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March 14, 2019

Mr. John Hunt
Wisconsin Dept. of Natural Resources
223 E Steinfest Road
Antigo, WI 54409

Subject: **Remedial Actions Options Report – Former Amoco Terminal**
Former Amoco Terminal and Barge Dock Properties
2904 Winter Street, Superior, Wisconsin
Antea Group Project No. WISUP191

FID No. 816009920
BRRTS No. 02-16-000331 (Former Amoco Terminal Property)

Dear Mr. Hunt:

Antea Group is submitting this report for the Former Amoco Terminal property in response to the request by the Wisconsin Department of Resources (WDNR) for a detailed Remedial Action Options Report in compliance with the requirements of NR 722 Wis. Adm. Code in its Closure Not Recommended letter from the WDNR, dated July 28, 2017. The requirements set forth in NR 722 have been followed to evaluate and select remedial action options that will address onsite contamination in an economically feasible and responsible manner. Antea Group requests that the WDNR responds to this report in a timely manner with acknowledgement of receipt and estimated date for completion of department review.

If you have any questions, please contact Jonathan Zimdars, Project Manager at 651-697-5219 or at Jonathan.Zimdars@anteagroup.com.

Sincerely,

Layne Kortbein

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Remedial Action Options Report

Former Amoco Terminal

Former Amoco Terminal
2904 Winter Street, Superior, Wisconsin

FID No. 816009920

BRRTS No. *02-16-000331*

Antea Group Project No. WISUP191

March 14, 2019

Prepared by:
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Table of Contents

Figures

Tables

Appendix

Remedial Action Options Report

Former Amoco Terminal

2904 Winter Street, Superior, Wisconsin

EXECUTIVE SUMMARY

Petroleum releases at the former Amoco Terminal occurred over the history of the property's use for petroleum storage and shipping operations. The site formerly contained 16 vertical aboveground storage tanks and 4 underground storage tanks that stored various grades of gasoline, kerosene, fuel oil, and ethanol, as well as an underground pipeline entering through the northeast corner of the site. Product releases from these operations are distinguished into 5 distinct light non-aqueous phase liquid (LNAPL) occurrences (AOC 1 through AOC 5), with product types recognized to include kerosene, diesel fuel, gasoline, and naphtha. The total volume of residual petroleum remaining in the subsurface at the Terminal has been calculated as 14,378 gallons.

Impacts to or from soil, vapor, LNAPL and dissolved-phase hydrocarbons have been evaluated as part of this Remedial Action Options Report prepared under guidelines provided in NR 722.13. Remedial responses for the various components are as follows:

Soil: Initial soil impacts were identified during a Site Investigation in 1990. Split spoon and hand auger borings identified the majority of impact was limited to a narrow soil band just above the water table. Screening of near surface soil (0-4 feet bgs) did not identify high concentrations of total organic vapors near the petroleum pipeline paths within and outside of the property. Surface soil that exceeded WDNR Industrial Direct Contact Residual Contamination Levels (IDC-RCLs) for benzene, ethylbenzene, and total xylenes were found during November 2003 soil borings at two areas on the Terminal.

Further investigation of near surface impacts was completed in October and November 2013. Seven parcels on the Terminal were investigated through the advancement of 49 shallow hand-auger borings. Eight of the borings had analytical results that exceeded direct contact limit concentrations for compounds including benzene, ethylbenzene, total xylenes, naphthalene, benzo(a)pyrene, and dibenz(a,h)anthradcene. In August 2014, an additional 82 hand-auger and Geoprobe® borings were advanced to delineate exceedance locations. The borings delineated in two to four directions based on previous delineation results. Soil excavation conducted in November and December 2014 removed 5,401 tons of soil.

Excavation actions eliminated potential direct contact impacts, and residual soil remains below direct contact depths (<4 feet bgs) underneath a dense, surficial clay layer. This clay layer ranges in thickness from 10 feet to at least 28 feet across the site, thereby providing a barrier to vertical migration of petroleum vapors or liquid and eliminating the potential to impact human health or the environment.

A special warranty deed was signed by Amoco Oil Company for the Terminal property on August 24, 2000 to set forth property restrictions in the case of divestment and redevelopment. The property use restrictions include all of the following:

1.) No part of the property will be used for the purpose of selling, handling, storing, wholesaling, or dealing in petroleum products (gasoline, diesel fuel, kerosene, distillates), benzol, naptha, greases, lubricating oils, oily water substances, or any fuel used for internal combustion.
2.) No water supply wells of any kind will be installed on the property.
3.) The property will be used solely and exclusively for commercial and/or industrial purposes.
4.) No basements or other underground improvements with the exception of building footings or slab-on-grade foundations will be constructed on the property.
5.) No part of the property will be used for child or elder care, nursing home facility or hospice, medical or dental facilities, school, place of worship, park, or a hospital.
6.) No soil will be removed from the property unless the soil is moved to a disposal facility or approved in advance by the Seller or directed by the Wisconsin Department of Natural Resources (WDNR).

These restrictions will allow for residual petroleum impacted soil to degrade through natural attenuation, while effectively controlling the potential for direct contact or impacts on human health or the environment.

Residual surface soil contamination lies north of the Terminal underneath Winter Street. The soil underlies known sanitary, gas, communication, and water utility lines, as well as the road, railroad tracks, and a petroleum pipeline owned by Murphy Oil. Because of these obstructions, soil excavation is not a feasible remediation option. Instead, an asphalt cap maintenance plan is recommended to address the residual petroleum contaminated north of the Terminal. The maintenance plan would include marking of an out of service pipeline beneath the Winter Street in the northeast corner of the Terminal, management of soil excavated through construction activities, and a cap maintenance plan to isolate the contaminated soil under Winter Street.

Vapor: The utility corridor that runs parallel to Winter Street and Susquehanna Ave was investigated for subsurface vapors in 2006 and 2007. Soil gas samples were collected from 31 borings at depths of 5 feet within the silty-clay layer, and at 16 to 17 feet within the underlying sand. Soil gas sample results from the underlying sandy layer (17-foot bgs samples) indicated concentrations of BTEX at area of residual petroleum located near the northeast corner of the former Terminal property, and an isolated accumulation at an area of a former monitoring well. Only five shallow samples contained elevated BTEX concentrations, and methane concentrations in undisturbed soil were minimal. These sampling results showed that the clay cap is effectively serving as a barrier to vapor migration to the surface.

The Lake City Towing office is the only potential receptor for vapors migrating through the subsurface as a result of volatilization or degradation of residual petroleum. Soil-gas surveys and sub-slab vapor sampling at the Lake City Towing office have demonstrated the silty-clay layer is an effective barrier to vapor migration, as all sampling results were below the Wisconsin sub-slab Vapor Risk Screening Level (VRSL) standards. Methane results were reported as no higher than 7 parts per million by volume (ppmv), which is equivalent to 0.00007% of the lower Explosive Limit (LEL).

Since the hydrocarbon vapors are sequestered beneath the silty-clay layer and do not pose a threat to the environment or human health, the selected remedial approach is to allow the hydrocarbon vapors to remain under the silty-clay layer. In addition, potential receptor construction is eliminated through the Real Estate Contract (July 19, 2000), which prohibits basements for any structure and no soil removal without the prior approval of the Seller or the Wisconsin Department of Natural Resources (WDNR).

LNAPL: Residual LNAPL at the Terminal has been assigned to five Areas of Concern (AOC 1 through AOC 5). The product types include mixtures kerosene, diesel fuel, gasoline and naphtha. Manual-skimmer tests conducted in wells located in AOC 1, AOC 2, AOC 4, and AOC 5 were within the lower limits (0.1 to 0.8 ft^2/day) of LNAPL recovery using pneumatic means suggested by the Interstate Technology and Regulatory Council (ITRC). Only one well, MW-32, had a higher transmissivity value, which underwent pneumatic LNAPL recovery from 2015 to 2017. In addition to transmissivity, LNAPL plume velocity results indicated that all but one location (MW-16, within the center of AOC 1) were less than the ASTM stability metric of 1 foot/year.

