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**From:** Dave Favero <dfavero@racertrust.org>
**Sent:** Monday, April 28, 2014 2:45 PM
**To:** Pardys, John-Eric; Tomka, Mike; Rousseau, Matthew
**Subject:** FW: SMI NAPL ~OUT-007878~
**Attachments:** 2013-1, Final LIF Report.pdf

For your info and review.

Thanks,
David Favero
Deputy Cleanup Manager - Michigan

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**From:** Kaelber-Matlock, Sue (DEQ) [mailto:MATLOCKS@michigan.gov]
**Sent:** Monday, April 28, 2014 4:43 PM
**To:** Dave Favero
**Subject:** SMI NAPL

Dave, I was at a DPH trustee meeting last week and it was brought to my attention by the Tetra Tech folks, who are the Trust consultants, that the LIF study, completed by ERM for Delphi, defined the NAPL to the SMI property boundary. Since we are going to have a discussion next week regarding the NAPL at SMI, I thought that you might want to look at the report since questions may come up. I will have to send it in a couple e-mails, as the files are large and I need to get them through my system. I will send the report and the figures. Please let me know if you want appendices A-J. Sue

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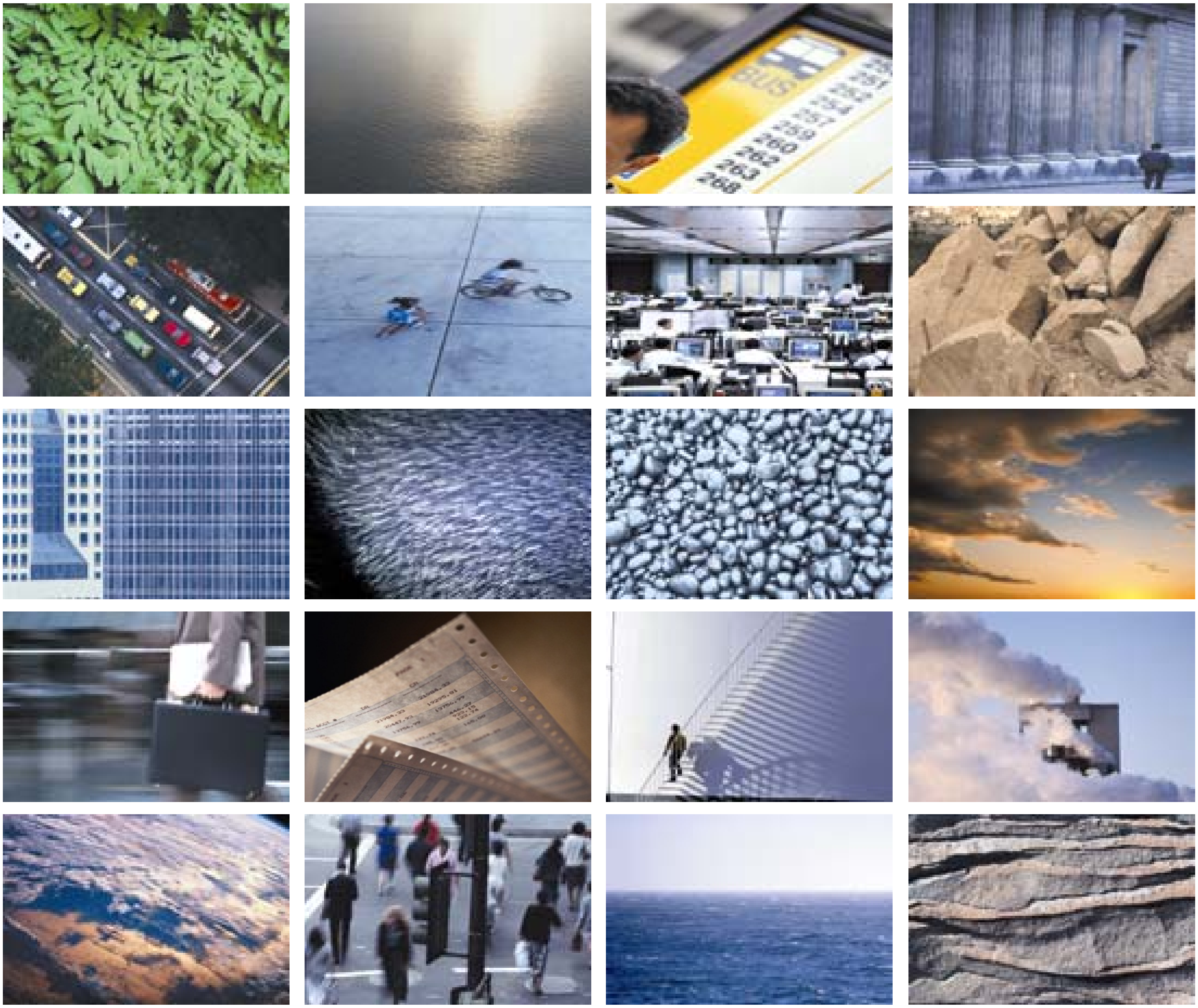

# LNAPL Evaluation Report

**DPH Holdings Corp.**
**Former Plant #2 Property**
**Saginaw, Michigan**

January 2013

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**FINAL REPORT**

DPH Holdings Corp.

# LNAPL Evaluation Report
## *Former Plant #2 Property*
## *Saginaw, Michigan*

January 2013

Project Number: 0177320

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## *List of Acronyms*

| | |
|---|---|
| AMSL | Above Mean Sea Level |
| API | American Petroleum Institute |
| AST | Aboveground Storage Tank |
| ASTM | American Society for Testing and Materials |
| bgs | Below Ground Surface |
| GAC | Granular Activated Carbon |
| GM | General Motors |
| ITRC | Interstate Technology Regulatory Council |
| LCM | LNAPL Conceptual Model |
| LCSM | LNAPL Conceptual Site Model |
| LDRM | LNAPL Distribution and Recovery Model |
| LIF | Laser Induces Fluorescence |
| LNAPL | Light Non-Aqueous Phase Liquid |
| µm | Micrometers |
| MW | Monitoring Well |
| O&M | Operation and Maintenance |
| PAH | Polynuclear Aromatic Hydrocarbons |
| PCBs | Polychlorinated Biphenyls |
| POTW | Publicly Owned Treatment Works |
| PZ | Piezometer |
| RI | Remedial Investigation |
| RW | Recovery Well |
| SB | Soil Boring |
| SMI | Saginaw Malleable Iron |
| TSCA | Toxic Substances Control Act |
| USGS | United State Geological Survey |
| UST | Underground Storage Tank |
| UV | Ultraviolet |
| UVOST® | Ultraviolet Optical Screening Tool |
| VOCs | Volatile Organic Compounds |
| WWTF | Waste Water Treatment Facility |

# *EXECUTIVE SUMMARY*

DPH Holdings Corp. ("DPH") requested Environmental Resources Management, Inc. ("ERM") perform a comprehensive evaluation of light non-aqueous phase liquid (LNAPL) mobility and recoverability at the former Plant 2 property in Saginaw, Michigan resulting from historical manufacturing operations. The objective of the evaluation is to support development of a LNAPL conceptual site model (LCSM) such that remedial alternatives for the Plant 2 property can be developed. The evaluation was performed using data that was obtained from performing a laser induced fluorescence (LIF) survey, from collection and analysis of soil cores, and by review of historical site investigation data.

The former Plant 2 property was originally developed by the Erdman-Guider Company in 1919, which went out of business in 1926. The site was subsequently developed by General Motors (GM), with the plant opening in March of 1941 to produce rifle and machine gun parts for World War II. The plant was later operated by GM and then Delphi Automotive Systems (Delphi) as the Saginaw Steering Gear Plant #2 manufacturing facility until August 2001. Most of the aboveground structures on the property were demolished in the summer of 2002 and the site is now a large, vacant, fenced lot. The only structures that remain include an electrical switch house and substation, and a former wet well (part of the process sewer).

From July 1995 until March 2002, LNAPL recovery was initiated as an interim response measure in four separate recovery wells. To accommodate site demolition, these interim LNAPL recovery systems were shut down and removed in early 2002. A new LNAPL recovery system was installed in September 2003, which had been designed to remove LNAPL via total fluid recovery pumps with subsequent oil/water separation and clay/granular activated carbon (GAC) treatment of groundwater. This system is currently active and housed in an on-site remediation system trailer.

In 2010, Delphi Automotive Systems became DPH Holdings Corp.

A LIF survey was conducted between 5 November and 14 November 2012. A total of 112 LIF direct-push borings were advanced in order to delineate the horizontal and vertical extent of LNAPL, to provide a semi-quantitative estimate of LNAPL saturation distribution, and to provide an understanding of the distribution of different LNAPL types.

In addition to the LIF study, field activities included sampling of LNAPL, water, and soil. These samples were submitted for laboratory analysis of a variety of parameters to provide an understanding of the LNAPL type, subsurface lithology, and LNAPL behavior including mobility and saturation.

Using these multiple lines of evidence, the following specific conclusions were derived from this data:

**LNAPL Types** - Fluid analysis and LIF waveform data indicates that LNAPL ranges from lighter end hydraulic oils to heavier end used motor oils. The primary LNAPL types observed were higher viscosity LNAPLs, similar to gear oil and used/weathered motor oil.

**LNAPL Extent** - The LIF investigation defined the lateral and vertical extents of both mobile and residual LNAPL. The distribution of LNAPL is consistent with historical site operations and indicates that multiple historical releases occurred at the site. LNAPL appears to be limited to the vicinity of suspected historical release areas, and the absence of significant lateral migration indicates that the LNAPL plume is stable.

**LNAPL Mobility** - Soil core data and fluid gauging data show that mobile LNAPL is present under the former main facility building, to the southeast of the former main facility building, and to the north in the vicinity of the former chip house. However, mobile LNAPL does not always indicate the presence of hydraulically "recoverable" LNAPL. The data also shows that the majority of the LNAPL present at the property is residual LNAPL.

**LNAPL Recoverability** - Soil core data and manual skimming data were evaluated for areas of the property with the highest LNAPL recoveries. The high viscosity of the LNAPL inhibits effective LNAPL recovery. Calculated LNAPL transmissivities indicate that LNAPL recovery at the site is not practicable using hydraulic recovery methods (i.e., cannot be efficiently removed using remedial technologies such as skimming, pumping, etc.), and these remedial technologies will not significantly reduce the overall LNAPL mass.

In summary, the LNAPL plume has low mobility, is laterally stable, and operation of LNAPL skimming/pumping systems is unlikely to appreciably reduce the overall LNAPL mass. Vertical redistribution of mobile LNAPL is occurring, and may reach the surface during high water table elevations.

