pore space between sediment grains with water and air. In order for LNAPL to be mobile and recoverable, it needs to be continuous or connected within the pore spaces. Within the saturated zone, where the pore spaces are primarily filled with water, LNAPL is generally present as less connected globules within the smaller pore spaces (2-phase conditions). That is, while some of the LNAPL might be connected and potentially capable of mobilizing to a well, much of it is often present as separate ganglia due to the majority of pore space being filled with water. Within the capillary fringe and vadose zone where water content is lower and air is also present (3-phase conditions), LNAPL tends to be more connected within the larger pore spaces. Put another way, LNAPL

residual saturation can vary depending on whether 2-phase or 3-phase conditions are present (Charbeneau 2007). When LNAPL saturations are high and/or water saturations are low, LNAPL is better connected and therefore potentially mobile (i.e., the LNAPL is above the residual saturation). LNAPL preferentially moves within coarse-grained sediments such as sand and gravel (i.e., lower pore entry pressure), and is less able to migrate through fine-grained sediments such as silt and clay (assuming similar water content within the pore space).

1.1.1 LNAPL RECOVERABILITY UNDER CONFINED CONDITIONS

The first part of the DOLR model states that under confining conditions (created when groundwater within the Main Sand stratum intercepts and is forced against overlying finer-grained stratum), hydrostatic forces drive LNAPL into wells that behave essentially as pressure relief points. This is schematically depicted in the first panel on Figure 2. As the water table rises, some LNAPL in the smear zone also rises within connected pore spaces between the coarse-grained sediments and eventually contacts the bottom of the overlying fine-grained stratum. Increases in the piezometric surface are directly proportional to increasing LNAPL thicknesses, as the LNAPL remains confined against the overlying fine-grained stratum and unable to displace water from the smaller pore spaces. Although the LNAPL is unable to move any further vertically, it is able to move laterally along the contact of the coarser Main Sand and overlying fine-grained stratum. This potential for lateral movement is limited under these confined conditions because any portion of the pore space not occupied by LNAPL tends to be filled with water (2-phase conditions). Still, if a well is screened across the contact of the confining stratum and the Main Sand, some fraction of LNAPL can move laterally into the well. Such a condition could mean relatively high initial LNAPL recoverability from the well if mobile LNAPL can collect at the base of the confining layer and water in the well does not exert a significant backpressure. However, under this condition the "mass of available mobile LNAPL is minimal since much of the LNAPL mass is trapped underneath this high water table" (p. 59 of Appendix E within the *Active LNAPL Recovery System 90% Design Report* [Clayton 2006]). As LNAPL is removed from the formation adjacent to the well, LNAPL saturations may decrease as water saturations increase, resulting in reduced recoverability. Only if LNAPL in the vicinity of the recovery well remains above residual saturations (i.e., has sufficient connectivity in this 2-phase condition) would recovery remain sustainable.

1.1.1.1 PILOT TESTING IN AREA A UNDER CONFINED CONDITIONS

Pilot testing of LNAPL recoverability under confining conditions was performed by WSP Environmental & Energy (WSP) in Area A between October 2011 and January 2012 (the WSP pilot test) with the primary objective of evaluating previously selected technologies for LNAPL recovery including soil vapor extraction (SVE), multiphase extraction (MPE), and dual phase extraction (DPE). As described in the *Light Non-Aqueous Phase Liquid Recovery Pilot Test Interim Report* (WSP 2012), groundwater and LNAPL were confined within the test well MPE-A001 throughout most of the WSP pilot test. Well MPE-A001 is located in Area A and screened across the top of the Main

Sand Stratum. Immediately prior to testing, the LNAPL thickness in well MPE-A001 was 3.24 feet, greater than that typically observed in this well under unconfined conditions, which is consistent with exaggerated LNAPL thicknesses observed in many of the wells under confined conditions across the Hartford Site (Trihydro 2014).

The LNAPL-water interface was present within the screened interval of the well. However, once a vacuum was induced on well MPE-A001 to evaluate SVE, the screened interval became submerged (also referred to as occluded). MPE was tested on November 7 through November 10, 2011. A drop tube was placed in the well with an applied vacuum for three hours the first day and nearly continuous thereafter. The drop tube diameter and elevation were varied during the testing, and airflow ranged from 13 standard cubic feet per minute (scfm) to 85 scfm. The applied vacuum achieved removal of fluids from well MPE-A001 with a maximum drawdown of 2.2 feet, but did not lower the fluid levels to below the top of the screen. Although an exaggerated LNAPL thickness was measured prior to testing, no measurable LNAPL recovery was achieved during the test. Instead, approximately 6,900 gallons of groundwater were extracted.

Pilot testing of DPE was planned, but based on the lack of significant drawdown during pilot testing of MPE, a pumping test was performed instead to assess achievable drawdown within the test well. Following a step test, a constant rate pump test was conducted at 20 gpm for 6.5 hours. Approximately 9 feet of drawdown was observed in the test well, exposing approximately 8 feet of the well screen. However, the LNAPL thickness in the well decreased from 2.89 feet to 0.14 feet during the pump test. Fluid level monitoring within the nearby wells indicated some influence within 50 feet of the test well, but LNAPL thicknesses did not increase during the pump test.

Overall, the pilot test resulted in no measureable LNAPL recovery using MPE, and insufficient drawdown in the well to expose the screen. Additionally, groundwater pumping did not affect LNAPL thickness in the test or nearby monitoring wells over the 6.5-hour test duration. The results suggested that MPE is not sufficient to achieve LNAPL recovery in Area A under confined conditions.

However, transmissivity testing conducted in October 2011 during confined conditions and in January 2012 during unconfined conditions indicated an increase in transmissivity from 0.0005 and 0.04 ft^2/day to 0.02 and 0.09 ft^2/day, respectively. The increase in transmissivity, observed as the ambient water table decreased, suggested that pumping under unconfined conditions might be a viable approach for additional LNAPL recovery in Area A.

1.1.1.2 LNAPL RECOVERABILITY UNDER UNCONFINED CONDITIONS

The second part of the DOLR model states that under unconfined conditions, LNAPL can vertically drain from the coarse-sediments within the Main Sand as the water table falls below the confining strata. Under intermediate

unconfined conditions (i.e., when the aquifer is unconfined but the water table is still relatively high), LNAPL thicknesses in wells can be relatively low because the confining pressure is no longer present and "much of the LNAPL is still submerged and entrapped under the water table" (p. 60 of Appendix E within the *Active LNAPL Recovery System 90% Design Report* [Clayton 2006]). LNAPL will subsequently accumulate above and below the water table, as depicted in the second panel on Figure 2.

If the water table falls further, "much of the submerged residual LNAPL drains from the Main Sand, (and) larger volumes of mobile LNAPL are available to accumulate in wells" (p. 60 of Appendix E within the *Active LNAPL Recovery System 90% Design Report* [Clayton 2006]). The further the water table falls, the more LNAPL that drains and accumulates near the water table. This LNAPL is also able to move laterally within the Main Sand. If the screen interval within a well intersects the mobile LNAPL interval and the water table is sufficiently low for a sustained period, LNAPL can enter it and have an elevation that is consistent with the vertical interval of recoverable LNAPL in the formation (i.e., no exaggerated thickness). As shown on the third panel on Figure 2, sustained LNAPL recovery may be attainable under these lower water table conditions due to a larger mass of mobile LNAPL present under 3-phase conditions (i.e., unsubmerged) and therefore potentially recoverable. Historical recovery modeling performed using soil cores collected in Area A has ignored LNAPL that is typically submerged in the Main Sand stratum (Trihydro 2014). In addition, pilot testing using an approach to expose mobile LNAPL that is typically submerged has not been performed at the Hartford Site and remains a data gap with respect to recoverability.

1.2 PURPOSE

As described in the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a), the purpose of the additional LNAPL recovery pilot test was to enhance exposure of the LNAPL smear zone within the Main Sand stratum, located between approximately 388 and 401 ft-amsl in Area A. Exposing deeper portions of the smear zone may enhance LNAPL transmissivity and mobility, which will allow further recovery of LNAPL in Area A. Exposing the deeper portions of the smear zone may also facilitate increased vapor recovery and smear zone mass depletion through the existing SVE system. This additional pilot test will evaluate the extent to which focused pumping can: (1) sustain unconfined conditions, (2) expose additional portions of the smear zone, and (3) allow recovery of mobile LNAPL and volatile petroleum hydrocarbons present in the Main Sand stratum beneath Area A. The remainder of this report is organized into the following sections:

- Section 2.0 – Describes the design and installation of the infrastructure necessary to complete the additional pilot test in Area A of the Hartford Site.
- Section 3.0 – Discusses the operations and maintenance of the temporary groundwater treatment system, including start-up and shutdown, as well as compliance monitoring results.
- Section 4.0 – Provides an analysis of the partial pilot test results including evaluation of hydraulic conditions, vapor phase mass recovery, LNAPL transmissivity, and dissolved phase conditions beneath Area A.
- Section 5.0 – Includes a summary of the lessons learned from the partial pilot test, recommendations for proposed pilot test modifications, and future stakeholder coordination.

2.0 PILOT TEST INFRASTRUCTURE

Prior to performing focused pumping, additional infrastructure was installed by Apex in Area A of the Hartford Site. Infrastructure included a groundwater production well, LNAPL recovery well, temporary groundwater treatment system, discharge conveyance line to the Village of Hartford combined sewer system, as well as a LNAPL collection system.