A variety of remediation initiatives have been conducted on the Terminal, including the use of pneumatic skimmer pumps, vapor extraction total fluids recovery, soil vapor extraction, vacuum-truck recovery, and manual recovery. Through the skimming system recovery events starting in 1995 and continuing into 2012, an estimated 28,467 gallons of LNAPL have been recovered from the Terminal property. This total does not include manual recovery events including hand bailing, as these events are difficult to quantify and summarize. A summary of cumulative recovery by method type is shown below:

Recovery Type	Gallons Recovered
Pneumatic Skimming System	6,794
Mobile Skimmer	1,641
SVE	10,813
VE-TFRT	9,219
Total	**28,467**

The volume of residual LNAPL estimated as remaining in the subsurface is 14,378 gallons. This suggests that more than 66% of the LNAPL originally in the subsurface has been recovered. Further recovery by passive skimmer pumps was modeled through the LNAPL Distribution and Recovery Model. Simulations included a passive skimmer pump in operation for 5 years, and recovery system enhancements through the addition of an applied vacuum to the skimmer pump and water level depression through pumping. The pneumatic skimming pump with groundwater pumping yielded the highest simulated recovery volume, but the amount of groundwater that would be required to be treated after operating the system at 2 gpm for five years did not create an economically feasible recovery method. The feasibility of a horizontal recovery well was also evaluated for LNAPL recovery, but it was determined that the effectiveness would be severely limited by the range of water table fluctuations and smear zone thickness.

Recovery of more than 60% of the LNAPL from the subsurface is indicative of very successful removal action that has reached the limits of recoverability, as evidenced my modeling recovery rates and feasibility assessments. No further LNAPL recovery is recommended, and the remaining product should be allowed to degrade through natural attenuation.

Dissolved-phase Hydrocarbons: Groundwater contaminated with dissolved-phase hydrocarbons have been identified in monitor wells across the Terminal site, with the vast majority of contaminated monitor wells being located in the northeast portion of the site (the Lake City Towing property and Parcel A). Dissolved-phase hydrocarbons have also been identified in the groundwater northwest of (hydrologically downgradient) the Terminal property. Benzene is the only petroleum hydrocarbon detected northwest of monitor well MWM-9RD in concentrations that exceed its NR 140 Enforcement Standard. The dissolved-phase hydrocarbons downgradient are isolated at least 50 feet bgs within the deep (D-level) water-bearing zone that is capped by the silty-clay layer.

The residual dissolved phase is defined vertically and horizontally, and does not present a threat to human health or the environment though any potential receptor. This is achieved for St. Louis Bay through the combination of the surficial silty-clay layer and the upward vertical hydraulic gradient in wells close to the bay. Exposure to dissolved-phase petroleum hydrocarbons through ingestion, direct contact or inhalation from well water is eliminated due to provisions in the existing Real Estate Contract (July 19, 2000) that prohibit “water supply wells of any kind” [Section (ii)] and the availability of public water from the City of Superior.

Considering the isolation and depth of the dissolved-phase benzene plume, and the lack of exposure pathways to receptors, natural attenuation was the remedy considered for evaluation and implementation. Natural attenuation, on both a spatial and temporal basis, is confirmed by declining trends in benzene concentration along a groundwater flow path (MWT-2D to MW-36D) and in key monitor wells (for instance, MWT-2D, MWM-9RD and MW-36D) over time. To further substantiate and quantify natural attenuation, sampling events will continue to be conducted to evaluate trends in benzene concentrations temporally and spatially. In addition, field parameters will be collected in addition to PVOC sampling in 2019 that will include field probe analysis of dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, pH, and specific conductivity, laboratory analysis of dissolved iron (Fe^{+2}), nitrate, and sulfate, and a field titration cell test for alkalinity. Biodegradation potential will be further evaluated through the use of laboratory detection method to quantify the presence of the functional genes associated with both aerobic and anaerobic bacteria. This laboratory technique is offered by Microbial Insights, trade named QuantArray® - Petroleum, and samples will be collected using Bio-Trap® samplers from select wells. This analysis, coupled with geochemical trend analysis, will provide a clear and comprehensive view of petroleum hydrocarbon degradation onsite.

BACKGROUND INFORMATION

Facility:	Former Amoco Oil Terminal 2904 Winter Street Superior, Wisconsin 54880
Responsible Party:	Atlantic Richfield (A BP Affiliated Company) 201 Helios Way 6th Floor Houston, Texas 77079
Report Preparer:	Wayne Hutchinson Antea Group 5910 Rice Creek Parkway Suite 100 Shoreview, Minnesota 55126
Site Regulatory Status:	FID No. 816009920 BRRTS No. 02-16-000331

GEOGRAPHY AND OPERATIONAL HISTORY

The Former Amoco Terminal has been used for petroleum storage by various entities since the late 1800s. It had been used by Amoco and its predecessors as a bulk petroleum storage terminal from 1908 until 1999, and formerly operated with ASTs, an office building, truck loading rack, and a railroad loading rack. The Terminal property was used primarily for petroleum storage until 1947 when an AST was removed from the northeast corner of the Terminal for construction of an Operations Building, manifold, and truck loading rack. The site contained 16 vertical above-ground storage tanks and four underground storage tanks which stored various grades of gasoline, kerosene, fuel oil, and ethanol. The tanks ranged in capacity from 500-gallons to 3.3 million gallons. Tanks, rail lines, and loading racks were removed from the former Terminal property in 2000. The Terminal property was ultimately subdivided into nine developable parcels (A through I) in 2006; including the original Operations Buildings which is occupied by Lake City Towing (LCT), as well as new construction for Boyer Trucks, Guardian Pest Solutions, and FedEx Ground Services (**Figure 1**).

The former Amoco Terminal operations included a narrow parcel north of Winter Street called the Barge Dock property. The Barge Dock property formerly included underground and above ground pipelines, a manifold, ASTs, a railroad loading rack, and a truck loading rack. The southern portion of the Barge Dock property is managed under BRRTS No. 02-16-11783 (Manifold, ASTs, and Truck Loading Rack), while the northern portion is managed under BRRTS No. 02-16-297979 (Railroad Loading Rack and Oil-Water Separator Area). Petroleum distribution, storage and sales operations at the Barge Dock property were transferred to the northeast corner of main Terminal in 1947.

All petroleum storage and distribution operations ceased at both properties in 1999. Pipelines that connected the Barge Dock to the Terminal were removed within the boundaries of the Barge Dock property in 2003.
Petroleum has impacted the soil and groundwater at the Terminal and migrated under Winter Street to affect third-party properties (primarily BNSF, City of Superior, C. Reiss Coal and Hallett Dock, located north of Winter Street). On-site and off-site petroleum impacts are found as free-phase hydrocarbon, or light non-aqueous phase liquid (LNAPL), adsorbed in soil and dissolved-phase hydrocarbons in groundwater.

SUMMARY AND NATURE OF EXTENT AND CONTAMINATION

At the Terminal property, five areas of light non-aqueous phase liquid (LNAPL) occurrence have been identified, which have been designated as AOC 1 through AOC 5. All five AOCs at the Terminal are managed under BRRTS No. 02-16-000331 (**Figure 2**). Two occurrences of LNAPL, AOC 1 and AOC 2, extend under Winter Street. AOC 1 is likely associated with the former railroad loading rack that was clearly in use as of 1978 (based on an aerial photograph held by Douglas County Land Records) but by 1990 the tracks had been removed (based on an aerial photograph held by Douglas County Land Records). AOC 2 may be associated with the AST that was located in the northeast corner of the Terminal prior to 1947, which was removed to accommodate a new operations Building, Truck Loading Rack and Manifold.

Other areas of LNAPL occurrence in the subsurface were identified on the Terminal property west of Maryland Avenue. These LNAPL occurrences appear to be associated with historical locations of a truck loading rack (AOC 3), a manifold (AOC 4), and a known leak at former AST 38 (AOC 5). The LNAPL types near Winter Street are light or middle distillate petroleum (such as kerosene or diesel fuel), while the occurrences of LNAPL west of Maryland Avenue are predominantly gasoline-range hydrocarbons with middle-distillate components. Based on the determination and analysis of oil-specific volumes described in Parker, Waddill and Johnson (1996), the estimated volume of residual LNAPL associated with the five occurrences at the Terminal is 14,378 gallons (**Table 1)**.

An initial site investigation of the Terminal property in 1990 included split spoon soil samples and hand auger borings. Contaminated soil on the parcel was found to be limited to depths ranging just above the water table, in line with seasonal water table fluctuations. Near surface soil from 0 to 4 feet bgs was found to exceed WDNR Industrial Direct Contact Residual Contamination Levels during November 2003 soil borings, and during parcel development for the existing FedEx commercial building in 2005. Compounds found to exceed these standards included benzene, ethylbenzene, total xylenes, naphthalene, benzo(a)pyrene, and dibenz(a,h)anthradcene. Seven parcels at the Terminal were further investigated for near surface impacts in 2013 and 2014, and included 131 hand-auger and Geoprobe® borings. A total of 5,401 tons of soil was removed in November and December 2014 from parcels A, B, C, F, H, I, and Lake City Towing.