ERM recommends that remedial actions focus on containing the mobile LNAPL and preventing it from day-lighting at the surface.  This may include barrier walls and a cap to reduce infiltration, and possibly the use of hydraulic controls if water levels inside the containment rise to the surface.

# *1.0 INTRODUCTION*

## *1.1 OBJECTIVES*

DPH Holdings Corp. ("DPH") requested Environmental Resources Management, Inc. ("ERM") perform a comprehensive evaluation of light non-aqueous phase liquids (LNAPL) mobility and recoverability at the former Plant 2 property in Saginaw, Michigan. The main objective of this scope of work was to further characterize the extent, mobility, and recoverability of LNAPL that has been observed in select on-site monitoring wells and the groundwater flow conditions at the site. The characterization will support the evaluation of remedial alternatives for the Plant 2 property.

## *1.2 SCOPE OF WORK*

ERM evaluated the LNAPL distribution and mobility by perfoming the following tasks:

### LNAPL Mapping with Laser Induced Fluorescence (LIF)

LIF technology was used to develop an understanding of the horizontal and vertical extent of LNAPL across the site. Matrix Environmental LLC (Matrix) was contracted to perform the LIF investigation. The digital data generated from the LIF tool was modeled and mapped using data visualization software to develop two- and three-dimensional graphics that supported development of a robust LNAPL Conceptual Site Model (LCSM). The intensity of the LIF response was also used to identify areas of higher LNAPL saturation.

### LNAPL Saturation

Three (3) soil cores were collected adjacent to select LIF locations and immediately frozen and shipped to PTS Laboratories, Inc. (PTS) in Santa Fe Springs, California for photography and analysis. The PTS data was used to develop detailed LNAPL Conceptual Models (LCMs) in the vicinity of the core locations. This data quantified the amount of mobile LNAPL versus the amount of residual LNAPL trapped in the soil pores at multiple depths within the core locations.

Data Compilation & Report

The LIF data and laboratory data from PTS was reviewed and compiled to improve the LCSM and understand the distribution of LNAPL at the property. The data was then used to refine long-term remedial options such as encapsulation of the LNAPL.

## *1.3 TERMINOLOGY*

The following definitions of terms are provided for clarification throughout this report:

- **Capillary Fringe**. The zone at the bottom of the vadose zone where liquid phases (e.g., water and LNAPL) are drawn upward by capillary force.

- **Capillary Pressure Head**. Capillary pressure head is defined as the difference between pressures of phases, such as air and groundwater or LNAPL and groundwater within a solid matrix.

- **Corrected Groundwater Elevation**. A theoretical surface representing the total head of groundwater in an aquifer, defined by the level to which water will rise in a well where no LNAPL exists.

- **Formation**. The subsurface soil through which LNAPL, water, and air exist within. For the purposes of this report, this term is used in general discussions rather than site specific examples.

- **Interval of Mobile LNAPL**. The vertical length of aquifer where free-phase LNAPL exists at a given location. The interval of mobile LNAPL represents the interval over which the LNAPL transmissivity is greater than zero.

- **LNAPL**. Light Non-Aqueous Phase Liquid (e.g., petroleum products) of varying compositions, characteristics, ages, and origins having a specific gravity less than 1 and are composed of one or more organic compounds that are immiscible or sparingly soluble in water. The term encompasses all potential states of LNAPL (for example, free-phase, residual, mobile, entrapped, etc.).

- **LNAPL Conceptual Model**. An interpretation or working description of the characteristics and dynamics of a physical system that is impacted by or influences the vertical distribution of LNAPL in the subsurface at a single location. This representation conveys what is known or presumed about the LNAPL saturation, transmissivity, mobility, and recoverability.

- **LNAPL Conceptual Site Model**. Describes the physical properties, chemical composition, occurrence, and geologic setting of the LNAPL body from which estimates of flux, risk, and potential remedial action can be generated.

- **LNAPL Distribution.** The concentration of LNAPL in the subsurface (laterally and vertically), and includes mobile and residual (i.e., immobile) LNAPL.

- **LNAPL Endpoint**. The point where LNAPL recovery is considered low enough for active remediation of recoverable LNAPL to be considered complete. LNAPL endpoints can be predicted through modeling or interpretation of empirical recovery rates over time. This LNAPL endpoint definition only applies to LNAPL recovery from recovery wells, as modeled by this document, and does not relate to LNAPL plume stability, dissolved-phase source removal, or vapor phase migration.

- **LNAPL Mobility**. The potential for LNAPL to migrate from one location to another.

- **LNAPL Properties**. The physical and chemical attributes of a specific LNAPL. Since many petroleum products are composed of multiple chemicals, and because of environmental interactions, both physical and chemical properties can be quite variable between LNAPLs, as are the associated potential environmental risks and amenability to different remedial actions.

- **LNAPL Recoverability**. The portion of LNAPL at a location (e.g., well) that is practicably recoverable using hydraulic remediation technologies such as skimming and pumping.

- **LNAPL Transmissivity**. The unit volume of LNAPL that will flow parallel to a pressure gradient, across a unit width of the porous media in a given time period for a unit gradient. In general, higher LNAPL transmissivity equates to higher LNAPL recoverability.

- **Mobile LNAPL**. LNAPL that is interconnected in pore space and has the potential to move under a hydraulic gradient.

- **Residual LNAPL**. The portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients. Residual LNAPL possesses an LNAPL transmissivity of zero.

- **Site-specific**. Activities, information, and data unique to a particular site.

- **Skimming**. The use of a skimming pump or vacuum truck to remove LNAPL from a well without the removal of groundwater.

- **Smear zone**. The vertical interval over which residual or entrapped LNAPL is present in the unsaturated, saturated, and capillary zones. Typically, the LNAPL is smeared in shallow groundwater by a fluctuating water table.

- **Source area(s)**. Either the location of LNAPL or the location of highest soil and groundwater concentrations of the constituent(s) of concern.

- **Vadose zone**. The unsaturated zone between the land surface and the water table. It includes the capillary fringe and may also include localized perched ground water. Pore-water pressure in the vadose zone is less than atmospheric, except for perched ground water. Except for the capillary fringe and perched ground water, pores in the unsaturated zone contain both water and air. The vadose zone (unsaturated zone) differs from the saturated zone, in which pores contain water at greater than atmospheric pressure and are almost always completely filled with water.

- **Water table**. The top of an unconfined aquifer where water pressure is equal to atmospheric pressure; in other words, the surface between the zone of saturation and the zone of aeration. In unconfined aquifers, the water table is equal to the corrected groundwater interface.

## 2.0 SITE SETTING

### 2.1 SITE DESCRIPTION

The DPH Former Plant #2 site (Plant #2) consists of 37 acres of land located at 1400 Holmes Street, Section 34, Township 12 North, Range 4 East, Saginaw, Charter Township, Michigan (Figure 1).

The site is currently a large, vacant, fenced lot, as all former buildings/structures at the site, except for a DTE electrical switch house and substation and the former wet well (part of process sewer), were demolished in the summer of 2002. The concrete slab floors from the former buildings and the site's asphalt/concrete paved access roads and parking/storage areas remain (see Figure 2). Other remnants of the former facility operations are located in the site's subsurface and include former building and machining center foundations, tank and equipment pits, basements, decommissioned utilities, etc. The only unpaved areas of the site are a small gravel area east of the former power house, a strip of grass outside the western wall of the former plant, the immediate area around the substation, and the very southern area of the site down to the southern property line.

A groundwater pump-and-treat system is the only active operation currently at the site. There is a small trailer installed at the site to house the treatment system. Weekly operation and maintenance (O&M) activities take place within the trailer and the system's recovery well/trench network. Additional O&M efforts may include monitoring well gauging and manual LNAPL recovery efforts.

### 2.2 NEIGHBORING PROPERTIES

Neighboring properties consist of the following (Figure 2):

- West, northwest, and north: Residential properties;
- Northeast and east: Former General Motors Saginaw Malleable Iron (SMI) Plant (now demolished and owned by The Racer Trust);
- Southeast and south: Two undeveloped parcels of property (i.e., peninsula property and wetland property), followed by the Green Point Landfill, all owned by The RACER Trust; and
- Southwest: An automobile salvage yard facility.

## *2.3 GROUNDWATER USE*

There is no groundwater use on-site or on surrounding properties. The site and surrounding area are serviced by municipal water from the City of Saginaw, which obtains its water from Lake Huron.

## *2.4 UTILITY LOCATION*

An extensive network of underground piping was present at the site and was used for storm water, sanitary sewer, and an auxiliary process waste sewer. The underground piping extended beneath the manufacturing plant building and under a parking lot area to the west of the building. Storm water and process wastewater from the site was conveyed via the GM SMI Plant sewer system to the City of Saginaw publically-owned treatment works (POTW). Sanitary and non-contact cooling water was discharged directly from Plant 2 to the municipal sewer along Salt Street to the north. A map showing the locations of sanitary, storm, and process sewers is provided in Appendix A. As described in Section 2.5.5, the sewers were plugged when the building was demolished.

## *2.5 SITE HISTORY*

### *2.5.1 Facility Background*

The site was originally developed in 1916 as an industrial mill and then further developed as a manufacturing facility in 1941 for the production of machine guns during World War II. Under General Motors' and Delphi Corporation's ownership, Plant #2 was expanded and utilized as an automotive steering gear machining and assembly plant; ownership of the decommissioned site was transferred to DPH Holdings Corporation in October 2010 upon Delphi's emergence from bankruptcy.

The former Plant 2 manufacturing building, shown in Figure 3, consisted of a 511,000 square foot, one-story building of concrete slab-on-grade construction with concrete foundation walls that extend down into the underlying clay. Certain portions of the plant also had subsurface pits, vaults, basements, and trenches for various operations, as well as subsurface machining center foundations and two former subsurface gun ranges.

In addition to the main plant, other buildings/structures that were formerly on-site included the following (see Figure 3):

- The original Erdman Guider Building was attached to the north side of the manufacturing building and was used for incoming parts storage.

- A Power House Building was located approximately 60 feet north of the former manufacturing building and contained boilers, plant support equipment, and a diesel fuel above ground storage tank (AST) that was located inside the building. The Power House Building also had a basement.

- A Fire Pump House, used for the fire protection system, was located approximately 260 feet north of the former manufacturing building. Associated structures included a water tower, a water tank, and a diesel AST located outside the building.