2.1 DIRECT PUSH BORINGS

Before installing the groundwater production or LNAPL recovery well in Area A, three direct push borings were installed approximately 15 feet north of 309 North Olive Street. These borings were installed to collect detailed information regarding the (1) lithology, (2) distribution of LNAPL in the smear zone, and (3) petroleum hydrocarbon concentrations in soil for the purpose of designing the groundwater production and LNAPL recovery wells.

2.1.1 LITHOLOGY

The first two borings (HUVOST-040 and HUVOST-040 Duplicate) were installed on September 9 and 10, 2013 by Matrix Environmental LLC to collect continuous laser induced fluorescence (LIF) and electrical conductivity (EC) data. These two borings were advanced to approximately 50 ft-bgs. EC is a measure of a material's ability to conduct an electrical current and has the units of millisiemens per meter (mS/m). EC is useful for assessing changes in lithology and is measured by applying a current to sediment present between two dipoles on the EC probe. Differences in the grain size are reflected as changes in the electrical conductivity. For instance, an electrical conductivity measurement that exceeds 100 mS/m is indicative of fine-grained sediments such as clay; whereas conductivity measurements below 10 mS/m may indicate the presence of coarse-grained sediments such as sand and gravel. A performance test of the EC probe is conducted before advancing each boring using a voltage meter and evaluating the EC response against a standard of known electrical conductance in the range expected for unconsolidated sediments. EC logs from borings HUVOST-040 and HUVOST-040 Duplicate are provided in Appendix A-1.

The third boring (HPW-01) was installed by Roberts Environmental Drilling, Inc. on September 25, 2013. Continuous cores were collected from this pilot boring, logged by a geologist, and field screened for total organic vapors to a total depth of 73 ft-bgs. Soil samples were also collected from select intervals within the LNAPL smear zone in the Main Sand stratum during installation of the boring, as described in Section 2.1.3. The lithologic description recorded during installation of boring HPW-01 is provided on the well completion construction diagrams in Appendix A-2.

In general the lithology represented by the EC log correlates well with the lithology described during installation of boring HPW-01 with alternating fine-grained alluvial deposits of clay and silt separating the coarser-grained hydrostratigraphic units. Specifically, the A Clay is present from ground surface to approximately 10 ft-bgs and consists of moderate to low plasticity silts and clays. The North Olive stratum, composed primarily of fine-grained sands with silts, underlies the A Clay and is located from approximately 10 to 16 ft-bgs. The B Clay is present between approximately 16 and 19 ft-bgs and is comprised of high plasticity silts and clays. Underlying the B Clay in Area A is the Rand stratum, consisting of fine-grained loose sands and silts. The Rand stratum is present between approximately 19 and 25 ft-bgs. The C Clay situated at approximately 25 to 30 ft-bgs separates the Rand and Main Sand strata. The C Clay is composed of dense, low plasticity clays. The Main Sand stratum was present from 30 ft-bgs to the total depth of the boring. The Main Sand primarily consisted of fine- to medium- grained, well-sorted sands, with lenses of coarse-grained sands, gravels, and fine pebbles.

2.1.2 VERTICAL DISTRIBUTION OF LNAPL

The LIF data from borings HUVOST-040 and HUVOST-040 Duplicate were collected in September 2013 using the Ultraviolet Optical Screening Tool (UVOST™). The LIF logs from these two borings are provided in Appendix A-1. To assess changes in the vertical distribution of the smear zone beneath Area A over the past decade, the LIF results from September 2013 were compared to LIF results from boring HROST-040 installed in January 2004 using the Rapid Optical Screening Tool (ROST™). A comparison of the LIF results from Area A collected in 2004 and 2013 is provided on Figure 3.

Both the ROST and UVOST make use of fluorescence and data acquisition systems developed wholly or in part by Dakota Technologies. These two methods differ primarily in the laser and associated wavelength used to excite polycyclic aromatic hydrocarbons (PAHs) within the LNAPL (290 and 308 nanometer wavelengths for ROST and UVOST, respectively). The PAH mixtures within the LNAPL emit photons of a distinctive wavelength irrespective of the excitation wavelength, although the intensity of the response may vary. By sampling the total fluorescence at different wavelength channels (which are nearly identical for both tools), a multi-wavelength waveform is generated. The waveform allows simultaneous description of the spectral and temporal qualities of the fluorescence with depth and can be used to identify different product types. The waveform data are referenced and displayed as a percent of the response compared to the calibration reference emitter (RE). The RE is similar to a calibration gas used in a flame ionization or photoionization detector, and is placed on the sapphire probe window before collecting fluorescence data at each boring. The same RE is used for the ROST and UVOST (that is to say, the RE produces the same multi-wavelength waveform). Fluorescence measurements generated in the borings are normalized to the RE

measurements which allows for spatial and temporal comparisons of the fluorescence results despite changes in the optics, laser energy drift, window, mirror, etc.

Both the ROST and UVOST readily detect most light- to mid-range product types including diesel and gasoline. The fluorescence response for these product types are generally linear, with higher concentrations of PAHs within a given product type resulting in a greater percent response relative to the RE (excluding any matrix interferences). With respect to gasoline, ROST will potentially have an advantage over UVOST since its laser system produces a shorter wavelength. However, much of this advantage may be normalized through comparison of the LIF results from ROST and UVOST to the same RE. Mid-range LNAPLs appear to be the predominant product type in Area A based on the LIF results from 2004 and 2013.

In general, the LIF results from the borings installed in 2013 are similar to the historical results collected in 2004, with the exception of significantly reduced LIF response observed within the North Olive stratum. Petroleum hydrocarbons within this shallowest hydrostratigraphic stratum are targeted for recovery using the SVE system. Natural smear zone depletion may also be occurring within the North Olive stratum via (1) volatilization and subsequent biodegradation within the vadose and (2) nutrient delivery within rainwater infiltrate and subsequent oxidation by petrophyllic bacteria in the saturated zone.

The LNAPL type, LIF response, and vertical distribution of LNAPL in the smear zone within the underlying Rand and Main Sand stratum appear to have changed very little over the past decade based on a comparison of the LIF results. Mid-range LNAPL is present between approximately 18 and 25 ft-bgs across the Rand stratum and from approximately 28 to 43 ft-bgs in the Main Sand stratum. The maximum fluorescence response relative to the RE was greater than 200% in the Rand (HUVOST-040) and Main Sand (HUVOST-040 Duplicate) strata.

2.1.3 SOIL QUALITY ANALYTICAL RESULTS

The LIF results from the two borings installed in Area A on September 9 and 10, 2013 were used to select soil sample locations across the smear zone present in the Main Sand stratum. Soil samples were collected from six intervals during installation of the pilot soil boring on September 25, 2013. Soil samples were submitted for laboratory analysis of volatile petroleum related constituents (USEPA Method 8260), semivolatile petroleum related constituents (USEPA Method 8270), and total petroleum hydrocarbons (USEPA Method 8015). Analytical results from the six soil samples are provided in Tables 1A through 1C. The laboratory analytical report is included in Appendix B-1.

The analytical results indicate that LNAPL present in soil generally consists of elevated concentrations of volatile petroleum related constituents including benzene, ethylbenzene, toluene, xylenes, heptane, hexane, and trimethylbenzene isomers. Semivolatile petroleum hydrocarbons were detected at lower concentrations and primarily composed of naphthalene and 2-methylnaphthalene. As expected, the soil analytical results reflect the composition of the LNAPL present in the Main Sand stratum, based on a comparison against the chromatogram for a LNAPL sample collected in 2005 from groundwater monitoring well HMW-044C located in Area A (Appendix B-2).

The concentration of volatile and semivolatile petroleum related constituents are greatest within the middle and lower portions of the smear zone (between 32 and 41 ft-bgs), which could indicate higher mass depletion rates within the upper portion of the smear zone. Mass depletion rates may be higher within the upper portions of the smear zone due to: (1) volatilization of petroleum hydrocarbons (and subsequent biodegradation or recovery via the SVE system) when groundwater is unconfined in the Main Sand, and/or (2) historical LNAPL skimming performed under confined and unconfined conditions. Concentrations of volatile and semivolatile petroleum related constituents are significantly lower (generally several orders of magnitude) in the two soil samples (44 to 45 ft-bgs and 48 to 49 ft-bgs) collected below the bottom of the smear zone.

2.2 LNAPL RECOVERY WELL

Based on detailed characterization of the lithology and smear zone, LNAPL recovery well HLRW-01 was installed by Layne Christiansen Company using a Sonic Drill Corporation drilling rig between October 14 and 17, 2013. The LNAPL recovery well is located approximately ten feet north of the northeast corner of 309 North Olive Street. A 10-inch diameter boring was installed using a sonic drilling method and 10-inch diameter temporary, threaded outer steel casing was advanced to a total depth of 45 ft-bgs. Following completion of the boring to the total depth, a 6-inch diameter continuous wrapped stainless steel screen (0.01-inch slot size [10-slot]) was installed from 30 to 45 ft-bgs (403.87 ft-amsl to 388.87 ft-amsl), corresponding to the approximate smear zone limits in the Main Sand. Blank 6-inch diameter steel casing was set from the top of the screen to approximately 3.2 feet above the ground surface. All well casing materials contained threaded joints. A No. 0-30 sand pack was placed from the bottom of the screen interval to approximately 24.5 ft-bgs. A 2.5-foot bentonite chip seal was placed from the top of the sand pack to 22 ft-bgs. The remaining annular space was filled with concrete-bentonite grout. The well construction completion diagram for LNAPL recovery well HLRW-01 is included in Appendix A-2.