Hydrocarbon contamination is found in water samples collected from most of the wells on the former Terminal property; especially those monitor wells on the Lake City Towing parcel, as well as Parcels A and B. Dissolved-phase hydrocarbons, including benzene, toluene, ethylbenzene, and xylenes (BTEX), and naphthalene are found to have migrated off-site following the groundwater gradient to the northwest (Figure 3).

The down gradient extent of dissolved-phase hydrocarbon contamination, defined by detectable concentrations of benzene, has been identified from monitor well MW-23 at the Terminal to monitor well MW-41D on the Hallett Dock property, a distance of approximately 2,360 feet (**Figure 4**). North of Winter Street, the hydrocarbon contamination affects the deeper portions of the aquifer (575 to 565 feet amsl or 50 to 60 feet bgs) with declining to non-detectable concentrations in the shallow portion of the aquifer (620 to 600 feet amsl or 10 to 30 feet bgs). The width of the dissolved-phase hydrocarbon impact is approximately 500 feet or less north of Winter Street.

SUMMARY OF GEOLOGIC AND HYDROGEOLOGIC CHARACTERISTICS

The surficial geology across the area consists of dense, reddish-brown clay which overlies a sequence of silts and silty sands. This is consistent with the regional geology where shoreline or lacustrine deposits are found to overlie till sequences. The clay layer has been observed to range in thickness from approximately 10 feet to at least 28 feet. The majority of the soil borings indicate the clay layer to be approximately 13 to 15 feet in thickness, though the clay thickness increases towards the western along Winter Street.

A water-bearing reddish-brown silty fine sand unit underlies the reddish-brown clay. In the northeastern portion of the Terminal, along Winter Street and Maryland Avenue, the depth to the silty fine sand under the Lake City Towing property is typically 10 feet below grade, with depth increasing to nearly 20 feet north and south of Lake City Towing. In the upper portion of the silty sand unit, Cone Penetration Testing (CPT) logs have indicated the presence of discontinuous silt lenses at multiple locations. The typical grain-size distribution in the silty fine sand unit is 80 to 90% fine sand, 10% silt, and 3 to 5% clay. The typical grain-size distribution in the overlying clay is 83% clay, 12% silt and 5% sand.

The contact between the overlying clay and silty fine sand generally dips to the west-northwest at 2.5% grade (2.5 feet vertical per 100 feet lateral). The water table is unconfined in the northeast portion of the Terminal, though periods when the water table is higher (>621 feet amsl) can produce confined conditions. Perennial confined conditions are found to the south and west of the Lake City Towing property. Underlying the silty fine sand unit, a firm dark gray-brown silt was identified 83 feet below grade which is at least 5 feet in thickness, based on the soil log for off-site monitor well MW-30DD.

Groundwater elevation decreases to the northwest across the Terminal site. Based on 30 years of gauging data (1988 to 2018), the average groundwater elevation for monitor wells completed in the shallow water table at the Terminal is typified by monitor well MW-3 at 621.85 feet amsl, 617.51 feet amsl at monitor well MW-22, and 615.85 feet amsl at monitor well MW-17. A seasonal variation is observed in the monitor wells across the site with groundwater elevations increasing in the autumn as compared to the spring.

Two monitor well nests (MW-4S/4D and MW-15S/15D) were established in 1994 at the Terminal. Water levels were gauged on a monthly to quarterly basis to mid-2013. Monitor well nest MW-4S/4D was located in the southeast corner of the Terminal property. It was sealed and abandoned in 2013. Monitor well nest MW-15S/15D was located in the northwestern portion of the Terminal property, east of Susquehanna Avenue. The vertical gradient has been consistently downward at monitor well nest MW-4S/4D with an average vertical gradient of 0.027 feet/foot. The vertical gradient at monitor well MW-15S/15D has been consistently downward with an average vertical gradient of 0.0019 feet/foot.

Contours of groundwater elevation data for the shallow monitor wells consistently indicates the groundwater gradient is directed towards the north and northwest. A typical groundwater elevation contour map with gradient arrows is included as **Figure 5**. The horizontal gradient for the deeper portion of the water-bearing silty sand is based on two deep monitor wells (MW-4D and MW-15D). The horizontal gradient is consistently directed from monitor well MW-4D towards monitor well MW-15D (northwest orientation), with an average of 0.0027 feet/foot.

Hydraulic conductivity was determined for three depths that represent the shallow (S), deep (D) and double deep (DD) well screening intervals for a set of nested wells just to the north of the Terminal. The shallow wells are screened across the water table and are typically less than 30 feet deep. Monitor wells in the deep zone are screened below the water table at depths between 50 to 60 feet below the ground surface (bgs), while monitor wells completed to double-deep depths are typically screened between 70 and 80 feet bgs. The hydraulic conductivities were determined in the laboratory by vertically oriented samples as 2.1 x 10^{-5} centimeters/second (cm/sec) for the S-zone monitor well, 3.0 x 10^{-4} cm/sec for the D-zone monitor well, and 5.6 x 10^{-6} cm/sec for the monitor well screened in the DD zone (Delta Environmental Consultants, *Site Investigation and Interim Response Actions Report,* dated June 6, 1999).

Analysis of in-situ hydraulic conductivity tests, or “slug tests”, conducted on monitor wells MW-14 and MW-27 reported hydraulic conductivities of 2.1 x 10^{-4} and 1.1 x 10^{-4} cm/sec, respectively. Drawdown data from an aquifer pumping test conducted on recovery well RW-1 produced transmissivities ranging from 0.26 to 2.18 square meters/day (m^2/day), or 2.8 to 23.5 square feet/day (ft^2/day). Recognizing an aquifer thickness of 32 feet (based on difference between depth to bottom of RW-1 and depth to water in the aquifer), the transmissivities can be cited as hydraulic conductivities ranging from 3.5 x 10^{-5} to 2.8 x 10^{-4} cm/sec, or 0.10 to 0.79 feet/day (Delta Environmental, *Supplemental Site Investigation Report*, dated March 14, 1991).

REMEDIAL ACTION OPTIONS

Soil

Characterization of Soil Constituents and Occurrence

Soil at the Terminal was first identified as impacted during the 1990 Site Investigation. The initial assessment included split spoon samples and hand auger borings. A majority of impacts were observed in a narrow band just above the water table, corresponding to seasonal fluctuations. The hand auger locations were intended to evaluate soil contaminant levels along the petroleum pipeline within and outside of the property, and only low concentrations of total organic vapors were detected.

Near surface soil (0 to 4 feet bgs) at the Terminal exceeded NR WDNR Industrial Direct Contact Residual Contamination Levels (IDC-RCLs) for benzene, ethylbenzene, and total xylenes during November 2003 soil borings at the northern edge of the remediation building, and at the eastern wall of the former manifold. Surface soil impacts were further evaluated after HCI Limited Partnership (FedEx) purchased parcel ID# 068060073905 in 2005. During parcel redevelopment in February 2006, 25 soil borings were advanced to 2 feet bgs. Six of these locations exceeded IDC-RCLs, and an unknown volume of soil was excavated.

Further investigation of near surface soil at the Terminal was completed in October and November 2013. The assessment included 49 shallow hand-auger borings (SB-1 through SB-49) advanced on seven parcels at the Terminal (Parcels A, B, C, F, H, I, and Lake City Towing). Compounds found to exceed their respective direct contact limits were identified at eight of the borings (SB-1, SB-2, SB-15, SB-18, SB-23, SB-24, SB-39, and SB-40), and included benzene, ethylbenzene, total xylenes, naphthalene, benzo(a)pyrene, and dibenz(a,h)anthradcene. To further delineate soil conditions at these exceedances, 82 additional hand-auger and Geoprobe® borings were advanced from June through August 2014. Borings started approximately 5-10 ft from the original exceedance and stepped out an additional 5-10 ft from the borehole in two to four directions based on previous delineation results (**Appendix A**). Borings continued until samples were under the IDC-RCLs.

Excavation of the delineated potential direct contact soil exceedance area was completed in November and December 2014. Total impacted volume of excavated soil was 5,401 tons. Soil was hauled to Waste Management's Voyageur Landfill located in Canyon, Minnesota for disposal. The completion of soil excavation successfully eliminated the direct contact soil hazard.