- A waste water treatment facility (WWTF) utilized for oily wastewater pre-treatment was located approximately 20 feet east of the former manufacturing building. The WWTF consisted of a treatment building that contained various process equipment and tanks; several associated ASTs located east, southeast, and north of the treatment building (including two 200,000-gallon batch treatment tanks); a large oil/water (O/W) separator (known as the API separator); and two skimmed-oil recovery tanks which stored oil from the O/W separator.

- A Tank Farm Building, located approximately 160 feet south of the manufacturing building contained ten ASTs with capacities ranging up to 17,000 gallons each. The Tank Farm Building was equipped with pumps to transfer various products stored in the ASTs through underground piping to appropriate locations inside the manufacturing building.

- An Equipment Storage Building, located approximately 100 feet east of the former manufacturing building, contained fork lifts and other manufacturing equipment.

- A canopy located approximately 80 feet south of the former manufacturing building covered three petroleum ASTs with capacities ranging from 275 to 550 gallons. These tanks were used to fuel company cars and facility material handling and maintenance equipment.

### 2.5.2 *Potential Sources of LNAPL*

There were a number of potential sources of LNAPL present at the site while it was still in operation, including ASTs, underground storage tanks (USTs), and various production and support operations that were associated with the use of petroleum hydrocarbons. Below is a detailed listing of the historical potential LNAPL sources identified at the Former Plant #2 site.

- USTs #1 through #10 located beneath the floor of the southern portion of the main manufacturing building, as shown in Figure 3. Tank capacities ranged from 8,000 to 15,000 gallons and contained various petroleum-based fluids such as quench oil, reclaimed oil, power steering fluid, hydraulic oil, mineral oil, grinding oil, way oil, soluble oil, and cutting oil.

- USTs #11 and #12 were centrally located 20 feet outside the southern building foundation wall. Tank capacities were 15,000 gallons each and both tanks contained hydraulic oil.

- USTs #13 and #14 were located below the former Chip House building. Tank capacities were 15,000 gallons each and the tanks contained cutting oil, soluble oil, and/or dirty quench oil.

- UST #15 was a possible UST reportedly located due northeast of the northern property gate at Holmes Street. The exact tank capacity was unknown, but the tank reportedly contained gasoline.

- Twenty nine (29) ASTs which had contents that included grinding oil, soluble oil, way oil, quench oil, cutting oil, hydraulic oil, used cutting and quench oil, power steering fluid, gasoline, diesel fuel, sodium hydroxide, ISC 400, aluminum sulfate, sulfuric acid, oily sludge, influent wastewater, pump-back coolant, and reclaimed oil.

- The main operations at the plant involved the wet machining of metal parts and utilized various cutting oils/metalworking coolants.

- A series of hydraulic units for equipment on the production floor above were housed in the Assembly Line Basement located on the eastern side of the plant.

- Eleven (11) cutting fluid filtration units (hydromation units) and their subsurface collection flume networks were located within the manufacturing building. These were closed-loop systems that filtered soluble or non-soluble cutting oils and pumped them back to machining or grinding equipment. Each self-contained filtration unit consisted of a process flow-through tank, pumps, and a filtration system to remove metallic fines.

- A Chip House was attached to the north side of the manufacturing building in the vicinity of the AA column line. The Chip House contained a ringer, a crusher, and truck and rail load-out areas for waste metal chips produced by metal milling and lathing operations in the plant. The chips were transported to the Chip House by a subsurface chip conveyor system built into a trench that varied from 3 to 10 feet in depth and spanned the entire north-south length of the Plant 2 building.

- An area for heat treating of metal parts was located in the southwest area of the plant. This operation involved the heating of metal parts to set temperatures followed by quenching in oil quench tanks for cooling and completion of the hardening process. The oil quench tanks were located in subsurface vaults in this area of the plant.

- A process sewer system and WWTF were operated at the facility. Machine pits in the building had sump pumps that sent oily wastewaters to the WWTF along with other sources of oily wastewater. At the WWTF, all influent first went to an O/W separator where non-soluble oils were pumped off to a storage tank. Solids were removed from the separator with a drag conveyor and sent to another storage tank. The wastewaters were then sent to one of two 200,000 gallon batch treatment tanks where the soluble oils were removed via treatment; this process generated a sludge waste stream. Recovered oil was sent off-site for recycling, sludge was sent off-site for disposal, and the treated effluent was discharged to the sanitary sewer.

- Roll-offs and grinding swarf were stored just off the edge of the concrete paved area located south of the plant. The grinding swarf area was reportedly provided with containment, but historical photographs of this area show that the containment area was small and materials were stored both in the containment and around it on the unpaved ground.

- A chemical storage crib was located in the east-central section of the manufacturing building and was used to store drums and various containers of liquid and non-liquid products used in the manufacturing operations.

- A hazardous waste (less than 90-day storage) and chemical storage area was located outside the north side of the building directly north of column J1. The area consisted of drum storage racks that were used to store 55-gallon drums of chemicals.

- For many years the plant operated with one, and later two, train track wells that ran the entire north-south length of the building.

### 2.5.3 *Potential LNAPL Release Scenarios*

Listed below is a summary of the potential LNAPL release scenarios that were known prior to completion of the LIF study.

- USTs #1 and #3 failed tightness testing performed in 1985; the leak rate on UST #3 was reported as "too fast to establish an exact leak rate." Records indicate that tanks #1 and #3 were "repaired" in November 1986 by lining the interiors of the tanks. Due to the funding required to bring the USTs up to code, in 1989 USTs #1 - #10 were collectively emptied, closed in place, and replaced with AST systems located in the former Tank Farm Building at the south end of the site; this AST system was dismantled during the 2002 plant demolition. During the 1989 UST closures, investigations confirmed LNAPL releases to the soil and groundwater around USTs #1-10. The types of LNAPL identified in the area included LNAPL attributable to tanks #1 and #3 and additional LNAPL types that did not appear to correlate to the materials formerly stored in tanks #1 and #3.

- USTs #11 and #12 were removed in 1989, and although UST #11 failed the tightness testing performed in 1985, no signs of petroleum impact were identified during the tanks' excavation and removal.

- USTs #13 and #14 failed tightness testing performed in 1985; the leak rate on UST #13 was reported as "too fast to establish an exact leak rate." USTs #13 and #14 were emptied and closed in place in 1990, as they could not be removed without compromising the structural integrity of the Chip House building. Groundwater was not present in the area at the time of the tank closures and the tanks were not excavated, so the investigation for petroleum impact in the area around USTs #13 and #14 was limited to soil borings. There was limited evidence of petroleum impact at the time of the closure, but notable volatile organic compound (VOC) impact (both chlorinated and non-chlorinated) was noted in area soils.

- UST #15 was reportedly closed in place, although no records of the tank closure or investigations into potential petroleum impacts in the area of UST #15 have been identified.

- LNAPL has been identified in wells near the fueling station for two ASTs (gasoline and diesel) located southwest of USTs #11 and #12.

- The daily operational use of oils inside the plant is also suspected to have contributed to LNAPL impact at the site, including the use of heat treat quench oils in subsurface quench tanks, widespread use of hydromation units and their subsurface collection flumes for the recycling of metalworking coolants/cutting oils, and oil reclamation operations/systems (e.g., chip house operations, chip trench, process sewers, etc.).

The confirmed releases from several USTs, along with suspected releases from operational uses of oils in the plant, have resulted in a large combined area of LNAPL under the central to southern portion of the former plant and several smaller LNAPL detections in other areas of the site. The LNAPL observed on-site appears to consist of several types of oil, ranging from a dark, thick oil to less viscous water soluble cutting oils. The LNAPL beneath the former Plant #2 building is confined within the building footprint by the intact exterior subsurface foundation walls.

### *2.5.4 LNAPL Recovery Efforts to Date*

From July 1995 until March 2002, LNAPL recovery was initiated as an interim response measure in four separate recovery wells located near USTs #1 through #10. To accommodate site demolition, these interim LNAPL recovery systems were shut down and removed in early 2002. A new LNAPL recovery system was installed in September 2003, which had been designed to remove LNAPL via total fluid recovery pumps with subsequent oil/water separation and clay/granular activated carbon (GAC) treatment of groundwater. This system was idled from November 2010 to June 2012 in order to study LNAPL rebound patterns in support of a remedial option feasibility study. During the LNAPL study, select wells with LNAPL were manually gauged and then pumped to recover LNAPL. This resulted in the manual recovery of 65 gallons of LNAPL during the study, as opposed to the approximately 26 gallons recovered the prior year with the full LNAPL recovery system.

### *2.5.5 Consequences of Demolition Practices*

Plant #2 was idled in August 2001 and subsequently ceased all manufacturing operations. The plant was then demolished in the summer of 2002, at which time all aboveground structures were removed; underground utilities were capped (i.e., “bulkheaded”) on-site or at the site property line and filled/grouted with flowable fill; subsurface voids (e.g., vaults, pits, basements, etc.) were backfilled with crushed concrete/gravel; and all subsurface building foundations/footings, machining center foundations, flumes, etc. were left in place. The former plant floor was also left in place and is now a large surface level concrete slab.

The bulk-heading of the underground storm, sanitary, and process sewers during site demolition caused groundwater levels within the former building footprint to rise an average of 5 to 7 feet within a few years; the still intact foundation walls anchored into a clay confining layer created a localized "bathtub effect" for perched water. The water table elevation inside the building footprint averages from 1 foot below ground surface (bgs) to right below the surface slab. The water level rise has also resulted in a submerged LNAPL smear zone extending from the base of the surface slab down to depths of approximately 18 feet bgs on the eastern and southern portions of the plant.

With the demolition of the neighboring SMI property, groundwater levels outside the former Plant #2 building footprint have also risen several feet and currently average around 1.5 to 6 feet bgs depending upon the location. The water elevation rise inside and outside the former plant foundation has rendered the majority of the pre-2006 monitoring wells and piezometers unsuitable for monitoring LNAPL (i.e., wells no longer screened at the water table) and the former LNAPL recovery system ineffective for recovering LNAPL (i.e., recovery wells and trench no longer screened at water table/LNAPL interface).

Due to the high water level under the slab, LNAPL at certain locations inside the building footprint occasionally seeps to the surface through cracks in the slab. When these seeps appear, they are managed (i.e., soaked up, management of residuals, etc.) as part of the monthly system O&M. A groundwater seep was also discovered along the southern end of the western foundation wall during an LNAPL rebound study conducted in 2011-2012 to assess the current recovery system effectiveness. During periods of high water table, the seep vents perched groundwater (no LNAPL) from under the slab to the surface, which subsequently migrates south via overland flow to the wetland located east of the substation and then onto the wetland property to the south. At the seep itself the groundwater is impacted with dissolved phase VOCs; however, to date VOCs have not been found in the water at the location it leaves the property and discharges to the southern wetland. At the end of the LNAPL rebound study, LNAPL had begun to move in the direction of this perched groundwater seep. The on-site LNAPL recovery system was restarted in June 2012 to lower the water table inside the foundation and maintain hydraulic control of the perched water/LNAPL under the slab, thereby managing both oil seepage to the surface of the slab and perched groundwater venting from the seep at the western foundation wall.