2.3 GROUNDWATER PRODUCTION WELL

Groundwater production well HPW-01 was installed by Layne Christiansen Company using a Foremost Industries DR-24 drilling rig between October 21 and November 1, 2013. The groundwater production well was installed

approximately ten feet east of the LNAPL recovery well HLRW-01. A 16-inch diameter boring was drilled to a total depth of 75.4 ft-bgs using a dual wall reverse circulation drilling methodology. A 16-inch diameter temporary, threaded outer steel casing was advanced to a depth of 75 ft-bgs. Following installation of the boring, 10-inch diameter continuous wrapped stainless steel screen (0.02-inch slot size [20-slot]) was set from 50 to 70 ft-bgs (more than five feet below the bottom of the smear zone), corresponding to an elevation of 380.90 and 360.90 ft-amsl. A five-foot section of blank 10-inch steel casing was set below the screen interval to act as a sump. Blank 10-inch diameter steel casing was set from the top of the screen to approximately three feet above the ground surface. All well casing materials were fitted with threaded joints.

A No. 1C sand filter pack was placed from 44.8 to 75.4 ft-bgs. A 16.3-foot bentonite seal was placed from the top of the sand pack to 28.5 ft-bgs. During installation of the filter pack, the well was developed by surging water through the screen and filter pack across 10-foot intervals. Surging was performed from approximately five feet above the top of the screen interval and continuing downward to prevent sand locking of the surge block. Each ten-foot section of the screen was surged for a minimum of 15 minutes. After setting the filter pack, a 16.3-foot bentonite seal was placed from the top of the sand pack to 28.5 ft-bgs. An exaggerated bentonite seal was used rather than concrete-bentonite grout in order to prevent the grout from reducing permeability within the Main Sand immediately adjacent to the LNAPL recovery well. The top of the bentonite seal corresponds to the contact between the Main Sand and the overlying C Clay. The well construction completion diagram for groundwater production well HPW-01 is included in Appendix A-2.

Following installation of the groundwater production well, the screened interval and filter pack were further developed by overpumping. Overpumping was performed at two discrete depths within the well screen (55 and 65 ft-bgs) with a maximum pump rate of 100 gpm. Approximately 25,550 gallons of groundwater were pumped from the newly installed groundwater production well and stored within steel frac tanks temporarily located at 309 North Olive Street. Following characterization, the groundwater was removed by Environmental Management Alternatives, Inc. and treated at the City of Wood River Wastewater Treatment Plant (WRWTP).

2.4 GROUNDWATER RECOVERY AND TEMPORARY TREATMENT SYSTEM

Following completion of development activities within production well HPW-01, a 6-inch diameter, 15-horsepower submersible pump (Grundfos 300S) was installed with 4-inch galvanized steel threaded riser pipe conveying groundwater to the ground surface. The submersible pump was connected to a variable frequency drive (VFD) installed within the master control panel. The VFD allowed for establishing variable flow rates needed to complete the short-term step test (Section 4.2). The pump had a nominal flow rate of 300 gpm, and the pump intake was set within

the sump at 70.5 ft-bgs (360.4 ft-amsl). A pressure transducer was attached to the riser pipe at approximately 51 ft-bgs to monitor groundwater levels during the step test and focused pumping. Four-inch diameter flexible hoses with cam and groove fittings affixed to the riser pipe conveyed water from groundwater production well HPW-01 to the temporary groundwater treatment system.

As shown conceptually on Figure 4 and the as-built on Figure 5, recovered groundwater from the production well was injected from a high-level inlet into a 21,000-gallon frac tank. This frac tank was intended to allow settling of any entrained sediment in the recovered groundwater. A transfer pump (Goulds 3656-M) conveyed the groundwater from the frac tank to an 18,100-gallon weir tank to promote additional settling of sediments. An additional transfer pump (Goulds 3656-S) conveyed recovered water from the weir tank into a series of four 10-micron bag filters to capture any remaining suspended particulates that may not have settled in the frac and/or weir tanks. Following bag filtration, a 10,000-pound vessel containing organoclay (Hyrosil International HS-200 Series) was used to adsorb dissolved phase petroleum related constituents including lead and arsenic from the extracted groundwater. As a final polishing step, a 10,000-pound vessel containing granular activated carbon (GAC) was used to further remove residual dissolved phase petroleum related constituents. In order to conduct compliance monitoring of the treatment system effectiveness (described in Section 3.5), sample ports, SP-1 and SP-2, were installed at the base of each treatment vessel. Sample port SP-1 was used to assess breakthrough of dissolved phase constituents through the organoclay vessel. The second sample port, SP-2, was monitored to ensure treated groundwater met agreed upon effluent limits prior to discharging to the Village of Hartford CSS and ultimately to the WRWTP. An eight-foot tall wooden privacy fence installed in compliance with the Village of Hartford building codes surrounded the entirety of the temporary groundwater treatment system.

2.5 TREATED WATER CONVEYANCE PIPELINE

Prior to mobilizing the temporary groundwater treatment system components, a 6-inch diameter SDR11 high-density polyethylene (HDPE) discharge pipeline was installed by Kelpe Contracting, Inc. The pipeline was installed below grade and extended from 309 North Olive Street to the 21-inch sewer main located on North Market Avenue. Prior to installation of the discharge line and tapping into the sewer main, an Industrial Sewer Connection Application was submitted to and approved by the Village of Hartford. The discharge line, oriented approximately east to west, was installed in the alley parallel to and between East Forrest Street and East Elm Street (Figure 6). The discharge line was terminated at the groundwater surface approximately two feet north of the northwest corner of 309 North Olive Street.

Construction of the discharge line began on November 22, 2013 and proceeded until December 19, 2013 when it was determined that connection of the 6-inch pipeline could compromise the structural integrity of the 21-inch clay sewer

main. Final connection to the sewer main was subsequently postponed until a cured-in-place process (CIPP) could be applied to the sewer main located beneath North Market Avenue. Insituform Technologies, Inc. completed the CIPP on February 21, 2014 allowing the final connection from the 6-inch discharge pipeline into the 21-inch sewer main to be completed on February 28, 2014. Field logs maintained during installation of the 6-inch discharge pipeline are provided in Appendix C.

As required by the Illinois Environmental Protection Agency (Illinois EPA) Division of Water, a photoionization detector (PID) was installed at the point of connection between the discharge line and the 21-inch sewer main beneath North Market Avenue. The PID was installed to measure the percent of the lower explosion limit (%LEL) in the headspace of the treated water being discharged into the sewer main. The results of the PID were displayed on the control panel located at 311 North Olive Street, and the treatment system was configured to shut down in the event that the %LEL exceeded 10% in the headspace of the sewer main.

2.6 LNAPL RECOVERY AND STORAGE

Two Clean Earth Technology, Inc. Magnum Spill Busters™ were installed within LNAPL recovery well HLRW-01 to extract and convey LNAPL to the storage tanks located south of 309 North Olive Street. The Spill Buster skimmer pumps employ an auto-seeking device that automatically adjusts the pump intake to the elevation of the LNAPL/water interface as it fluctuates. The LNAPL storage tanks consist of two, 1,000 gallon, double-walled storage tanks (Modern Welding Company Ultra Lube Cube®), which provide UL-listed integral secondary containment. As shown on Figure 5, the LNAPL storage tanks were positioned within the 8-foot wooden privacy fence south of 309 North Olive Street and installed in accordance with Illinois State Fire Marshal requirements (e.g., appropriate offset distances from structures and roadways) and were inspected on March 6, 2014 by the Village of Hartford Fire Chief.

3.0 SYSTEM OPERATIONS, MAINTENANCE, AND MONITORING

Between February 26 and 27, 2014, after mobilizing and placing the temporary groundwater treatment system components described in Section 2.4 onto the gravel pad prepared to the north of 309 North Olive Street, transducers were installed within the frac tank, wier tank, and treatment vessels. After installing the transducers, final electrical connections were made from the control panels to the submersible pump, transfer pumps, and transducers. Finally, temporary plumbing connections were completed between the submersible pump and treatment system components and the first batch of groundwater was extracted and treated to determine the effectiveness of the temporary groundwater treatment system prior to discharging water into the Village of Hartford CSS.

3.1 AGREEMENTS AND PERMITS

A September 9, 2013 agreement with the City of Wood River described the purpose and duration of the pilot test, rates of groundwater extraction during focused pumping, treatment of the extracted groundwater, compliance monitoring of the temporary treatment system, and triggers for discontinuing the focused pumping pilot test. In addition, this agreement established user rates for treatment of water at the WRWTP.

A separate agreement with the Village of Hartford dated September 24, 2013, established prior to the commencement of construction activities, consented to the installation of the treatment system infrastructure including the 6-inch pipeline and provided access to the rights of way maintained by the Village of Hartford. This agreement also established operational limits for focused pumping (i.e., duration and shutdown criteria), as well as payment terms for discharging treated water into the Village of Hartford CSS. In an October 23, 2013 addendum to this agreement, the Village of Hartford provided Apex a permanent easement for the discharge line with specific provisions for reverting line ownership back to the Village of Hartford under certain circumstances.