Soil Remedial Options

Potential sources of petroleum impact were identified and removed from the property in 2000 and included aboveground and underground storage tanks, rail lines, and loading racks. Near surface soil impacts were excavated in November and December 2014 and 5,401 tons of soil was removed. This action eliminated potential direct contact impacts, and residual soil remains below direct contact depths (<4 feet bgs) underneath the dense, surficial clay layer. This clay layer ranges in thickness from 10 feet to at least 28 feet across the site, and does not have the potential to impact human health or the environment.

A special warranty deed was signed by Amoco Oil Company for the Terminal property on August 24, 2000 to set forth property restrictions in the case of divestment and redevelopment. The property use restrictions include all of the following:

1.) No part of the property will be used for the purpose of selling, handling, storing, wholesaling, or dealing in petroleum products (gasoline, diesel fuel, kerosene, distillates), benzol, naptha, greases, lubricating oils, oily water substances, or any fuel used for internal combustion.
2.) No water supply wells of any kind will be installed on the property.
3.) The property will be used solely and exclusively for commercial and/or industrial purposes.
4.) No basements or other underground improvements with the exception of building footings or slab-on-grade foundations will be constructed on the property.
5.) No part of the property will be used for child or elder care, nursing home facility or hospice, medical or dental facilities, school, place of worship, park, or a hospital.
6.) No soil will be removed from the property unless the soil is moved to a disposal facility or approved in advance by the Seller or directed by the Wisconsin Department of Natural Resources (WDNR).

These restrictions will allow for residual petroleum impacted soil to degrade through natural attenuation, while effectively controlling the potential for contact or impacts on human health or the environment.

Residual soil that lies underneath Winter Street can be managed through excavation or paving (capping). Residual soil lies under Winter Street, railroad tracks owned by BNSF, a petroleum pipeline owned by Murphy Oil, and gas and electric utility lines. All of these utilities and transportation routes would need to be removed and replaced to allow for soil excavation, which would be technically challenging and extremely costly. Therefore, this option is not considered feasible.

An asphalt cap maintenance plan is an additional remedial option to control the potential for soil direct contact road construction crews in this area. An out of service petroleum pipeline is known to exist under Winter Street in the northeast corner of the Terminal property, but its exact location is unknown. It is suggested that this location be marked before any road construction activities occur along Winter Street. The maintenance plan will also include management of excavated soil, and cap maintenance to isolate the contaminated soil. All excavated impacted soil would need to be disposed of at an off-site authorized disposal facility. A maintenance plan with a schedule and frequency approved by the WDNR will be conducted for cap maintenance. This includes inspections for cracks and buckling, as well as all necessary repairs and restoration. The existing cap includes asphalt pavement, which is considered sufficient to isolate the contaminated soil from direct contact with construction workers.

Vapor

Vapor Constituents and Occurrence

Subsurface vapor investigations were conducted in September 2006, December 2006, and October 2007 along the utility corridor that parallels Winter Street and Susquehanna Avenue (**Figure 7**). Soil gas samples were collected from 31 soil borings along Winter Street and the northern part of Susquehanna Avenue. Soil gas samples were collected from within the overlying silty-clay layer at a depth of 5 feet and from the underlying sand layer beneath the clay at a depth of 16 to 17 feet below ground surface (bgs).

Soil gas sample results from the underlying sandy layer (17-foot bgs samples) indicated concentrations of BTEX at several sample points, these include; SGS-3, SGS-4, SGS-7, SGS-8, SGS-9, SGS-10, SGS-11, SGS-12, SGS-28, SGS-30, and SGS-31. Most of the soil gas sample points are associated with the location of an area of residual petroleum located near the northeast corner of the former Terminal property. Detectable BTEX was also found at soil-gas probe SGS-28; located adjacent to former monitor well MW-19R. Monitor well MW-19R contained measurable LNAPLs, but it appears to be an isolated accumulation based upon an extensive subsurface laser-induced fluorescence investigation (Delta Consultants; *Progress Report – June 2004 through December 2007*, dated May 13, 2008). Elevated readings of organic vapors, methane, and % LEL, were generally present at the sample points that also registered significant concentrations of BTEX.

Obtaining a soil gas sample in the silty clay layer was difficult due to the impermeable nature of the silty-clay layer. No samples were obtained at several locations where the sampling pump was unable to recover a sufficient volume of soil gas for analysis. These locations included the 5-foot depths at soil gas sampling locations SGS-7 through SGS-10, SGS-14, SGS-16, SGS-18, SGS-20 through SGS-22, and SGS-24.

At only five locations were elevated total BTEX concentrations (> 5,000 ug/m^3) observed for the five-foot depth samples. Those were at SGS-2, SGS-6, SGS-12, SGS-19, and SGS-25. Although BTEX concentrations at these three points were elevated, the methane concentrations were only 43.6% of LEL at SGS-2, 0.0% of LEL at SGS-6, 0.0% of LEL at SGS-12, 0.0% of LEL at SGS-19, and 4.0% of LEL at SGS-25. The clay cap is effectively serving as a barrier to vapor migration to the surface, though it appears the overlying clay may have been disturbed at SGS-2 as result of pipeline removal.

The former Terminal Operations Building, and current office for Lake City Towing, likely overlies residual or dissolved-phase hydrocarbons in the subsurface. To evaluate if hydrocarbon vapors could pose a threat to indoor air at the Lake City Towing, a vapor pin (VP-1) was installed through the concrete slab at the office on September 13, 2016. The vapor pin was sampled four times, on September 15, 2016; October 13, 2016; September 19, 2017, and November 8, 2017. All laboratory results for petroleum hydrocarbons and MTBE were below the Wisconsin sub-slab Vapor Risk Screening Level (VRSL) standards. Methane results were reported as no higher than 7 parts per million by volume (ppmv), which is equivalent to 0.00007% of the lower Explosive Limit (LEL). This provided further evidence that the silty-clay layer provides an effective barrier to hydrocarbon vapor migration from the underlying sand unit.

Vapor Remedial Options

Approaches to ensuring that vapors do not pose a threat to the health and safety of occupants at Lake City Towing included soil-vapor extraction and maintaining, or enhancing, the integrity of the silty-clay layer. A pilot program for soil-vapor extraction (SVE) was initiated in 1994 with the installation of 10 SVE points, connections to two existing recovery wells (RW-1 and RW-4), a small building to house the blower, a control panel, and a condensate sump. The SVE array and system building were located between the former Amoco Operations Building (currently Lake City Towing) and Winter Street (**Figure 8**).

The SVE system was operated from 1994 to 2004, during which time approximately 68,842 pounds of hydrocarbons were recovered. This equates to approximately 10,624 gallons over the 9½-year operational period of the system, or about 1,118 gallons/year. However, in the last three years of operation the average annual recovery dropped to an average of 400 gallons/year and registered no recovery from May to August 2004. Due to diminished recovery and construction of a new total fluid/vacuum extraction system, the original SVE was shut down after August 2004. Following the soil-gas surveys conducted in 2006 and 2007, the existing SVE system was refurbished and operation resumed in 2009. Active vapor extraction points included RW-1, SV-2, SV-3, and SV-5. Vapor monitoring included total gasoline-range hydrocarbons and methane. After two months of operation, the system was found to have removed 110 pounds of gasoline-range hydrocarbons and 220 pounds of methane. Through 2012, the refurbished SVE system had recovered 3,777 pounds of methane and 1,183 pounds (equivalent to 189 gallons) of total hydrocarbons. However, the air flow had declined from 15 standard cubic feet per minute (SCFM) in 2009 to 1.6 SCFM in 2012. The system operated from January to August 2013, but only removed an estimated benzene mass of 0.6 pounds. With the concurrence of the WDNR, operation of the original SVE system was not continued for 2014.

Four new vapor extraction wells (VE-1, VE-2, VE-3, and VE-4) were installed south of Winter Street on Terminal property between 100 and 400 feet west of Maryland Avenue in July 2011 (**Figure 9**). The purpose of the new vapor extraction wells was to test the viability of venting petroleum hydrocarbons and methane from beneath the silty-clay layer using wells designed specifically to enhance vapor extraction. Each well was outfitted with a solar-power turbine fan to enhance the venting of petroleum hydrocarbons and methane from the vadose zone beneath the silty-clay layer.