# *3.0 GEOLOGY/HYDROGEOLOGY*

## *3.1 SUBSURFACE STRATIGRAPHY*

The glacial geology of the site is characterized as an end moraine of fine-textured till (Ferrand and Bell, 1982). This is described as non-sorted glacial debris in a matrix that is predominantly clay. The glacial soils are underlain by shale from the Saginaw Formation of the Pennsylvanian epoch (Western Michigan University, 1981). A soil boring for MW-139, which was installed in the northwest portion of the Plant 2 property, showed that the shale lies at a depth of approximately 81 feet bgs. Consistent with the description of the glacial geology, clay at that location extended from near the ground surface to the top of shale bedrock.

Site-specific geology and hydrogeology was determined based on numerous monitoring wells and soil borings that have been drilled on-site in the past. Monitoring well locations are shown in Figure 4.

Concrete covers most of the site, including the northern portion of the study area; however, the southernmost portion of the site and the adjacent Racer Trust Peninsula property are unpaved. Beneath the concrete and topsoil is a 3- to 15-foot thick layer of fill material consisting mainly of black, very fine-grained, silty sand. The fill appears to be foundry sand that was used historically to fill in low or wet areas as the site was developed. Frequently, construction debris consisting of bricks and concrete pieces are encountered in the shallow fill above the foundry sand. At some locations, a thin (approximately 6-inch-thick) organic silt layer is present below the foundry sand. This silt layer likely represents the remnants of the original ground surface prior to filling. At some locations, a similar organic silt layer is present directly above the regional clay unit.

Underlying both the fill and the organic silt layer is a sand unit. At several locations within the study area, this unit varies from fine-grained sand to very fine-grained silty sand, which is similar to the foundry sand, but differs in color (a light gray to grayish brown versus black foundry sand) and often contains trace shell fragments.

Beneath the sand unit lies a silty clay unit. This silty clay unit likely represents the glacial till and is considered a regional aquitard because of its low permeability and consistency beneath the site. The depth to the regional clay varies from 0.6 feet bgs in the very northern portion of the site to 24 ft bgs between the former Plant #2 main building and the southern site boundary. Appendix B contains various geologic cross sections that were previously constructed based on historic boring/monitoring well logs.

Cross sections that include LIF response data are also discussed in Section 5.2.

## 3.2 HYDRAULIC CONDUCTIVITY

More than 200 in-situ hydraulic conductivity (slug) tests were completed by Blasland, Bouck & Lee (BBL) as part of a 1999 remedial investigation (RI) of the adjacent GM SMI property. As summarized in the BBL RI report for the Plant 2 property (BBL, August 1999), because the geology of the GM SMI property is similar to the Plant 2 property, this information was used to provide an estimate of the hydraulic conductivity of the lithologic units at Plant 2. Average hydraulic conductivities for these units are as follows:

| Lithologic Unit | Hydraulic Conductivity (cm/sec) | Hydraulic Conductivity (ft/day) |
|---|---|---|
| Fill (foundry sand) | 1.54E$^{-3}$ | 4.4 |
| Sand | 2.8E$^{-3}$ | 8.1 |
| Silty Clay | 1.71E$^{-6}$ | 4.4E$^{-3}$ |

## 3.3 AQUIFER DESCRIPTION

The uppermost aquifer beneath the site is within the Saginaw formation, typically in the Parma sandstone. Based on information from the U.S. Geological Survey (USGS), groundwater from the Saginaw formation is typically highly mineralized, with elevated concentrations of dissolved solids, chloride, iron, and other minerals (USGS 1989, USGS 1990). As such, the City of Saginaw obtains its drinking water from Lake Huron.

## 3.4 HYDROGEOLOGIC CONDITION FOR GROUNDWATER

Shallow groundwater at the site is perched on the clay aquitard and occurs in the foundry fill or uppermost sand unit.

Figure 5 shows a groundwater contour map based on water levels measured in February 2012. The table in Appendix C provides liquid level measurements used to create this map. The contour map shows groundwater elevations of 591 to 593 ft above mean sea level (AMSL) within the former building footprint. The withdrawal of groundwater in conjunction with the recovery of LNAPL in the former building area has a localized effect on surrounding monitoring wells beneath the former

Plant #2 structure; however, it does not appear to have any effect on groundwater flow south of the former building or in off-site areas. Outside of the building foundation, groundwater south of the plant flows in a south-southwesterly direction at a gradient of 0.010 ft/ft.

The DPH site has various subsurface structures (e.g., old building and machine foundations, etc.) that likely influence and/or limit groundwater and LNAPL movement beneath the former building, and in the area between the former building and the southern site boundary. In addition, subsurface soils, through which the shallow groundwater moves, consists of assorted fill materials, which may also influence groundwater flow patterns at the local scale.

Within the foundation of the former Plant #2 main building, the depth to groundwater varies from approximately 0 to 3 ft bgs. Groundwater levels rise rapidly and fall slowly in response to precipitation events. Pumping in some areas can lower the groundwater levels more rapidly than in other areas, while many areas are unaffected by pumping within the foundation regardless of flow rate, indicating all areas are not hydraulically connected.

Due to the substructures (i.e., vaults, pits, and basements backfilled with crushed concrete; interior building foundations/footings; machining center foundations, etc.) remaining under the slab, the hydraulic environment under the slab is moderately to highly discontinuous with potentially isolated pockets of LNAPL and preferential pathways.

Figure 6 shows the estimated extent of LNAPL based on observed LNAPL thicknesses in monitoring wells measured in May 2008 and September 2011. Because observed LNAPL does not necessarily provide an indication of what is recoverable or provide an indication of residual LNAPL in the subsurface, the LIF investigation was undertaken to better understand the LNAPL characteristics and recoverability.

## *3.5 GROUNDWATER/SURFACE WATER INTERACTION*

There are no surface water bodies on the site. The closest surface water feature is a wetland area present on the Racer Trust property adjacent to the southern property boundary and due west of the Racer Trust Peninsula property. The regional groundwater flow direction in the vicinity of the site is towards the confluence of the Shiawassee and Tittabawassee Rivers located southeast of the site. On the Racer Trust Peninsula property, shallow groundwater generally flows southwest toward the wetland area.

Just south of the former Plant #2 building, the depth to groundwater generally varies from 3.0 to 4.5 ft. bgs. At the southern site boundary, the depth to groundwater is generally 3.0 to 5.5 ft. bgs. Near the eastern wetland boundary (between the Peninsula property and the wetland), the average depth to groundwater is 5.8 to 6.7 ft. bgs. Within the wetland area itself, the depth to groundwater varies from 0.1 to 3.5 ft. bgs.

## *4.0 DATA COLLECTION AND ANALYSIS METHODS*

Site-specific soil, groundwater, and LNAPL parameters were collected in order to develop the LNAPL conceptual site model and included the following information:

- Soil lithological data
- Ultra-Violet Optical Screening Tool (UVOST®) data
- Porosity
- Grain size distribution
- Water and LNAPL saturations with depth
- Capillary pressure (moisture retention) curves
- Hydraulic conductivity
- LNAPL density
- LNAPL viscosity
- Air/water surface tension
- Air/LNAPL surface tension
- LNAPL/water surface tension
- LNAPL residual saturation (1000 gravity spin test)
- Gauged LNAPL thickness in wells over time
- Hydrographs
- Historical LNAPL recovery

The methods of data collection are described below.

### *4.1 LIF INVESTIGATION*

A laser-induced florescence (LIF) investigation was conducted between 5 November and 14 November 2012 by Matrix using Dakota Technologies' ultra-violet optical screening tool (UVOST®) in order to delineate the horizontal and vertical extents of LNAPL. Prior to conducting the LIF investigation, samples of LNAPL were submitted to Matrix to confirm that the LNAPL at the site would show a response with the UVOST® technology. The LIF investigation was conducted using direct-push boring methods and allowed collection of digital data that represents the degree of response of the UVOST® equipment to LNAPL present in the subsurface. A total of 112 UVOST® direct-push borings were advanced to depths of up to 24.3 feet bgs in a grid pattern across the extent of the former operational areas at the site. The locations of the LIF borings are shown in Figure 7.

## 4.2 CORE SAMPLING AND SAMPLE INTERVAL SELECTION

Soil borings were advanced at three locations at the site and undisturbed soil cores were collected for specialized LNAPL testing. Cores were collected adjacent to LIF locations LIF-009, LIF-038, and LIF-101, which were in areas of LIF response and near monitoring wells which previously contained LNAPL.

The cores were collected using a hollow-stem auger drilling rig. Cores were retrieved with a 3-inch diameter x 24 inch long split spoon sampler lined with polycarbonate liners. The liners served to contain the core and pore fluids and maintain the core in pristine condition during handling and shipping to the laboratory. After collection, the core and liner were capped and sealed on each end to preserve the fluids, labeled, and frozen on dry ice. The cores were examined prior to shipment to confirm that they were fully frozen and the core sleeves were inspected for possible expansion and splitting. The cores were packaged in a large cooler with 50 to 75 pounds of dry ice for shipment to the laboratory.

The cores were shipped under chain-of-custody control to PTS Laboratories, Inc. (PTS) in Santa Fe Springs, California where they were photographed and analyzed for soil and soil-fluid interaction parameters. The soil cores were maintained in a frozen state by PTS, photographed under visible light to identify changes in soil type (color and texture), and again under ultraviolet (UV) light, which induces fluorescence if aromatic hydrocarbons are present.

## 4.3 FLUID SAMPLING

Groundwater and LNAPL (fluid) samples were collected from monitoring wells adjacent to the core sample locations, where present, and sent to PTS for analysis. Fluid samples were collected using disposable bailers and were transferred to laboratory-prepared unpreserved sample containers. Laboratory report summaries of fluid properties are provided in Appendix D.

## 4.4 LABORATORY SOIL CORE TESTING

Soil core analyses were conducted to estimate the in-situ pore fluid saturations, soil-fluid interaction properties, and general soil properties for intervals where LNAPL impacts existed. Soil core analysis locations were selected based on the review of the visible and UV soil core photographs as well as soil boring logs, UVOST® data, fluid gauging data, well construction data, and historic recovery data. Specific sample intervals were identified for the various laboratory tests, as outlined below. All tests were conducted on plug samples drilled out of the core by PTS. The plugs were drilled while the core was in a frozen state.