In addition, the Village of Hartford and City of Wood River provided consent to conduct pilot testing activities by signing the Illinois EPA Division of Water Application for Permit of Construction/Operation Approval (Application). The Application was accepted and Permit No. 2014-EE-58312 was issued by the Illinois EPA on January 23, 2014. The Permit granted permission to construct and operate the temporary groundwater treatment system as described in the Application and in accordance with the Special Conditions stipulated within the Permit. Appendix D includes Permit No. 2014-EE-58312.

3.2 PILOT TEST START UP

As described in the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a), focused pumping at a rate of 300 gpm, is only capable of exposing additional portions of the LNAPL smear zone within the Main Sand stratum when groundwater conditions are unconfined (groundwater generally below 400 ft-amsl beneath Area A). In order to track groundwater conditions in Area A, fluid level measurements were gauged weekly within three trigger wells (ASW-003, HMW-044C, and MPE-A003). Focused pumping could only proceed when ambient groundwater elevations were below the 400 ft-amsl trigger elevation in at least two of the three trigger wells. As depicted on Figure 7, groundwater elevations were below 400 ft-amsl in all three trigger wells beginning on September 16, 2013 and remained so until April 27, 2014.

On February 27, 2014, an initial 10,000-gallons of groundwater were extracted from production well HPW-01 and processed within the temporary treatment system installed in Area A in order to confirm the adequacy of treatment prior to discharging water to the Village of Hartford CSS. In order to treat this first batch of groundwater, the system was reconfigured so that extracted groundwater was pumped directly into the weir tank, bypassing the frac tank. Groundwater was then pumped from the weir tank through the bag filters, organoclay vessel, and GAC vessel before being stored within the frac tank. Treated groundwater samples were then collected from the frac tank and submitted to Teklab, Inc. for expedited analysis of volatile petroleum related constituents via USEPA Method 8260, polycyclic aromatic hydrocarbons (PAHs) via USEPA Method 8270, oil and grease using USEPA Method 1664A, dissolved arsenic and lead via USEPA Method 6020, chemical oxygen demand (COD) by USEPA Method EPA 410.4, and biological oxygen demand (BOD) by Standard Method 5210B. The analytical results for this first batch of treated water including a comparison to the effluent limits are provided on Tables 2A and 2B. The analytical reports provided by the laboratory are included in Appendix E.

Due to sub-freezing ambient air temperatures that occurred while awaiting the analytical results from the batch test, treated water within the system was recirculated, pond heaters were deployed inside the tanks, and heat tracing applied to frost sensitive locations. Upon receipt of the analytical results demonstrating that the temporary treatment system was effective at reducing concentrations in extracted groundwater below the effluent limits, the first batch of treated water stored within the frac tank was discharged to the Village of Hartford CSS. Following the conclusion of the batch test, the treatment system was reconfigured for continuous operation.

3.3 TEMPORARY TREATMENT SYSTEM OPERATION

Pumping commenced on March 7, 2014 with a short-term step test consisting of discrete pumping rates ranging from approximately 50 to 250 gpm. Pumping rates were increased in approximate 50 gpm increments. Each step consisted

of a short time segment during which groundwater was extracted at a constant rate while fluid levels were monitored within the groundwater production and LNAPL recovery wells. The groundwater extraction rate for each step was measured using an in-line flow meter. Results of the short-term step test are summarized in Section 4.2.

On March 8, 2014, focused pumping proceeded following the increase in the pumping rate to 300 gpm. During focused pumping, system operational data (i.e., fluid levels, flowmeter readings, and sewer headspace measurements) were recorded. A summary of the system operations during focused pumping is provided in Section 4.3. In addition, operational data recorded during the step test and focused pumping test are provided in Table 3.

During focused pumping, constant groundwater extraction rates were maintained with the exception of brief periods when the pumping rate was either reduced or suspended due high water level conditions and/or maintenance activities. Maintenance activities consisted of bag filter replacements and periodic backwashing of the organoclay media. A summary of the intermittent reductions in the flow rate, suspensions in groundwater recovery, and maintenance activities performed on the temporary treatment system is provided in Table 4.

3.4 TREATMENT SYSTEM COMPLIANCE MONITORING

Effluent concentration limits for discharge of treated groundwater into the Village of Hartford CSS were established within the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a) for benzene, ethylbenzene, toluene, and xylenes; as well as agreements with the Village of Hartford (oil & grease) and City of Wood River (BOD and COD). Treated groundwater samples were collected at sample port SP-2 prior to discharge to the Village of Hartford CSS on a weekly basis following system startup. Weekly samples were also collected from the sample port SP-1 to monitor breakthrough of constituents within the organoclay treatment vessel. Samples collected from SP-1 were not analyzed for BOD, COD, and oil and grease. Results of the treatment system compliance monitoring and comparison to the effluent discharge limits are summarized in Tables 2A and 2B. Analytical results demonstrate that the discharge limits were not exceeded at any time during operation of the temporary treatment system. In addition, breakthrough of dissolved phase petroleum related constituents within the effluent samples collected from the organoclay vessel (SP-1) was not observed.

3.5 AMBIENT AIR MONITORING

Modelling of potential volatile emission rates prior to the pilot test determined that an air permit would not be required and that operations of the temporary treatment system was instead eligible for registration under the Illinois EPA Registration of Smaller Sources (ROSS) program. Monitoring of ambient air quality was performed at the start-up of the pilot test and appropriate recordkeeping procedures were followed to demonstrate compliance with the ROSS

program and to evaluate future air permitting requirements. Specifically, the effects of focused pumping and subsequent treatment of extracted groundwater on the ambient air quality immediately adjacent to the treatment system (within the fenced area adjacent to 309 North Olive Street) was assessed via collection of ambient air samples at one upwind (i.e., background) and one downwind location (as determined at the time of sample collection). Ambient air samples were collected using passivated Summa canisters and submitted to Eurofins Air Toxics, Inc. for analysis of volatile petroleum related constituents using USEPA Method TO-15LL, which yields reporting limits approximately one-fifth of that provided via the standard TO-15 Method.

During the first week of the pilot test, ambient air samples were collected over a 24-hour period during three separate days and submitted for expedited analysis to Eurofins Air Toxics, Inc. In subsequent weeks, 72-hour ambient air samples were collected on a weekly basis and submitted to the analytical laboratory for standard analysis. A summary of the analytical results is provided in Table 5. Laboratory analytical reports and data validation reports for the ambient air samples collected during the pilot test are included in Appendix F-1 and F-2, respectively.

Results from the 24-hour samples collected during the first week of the pilot test indicated volatile petroleum related constituents in downwind ambient air samples exceeded the upwind samples by a relative percent difference (RPD) greater than 25% for select constituents. The highest RPD was observed from air samples collected on March 10, 2014. In accordance with the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a), leak detection monitoring was conducted on March 14, 2014 using a flame ionization detector (FID) to locate and mitigate the source(s) of the volatile emissions. Leak detection monitoring identified the top hatch of the frac tank and the flip-top lids of the weir tank as potential sources of hydrocarbon emissions. In response, these openings were sealed shut, and administrative controls were implemented to minimize reopening the tank hatches and flip-top lids.

Results from subsequent ambient air samples indicated an overall reduction in volatile petroleum related constituent concentrations and a reduction in the RPD between upwind and downwind samples; however, the RPD between samples collected on March 17, 2014 remained higher than 25% for benzene. Therefore, additional leak detection monitoring was conducted using the FID, the results of which indicated volatile emissions emanating from the vent on the frac tank. On March 28, 2014, a custom cover with GAC was affixed to the existing vent on the frac tank in order to further reduce volatile emissions while still allowing for tank venting.

An evaluation of the ambient air monitoring results indicated that four of the six sample pairs (upwind/downwind) exhibited a minimum of one negative RPD, or in other words, the upwind samples had higher concentrations of volatile petroleum related constituents compared to the downwind sample. This increase in volatile petroleum related

constituents from downwind to upwind could be a result of several factors including: (1) close proximity of the samples to the temporary treatment system, (2) changes in wind direction and velocity during the test, and (3) alternate source of volatile petroleum related constituents in ambient air. In order to evaluate the contribution of volatile petroleum related constituents attributed to alternate sources, an additional ambient air sample was collected in Area A on April 21, 2014 following shutdown of the focused pumping pilot test. As shown on Table 5, detectable concentrations of benzene, butane, hexane, and isopentane were measured in the ambient air sample collected in Area A, indicating some contribution of volatile petroleum related constituents from alternate sources unrelated to the temporary treatment system.

3.6 DISCONTINUANCE OF FOCUSED PUMPING

In accordance with the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a), Permit No. 2014-EE-58312, and agreements with the Village of Hartford and City of Wood River, focused pumping was to be suspended if precipitation exceeded (or was anticipated to exceed) more than 0.5 inches in a 24-hour period or if the Mississippi River exceeded 410 ft-amsl at Lock and Dam No. 26. Focused pumping was suspended on April 2, 2014 due to significant rainfall events that took place with nearly 4.0 inches of rainfall recorded over a three-day period. There was a corresponding increase in the river elevation, which reached a maximum of 413.78 ft-amsl on April 5, 2014, more than 13 feet higher than at the start of the test and above the 410 ft-amsl threshold. Daily measurements of precipitation and river elevation recorded during the pilot test are presented on Figure 8.