The new vapor extraction system was pilot tested in the 4th quarter of 2012. Vapor samples were collected from the new vapor extraction wells (VE-1, VE-2, VE-3, and VE-4) and four additional perimeter points (SG-2D, EW-6, EW-7, and MW-27) on three occasions during the 3-month pilot test. Vapor-phase benzene concentrations declined by 2 to 3 orders of magnitude at most monitoring locations, while total hydrocarbons (THC) as gas declined at the perimeter monitor points, but remained fairly stable at the new vapor extraction wells.

The occurrence and magnitude of hydrocarbon vapors in the subsurface has been evaluated through several investigations and remedial pilot testing. It has been established that hydrocarbon vapors are present beneath the silty-clay layer on the Lake City Towing property, but hydrocarbon vapors are not present in the undisturbed silty-clay layer nor in the vapor samples collected beneath the slab of the Lake City Towing office building. It has been established that the hydrocarbon vapors are sequestered beneath the silty-clay layer and do not pose a threat to the environment or human health. The selected remedial approach is to allow the hydrocarbon vapors to remain under the silty-clay layer. To ensure this, the Real Estate Contract (July 14, 2000) limits new construction to slab-on-grade with no basements and requires that any contaminated soil removal be approved in advance by the Seller or directed by the Wisconsin Department of Natural Resources (WDNR).

LNAPL

LNAPL Characterization and Occurrence

An investigation at the Terminal in February 1988 included the installation of 13 monitor wells. Three of the monitor wells were found to have measurable light non-aqueous phase liquid (LNAPL) and groundwater samples from 4 other monitor wells were reported to have detectable concentrations of petroleum hydrocarbons (Delta Environmental Consultants; *Supplemental Site Investigation*; dated November 1, 1990). Subsequent investigations have refined the conceptual site model for LNAPL occurrence and characteristics to five “Areas of Concern”, or AOCs numbered from north to south as AOC 1 through AOC 5 (**Figure 2**). AOC 1 and AOC 2 have the largest areal extents and estimated LNAPL volumes, as described below (Antea Group; 2017; *2017 Amoco Oil Terminal Site Investigation Report*; dated December 15, 2017):

AOC 1, located south of Winter Street, is estimated to have an aerial extent of 16,214 square feet (ft^2) and a volume of residual LNAPL of 7,264 gallons (based on an oil-specific volume of 0.0599 feet). The LNAPL is likely associated with the former railroad loading rack that formerly was located south of Winter Street on Terminal property. Analyses of LNAPL samples from wells in AOC 1 (MW-16 and RW-4) indicated the petroleum is a mixture of kerosene with subordinate naphtha-range hydrocarbons, with relatively low amounts of aromatics.

AOC 2 is interpreted to extend from the northeast corner of the Terminal property (near former extraction well EW-5) to the southernmost part of C. Reiss Coal property (near monitor well MW-32). The areal extent of AOC 2 is estimated as 66,682 ft^2, with a volume of 3,362 gallons of residual LNAPL (based on an oil-specific volume of 0.0067 feet). Samples of LNAPL collected from monitor wells MW-14, MW-27 and MW-32 indicated the petroleum chemistry is the same as AOC 1.

The remaining three AOCs are of much small areal extent and are estimated to contain much less residual LNAPL. As noted below:

AOC 3, which is located at the old truck loading rack, has an estimated extent of 12,222 ft^2 but due to small oil-specific volume (0.0003 feet) has an estimated volume of residual LNAPL of 26 gallons. Based on an LNAPL sample from recovery well RW-2, within AOC 3, the characteristics of the petroleum in AOC 3 are possibly a mix of midgrade gasoline with a lesser amount of diesel fuel or No. 2 fuel oil.

AOC 4 encompasses an are about 44,646 ft^2 and is probably associated with the former manifold. The oil-specific volume of 0.0089 feet produces an estimated volume of residual LNAPL in AOC 4 of 2,968 gallons.

AOC 5 is the farthest south on Terminal property and may be associated with Tank 38, that was assumed to be the site of a chronic release. Tank 38 was reported to contain No. 2 fuel oil. A chromatogram analysis of an LNAPL sample collected from monitor well MW-23 indicates the residual LNAPL in AOC 5 is a mixture of kerosene with subordinate naphtha-range hydrocarbons, with relatively low amounts of aromatics. The estimated area for AOC 5 is 8,303 ft^2.

The oil-specific volume was calculated as 0.0122 feet, which yields an estimated volume of residual LNAPL within AOC 5 of 758 gallons.

The total area of the 5 AOCs is estimated as 148,067 ft^2 with an estimated total volume of residual LNAPL of 14,378 gallons.

The Interstate Technology and Regulatory Council (ITRC) recognized that many LNAPL remedial projects have failed due to an insufficient LNAPL characterization, inadequate site understanding, poorly defined remedial objectives, and poor selection or design of remedial strategies (ITRC, 2009, *Evaluating LNAPL Remedial Technologies for Achieving Project Goals*). Such directives as "recover LNAPL to the maximum extent practicable" or setting a maximum allowable in-well LNAPL thickness have little, if any, correlation with LNAPL mobility or recoverability. A better metric for assessing if LNAPL is recoverable or has the potential to migrate is LNAPL transmissivity. The ITRC (2009) suggests that the lower limit of LNAPL recoverability using pneumatic means (pumps and vapor enhancement, for instance) is achieved when the LNAPL transmissivity falls within a range of 0.1 to 0.8 square feet/day (ft^2/day). Manual-skimmer tests have been conducted at the Terminal in wells located in AOC 1, AOC 2, AOC 4, and AOC 5. The highest LNAPL transmissivity determined for a well on the Terminal property was 0.52 ft^2/day at monitor well MW-27 (**Figure 10**), which is below the LNAPL transmissivity that the ITRC (2009) considers conducive for LNAPL recoverability.

The exception regarding LNAPL transmissivity was found at monitor well MW-32, where the LNAPL transmissivity was determined to be 2.25 ft^2/day, and active recovery from MW-32 has produced 1330 gallons of LNAPL from 2015 to 2017. The recovery of LNAPL from monitor well MW-32 was the result of a persistent high groundwater elevation that created confined conditions below the thick surficial silty-clay layer which then optimized LNAPL mobility into the monitor well and recoverability. The groundwater elevation has declined in monitor well MW-32 from a high of 619.74 feet amsl (July 2016) to 617.33 feet amsl (August 2018), which reduced the LNAPL recovery to 1.55 gallons for the entire 2018 recovery season and reduced the LNAPL transmissivity to zero.

In addition to LNAPL transmissivity, the migration potential of the LNAPL supports the conclusion that the LNAPL is not recoverable and is not migrating. Potential LNAPL plume velocities were calculated at locations within AOCs 1, 2, 4 and 5 (Antea Group; January 24, 2017; *2016 Progress Report and Site Closure Request: July – December 2016, Former Amoco Terminal*). The results indicated that all but one location (MW-16) registered below the suggested stability metric of less than 1 foot/year (ASTM; E2531-06 – *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Nonaqueous-Phase Liquids Released to the Subsurface*, Table X5.1). The maximum calculated potential LNAPL velocities ranged from 0.00096 feet/year (AOC 1) to 0.233 feet year (AOC 2); all of which are below the suggested stability metric of 1 foot/year. The maximum potential LNAPL velocity calculated for monitor well MW-16 in AOC 1 was 4.88 feet/year, though it should be noted that monitor well MW-16 is within the interior of AOC 1 and does not indicate that the actual LNAPL body is expanding.

LNAPL Remedial Options

LNAPL recovery using pneumatic means has been evaluated on a pilot test and interim basis. The first effort at LNAPL recovery was a skimming system installed in 1991. Recovery wells RW-1 (AOC 2), RW-2 (AOC 3) and RW-6/MW-2 (near AOC 5) were operated until August 2004 recovering approximately 6,794 gallons of LNAPL. On a monthly basis, LNAPL recovery ranged from 0 to 276 gallons/month, with an average of 10 gallons/month. The skimming system was shut down in August 2004 due to diminishing recovery and start-up of the Vapor Extraction – Total Fluids Recovery Treatment (VE-TFRT) system.

Besides the skimming system, various interim means to recover LNAPL were evaluated at the Terminal, including manual recovery, vacuum-truck recovery and soil-vapor extraction (SVE). The SVE system was described above in *Vapor Remedial Options* section. LNAPL recovery using SVE relies upon inducing volatilization of the residual LNAPL. As described above, the SVE operated for about 9½ years and recovered 10,813 gallons. However, in the last three years of operation the average annual recovery dropped to an average of 400 gallons/year and registered no recovery from May to August 2004. The occurrence of LNAPL in nearby wells and through the analysis of soil samples for total petroleum hydrocarbons (TPH) confirms residual LNAPL remains within the area. However, the sharp decline in recovery for the SVE system may have been related to the composition of the residual LNAPL (kerosene and secondary naphtha) and the depletion of the volatile hydrocarbons.