Soil samples selected from the cores were analyzed for total organic carbon, fluid saturation, grain size distribution, capillary pressure, and free product mobility. The objective of the analysis was to obtain quantitative estimates of LNAPL saturation versus depth/grain size and estimate the LNAPL mobility.

The following sections describe the specific soil and fluid analyses performed by PTS. The specialized soil core analyses used in the LNAPL recovery evaluations are summarized in the PTS laboratory data reports included in Appendix E.

### *4.4.1 Fluid Analyses*

Fluid properties were measured by PTS to characterize the groundwater and LNAPL. The fluid samples were analyzed for density and viscosity by American Society for Testing and Materials (ASTM) Method D445 and American Petroleum Institute (API) Publication Method RP-40 (API RP 40). They were also analyzed for LNAPL-water interfacial tension and LNAPL and groundwater surface tensions by a DuNouy ring tensiometer using ASTM Method D971.

### *4.4.2 Soil Analyses*

Grain size samples were collected to characterize soils with evidence of LNAPL to provide quantitative data regarding soil type. The soil grain size distributions of particle sizes larger than 75 micrometers (μm) (retained by the No. 200 sieve) were evaluated by sieving following ASTM Method D422. The grain-size distributions of particle sizes finer than 75 μm (passing the No. 200 sieve) were evaluated using a Laser Method (ASTM method D4464M).

### *4.4.3 Dean-Stark Analyses*

Pore fluid (i.e., water, LNAPL, and air) saturations in each sample were analyzed using a method known as the Dean-Stark analysis, API RP 40. The results also include the measurement of bulk density and porosity by API RP 40. The Dean-Stark analysis is a distillation extraction method to determine fluid saturations. It is based upon the distillation of the water fraction of a sample and the solvent extraction of LNAPL from a sample. The sample is weighed and the water fraction is vaporized by boiling solvent rising through the core. The water is condensed and collected in a calibrated receiver. Vaporized solvent also extracts the LNAPL from the sample and condenses in a separate container. The sample is oven-dried to ensure no solvent remains and weighed. The LNAPL content is then determined by gravimetric difference.

### 4.4.4 *Free-Product Mobility (1,000G Centrifuge Test)*

LNAPL centrifuge tests were performed on selected core samples to provide an indication of the residual LNAPL saturation value for a particular sample interval and soil type. Sample locations were collected in the intervals estimated to represent the mobile LNAPL in the formation. The testing consists of the centrifugal technique following ASTM Method D425M where samples are centrifuged for 1 hour at a rate that simulates 1,000 times the gravitational force to provide an estimate of the residual LNAPL saturation (ASTM Method D425M). Samples were spun under air to simulate mobility under unconfined conditions.

### 4.4.5 *Capillary Pressure Analyses*

Capillary pressure versus saturation analyses were performed to give an indication of the LNAPL saturation for a given capillary pressure. Air/water drainage capillary pressure versus saturation curves and LNAPL/water drainage capillary pressure versus saturation curves were measured using the centrifugal technique following ASTM Method D425M. These data supplement the measured saturation profile by providing an additional means to estimate the vertical distribution of LNAPL saturation within the interval of mobile LNAPL. Therefore, they are used as an independent data set from the pore fluid saturation data determined by the Dean-Stark analyses. These data can be used to develop models of LNAPL behavior using the LNAPL Distribution and Recovery Model (LDRM). These samples were collected within the intervals estimated to represent the mobile LNAPL in the formation, as well as to characterize formation types in which LNAPL appears to be residual.

## *5.0 LNAPL EVALUATION*

## *5.1 LNAPL FLUID PROPERTIES*

### *5.1.1 LNAPL Sample Analysis*

Samples of LNAPL and water were collected from monitoring wells with sufficient measurable thicknesses of LNAPL on 19 January 2012. The fluids were submitted to PTS Laboratories for analysis of LNAPL/water density and viscosity, and interfacial tensions, as summarized in Tables 1 and 2 below.

*Table 1 Summary of LNAPL Density and Viscosity*

| Location | Temperature | Density (g/cc) | Viscosity (cSt) |
|---|---|---|---|
| **MW-98-116WT** | 50F | 0.8958 | 147 |
| **RW-10-08** | 50F | 0.9065 | 250 |
| **RW-10-06** | 50F | 0.8914 | 139 |
| **UST Vault#3** | 50F | 0.9044 | 580 |
| **MH-1** | 50F | 0.9018 | 266 |

*Table 2 Summary of LNAPL Interfacial Tensions*

| Location | Temperature | Surface Tension [oil-air] (dynes/cm) | Interfacial Tension [oil-water] (dynes/cm) |
|---|---|---|---|
| **MW-98-116WT** | 70F | 30.5 | 12.0 |
| **RW-10-08** | 72F | 31.2 | 5.9 |
| **RW-10-06** | 71F | 30.0 | 7.9 |
| **UST Vault#3** | 73F | 31.5 | 10.0 |
| **MH-1** | 73F | 31.0 | 10.5 |

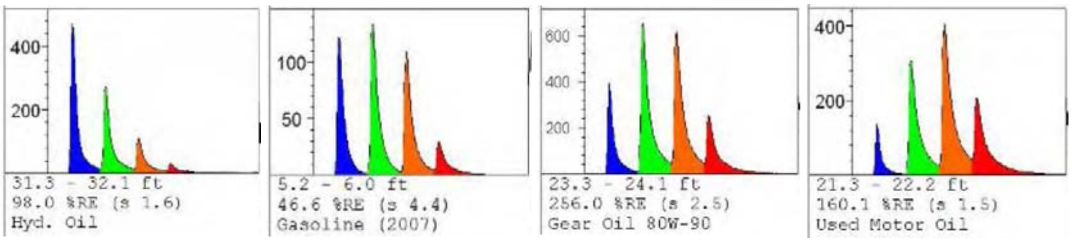
The LNAPL density, viscosity, and surface/interfacial tension ranges indicate that the LNAPL sampled from the site has characteristics similar to weathered lubricating/motor oils. Variations in the characteristics of the LNAPL are likely due to the degree of weathering that has occurred in the subsurface and also the original source of the oil, such as new or used lubricating oil. Laboratory analytical data is provided in Appendix D.

### *5.1.2 LIF Waveform Data*

The LIF method can detect gasoline, diesel fuel, jet fuel, fuel oil, motor oil, grease, and coal tar in the subsurface. Light at a specific wavelength generated from a laser is passed down a fiber optic cable to a sapphire window in the tip of a direct-push rod string as it is advanced into the subsurface. The laser light excites two- or three-ring aromatic compounds, or polycyclic aromatic hydrocarbons (PAH), in the soil adjacent to the sapphire window, causing them to fluoresce. The relative response of the sensor depends on the specific analyte being measured because of the varying ratios of PAHs in each hydrocarbon mixture. The induced fluorescence from the PAHs is returned over a second fiber to the surface where it is quantified using a detector system.

The peak wavelength and intensity provide information about the LNAPL type or potential interferences as shown below. The intensity of the fluorescence is used as an indicator of the relative contaminant concentration.

***UVOST® Response of Various NAPLs***
***(highly dependent on soil, weathering, etc.)***

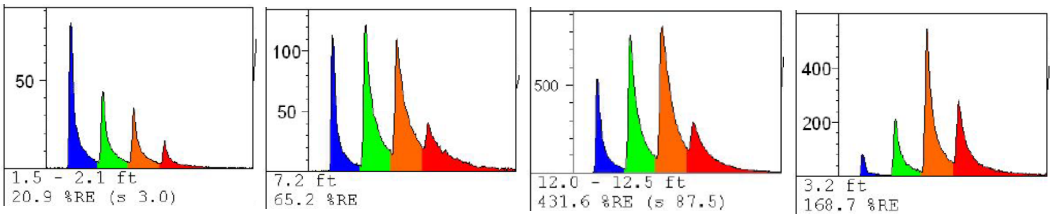


Lighter End LNAPLs → Heavier End LNAPLs

Source: New Generation Optical Sensors for Characterizing NAPL Source Zones, Dakota Technologies, 2008

A variety of LIF waveforms were observed at the site and indicate that there are multiple LNAPL types present in the subsurface. LNAPL types ranged from lighter end hydraulic oils to heavier end used motor oils based on review of typical UVOST® responses prepared by Dakota Technologies, Inc. Variations in LNAPL type were not only observed laterally from location to location, but also vertically within the profile of individual locations. For example, LIF-009 had waveform responses similar to hydraulic oil from 2-2.8 ft bgs, similar to gasoline at 4.1 ft bgs, and similar to gear oil from 12.0-12.5 ft bgs. LIF logs with waveform responses are provided as Appendix F. Examples of the variety of waveform responses observed at the site are provided below:

*UVOST® Response of Various NAPLs at the Site*



LIF-056 LIF-043 LIF-009 LIF-45a

Although multiple waveform types were observed at the site, the primary waveform response types were most similar to gear oil and used/ weathered motor oil. The variation in waveform responses is likely due to both the degree of weathering that has occurred in the subsurface and also the original source of the LNAPL.

## 5.2 LNAPL EXTENT AND PLUME STABILITY

### 5.2.1 LIF Site Investigation

A total of 112 LIF locations were advanced to depths of up to 24 ft bgs in a grid pattern across the extent of the former operational areas at the site. The locations of the LIF borings are presented on Figure 7. To effectively evaluate the significant quantity of data the UVOST® provides, the data was input into a three-dimensional visualization program. The program was used to develop three-dimensional renderings of greater than 7.5% of total LIF response, and to develop two-directional plan views and cross-sections which are provided in Appendix G. (Note that the cross sections sometimes indicate the presence of LNAPL below the terminal depth of a boring due to the projection and interpolation of data from an adjacent boring).

#### 5.2.1.1 *Lateral Extent*

Based on review of the renderings of the total LIF response, LNAPL impacts were identified in the following areas (see Figure 8 – note that the numbers on the figure correspond to LIF borings; e.g., 9 on the map refers to LIF-009).

- An area of high LIF response was observed in the southern portion of the former Plant 2 building. The response area is generally located between LIF-009, LIF-44, LIF-54, and LIF-006.

- Areas of moderate to high LIF response were observed in the northeastern portion of the former Plant 2 building. The response area is generally located between LIF-043, LIF-70, LIF-067, and LIF-051.