On Thursday April 10, 2014, Apex and USEPA discussed the pilot test status and determined that restarting focused pumping would not yield additional information regarding LNAPL recovery that could be used for designing a final remedy. Following suspension of the pilot test, the river stage generally remained above 405 ft-amsl and groundwater elevations across Area A (including the trigger wells for the pilot test) continued to steadily increase.

A request to clean and demobilize the temporary treatment system was submitted to the USEPA on April 12, 2014, with an understanding that the temporary treatment system may need to be remobilized and additional pilot testing conducted in Area A in 2014, should trigger groundwater elevations be reached later in the year. USEPA approved this request on April 23, 2014.

3.7 TEMPORARY TREATMENT SYSTEM DECOMMISSIONING

On May 2, 2014, decommissioning of the temporary treatment system began with the draining and cleaning of the frac tank and weir tank, containerizing and disposal of the spent bag filters, and draining any remaining treated groundwater

from the organoclay and GAC vessels. The frac tank and weir tank were demobilized on May 5, 2014. On May 7, 2014, a 13-ton crane was used to load the organoclay and GAC vessels onto separate flatbed trailers for subsequent transport off-site. The spent organoclay was extracted and disposed of following characterization, while the spent GAC was extracted and regenerated. Additional equipment such as the transfer pumps and LNAPL skimming pumps were also shipped off-site.

4.0 PARTIAL PILOT TEST RESULTS

The additional LNAPL recovery pilot test was designed to determine if a focused pumping approach could: (1) sustain unconfined conditions in the Main Sand stratum, (2) expose additional portions of the smear zone that are typically submerged beneath the water table, and (3) enhance recovery of potentially mobile LNAPL and volatile petroleum hydrocarbons present in the Main Sand stratum beneath Area A. Performance monitoring was conducted prior to initiating focused pumping to establish baseline conditions, as well as during and following completion of the pilot test to evaluate the effects of focused pumping on hydraulic conditions, LNAPL mobility, and mass recovery. Performance monitoring included manual and automated gauging of fluid levels, LNAPL baildown testing, vapor screening in the HSVE- and MPE-series wells located in Area A, as well as dissolved-phase monitoring. A summary of performance monitoring conducted prior to, during, and following focused pumping is provided in Table 6.

4.1 FLUID LEVEL MONITORING

Fluid levels were manually gauged in 28 wells in Area A and background locations beyond Area A as listed on Table 6. Gauging was conducted once each week beginning in September 2013 to provide baseline monitoring data and to track groundwater trigger elevations. During focused pumping, manual fluid level measurements were generally collected three times each week to assess drawdown across Area A. Fluid levels were recorded within multipurpose monitoring points MP-035D and MP-085D to determine ambient fluctuations in fluid level elevations attributed to precipitation events, changes in the Mississippi River stage, and pumping from nearby facilities. A summary of manual fluid level measurements recorded prior to and during focused pumping is included in Appendix G-1.

In addition, pressure transducers were deployed within eleven groundwater monitoring locations screened within the Main Sand including ASW-01, ASW-03, HMW-044C, MP-035D, MP-054C, MP-055C, MP-085D, MP-133, MP-134, MP-135, and MP-137. A pressure transducer was also deployed within multipurpose monitoring point MP-136; however, prior to the commencement of focused pumping, it was determined that the transducer was malfunctioning. The transducer was removed from service and a replacement had not been installed by the time focused pumping began. According to the work plan, a transducer was also scheduled to be deployed within well MPE-A003; however, this transducer was moved to multipurpose monitoring point MP-133. The MPE-wells were under vacuum during focused pumping, and therefore, it was determined that MP-133 would provide a more representative measurement of drawdown in Area A during focused pumping.

The transducers recorded the piezometric surface within selected monitoring locations on 8-hour intervals. Figure 9 presents the hydrographs prepared using the transducer results from select monitoring locations including ASW-003,

MP-054C, MP-085D, MP-133, MP-135, and MP-137. Piezometric data from the pressure transducers is included in Appendix G-2. As shown on Figure 9, the piezometric surface decreased steadily across Area A between September 2013 and February 2014. There was a rebound in the piezometric surface in late February 2014, just before focused pumping began.

4.2 SHORT-TERM STEP TEST

As described in Section 3.3, a short-term step test was performed between March 7 and March 8, 2014. The purpose of the step test was to estimate sustainable flow rates within production well HPW-01. The extraction rate for each step was measured using the in-line flow meter. Groundwater levels were manually gauged and the piezometric surface recorded using a pressure transducer installed in production well HPW-01. The average pumping rates for the individual steps were 54.4, 95.9, 147.9, 194.0, and 249.8 gpm. As shown on Figure 10, drawdown was initially steep as each step was initiated, after which drawdown stabilized within a short timeframe. The relationship between drawdown and discharge in a pumping well is described using the following equation (Jacobs 1947):

$$s_T = BQ + CQ^2$$

Where:

s_T = total drawdown (feet)

B = aquifer loss coefficient (feet/gpm)

C = well loss coefficient (feet/gpm^2)

Q = discharge at each step (gpm)

The aquifer loss (B) and well loss (C) coefficients for the production well can then be calculated using Bierschenk's Method (Kasenow 2001), which applies a linear regression to the step-drawdown results. The aquifer loss coefficient (B) can be used to describe the drawdown in the pumping well attributed to laminar flow using the following equation from Bierschenk's Method:

$$B = \frac{\sum \frac{s}{Q} \sum Q^2 - \sum Q \sum s}{n \sum Q^2 - (\sum Q)^2}$$

The well loss coefficient can be used to describe the drawdown in the pumping well attributed to turbulent flow through the formation using the equation:

$$C = \frac{n\sum s - \sum Q \sum \frac{s}{Q}}{n\sum Q^2 - (\sum Q)^2}$$

Where:

n = step number

s = drawdown at each step (feet)

In a partially penetrating well, such as HPW-01, both laminar and turbulent flow will contribute to the discharge; however, the dominant mechanism for groundwater flow into the pumping well would be laminar flow. This can be demonstrated using the following equations:

If:

$$s_a = BQ$$

And:

$$s_w = CQ^2$$

Then:

$$\mathrm{Q} = \frac{s_a}{B} + \sqrt{\frac{s_w}{C}}$$

Where:

s_a = drawdown due to laminar flow (feet)

s_w = drawdown due to turbulent flow (feet)

The total drawdown observed at the production well can be determined by the sum of the drawdown attributed to laminar flow and the drawdown attributed to turbulent flow. The head loss coefficient and aquifer loss coefficient can be used to determine the well efficiency (*Ew*) for each step during the test using the following equation:

$$E_w = \frac{100BQ}{BQ + CQ^2}$$

A summary of the step-test analysis using Bierschenk's Method including the drawdown due to laminar flow, drawdown due to turbulent flow, and the well efficiency is provided in Table 8. The well efficiency will vary with increased discharge, and in the case of production well HPW-01, the efficiency decreased with each step due to the decrease in the specific capacity of the well (*Q/s*) as time progresses and discharge increases. The aquifer loss coefficient (*B*) and the well loss coefficient (*C*) for the production well were calculated to be 0.0179 feet/gpm and 1.144 x 10-5 feet/gpm^2, respectively. As expected, the head loss coefficient is substantially greater than the well loss

coefficient due to the greater influence of laminar flow versus turbulent flow to the production well. Based on the results of the step test, the well efficiencies estimated for production well HPW-01 exceeded 80% for discharges up to 300 gpm, indicating a sustainable recovery rate in this production well over time. Productions wells that are properly designed, constructed, and developed do not generally exhibit well efficiencies greater than 80% (Patchick 1967, Driscoll 1986). These results also indicate that increased flow rates from the production well HPW-01 may also be achieved in a sustainable manner.

4.3 LONG-TERM FOCUSED PUMPING TEST

Long-term focused pumping began at a rate of approximately 300 gpm on the afternoon of March 8, 2014 following the completion of the short-term step test. Temporary deviations from the pumping rate occurred due to: (1) maintenance issues with the groundwater treatment system (i.e., changing out bag filters, backwashing the treatment vessels), (2) weekly maintenance activities performed by the Village of Hartford associated with the municipal potable water treatment system (i.e., backwashing filters), and (3) changes to hydraulic conditions associated with fluctuations in river stage and precipitation rates. Table 4 provides a summary of the intermittent reductions in the flow rate and any suspensions in groundwater recovery during focused pumping.

Manual fluid level measurements were collected from the groundwater production well, LNAPL recovery well, in addition to 16 multipurpose monitoring points and groundwater monitoring wells screened within or across the Main Sand stratum. The manual fluid level gauging results are summarized on Table 8. Pressure transducers were also deployed in 11 wells screened within or across the Main Sand stratum to supplement the manual fluid level measurements (Appendix G-2). The fluid level monitoring results were used to estimate corrected drawdown and to assess the radius of influence of the production well. In addition, the focused pumping test results were used to estimate aquifer parameters such as hydraulic conductivity (K) and transmissivity (T).

The ambient groundwater elevation (i.e., background) beyond the influence of the pumping well in Area A was measured at approximately 396 ft-amsl within multipurpose monitoring points MP-035D at the start of the pilot test. These ambient groundwater elevations reached a low of approximately 395.5 ft-amsl on March 12, 2014, as shown on the hydrograph for monitoring point MP-035D included on Figure 11. The ambient water table elevation began increasing thereafter due to a precipitation event that occurred on March 11, 2014 (Figure 8) and subsequent 3-foot increase in the Mississippi River Stage that occurred on March 12, 2014 (Figure 11).