As noted earlier, a Vapor Extraction – Total Fluids Recovery Treatment (VE-TFRT) system was installed at the Terminal in 2004. A total of 11 extraction wells (EW-1, EW-2, and EW-3 through EW-11) were installed on the Lake City Towing property and Parcel A. The active VE-TFRT system included 5 extraction wells: EW-1, EW-3, EW-4, EW-5, and existing recovery well RW-2. Each extraction well was equipped with a pneumatic pump that recovered total fluids. Each extraction well was also piped to the SVE system so that vacuum could be applied to each extraction well to increase the effective drawdown, enhance LNAPL recovery, and recover hydrocarbon vapor. Recovery of LNAPL steadily declined at extraction wells EW-1, EW-3, and RW-2 necessitating a limitation of fluid extraction to extraction wells EW-4 and EW-5 in December 2011. Vapor extraction remained in effect at all extraction wells. The VE-TFRT system was operated until July 2012. LNAPL recovery for the entire system had declined to approximately 1.3 gallons per day (gpd), after having averaged 3 gpd since January 2005. Over its lifetime, the VE-TFRT system recovered 7,536 gallons of LNAPL. The VE-TFRT system also extracted and treated 1,464,026 gallons of groundwater, and in the process removed an equivalent volume of 160 gallons of LNAPL. Vapor-phase recovery since system start-up was 9,519 pounds of hydrocarbons (181 pounds of benzene), which is equivalent to 1,523 gallons of LNAPL. By 2012, benzene recovered in the vapor phase had declined to 6 pounds.

A further evaluation of LNAPL recovery was accomplished through recovery modeling using the LNAPL Distribution and Recovery Model (LDRM) published by the American Petroleum Institute (Charbeneau, 2007). The LDRM was used to evaluate recovery wells outfitted with passive skimmer pumps, as well as recovery enhancements through applied vacuum and groundwater pumpage. The results of the LDRM simulations indicate that soil conditions, LNAPL saturations, and LNAPL saturations are not conducive to effective LNAPL recovery.

A passive skimmer pump was simulated for 5 years of operation and is predicted to recover a total of 182.6 gallons of LNAPL. The effect on LNAPL recovery with applied vacuum was simulated by with 0.2 atmospheres (or 81 inches of H_2O vacuum), which induced 0.863 feet of upwelling. The predicted recovery after 5 years was just 12 gallons, which is significantly less than for a passive skimmer pump. The reduced recovery for a vacuum-enhanced skimmer pump may be the result of upwelling that blocks migration from higher LNAPL saturation intervals. The recovery of LNAPL was also evaluated if the water level in the recovery well was depressed with a pump, thereby creating a drawdown cone in the aquifer. As with the other simulations, the skimmer pump enhanced by groundwater pumpage was operated for 5 years. The groundwater pumpage rate was set at 2 gpm, which induced a drawdown of 0.558 feet in the well. After 5 years of operation, the LDRM predicted that 1,504 gallons of LNAPL may be recovered, which represents 50% of the modeled LNAPL within the smear zone. For each 5-year simulation, the LNAPL recovery cited represent asymptotic conditions. Therefore, it should be noted that the LDRM simulations are more optimistic about LNAPL recovery than the volume recovered by the VE-TFRT system, which operated 2 to 5 wells over a 9½-year period.

The feasibility of a horizontal recovery well was evaluated for LNAPL recovery. A horizontal recovery well is an attractive remediation option because:

1. The overlying silty-clay layer would not be disturbed where LNAPL is known to exist,
2. Exposure to LNAPL and petroleum hydrocarbon vapors is severely limited,
3. Stability of underlying silty sand is not an issue, and
4. The effective seepage area is much larger than for a vertical well.

The horizontal well would be located south of Winter Street through AOC 1 and AOC 2. The designed length of the horizontal well was 400 feet. The designed depth of installation was 20 feet below ground surface (bgs), which corresponds with the average depth to the water table. The objective of the horizontal well was to provide an effective approach for LNAPL recovery with little or no water recovery. To accomplish that objective the horizontal well needs to be located in the smear zone just above a reasonably stable water table where the highest LNAPL saturations would be expected. As noted earlier, the average depth to the water table is 20 feet bgs but the range of water-table depth is 8.38 feet with an equally thick smear zone. These conditions limit the effectiveness of a horizontal well where positioning in relation to the water table is a critical requirement. With a water-table range of 8.38 feet, the horizontal well would most likely be submerged below the water or suspended above it most of the time which would inhibit any effective LNAPL recovery.

Recovery of LNAPL has been evaluated, tested and implemented at the Terminal through pneumatic means from wells or vapor-extraction points. Through skimmer pumps, vacuum-enhanced total fluids pumpage, and vapor extraction an estimated 28,467 gallons of LNAPL have been recovered from the Terminal property. This total does not include manual recovery events including vacuum truck recovery, portable spill buddy skimmer recovery, and hand bailing, as these events are difficult to quantify and summarize. A summary of recovery totals through each recovery method is presented below.

Recovery Type	Gallons Recovered
Pneumatic Skimming System	6,794
Mobile Skimmer	1,641
SVE	10,813
VE-TFRT	9,219
Total	**28,467**

An evaluation of LNAPL contained in AOC 1 through AOC 5 calculated a volume of 14,378 gallons in the subsurface (**Table 2**) suggests that more than 66% of the LNAPL originally in the subsurface has been recovered. Recovery of more than 60% of the LNAPL from the subsurface is indicative of very successful removal action that has reached the limits of recoverability.

Dissolved Phase Hydrocarbons

Dissolved Phase Hydrocarbons Characterization and Occurrence

Groundwater contaminated with dissolved-phase hydrocarbons have been identified in monitor wells across the Terminal site, with the vast majority of contaminated monitor wells being located in the northeast portion of the site (the Lake City Towing property and Parcel A). Using benzene occurrence above the NR 140 Enforcement Standard (5 micrograms/liter) as indicative of dissolved-phase hydrocarbon contamination, impacted wells at the Terminal site included MW-3, RW-3, EW-8, and EW-9 (**Figure 11**).

Deep monitor wells (top of screen set at 583 to 577 feet amsl) located at the Terminal (MW-4D on Parcel C and MW-15D on Parcel I) have had only occasional detections of benzene. Twenty-six groundwater samples were collected from monitor well MW-4D between 1994 and 2009, with a single reported detection of benzene (1.5 micrograms/liter) in November 1997. Thirty-three groundwater samples were collected from monitor well MW-15D from 1994 to 2012, with 6 reporting detectable benzene concentrations ranging from 0.13 to 25.1 micrograms/liter (μg/L).

Dissolved-phase hydrocarbons in the groundwater have been identified in the groundwater northwest of (hydrologically downgradient) the Terminal property. Detectable hydrocarbon concentrations in the shallow monitor wells (well screen intersects water table), that may be attributed to petroleum releases at the Terminal, are found in monitor wells MW-30S and MWT-2S. Groundwater samples collected from shallow monitor wells northwest of monitor well MWT-2S report only sporadic detections of benzene or other petroleum hydrocarbons at concentrations below the applicable NR 140 Enforcement Standard.

Detectable benzene concentrations define the lateral and downgradient extent of dissolved-phase hydrocarbons in the deep monitor wells (see **Figure 4**). The top of the screen for the deep monitor wells is set from 578 to 567 feet amsl north of Winter Street; comparable to the two deep monitor wells at the Terminal. Benzene concentrations have been reported above the NR 140 Enforcement Standard for samples collected from the deep monitor wells between monitor well MW-30D and MW-41D, producing a plume length of approximately 1,385 feet. Laterally, the widest extent of benzene concentrations exceeding the NR 140 Enforcement Standard is on the order of 500 feet. The approximate areal extent of dissolved-phase benzene (>5 μg/L) is 10.1 acres.

The dissolved-phase hydrocarbons are isolated at least 50 feet bgs within the deep (D-level) water-bearing zone that is capped by silty-clay layer. The silty-clay layer also prohibits discharge of impacted groundwater to St. Louis Bay. The "D-level" monitor wells located north of Winter Street are hydrogeologically down gradient of the residual LNAPL associated with the Terminal. The "D-Level" monitor well closest to the Terminal (and outside the area of residual LNAPL) is MWT-2D, and the farthest down-gradient monitor well (MW-41D) is located approximately 1,165 feet to the northwest.