- An area of moderate LIF response was observed in the currently unpaved area in the southeastern portion of the property. The response area is generally located between LIF-106, LIF-027, LIF-032, and LIF-109.

- Multiple isolated areas of moderate to high LIF response were observed across the property. The response areas in the east include LIF-012/LIF-101, LIF-034/LIF-035, LIF-094/LIF-095/LIF-42; areas in the south include LIF-019 and LIF-021/LIF-033; and areas in the north include LIF-065, LIF-057/LIF-059/LIF-60, LIF-56, LIF-80, and LIF-83.

To evaluate the distribution of different LNAPL types at the site, the LIF response data greater than 7.5% was filtered based on the LIF waveform data.

- Lighter end LNAPL types were filtered based on a C1 (blue) response greater than 25% of total response.

- Heavier end LNAPL types were filtered based on a C3 and C4 (orange and red) response greater than 60% of total response;

- Medium end LNAPL types were filtered based on a C1 (blue) response less than 25% of total response and also C3 and C4 (orange and red) response less than 60% of total response.

Plan views of the distribution of light end, medium end, and heavier end LNAPL types are provided in Appendix H. The scattered distribution of each of the LNAPL type indicates that there are likely multiple historical sources of different types of LNAPL at the site.

To understand the potential sources of LNAPL, LIF response data was overlaid on known historical site features as presented on Figure 9. The figure shows that the subsurface distribution of LNAPL is most likely the result of multiple different historical sources. Areas of elevated LIF response appear to correlate to historical site features such as underground storage tanks (USTs), above ground storage tanks (ASTs), fueling areas, hydromation units, the WWTF, the former Chip House, the former train wells, the chip trench, the former heat treat operations, the former roll-off storage area, and the cross boundary LNAPL area with SMI.

Overall, the LIF results indicate that the lateral extents of LNAPL areas are generally well defined, and appear to be limited to areas in relatively close proximity to the original source release areas. This indicates that although LNAPL appears to be present across the property, significant ongoing lateral migration of LNAPL beyond the original source areas has not occurred.

#### *5.2.1.2 Vertical Extent*

Based on review of the renderings of the total LIF response, the vertical extent of LNAPL was well defined across the site. Cross-sections of the LIF response are provided in Figures 10 and 11 and in Appendix G. The only locations where the vertical extent of LNAPL was not fully defined were at LIF-009 and LIF-045a. LIF response at LIF-009 peaked at approximately 12 ft bgs, and was generally reducing below that depth. LIF response at LIF-45a peaked at approximately 3 ft bgs and had a smaller peak at approximately 11 ft bgs, but was generally reducing below that depth. At other locations across the site, total LIF response greater than 7.5% was typically at depths less than 15 ft bgs, and was primarily observed between 2 ft bgs and 10 ft bgs.

The vertical extent of LNAPL is consistent with the historically observed fluctuations in groundwater elevation at the site. The presence of LNAPL in both shallow and deep soils indicates that vertical redistribution of LNAPL is occurring as groundwater levels rise and fall. In addition, the observation of LNAPL seeps at the surface during very high water elevations also indicates that vertical redistribution of LNAPL is occurring.

## *5.3 LNAPL MOBILITY*

### *5.3.1 Monitoring Well Gauging Data*

Previous fluid gauging data was evaluated to identify monitoring wells with historical gauged thicknesses of LNAPL. Fluid gauging data for monitoring events performed in May 2008 and September 2011 are shown on Figure 6. The presence of gauged thicknesses of LNAPL in these wells indicates the historical presence of mobile LNAPL at these locations. A total of 19 wells have previously had gauged thicknesses of LNAPL and the locations of mobile LNAPL are generally consistent with the areas of LNAPL identified by the LIF investigation (the southern portion of the former Plant 2 building and in the vicinity of LIF-012/LIF-101).

Both LIF data and previous fluid gauging data were used to estimate the extent of mobile LNAPL, as shown on Figure 12. Using both the LIF data and fluid gauging data enabled refinement of the extent of mobile LNAPL. Although the LIF investigation indicated that there was an area of relatively high LIF response in the southeast corner of the property, fluid gauging data from monitoring wells did not indicate the presence of mobile LNAPL. As such, the LIF response in this area is interpreted to be residual LNAPL. Conversely, although LIF data indicated low response in the vicinity of LIF-040, gauged thicknesses of LNAPL were recently observed in wells PZ-41, PZ-46, and RW-10-5, indicating the presence of mobile LNAPL in the area.

### 5.3.2 *Core Sample Analysis*

Three soil cores were collected at locations selected based on the results of the LIF survey. Soil cores were collected adjacent to LIF locations LIF-009, LIF-038, and LIF-101 as shown on Figure 7. Undisturbed soil cores were collected and immediately placed on dry ice to freeze the fluids contained within the cores in place. The samples were then sent to PTS for analysis.

#### 5.3.2.1 *Soil Core Fluorescence and Sample Selection*

Once received by PTS, the soils cores were maintained in a frozen state and cut in half lengthwise. The soil cores were then photographed under both natural and ultraviolet light and core photography logs were provided to ERM for review. The core photograph logs are provided in Appendix E and a summary of observations from the photographs is provided in Table 3 below.

***Table 3 LNAPL Core Photography Log Summary***

| Core Location | Sample Interval (ft bgs) | % Recovery | Description |
|---|---|---|---|
| LIF-009 | 3-4 | 60% | Low fluorescence LNAPL increases with depth. Soil appears to be fine sand fill material. |
| LIF-009 | 6-7 | 95% | Low fluorescence LNAPL increases with depth, becoming high at 6.5 ft bgs. Soil appears to be fine sand fill material. |
| LIF-009 | 8-10 | 75% | High fluorescence LNAPL distributed somewhat uniformly, becoming highest at 9.0 ft bgs. Soil appears to be fine sand fill material. |
| LIF-009 | 12-14 | 60% | High fluorescence LNAPL distributed somewhat uniformly, becoming highest at 12.9 ft bgs. Soil appears to be fine sand fill material. |
| LIF-101 | 3-5 | 60% | Low fluorescence LNAPL increases with depth to high fluorescence from 3.7 to 4.3 ft bgs. Soils appear to be mixed grained fill materials ranging from sands and gravels to silts and clays. |
| LIF-101 | 5-7 | 75% | Very low fluorescence observed from 5 to 5.7 ft bgs, rapidly becomes high fluorescence from 5.7 to 5.8 ft bgs and highest fluorescence observed from 6 to 6.5 ft bgs. Soils between 5 and 6 ft bgs appear to be mixed grained fill materials ranging from sands and gravels to silts. Soil between 6 and 6.5 ft bgs appear to be sandy. |

| Core Location | Sample Interval (ft bgs) | % Recovery | Description |
|---|---|---|---|
| LIF-101 | 7-9 | 75% | Very low fluorescence observed from 7 to 7.6 ft bgs. No fluorescence observed between 7.6 and 8.5 ft bgs. Soil between 7 and 7.7 ft bgs appear to be sandy with some gravel. Soils from 7.7 to 8.5 appear to be fine sands. |
| LIF-038 | 5-7 | 80% | No fluorescence observed in what appears to be mixed grained fill materials ranging from sands and gravels to silts and clays. |
| LIF-038 | 9-11 | 80% | No fluorescence observed in what appears sandy material from 9 to 9.5 ft bgs; mottled LNAPL fluorescence observed from 9.5 to 10.7 ft bgs in what appears to be primarily silts and clays. |

Based on the logs, intervals of each of the cores were selected for further analysis. A detailed list of the exact core sample intervals and selected analysis is provided in Appendix E. A summary of the rationale for each of the selected intervals is provided as Table 4.

### *Table 4 Selected Core Sample Intervals and Rationale*

| Core Location | Sample Interval (ft bgs) | Core Fluorescence | Rationale |
|---|---|---|---|
| LIF-009 | 3.1-3.7 | Low | Shallow zone of LNAPL within what appears to be sandy material |
| LIF-009 | 8.9-9.5 | High | Zone of LNAPL within what appears to be sandy material |
| LIF-009 | 12.0-12.6 | High | Zone of LNAPL within what appears to be sandy material |
| LIF-009 | 12.6-13.2 | High | Zone of LNAPL within what appears to be sandy material |
| LIF-101 | 3.6-4.3 | High | Zone of LNAPL within what appears to be mixed fine grained and sandy material |
| LIF-101 | 5.0-5.6 | Low | Zone of limited fluorescence between high fluorescence zone in what appears to be mixed fine grained, sandy, gravelly material |
| LIF-101 | 5.9-6.5 | High | Zone of LNAPL within what appears to be sandy material |
| LIF-038 | 10.1-10.6 | Low | Zone of deeper LNAPL appears trapped within silt/clay material |

#### 5.3.2.2 *Soil Properties and Hydraulic Conductivity.*

Subsurface soil properties including bulk density, porosity, grain size, and hydraulic conductivity were obtained for each of the sample intervals specified in Table 5. Grain size data shows that subsurface lithology consists primarily of fill materials that range from fine sand to gravel. However, there was significant variability in the hydraulic conductivity. A summary of the results of the soil properties analysis is provided in Table 5.

*Table 5* *Summary of Soil Properties*

| Core Location | Sample Interval (ft bgs) | Dry Bulk Density (g/cc) | Porosity (%vb) | Grain Size | Fraction Organic Carbon (g/g) | Hydraulic Conductivity (cm/s) |
|---|---|---|---|---|---|---|
| LIF-009 | 3.1-3.7 | 1.56 | 40.5 | Fine sand | 8.55E-03 | 5.96E-04 |
| LIF-009 | 8.9-9.5 | 1.34 | 47.0 | Fine sand | 9.65E-03 | 1.05E-03 |
| LIF-009 | 12.0-12.6 | 1.56 | 40.5 | Fine sand | 1.35E-03 | 3.87E-03 |
| LIF-009 | 12.6-13.2 | 1.60 | 38.9 | Fine sand | 8.10E-03 | 1.95E-03 |
| LIF-101 | 3.6-4.3 | 1.66 | 38.9 | Gravel | 1.12E-02 | 3.12E-05 |
| LIF-101 | 5.0-5.6 | 1.63 | 37.7 | Fine sand | 7.50E-03 | 1.57E-04 |
| LIF-101 | 5.9-6.5 | 1.61 | 38.9 | Fine sand | 6.45E-03 | 5.28E-04 |
| LIF-038 | 10.1-10.6 | 2.00 | 34.7 | Medium sand | 1.61E-02 | 4.27E-07 |

The proportion of fine-grained materials ranged from 5.85% at LIF-009 at 12.2 ft bgs to 16.67% at LIF-101 at 5.5 ft bgs. Although the grain-size at LIF-038 at 10.1-10.6 ft bgs was described as medium sand, the grain size contained 22.51% gravel, 11.55% coarse sand, 26.22% medium sand, 27.16% fine sand, and 12.55% silt and clay. The soil density for LIF-038 at 10.1-10.6 ft bgs was also relatively high compared to the other samples and the porosity was relatively low. This indicates that the soil at LIF-038 at 10.1-10.6 ft bgs is highly compacted. The result is that the hydraulic conductivity for LIF-038 at 10.1-10.6 ft bgs is approximately two to three orders of magnitude lower that other sands at the site. It is suspected that this material is possibly flowable fill material used during the abandonment of the former USTs in the vicinity of LIF-038. The laboratory results of the particle size analysis are provided in Appendix E.