As a result of the increase in the ambient groundwater elevation, drawdown in the production well and the Area A monitoring network did not continue to increase as expected but instead remained somewhat steady until March 17,

2014, after which decreasing drawdown was observed within the production well and groundwater monitoring network. LNAPL was not observed within the LNAPL recovery well, and LNAPL thicknesses within several monitoring wells in Area A decreased, as maximum, steady-state drawdown was not achieved and LNAPL likely remained trapped in the pore spaces as groundwater was not able to vertically drain from the smear zone within the Main Sand stratum.

It is believed that drawdown observed across the monitoring network in Area A may have also been affected by the manner in which the production well was constructed. As described in Section 2.3, the screen interval in production well HPW-01 was installed from 360.9 to 380.9 ft-amsl, in order to minimize entrained LNAPL and dissolved phase petroleum hydrocarbons during focused pumping. The submersible pump was installed with the intake below the bottom of the screened interval within the sump at approximately 360.4 ft-amsl. Therefore, groundwater was being extracted more than 30 feet below the top of the water table within the Main Sand stratum. The majority of the monitoring wells in Area A are screened across the upper portions of the Main Sand stratum. The short duration over which the ambient water table was stable or decreasing during pumping (four days) and the location of the pump intake more than 30 feet below the water table surface, may have resulted in delayed recharge within the Main Sand stratum.

Delayed recharge occurs due to elastic storage in the aquifer, in which little water actually drains from the pore space after initiating pumping. In an unconfined aquifer with delayed response, the release of water from the pore space may take anywhere from minutes to days (Kasenow 2001). Over this period, groundwater remains in the pore spaces due to adhesion and cohesion processes, until such time that these hydrostatic forces can be overcome by gravity (Kasenow 2001). It seems likely that the exaggerated drawdown observed in the groundwater production well compared to the relatively constant drawdown observed across the monitoring network in Area A is attributable to delayed recharge (Figure 11). It also is likely that the delay in the rebound of the groundwater elevations observed in the monitoring wells in Area A, following the precipitation event and increase in the Mississippi River stage beginning on March 12, 2014 (compared to the background monitoring point MP-035D as shown on Figure 11) could also be attributed to the elastic storage within the Main Sand stratum.

4.3.1 RADIUS OF INFLUENCE

In order to evaluate the radius of influence (ROI) of focused pumping, the maximum drawdown determined using the corrected manual groundwater elevations from the wells screened within or across the Main Sand Stratum were plotted as a function of the radial distance from the production well HPW-01 on a semi logarithmic plot (Figure 12). The drawdown data were conservatively adjusted by the maximum decrease in the ambient groundwater elevation observed in the two background wells between March 8 and March 13, 2014 (0.88 feet measured in MP-085D). This correction was applied to account for ambient decreases in the water table in Area A unrelated to the focused pumping. As shown

on Figure 12, the ROI is conservatively estimated to be greater than 350 feet beneath Area A during focused pumping at a rate of 300 gpm. This exceeded the modelled ROI of 300 feet despite never achieving steady-state drawdown during the partial pilot test. The measured ROI is also comparable with the upper-end radius of capture of 300 feet for production well RPW-01 located on the Premcor Facility, as reported in the memo entitled *Use of LNAPL Transmissivity Values as a Decision Making Tool for LNAPL Recovery in Hartford, Illinois* (AECOM 2010).

4.3.2 GROUNDWATER TRANSMISSIVITY AND HYDRAULIC CONDUCTIVITY

The drawdown data was also used to estimate hydraulic conductivity (*K*) and transmissivity (*T*) within the Main Sand stratum beneath Area A. As described in Section 4.3, steady-state drawdown was not achieved due to increases in ambient groundwater elevation within four days of starting focused pumping. The drawdown observed within the monitoring network installed in the Main Sand stratum in Area A may also have been affected by delayed response within the aquifer. As a result, the draw down results did not allow for use of the Theis Method for calculating transmissivity, as a curve match for an unconfined aquifer could not be accurately correlated. Therefore, the Cooper-Jacob Method was utilized, which evaluates distance versus drawdown on a semi logarithmic plot, similar to the method used to calculate the ROI. Figure 12 provides the maximum drawdown observed during focused pumping (March 13, 2014) within the monitoring wells and points installed in the Main Sand as a function of the radial distance from the production well HPW-01. Transmissivity was calculated using the following equation:

$$T = \frac{2.3Q}{2\pi\Delta s}$$

Where:

T = transmissivity (feet^2 per day)

Δs = slope of the best-fit line for drawdown versus distance on a semi logarithmic plot (feet)

Based on the Cooper-Jacob Method, the transmissivity of the Main Sand stratum was calculated to be 27,004 feet^2 per day. Using the calculated transmissivity (*T*) and the estimated saturated thickness (*b*) of the Main Sand stratum in Area A, the horizontal hydraulic conductivity can be calculated using the equation:

$$K_H = \frac{T}{b}$$

Where:

K_H = horizontal hydraulic conductivity (feet per day)

b = thickness of the aquifer (feet)

With an estimated saturated thickness of the Main Sand stratum in Area A of 75 feet, the horizontal hydraulic conductivity was calculated to be 360 feet/day. The vertical hydraulic conductivity was not able to be calculated due to the limitations in the drawdown data and inability to appropriately fit to a Theis curve for an unconfined aquifer. However, the dominant mechanism of groundwater transport to the pumping well would be expected to be in the horizontal direction due to vertical anisotropy (Kasenow 2001).

4.4 VAPOR PHASE RECOVERY

Field screening of soil vapor, fixed gases, and air flow parameters (e.g., temperature, vacuum) within eight vapor recovery wells located in Area A was conducted prior to, during, and following focused pumping to determine the influence of water table depression on mass recovery via SVE. Field screening was completed within multiphase extraction wells MPE-A001 through MPE-A005 and soil vapor extraction wells HSVE-028S, HSVE-028D, and HSVE-084, in accordance with the procedures presented in Appendix D of the *Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan* (WSP 2011). Table 9 provides a summary of the SVE screening results.

The vacuum, differential pressure (within the Venturi tube), and temperature were measured within each of the MPE- and SVE-wells to calculate the airflow rate (*scfm*). The volatile hydrocarbon mass removal rate (*M*) was then calculated using the following equation:

$$M = 1.557E\text{-}7 * C_{gas} * MW * scfm$$

Where:

M = rate of volatile petroleum hydrocarbons recovered (pounds per hour)

C_{gas} = total organic vapor concentration relative to methane (parts per million by volume)

MW = molecular weight of recovered volatile petroleum hydrocarbons (95 grams/mol)

$scfm$ = soil vapor flow rate (standard cubic feet per minute)

$1.557E\text{-}7$ = conversion constant derived as (1 mol/24.06 liters) x (1 pound/453.6 grams) x (1 cubic meter/35.3 cubic feet) x (60 minutes/hour) x (1 liter/1,000milliliters)

The mass removal rate was converted to equivalent gallons per day assuming a LNAPL density of 6.2 pounds per gallon. Individual and combined volatile petroleum hydrocarbon recovery rates for the MPE-wells, along with the corrected groundwater elevation for trigger monitoring well ASW-03 are presented on Figure 13. The combined volatile petroleum hydrocarbon recovery rate measured within the MPE-wells was less than 50 gallons per day on March 4, 2014, prior to the start of focused pumping. During the pilot test, vapor recovery rates increased, with a maximum combined recovery rate of 554 gallons per day occurring on March 14, 2014. Volatile petroleum hydrocarbon recovery rates decreased after March 14, 2014 as groundwater elevations increased in Area A. The increase in volatile petroleum hydrocarbon recovery rates appears inversely correlated with groundwater elevations measured within monitoring well ASW-03, with a marked increase in recovery rates when the groundwater elevation is measured below 397 ft-amsl.

This ten-fold increase in volatile petroleum hydrocarbon recovery rates occurred after less than one week of focused pumping at which point drawdown began trending upward (Figure 11). Volatile petroleum hydrocarbon recovery rates within Area A would likely have continued to increase if steady-state drawdown was achieved within the groundwater production well and across Area A. It appears that focused pumping, if performed in a manner that sustains the groundwater elevation below 397 ft-amsl, represents an effective method to achieve smear zone mass reduction using SVE.

4.5 LNAPL TRANSMISSIVITY

In February 2014, baseline LNAPL transmissivity testing was performed within wells MP-054C and MP-055C as these were the only two wells screened within the Main Sand stratum in Area A (Table 6) with sufficient LNAPL thickness (i.e., greater than 0.5 feet) to perform baildown testing. LNAPL baildown tests were performed in accordance with the *Standard Guide for Estimation of LNAPL Transmissivity* (ASTM 2011). Based on the groundwater elevation and depth of the C Clay in Area A, baildown testing was conducted under unconfined conditions.