Benzene is the only petroleum hydrocarbon detected northwest of monitor well MWM-9RD in concentrations that exceed its NR 140 Enforcement Standard. The average benzene concentration at monitor well MW-30D between 2011 and 2017 is 1,845 μg/L, while at monitor well MW-41D the average benzene concentration is 4.9 μg/L over the same time period. The downward vertical hydraulic gradients and generally northwest groundwater gradient produce benzene concentrations at monitor well MWT-2D that substantially exceed the Enforcement Standard (average concentration of 3,565 μg/L between 2011 and 2017); however, benzene concentrations decline in monitor wells along the inferred groundwater flow path to the northwest.

It should be noted that the vertical hydraulic gradient between monitor wells MW-41D and MW-41S has been consistently upward (average of -0.095 ft/ft) from the D-Level to the S-Level since October 2011. The BTEX, trimethylbenzenes, MTBE, and naphthalene concentrations for all samples collected from monitor well MW-41S have been reported as non-detectable (with one exception for benzene at 3.1 μg/L on April 18, 2012) since 2011. This indicates that benzene reported for samples from monitor well MW-41D is not being transported into the shallow (S-Level) water-bearing zone immediately below the silty-clay layer (Antea Group; *2017 Amoco Oil Terminal Site Investigation Report*; dated December 15, 2017; Table 5). Furthermore, the consistent report of non-detectable petroleum hydrocarbons for samples collected from monitor well MW-41S indicates there are no petroleum hydrocarbons available in the "S-Level" to migrate through the silty-clay layer into St. Louis Bay.

Six DD-level monitor wells have been installed north of Winter Street from monitor well MW-30DD (Delta Environmental Consultants; 1999; *Site Investigation and Interim Response Actions Report: July 1997 – November 1998*; dated June 17, 1999) to monitor well MW-41DD (Antea Group; 2018; *2018 Progress Report: January 2018 – June 2018*; dated August 14, 2018), a distance of about 1,370 feet in a northwest direction. To intersect the DD-level of the aquifer, the top of the screen typically is set at 548 to 536 feet amsl, or 71 to 84 feet bgs. Detectable benzene concentrations have only been detected in groundwater samples collected from monitor well MW-37DD. A monitor well (MW-37DDD) was installed with the top of the screen set 6 feet below monitor well MW-37DD (Antea Group; 2018; *2018 Progress Report: January 2018 – June 2018*; dated August 14, 2018). Two rounds of groundwater samples collected from monitor well MW-37DDD reported benzene concentrations below the NR 140 Enforcement Standard; toluene, ethylbenzene, xylenes, total trimethylbenzenes, methyl-tert butyl ether (MTBE), and naphthalene were reported as non-detected for both rounds of samples.

Dissolved Phase Hydrocarbons Remedial Options

Remediation of the dissolved-phase petroleum hydrocarbons is considered to occur as a direct benefit of LNAPL source zone depletion. The ITRC (2009) considers natural source zone depletion (NSZD) to be accomplished through volatilization, dissolution, biodegradation and sorption. Direct biodegradation or sorption of hydrocarbons occurs with the LNAPL body of the source zone, while volatilization and dissolution subject the petroleum hydrocarbons to degradation in the vadose zone and phreatic zone, respectively.

Sorption of petroleum within the source zone has been demonstrated by the laboratory analysis of multiple soil samples for total petroleum hydrocarbons (TPH), as well as individual compounds such as benzene, toluene, ethylbenzene, and xylenes (BTEX). Volatilization was shown to be occurring in the source zone by an aerially extensive soil-gas investigation (Antea Group; *Soil Vapor Abatement Activities Along Winter Street*; October 19, 2009) which has shown the presence of BTEX and methane below the silty-clay layer. Biodegradation shown to be occurring by the decline in BTEX concentrations in groundwater samples from downgradient monitor wells, especially for toluene, ethylbenzene, and xylenes.

Benzene is the primary petroleum hydrocarbon in the dissolved-phase plume north of Winter Street that occurs in concentrations above its NR 140 Enforcement Standard. Naphthalene and MTBE are also found in groundwater samples collected from monitor wells north of Winter Street, but their occurrence does not persist northwest of monitor well MWM-9RD.

Benzene concentrations that exceed the NR 140 Enforcement Standard are found from just north of Winter Street (monitor well MW-30D) to monitor well MW-41D, as described previously. The benzene plume appears be stable and restricted to the “D-level” water-bearing zone, which was also found to have a higher hydraulic conductivity than the “S-zone” or the “DD-zone”. The depth of occurrence of the dissolved-phase benzene and persistence of the extensive overlying silty-clay layer eliminates the vapor pathway to surficial receptors or discharge to St. Louis Bay.

In support of the conclusion that degradation of petroleum hydrocarbons is occurring, benzene trends in individual monitor wells and along inferred groundwater flow paths were developed. The down-gradient deep monitor well nearest to (but not within) the area of residual LNAPL is MWT-2D. Down gradient of monitor well MWT-2D along an inferred flow path are monitor wells MWM-9RD and MW-36D, as depicted in the groundwater elevation contour map (**Figure 12**). On an individual well basis, plots of benzene concentration over time demonstrate declining to essentially stable concentrations. For instance, the graph of benzene concentrations reported for monitor well MWT-2D since 2006 shows a negatively correlated trend with a declining slope of -0.4179 μg/L per day (**Figure 13a**). Approximately 275 feet down gradient, monitor well MWM-9RD shows a somewhat more pronounced decline in benzene concentration of -0.992 μg/L per day (**Figure 13b**). The declining trend in benzene concentration persists at monitor well MW-36D, approximately 458 feet down gradient of monitor well MWT-2D, with a slope of -0.0652 μg/L per day (**Figure 13c**).

Evaluating the synoptic pattern of benzene concentrations along a groundwater flow path can provide insights into and substantiation of degradation and bulk attenuation rate. For such an analysis, it is best to use monitor wells located on or near an inferred groundwater path. Monitor wells MWT-2D, MWM-9RD, and MW-36D qualify as being aligned on or near an inferred groundwater flow path, with monitor well MWT-2D being designated as the up-gradient well and monitor well MW-36D being at the down-gradient terminus. Data from 9 sampling events conducted between May 2013 and October 2017 were used for the analysis (**Figures 14a and 14b**). In each case, the trend line was negatively correlated, with the earliest sampling event (May 7, 2013) producing the steepest slope (-6.8338 μg/L per foot). The latest sampling event included in the analysis (October 4, 2017) produced a less steep slope (-3.3753 μg/L per foot), which still represents an overall and continuing reduction in benzene mass.

Exposure to dissolved-phase petroleum hydrocarbons through ingestion or inhalation from well water is eliminated due to provisions in the Real Estate Contract (July 14, 2000) that prohibit "water supply wells of any kind" [Section 6(ii)] and the availability of public water from the City of Superior.

Considering the isolation and depth of the dissolved-phase benzene plume, and the lack of exposure pathways to receptors, natural attenuation is an appropriate remedial option for the remaining dissolved-phase. In order to further evaluate the effectiveness of natural attenuation as a remedial option, trends in geochemical parameters are proposed to be analyzed. Geochemical trends can be assessed through monitoring of electron acceptors, metabolic byproducts such nitrate and sulfate, dissolved iron, or through alkalinity. The easiest option would be a measurement that can be conducted in the field, so that immediate data can be obtained. One option for this is to measure alkalinity through field test kits or instruments. The alkalinity will be measured in LNAPL source areas as well as wells surrounding the AOCs, and an isoconcentration map or data plots will be prepared to determine if alkalinity increases within the plume. Alkalinity is expected to increase across the site where biological activity is occurring. Measurement of the alkalinity, along with the pH and temperature, will also allow for calculation of the concentration of CO_2 in the groundwater. Carbon dioxide is a distinct metabolic by-product of natural attenuation, and its enrichment in the groundwater would confirm natural attenuation is an effective remedial process at the Barge Dock. Additional geochemical parameters that can be monitored in the field include measurement of dissolved oxygen, specific conductivity, and oxidation-reduction potential, which can be measured through a multi-parameter water quality meter. Laboratory analysis would be required for the measurement of nitrate, sulfate, and dissolved iron in groundwater.