#### 5.3.2.3 *Pore Fluid Saturations and LNAPL Mobility Testing*

The pore fluid saturations within the subsurface were quantified using the Dean-Stark analyses for each of the sample intervals specified in Table 5. Select intervals were also evaluated for free product mobility under unconfined/unsaturated conditions. These data also provide an estimation of the residual LNAPL and water saturations. The residual LNAPL saturation is the portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients. Residual LNAPL possesses an LNAPL transmissivity of zero. A summary of the results of the pore fluid saturation analysis and free product mobility testing are provided in Table 6.

*Table 6 Summary of Pore Fluid Saturations and Free Product Mobility Testing*

| | | In-Place Conditions | | Residual Conditions | | | |
|---|---|---|---|---|---|---|---|
| **Core Location** | **Sample Interval (ft bgs)** | **Water Saturation** | **LNAPL Saturation** | **Residual Water Saturation** | **LNAPL Residual Saturation** | **% Mobile LNAPL** | **LNAPL Produced** |
| LIF-009 | 3.4 | 52.5 | 15.7 | 11.1 | 15.1 | 0.61 | Yellow |
| LIF-009 | 3.6 | 57.9 | 17.8 | | | | |
| LIF-009 | 9.2 | 58.9 | 21.7 | 15.0 | 20.5 | 1.22 | Light Brown |
| LIF-009 | 9.4 | 60.1 | 24.0 | | | | |
| LIF-009 | 12.3 | 66.5 | 20.1 | 7.0 | 19.3 | 0.74 | Light Brown |
| LIF-009 | 12.5 | 65.0 | 23.8 | | | | |
| LIF-009 | 12.9 | 56.1 | 20.7 | 8.2 | 19.3 | 1.37 | Light Brown |
| LIF-009 | 13.1 | 43.8 | 36.3 | | | | |
| LIF-101 | 3.9 | 40.1 | 19.1 | | | | |
| LIF-101 | 4.2 | 56.1 | 11.8 | 17.2 | 10.2 | 1.59 | Light Brown |
| LIF-101 | 5.3 | 59.9 | 13.8 | 32.9 | 13.7 | 0.06 | Light Brown |
| LIF-101 | 5.5 | 71.7 | 2.0 | | | | |
| LIF-101 | 6.2 | 21.6 | 59.1 | 12.1 | 21.1 | 38.05 | Dark Brown |
| LIF-101 | 6.4 | 42.2 | 38.8 | | | | |
| LIF-038 | 10.15 | 55.4 | 2.6 | 43.3 | 2.5 | 0.11 | Trace |
| LIF-038 | 10.3 | 84.6 | 1.9 | | | | |

Total pore fluid saturations were generally between 70% and 90% and indicate that pore fluids were successfully retained during the soil coring and extraction process. Total pore fluid saturations were below 70% in the shallow samples collected from LIF-009 at 3.4 ft bgs, and LIF-101 at 3.9 and 4.2 ft bgs. The lower total pore fluid saturations at these locations are due to the proximity of these samples to the groundwater table and capillary fringe. The only unusual exception was at LIF-038 at 10.15, where the total pore fluid saturation was 58.4%. However, this is likely due to suspect flowable fill material at LIF-038.

LIF-009

In-place subsurface LNAPL saturations ranged from 15.7% to 36.3% and residual LNAPL saturations ranged from 15.1% to 20.5%. The calculated percentage of mobile LNAPL relative to the overall LNAPL saturation at LIF-009 ranged from 0.61% to 1.37%. The data indicates that although mobile LNAPL is present at LIF-009, the portion of LNAPL is small, and the in-place LNAPL saturations are close to residual saturation limits.

LIF-101

In-place subsurface LNAPL saturations ranged from 2% to 59.1% and residual LNAPL saturations ranged from 10.2% to 21.1%. The calculated percentage of mobile LNAPL relative to the overall LNAPL saturation at LIF-101 ranged from 0.06% to 38.05%. The interval with the highest LNAPL saturation of LNAPL was observed at 6.2 ft bgs. The data indicates that although mobile LNAPL is present at multiple depths within LIF-101, mobile LNAPL present at approximately 6.2 ft bgs is the only interval that may be potentially recoverable. However, the LNAPL saturation at LIF-101 at 5.2 ft bgs was only 2% and indicates that vertical redistribution of mobile LNAPL at 6.2 ft bgs is not occurring and may be confined.

LIF-038

In-place subsurface LNAPL saturations ranged from 1.9% to 2.6% and the residual LNAPL saturation was 2.5%. The calculated percentage of mobile LNAPL relative to the overall LNAPL saturation at LIF-009 was 0.11%. The data indicates that LNAPL present at LIF-038 is residual and not mobile.

## *5.4 LOCATION-SPECIFIC LNAPL CONCEPTUAL MODELS*

LNAPL conceptual models (LCMs) were developed for the vicinity of LIF-009 and LIF-101 to understand the distribution of LNAPL in the subsurface. These locations were selected based on the historical presence of mobile LNAPL, the elevated LIF response, and the availability of core analysis data. The provided LCMs are not intended to be a final product and should be refined as needed if additional data is obtained. Interpretation of a LCM involves professional judgment and the exact values in this discussion do not equate to a level of certainly but rather represent the current interpretation of the data.

RW-10-7/LIF-009

The LNAPL conceptual model for the vicinity of RW-10-7/LIF-009 is illustrated using a hydrograph containing gauging data for well RW-10-7. A figure showing LIF response data, soil core fluorescence data, LNAPL saturation data, soil core photography data, well screen interval, field screening data and subsurface soil characterization data is provided in Appendix I.

Evaluation of the LCM data indicates that LNAPL exists within fine sand fill materials at elevations from approximately 592 to 577 ft AMSL. LNAPL saturation and mobility samples were collected and analyzed at multiple locations within the interval of LNAPL. LNAPL saturations were quantified to be from 15.7% to 36.3%, but were generally close to residual saturation limits. LNAPL mobility samples produced yellow LNAPL at 589.58 ft AMSL and light-brown LNAPL at 583.78, 580.68, and 580.08 ft AMSL.

The elevations of the air/LNAPL interface measured in well RW-10-7 between January 2010 and May 2012 were observed during LNAPL manual skimming activities and do not represent equilibrium conditions. In addition, the elevations of the air-LNAPL and LNAPL-water interfaces were frequently above the screened interval of the well. However, it appears that LNAPL thicknesses were observed during periods when either the LNAPL-water interface or both interfaces were within the screened interval of the well. This indicates that mobile LNAPL is present in the formation and vertically redistributes with fluctuations in groundwater elevation. This also indicates that mobile LNAPL is present in unconfined conditions. The oil-water interface does not appear to have equalized below 589.2 ft AMSL, and indicates that LNAPL present below this elevation is currently present as residual LNAPL during saturated formation conditions. LNAPL mobility testing indicates that only between 0.74% and 1.37% of the residual LNAPL mass may become mobile during unsaturated conditions.

In conclusion, the interval of mobile LNAPL appears to be present in an unconfined state in the shallow fine sand fill materials. Based on the LIF waveform response and the yellow color of the LNAPL, the mobile LNAPL is likely a lighter end LNAPL. A LNAPL thickness of 0.56 ft was observed in RW-10-7 on 27 September 2012 under what appears to be equilibrium conditions, and appears to represent the mobile interval of LNAPL in the formation in the vicinity of RW-10-7.

### MW-98-116WT/LIF-101

The LNAPL conceptual model for the vicinity of MW-98-116WT/LIF-101 is illustrated using a hydrograph containing gauging data for well MW-98-116WT. A figure presenting LIF response data, soil core fluorescence data, LNAPL saturation data, soil core photography data, well screen interval, field screening data, and subsurface soil characterization data is provided in Appendix I.

Evaluation of the LCM data indicates that LNAPL exists within fine sand to fine sand/gravel fill materials from approximately 593 to 585 ft AMSL. LNAPL saturation and mobility samples were collected and analyzed at multiple locations within the interval of LNAPL. LNAPL saturations were quantified to be from 2% to 59.1% and were generally close to residual saturation limits with the exception of an interval of LNAPL from approximately 587 to 586 ft AMSL. LNAPL mobility samples produced light brown LNAPL at 588.88, 587.78, and 586.88 ft AMSL.

The elevations of the air/LNAPL interface measured in well MW-98-116WT between January 2010 and May 2012 were observed during LNAPL manual skimming activities and do not represent equilibrium conditions. The elevation of the air-LNAPL interface was frequently above the screened interval of the well; however, the LNAPL-water interface was predominantly within the screened interval of the well. The LNAPL saturation and mobility data indicates that the highest saturation of LNAPL is present between 587 and 586 ft AMSL in a fine sand. Vertical redistribution of the LNAPL in this zone appears to be limited by a confining layer that exists between 588.5 and 587.5 ft AMSL. The confining layer had low LIF response, low core fluorescence, and a LNAPL saturation of only 2% was observed at 587.58 ft AMSL. This indicates that mobile LNAPL is present in confined conditions. Recent gauging data shows that the oil-water interface has not fully equalized and continues to fall towards the interval of suspected confined LNAPL. LNAPL mobility testing indicates that approximately 38% the LNAPL mass in this confined layer may become mobile during unsaturated conditions.

In conclusion, an interval of mobile LNAPL appears to be present in a confined state in the fine sand fill materials located between 587 and 586 ft AMSL. Based on the LIF waveform response and the light-brown color of the LNAPL, the mobile LNAPL is likely a medium to heavier end LNAPL. Although a LNAPL thickness of 2.81 ft was observed in MW-98-116-WT on 28 November 2012, the gauged thickness of LNAPL may not accurately represent the formation thickness of mobile LNAPL in the vicinity of MW-98-116WT due to confined LNAPL conditions. Based on LNAPL saturation data and lithological data presented in the LCM, the mobile interval of LNAPL is estimated to be approximately 1 ft.