Data for these tests were evaluated using the *API LNAPL Transmissivity* numeric modeling spreadsheets (a summary of the results is provided in Appendix H). Quantified LNAPL transmissivity values (T_n) could not be calculated, as the data did not conform to the analyses prescribed in Section 8.1.4 of the *Standard Guide for Estimation of LNAPL Transmissivity* (ASTM 2011). Specifically, relatively thin LNAPL thicknesses (b_n) and low drawdown (s_n) during recharge rendered plots of discharge (Q_n) versus drawdown (s_n) with significant scatter that could not be processed quantitatively. However, qualitatively the data indicate low baseline LNAPL transmissivity (T_n) as evidenced by:

- LNAPL thickness (b_n) during recharge did not approach 50% of the initial drawdown (s_n). LNAPL thickness was recorded at a maximum of 0.28 feet during recharge versus 0.73 feet prior to removing LNAPL within monitoring point MP-054C and 0.25 feet versus 0.61 feet within monitoring point MP-055C.
- Significant LNAPL drawdown (s_n) was unable to be achieved with 0.04 feet and 0.11 feet measured within monitoring points MP-054C and MP-055C, respectfully.
- The LNAPL drawdown (s_n) remained relatively steady over the test indicating that the wells recharged primarily with water and not LNAPL.

Additional LNAPL baildown testing was proposed to be conducted during focused pumping once maximum, steady-state conditions were achieved as described within the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a). As previously described in in Section 4.3, steady-state conditions were not achieved in Area A due to the short duration over which the ambient water table was stable or decreasing during pumping (four days) and the effects caused by delayed recharge within the Main Sand stratum; therefore, subsequent transmissivity tests to evaluate the effects of focused pumping were not performed during the partial pilot test.

4.6 DISSOLVED PHASE MONITORING

Due to the proximity of the operating production wells, the ROI associated with hydraulic control being performed on the former Premcor refinery and focused pumping from groundwater production well HPW-01 installed in Area A may overlap creating a potential for redistribution of dissolved phase petroleum hydrocarbons during the additional LNAPL recovery pilot test. To assess any change in dissolved phase concentrations associated with focused pumping, groundwater samples were collected once from the monitoring locations identified in Table 6, prior to the start of focused pumping and will continue to be collected monthly for a six-month period following completion of focused pumping, with the final sample scheduled to be collected in September 2014.

Groundwater samples were collected using a low flow sampling methodology as described in the *Dissolved Phase Investigation Work Plan* (Trihydro 2013b). In accordance with this work plan, samples were only collected when groundwater elevation was gauged within the screened interval of the monitoring well. Groundwater samples were not collected if LNAPL was measured within a monitoring location or a sheen was observed on the groundwater during purging activities. Groundwater samples were analyzed for select petroleum-related constituents including benzene, toluene, ethylbenzene, total xylenes, and methyl tert-butyl ether via USEPA Method 8260B by Teklab, Inc. Field forms generated during groundwater monitoring are provided in Appendix I-1. Laboratory analytical reports and data validation reviews are included in Appendix I-2 and I-3, respectively. Table 10 provides a summary of the dissolved phase analytical results for the monitoring event performed before the start of focused pumping (November 2013 or

February 2014) and then monthly monitoring completed in April and May 2014, following completion of the partial pilot test.

As summarized on Table 10, there were not any notable increases in the dissolved phase concentrations reported in the samples collected prior to and then following the partial pilot test. In most cases, dissolved phase concentrations decreased when comparing the analytical results for groundwater samples collected prior to the start of focused pumping and those collected following the partial pilot test. It should be noted that concentrations of dissolved phase benzene exceeded 20 milligrams per liter in all of the samples, with the exception of groundwater collected from monitoring point MP-137 in May 2014. These elevated dissolved phase benzene concentrations appear to be at the effective solubility limit calculated for benzene present in the LNAPL source as described within the *Revised LNAPL Component to the Conceptual Site Model* (Trihydro 2014). Since the concentrations appear to be at equilibrium with the LNAPL source beneath Area A, it is not anticipated that there will be redistribution of dissolved phase petroleum hydrocarbons within the ROI for the production well during the additional LNAPL recovery pilot test.

5.0 CONCLUSIONS AND PATH FORWARD

Focused pumping was suspended on April 2, 2014 due to precipitation totals exceeding 0.5 inches within a 24-hour period, followed by the Mississippi River exceeding 410.5 ft-amsl as measured at the Mel Price Lock and Dam. On April 10, 2014, it was determined that due to the increasing trend in groundwater elevations beneath Area A, the additional pilot test would not resume. Despite the truncated duration of focused pumping, the results obtained during this partial test helped to inform future activities when the pilot test is restarted. A discussion of the lessons learned, proposed pilot test modifications, and future stakeholder coordination is described within this section.

5.1 LESSONS LEARNED

Due to delays in installation of the treated water conveyance pipeline described in Section 2.5, focused pumping was not started until March when the water table beneath the Hartford Site typically begins to rebound. The pilot test was suspended in early-April before maximum, steady-state water table drawdown was achieved. As a result, the effect of focused pumping on LNAPL recoverability could not be measured. However, there were other lines of evidence suggesting that focused pumping may be effective at reducing hydrocarbon mass beneath Area A including:

- Focused pumping at 300 gpm over a period of four days resulted in an ROI greater than 350 feet (Section 4.3.1). It is anticipated that drawdown in Area A would have continued to trend downward (with a more dramatic increase in drawdown observed with decreasing radial distance from the production well) once the effects of delayed recharge within the aquifer were overcome by vertical drainage. It is also anticipated that once maximum, steady-state drawdown conditions are achieved, the ROI for focused pumping within production well HPW-01 will increase.
- As discussed in Section 4.3.3, the rate of recovery of volatile petroleum hydrocarbons in soil vapor increased substantially within Area A during focused pumping, with a ten-fold increase during the first week of the pilot test. These results highlight the importance of operating existing MPE- and SVE-wells in Area A during focused pumping. As drawdown is greatest near the production well, performing SVE within the LNAPL recovery well HLRW-01 may result in significant vapor phase recovery, as well as augment LNAPL recovery.

5.1.1 TREATMENT SYSTEM CONFIGURATION

Analytical results of the groundwater treatment compliance samples (Table 2a and 2b) indicated that the organoclay and GAC treatment media were effective at decreasing the concentrations of dissolved phase petroleum related constituents to below the discharge limits. However, the treatment capacity of the media vessels was not able to be determined for possible future testing due to the short duration of the partial pilot test. The analytical result for the untreated groundwater collected from the frac tank on March 17, 2014 did not have elevated concentrations of lead (0.0027 mg/L), and based on the analytical results from compliance samples collected from the temporary groundwater

treatment system, dissolved lead concentrations were not substantially reduced by the organoclay media. As such, it may be appropriate to evaluate the use of an additional GAC vessel as opposed to an organocaly vessel in the temporary groundwater treatment system. A GAC vessel provides greater capacity for hydrocarbon sorption per unit volume and may extend the overall life of the treatment system.

Dissolved iron is also present in groundwater due to the reducing conditions associated with the presence of petroleum hydrocarbons within upper portions of the Main Sand stratum. The dissolved iron subsequently precipitated out of the extracted groundwater forming solid iron oxide once the extracted water was exposed to atmospheric air within the frac and weir tanks. Aeration of the groundwater was most significant within the frac tank, which was designed so that extracted groundwater was injected near the top of the tank above the water line. Iron precipitate was collected within the 10-micron bag filters, as well as the organoclay treatment vessel during the pilot test, and resulted in substantial maintenance at an increasing frequency as the test proceeded. During the first week of focused pumping, the pressure differential (an indication of the degree of precipitate accumulation) across the bag filters and the organoclay vessel was low. However, as the pilot test progressed, the pressure differential across these components increased significantly over shorter timeframes, requiring more frequent replacement of the bag filters and backwashing of the organoclay vessel. During the final week of operation of the temporary treatment system, the bag filters were being replaced daily and the organoclay vessel was backwashed several times.

5.1.2 VOLATILE PETROLEUM HYDROCARBON EMISSIONS

As discussed in Section 3.5, there appears to be the potential for emissions of volatile petroleum related constituents from the temporary treatment system, most notably from hatches and lids on the frac and weir tanks. While engineered (e.g., hatch sealing) and administrative controls largely mitigated such emissions, volatile petroleum related constituents continued to be measured in the up- and down-wind ambient air samples collected adjacent to the temporary treatment system. The volatile petroleum related constituents measured in ambient air appear to be emitted from the tank vents (which cannot be sealed). A custom covering filled with GAC was affixed to the vent on the frac tank during the final week of operating the temporary treatment system. As described in Section 5.2, administrative and engineered controls that include treating air emitted through the frac tank vents using GAC will be performed during future pilot testing.

5.1.3 COMMUNICATION WITH THE VILLAGE OF HARTFORD

During the first week of initiating the pilot test, focused pumping was temporarily reduced below 300 gpm to allow the Village of Hartford to perform weekly maintenance activities, such as backwashing the filters at the municipal potable water treatment system. During these maintenance activities, large volumes of water were discharged from the treatment system into the Village of Hartford CSS, reducing the overall sewer capacity. Following the first week of

focused pumping, extracted groundwater within the frac tank, wier tank, and treatment vessels was treated and discharged into the Village of Hartford CSS (to minimize the water levels within each of the tanks and vessels) just prior to the Village of Hartford conducting weekly maintenance activities. The tanks and vessels were subsequently filled while the Village of Hartford completed maintenance activities. This allowed focused pumping to continue at 300 gpm, but reduced the volume of treated water discharged into the Village of Hartford CSS during the period when maintenance activities were being performed at the municipal potable water treatment system.

5.2 PROPOSED MODIFICATIONS

Based on the lessons learned and partial pilot test results, several modifications are proposed to the additional LNAPL recovery pilot test as approved by the USEPA and Illinois EPA within the *Final Light Non-Aqueous Phase Liquid Recovery Pilot Test Work Plan Addendum* (Trihydro 2013a). Proposed modifications include the following:

- **Revision of the pilot test start-up criteria:** The existing criteria for restarting the pilot test relate solely to groundwater elevations in the three trigger wells descending below 400 ft-amsl. This criteria should be amended to include the condition that focused pumping will be restarted when the water table has been observed to be consistently descending or stable (i.e., without intermittent increases of more than 0.5 foot) for a period of up to two weeks. The addition of these secondary criteria will increase the likelihood that steady-state conditions can be achieved, and the maximum drawdown and ROI will be observed across Area A.
- **Augmentation of the pumping rate**: If agreed to by the Village of Hartford and City of Wood River, the groundwater extraction rate should be increased to 350 gpm. Increasing the pumping rate to 350 gpm (a 15% increase in the flow rate) should enhance LNAPL accumulation, mobility, and recovery commensurate with the degree of the increase. Based on field measurements collected during the step test (described in Section 4.2), pumping at rates above 350 gpm may result in a combined sewer overflow event. During the step test, fluid levels within the Village of Hartford combined sewer monitoring location were gauged on 10 to 15 minute intervals. While groundwater was extracted at a discrete, steady flow rate from production well HPW-01, a transfer pump conveyed water through the treatment vessels and into the sewer in slugs resulting in pulses of high water observed at the combined sewer monitoring location. Figure 15 shows the maximum fluid level thickness observed at the combined sewer monitoring location. The maximum fluid level thickness occurred at an average flow rate of 300 gallons per minute. While the amplitude of the slugs of the treated groundwater may be reduced by extending the duration of transfer pump activation (i.e., restricting flow through the final treatment media to achieve near constant pumping), it is unlikely that doing so will allow pumping at rates above 350 gallons per minute without incurring a combined sewer overflow event. At this time, there is not an alternative method for managing treated groundwater during the resumed additional LNAPL recovery pilot test and the pumping rate will be limited by the current flow rate constraints within the Village of Hartford combined sewer system. Furthermore, as an increase in

the discharge rate to the Village of Hartford CSS increases the potential for a combined sewer overflow event, techniques to more closely monitor the fluid levels within the combined sewer monitoring location (e.g., data logging pressure transducers) to establish this maximum pumping rate will be discussed with Village of Hartford. Agreements with the Village of Hartford and City of Wood River, as well as the Application for Permit of Construction/Operation Approval (Permit No. 2014-EE-58312) will be amended to reflect any proposed changes in the pumping rate, or temporary shut-down criteria (e.g., threshold of precipitation over a 24-hour period) associated with avoidance of a combined sewer overflow event.

- **Application of vacuum to the LNAPL recovery well HLRW-01:** Given the significant increase in volatile petroleum hydrocarbon recovery observed during the partial pilot test, vapor extraction within the LNAPL recovery well HLRW-01 is recommended during future pilot testing. This would be performed by extending a temporary vacuum hose from well MPE-A003 to a sealed cap on the LNAPL recovery well (constructed to allow simultaneous LNAPL and vapor recovery) and extracting vapors between 8 and 10 hours during each day of focused pumping.
- **Installation of three piezometers around the groundwater production and LNAPL recovery wells**: The installation of three 2-inch diameter piezometers screened across the upper portions of the Main Sand stratum from approximately 30 to 45 ft-bgs (as shown on Figure 14) will improve the understanding of drawdown and delayed recharge in Area A. In addition, if LNAPL is measured within a piezometer at a substantial thickness (greater than measured in the LNAPL recovery well HLRW-01), LNAPL recovery can be performed within the piezometer using a skimming pump.
- **Alterations to the temporary treatment system**: To reduce the degree of iron precipitation, the groundwater treatment system should be modified to minimize the contact between atmospheric air and extracted groundwater. To accomplish this, groundwater would enter the frac tank at a bottom inlet, which remains submerged. As extracted water flows over the baffles within a weir tank, enhanced contact between extracted groundwater and atmospheric air also occurs; therefore a frac tank may be substituted for the weir tank during continuation of the pilot test. In addition, the size of the treatment vessels and media used to treat groundwater will be modified such that three or four smaller treatment vessels filled with GAC will be used for future pilot testing. Dissolved lead was not measured at elevated concentrations during the partial test in untreated water samples and therefore organoclay media is not necessary. A schematic showing the proposed modifications to the temporary groundwater treatment system to be used during the resumed additional LNAPL recovery pilot test is provided as Figure 16.
- **System alterations to reduce the potential for air emissions:** Additional air emission controls and modifications to the monitoring methodology should be conducted during continuation of the additional LNAPL recovery pilot test in Area A. To mitigate air emissions, tank hatches and lids will be sealed prior to initiating pumping and only

opened when necessary to fulfill maintenance requirements. As frac tank vents are a safety feature that cannot be sealed, the degree of venting will be limited by minimizing the range of water level change within the tank (e.g., cycling tank levels over a 0.5-foot interval). In addition, air emitted from the vents will be treated using GAC. To improve the representativeness of ambient air monitoring, up- and down-wind sample locations will be located a minimum of 30 feet beyond the fence line in Area A.

5.3 STAKEHOLDER COORDINATION

In order for the additional LNAPL recovery pilot test to be resumed in 2014 (provided trigger criteria are achieved in Area A) coordination with multiple stakeholders is required. The following coordination activities have been performed or are planned. A schedule of proposed meetings, submittals, and activities that will be necessary prior to continuation of the additional LNAPL recovery pilot test is summarized on Table 11.

- **City of Wood River**: On June 10, 2014, Apex met with the City of Wood River to discuss renewal/extension of the existing agreement to discharge treated water generated during the resumed pilot test to the WRWTP. The agreement with the City of Wood River will be modified to reflect the proposed increase in groundwater production rate and submitted to the Wood River City Council within 30-days of the USEPA and Illinois EPA approval of the proposed pilot test modifications included herein.
- **Village of Hartford:** On June 10, 2014, a meeting with Village of Hartford Mayor and Board of Trustees was conducted during which the partial pilot test results and proposed path forward were discussed. Village officials understood the need to resume the pilot test in 2014 with the modifications proposed herein. The existing agreement with the Village of Hartford allows for re-use of the conveyance pipeline and discharge of treated water into the Village of Hartford CSS. However, coordination with Village of Hartford to determine the maximum discharge rate for treated water, as well revised temporary shutdown criteria (e.g., threshold of precipitation over a 24-hour period) associated with avoidance of a combine sewer overflow event, will be completed within 30-days of the USEPA and Illinois EPA approval of the proposed pilot test modifications included herein.
- **Illinois EPA**: A supplemental permit, or permit modification, to the Application for Permit of Construction/ Operation Approval (Permit No. 2014-EE-58312) will be submitted to Illinois EPA to reflect revisions to the temporary groundwater treatment system including infrastructure, discharge rates, and temporary shutdown criteria within 30-days of the USEPA and Illinois EPA approval of the proposed pilot test modifications included herein.
- **USEPA**: Additional discussions with USEPA will be performed as needed to gain concurrence with the approach outlined in this report and to allow continuance of the pilot test during 2014.

6.0 REFERENCES

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TABLES

FIGURES

APPENDICES A THROUGH I

(PLEASE SEE ATTACHED CD)

APPENDIX A-1

ELECTRICAL CONDUCTIVITY AND LASER INDUCED FLUORESCENCE LOGS FROM BORINGS HUVOST-040 AND HUVOST-040 DUPLICATE

APPENDIX A-2

WELL COMPLETION CONSTRUCTION DIAGRAMS FOR GROUNDWATER PRODUCTION WELL HPW-01 AND LNAPL RECOVERY WELL HLRW-01

APPENDIX B-1

PILOT BORING ANALYTICAL REPORT

APPENDIX B-2

CHROMATOGRAM FOR LNAPL SAMPLE COLLECTED FROM GROUNDWATER MONITORING WELL HMW-044C IN 2005

APPENDIX C

FIELD LOGS FOR 6-INCH TREATED WATER CONVEYANCE PIPELINE INSTALLATION

APPENDIX D

ILLINOIS EPA DIVISION OF WATER PERMIT OF CONSTRUCTION/OPERATION APPROVAL (PERMIT NO. 2014-EE-58312)

APPENDIX E

TEMPORARY TREATMENT SYSTEM COMPLIANCE ANALYTICAL REPORTS

APPENDIX F-1

AMBIENT AIR MONITORING ANALYTICAL REPORTS

APPENDIX F-2

AMBIENT AIR MONITORING DATA VALIDATION REPORTS

APPENDIX G-1

MANUAL FLUID LEVEL MEASUREMENTS

ON CD IN EXCEL FORMAT ONLY

APPENDIX G-2

PRESSURE TRANSUCER MEASUREMENTS

ON CD IN EXCEL FORMAT ONLY

APPENDIX H

LNAPL BAILDOWN MONITORING RESULTS AND LNAPL DISCHARGE VERSUS DRAWDOWN

APPENDIX I-1

DISSOLVED PHASE MONITORING FIELD FORMS

APPENDIX I-2

DISSOLVED PHASE MONITORING ANALYTICAL REPORTS

APPENDIX I-3

DISSOLVED PHASE MONITORING DATA VALIDATION REPORTS