## *5.5 LNAPL RECOVERABILITY EVALUATION*

LNAPL recovery efforts have included operation of multiple LNAPL recovery systems; however, recovery efforts have had very limited success in recovering a significant mass of LNAPL. The current LNAPL recovery system was idled in November 2011 and had yielded only 26 gallons of LNAPL in the previous year of operation. An evaluation was conducted utilizing existing site data to determine if continued operation of LNAPL recovery would be effective at reducing the overall mass of LNAPL in the subsurface at the site.

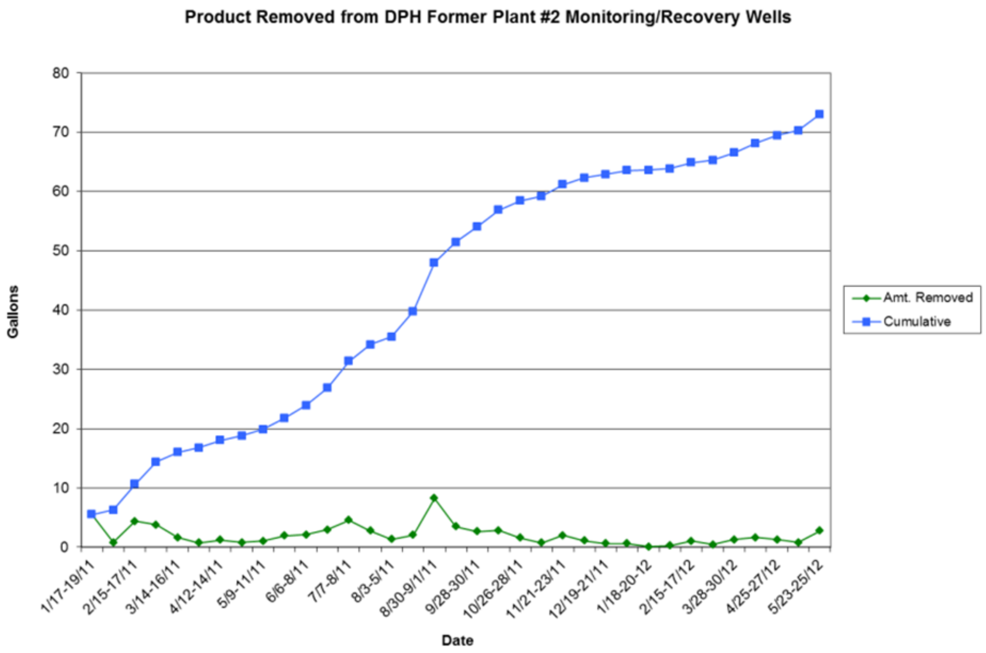
### *5.5.1 Technical Approach to Evaluation of LNAPL Recoverability*

Historically, the feasibility of LNAPL recovery has been evaluated based on measured hydrocarbon thickness; however, hydrocarbon thickness by itself is not a reliable indicator of hydrocarbon mobility or recoverability. In fact, certain common geologic and hydrogeologic conditions will result in an exaggerated accumulation of hydrocarbon in a well that does not represent hydrocarbon impacts in the adjacent formation. More recently, evaluation of the feasibility of hydraulic LNAPL recovery to remediate mobile LNAPL has centered on understanding of the LNAPL transmissivity. The methods and techniques to estimate LNAPL transmissivity are provided in the ASTM Standard Guide for Estimation of LNAPL Transmissivity – E2856-11 (*ASTM LNAPL Transmissivity Guidance)*, and an evaluation of existing data was performed in accordance with this document.

### 5.5.2 *Estimation of LNAPL Transmissivity*

ERM reviewed the existing data to determine if sufficient information was available to estimate LNAPL transmissivity at the site. Calculated estimates of LNAPL transmissivity can be developed using LNAPL baildown/slug tests, manual skimming tests, recovery data based methods, and tracer test methods (ASTM 2012). Unfortunately, LNAPL baildown tests could not be conducted during site activities due to fluid levels being higher than the screened intervals of most monitoring wells.

Manual LNAPL recovery data, however, was available for review. As such, the evaluation of LNAPL transmissivity at the site was based on the LNAPL manual skimming data. The cumulative volume, measured in gallons, of LNAPL recovered during the period of manual skimming is presented on the chart below.



ERM selected monitoring well MW-98-116WT to calculate LNAPL transmissivity due to the highly developed conceptual model, and also due to the well having some of the highest LNAPL recovery rates for the site.

LNAPL manual skimming data was tabulated and included fluid level gauging data and cumulative LNAPL recovery in gallons and is provided in Appendix J. Fluid level gauging data collected after stopping LNAPL recovery indicated that LNAPL did not fully recover between skimming events, and as such can be used to calculate transmissivity. The LNAPL transmissivity for MW-98-116WT was calculated using Equations 16 and 10 from the *ASTM LNAPL Transmissivity Guidance* for calculation of LNAPL transmissivity from manual skimming test data.

Equation 16:

$$T_n = \frac{Q_n \ln\left(R_{oi}/r_w\right)}{2\pi s_n}$$

(Charbeneau, 2007)

*Where:*
$T_n$ – LNAPL transmissivity ($L^2/t$)
$Q_n$ – Measured LNAPL recovery rate ($L^3/t$)
$R_{oi}$ – Radius of influence (L)
$r_w$ – Well radius (L)

Equation 10:

$$S_{nt} = b_{nf}\frac{1-\rho_r}{\rho_r}$$

*Where:*
$s_{nt}$ – LNAPL drawdown at time t (L)
$b^{nf}$ – formation LNAPL thickness (L)

In accordance with the ASTM Guidance, $\ln(R_{oi}/r_w)$ was assumed to equal 4.6. Values for $b_n$ were estimated to be 1 ft based on review of the LCM developed for MW-98-116WT/LIF-101; however, values for transmissivity were also calculated for a $b_n$ of 0.5 ft to be conservative. The calculated estimated LNAPL transmissivities are presented in Table 7 below. A summary of the calculated transmissivities is provided below:

***Table 7 Summary of LNAPL Transmissivities for MW-98-116WT***

| | **LNAPL $T_n$ ($ft^2$/day)** | |
|---|---|---|
| | **MW-98-116WT ($b_n$ – 1 ft)** | **MW-98-116WT ($b_n$ – 0.5 ft)** |
| Low | 0.001 | 0.002 |
| High | 0.017 | 0.035 |
| Average | 0.008 | 0.016 |

The LNAPL transmissivities calculated are below the 0.1 to 0.8 $ft^2$/day range of transmissivities that were demonstrated as practical endpoints for hydraulic recovery at a variety of sites, as provided in the Interstate Technology Regulatory Council (ITRC) guidance titled *Evaluating LNAPL Remedial Technologies* dated December 2009. ERM understands that the ITRC ranges are not definitive limits, but provide guidance from which to evaluate LNAPL transmissivities within the context of site-specific conditions. The range of transmissivities calculated for MW-98-116WT is one to two orders of magnitude below the ITRC ranges. In addition, very low recovery volumes have been documented at the site (approximately 70 gallons in 2 years). Based on these observations and the current LCSM, it is likely that the practical endpoint for hydraulic recovery has been reached.

## 6.0 DISCUSSION AND CONCLUSIONS

The LNAPL site investigation and evaluation activities conducted for the DPH Holdings former Plant 2 property enabled further development of the site LCSM. The purpose of development of the LCSM is to provide a solid foundation from which remedial alternatives for the former Plant 2 property can be evaluated. Specific tasks performed in the development of the LCSM included:

- Conducting an LIF investigation to delineate the horizontal and vertical extent of LNAPL, provide a semi-quantitative estimate of LNAPL saturation distribution, and provide understanding of the distribution of different LNAPL types.

- Collect frozen soil core samples and samples of LNAPL and water and submit for laboratory analysis for a variety of parameters. The data provides an understanding of the LNAPL type, subsurface lithology, and LNAPL behavior including mobility and saturation.

- Develop detailed location-specific LCMs using both recently collected data and historical data to evaluate LNAPL behavior at areas of the property with evidence of mobile LNAPL.

- Analyze existing LNAPL recovery data to evaluate the feasibility of LNAPL recovery.

As presented in this document, the approach to evaluate LNAPL at the property relied on the development of multiple detailed lines of evidence. Based on the current LCSM, the following specific conclusions were made:

1. *LNAPL Types* - Fluid analysis and LIF waveform data indicates that LNAPL ranges from lighter end hydraulic oils to heavier end used motor oils. The primary LNAPL types observed were higher viscosity LNAPLs, similar to gear oil and used/weathered motor oil.

2. *LNAPL Extent* - The LIF investigation defined the lateral and vertical extents of both mobile and residual LNAPL. The distribution of LNAPL is consistent with historical site operations and indicates that multiple historical releases occurred at the site. LNAPL appears to be limited to the vicinity of suspected historical release areas, and the absence of significant lateral migration indicates that the LNAPL plume is stable.

3. *LNAPL Mobility* - Soil core data and fluid gauging data show that mobile LNAPL is present under the former main facility building, to the southeast of the former main facility building, and to the north in the vicinity of the former chip house. However, mobile LNAPL does not always indicate the presence of hydraulically “recoverable” LNAPL, and the data also shows that the majority of the LNAPL present at the property is residual LNAPL.

4. *LNAPL Recoverability* - Soil core data and manual skimming data were evaluated for areas of the property with the highest LNAPL recoveries. The higher viscosity of the LNAPL inhibits LNAPL recovery. For example, the calculated LNAPL transmissivities at MW-98-116WT of between 0.001 and 0.035 $ft^2$/day indicate that LNAPL recovery at the site is not practicable using hydraulic recovery methods (i.e., cannot be efficiently removed using remedial technologies such as skimming, pumping, etc.), and these remedial technologies will not significantly reduce the overall LNAPL mass.

In conclusion, historical releases of multiple LNAPL types have resulted in subsurface impacts. The LNAPL plume has low mobility, is laterally stable, and operation of LNAPL skimming/pumping systems is unlikely to appreciably reduce the overall LNAPL mass. Vertical redistribution of mobile LNAPL is occurring, and may reach the surface during high water table elevations. ERM recommends that remedial actions focus on containing the mobile LNAPL and preventing it from day-lighting at the surface. This may include barrier walls and a cap to reduce infiltration, and possibly the use of hydraulic controls if water levels inside the containment rise to the surface.

# 7.0 REFERENCES

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