Biodegradation potential can be further evaluated by detecting and quantifying presence of the functional genes associated with both aerobic and anaerobic bacteria. Using a technique called quantitative polymerase chain reaction (qPCR) the genes indicative of specific bacteria active in biodegrading petroleum hydrocarbons and MTBE will be identified and quantified. The trade name for the laboratory technique specifically designed to identify aerobic and anaerobic bacteria that degrade petroleum hydrocarbons is QuantArray® - Petroleum, offered by Microbial Insights of Knoxville, Tennessee. Samples must be collected using the Bio-Trap® sampler or another appropriate sample-collection method. This analysis, coupled with geochemical trend analysis, will provide a clear and comprehensive view of petroleum hydrocarbon degradation onsite.

SELECTED REMEDIAL ACTIONS

Soil

Potential sources of petroleum impact were identified and removed from the property in 2000 and included aboveground and underground storage tanks, rail lines, and loading racks. Near surface soil impacts were historically identified and were further investigated through the advancement of 49 hand-auger borings on seven parcels of the Terminal in October and November 2013. Eight of these borings had contaminant levels that exceeded IDC-RCLs. Each of these locations was delineated in two to four directions until samples were under IDC-RCLs (**Appendix A**). Soil excavation was completed in November and December 2014 with the removal of 5,401 tons of soil on five parcels of the Terminal. On a parcel-by-parcel basis the tons of soil excavated are listed below:

Parcel A: A total of 19.94 tons of impacted soil were removed around SB-18 which is located south of Lake City Towing.

Parcel B: A total of 3,194.29 tons of impacted soil were removed around SB-22, SB-23, SB-39, SB-40 and SB-48, and a total of 2,076.71 tons of impacted soil were removed around SB-24, SB-25 and SB-32. All of these locations are north of Halvor Lane.

Parcel C: A total of 67.87 tons of impacted soil were removed around SB-1 which is located south of Halvor Lane.

Parcel F: A total of 19.65 tons of impacted soil were removed around SB-2 which is located south of Halvor Lane.

Parcel H: A total of 22.28 tons of impacted soil were removed around SB-15 which is located west of Lake City Towing.

Soil was disposed of at Waste Management's Voyageur Landfill in Canyon, Minnesota. All of the excavation areas were completed to a depth of 4 feet bgs, except for SB-1 which was completed to a depth of 3 feet bgs and SB-2 which was completed to a depth of 2 feet bgs. This action eliminated potential direct contact impacts, and residual soil remains below direct contact depths (<4 feet bgs) underneath the dense, surficial clay layer. This clay layer ranges in thickness from 10 feet to at least 28 feet across the site, and does not have the potential to impact human health or the environment.

A special warranty deed was signed by Amoco Oil Company for the Terminal property on August 24, 2000 to set forth property restrictions in the case of divestment and redevelopment. The property use restrictions included all of the following:

1.) No part of the property will be used for the purpose of selling, handling, storing, wholesaling, or dealing in petroleum products (gasoline, diesel fuel, kerosene, distillates), benzol, naptha, greases, lubricating oils, oily water substances, or any fuel used for internal combustion.
2.) No water supply wells of any kind will be installed on the property.
3.) The property will be used solely and exclusively for commercial and/or industrial purposes.
4.) No basements or other underground improvements with the exception of building footings or slab-on-grade foundations will be constructed on the property.

5.) No part of the property will be used for child or elder care, nursing home facility or hospice, medical or dental facilities, school, place of worship, park, or a hospital.
6.) No soil will be removed from the property unless the soil is moved to a disposal facility or approved in advance by the Seller or directed by the Wisconsin Department of Natural Resources (WDNR).

These restrictions will allow for residual petroleum impacted soil to degrade through natural attenuation, while effectively controlling the potential for contact or impacts on human health or the environment.

The LNAPL plume and thus contaminated soil on the Terminal is known to extend beneath Winter Street as evidenced by monitoring wells MW-26 and MW-32. In order to mitigate the risk of potential direct contact by road crew, Antea Group recommends an asphalt cap maintenance plan including marking the out of service pipeline beneath the road, management of excavated soil, and cap maintenance to isolate the contaminated soil.

All excavated impacted soil would need to be disposed of at an off-site authorized disposal facility. A maintenance plan with a schedule and frequency approved by the WDNR will be conducted for cap maintenance. This includes inspections for cracks and buckling, as well as all necessary repairs and restoration. The existing cap includes asphalt pavement, which is considered sufficient to isolate the contaminated soil from direct contact with construction workers.

Vapor

The Lake City Towing office is the only potential receptor for vapors migrating through the subsurface as a result of volatilization or degradation of residual petroleum. Soil-gas surveys and sub-slab vapor sampling at the Lake City Towing office have demonstrated the silty-clay layer is an effective barrier to vapor migration. Sampling results from the vapor pin in Lake City towing have remained below the Wisconsin sub-slab VRSL standards for petroleum hydrocarbons and MTBE for all four rounds of sampling, and the highest methane concentrations were reported at 0.00007% of the LEL.

The selected remedial approach is to ensure the silty-clay layer is not breached in a manner that would allow unmitigated migration of hydrocarbon vapors to the surface. Integrity of the silty-clay layer is ensured through Deed Restrictions in the Real Estate Contract (July 19, 2000) as follows:

3.) "[N]o basements or other underground improvements (with the exception of building footings and slab on grade foundations with the top of the slab at or above surface level) shall be constructed on the Property."

6.) "[N]o soils shall be removed from the Property unless the soil is moved to a disposal facility approved in advance by the Grantor, which approval shall not unreasonably be withheld, provided, if the Government (as hereinafter defined) requires the removal of any such soils, such soils may be moved to a disposal facility approved by the Government."

LNAPL

The LNAPL Distribution and Recovery Model was used to simulate three different recovery methods. A passive skimmer pump was simulated for 5 years of operation, and the effect on recovery was also simulated through the addition of an applied vacuum to the skimmer pump and water level depression through pumping. The pneumatic skimming pump with groundwater pumping yielded the highest simulated recovery volume, but the amount of groundwater that would be required to be treated after operating the system at 2 gpm for five years did not create an economically feasible recovery method. The feasibility of a horizontal recovery well was also evaluated for LNAPL recovery, but it was determined that the effectiveness would be severely limited by the range of water table fluctuations and smear zone thickness.

Recovery of LNAPL has been successfully accomplished through the use of pneumatic skimmer pumps, vapor extraction total fluids recovery, soil vapor extraction, vacuum-truck recovery, and manual recovery. Through these methods, a total of 28,467 gallons of LNAPL are estimated to have been recovered from the Terminal property. A summary of these recovery efforts and cumulative LNAPL recovery is presented below.

Recovery Method	Wells	Years of Operation	Gallons Recovered
Pneumatic Skimming System	RW-1, RW-2, RW-6, MW-2	1991-2004	6,794
Mobile pneumatic skimming systems	EW-11, RW-5, RW-6, MW-32	2009-2012	1,641
Soil-Vapor Extraction	10 SVE points, RW-1, RW-4	1994-2004, 2009-2012 (RW-1, SV-2, SV-3, SV-5)	10,813*
Vapor Extraction – Total Fluids Recovery Treatment (VE-TFRT)	EW-1, EW-2, and EW-3 through EW-11	2011-2015	9,219**
		Total Recovered LNAPL	**28,467**

* = Soil-vapor extraction recovery measured as vapor equivalent LNAPL gallons

** = VE-TFRT system recovery totals include liquid, dissolved, and vapor phases measured in LNAPL gallons and vapor equivalent gallons

This total does not include manual recovery events including hand bailing, as these events are difficult to quantify and summarize. An evaluation of LNAPL volume remaining at the Terminal in the subsurface calculated a volume of 14,378 gallons distributed between the 5 AOCs. A comparison of recovered and remaining LNAPL volumes suggests that more than 66% of the LNAPL originally in the subsurface has been recovered. Recovery of more than 60% of the LNAPL from the subsurface is indicative of very successful removal action that has reached the limits of recoverability.

The recommended remedial approach is to allow the LNAPL to remain undisturbed under the silty-clay layer. This approach would eliminate the potential for exposure, especially noting that the Real Estate Contract (July 19, 2000) prohibits building foundations other than slab-on-grade or private wells. In order to evaluate natural attenuation effectiveness in the source areas, field parameters will be collected including dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, pH, specific conductivity, dissolved iron (Fe^{+2}), nitrate, sulfate, and alkalinity as described below.

Dissolved-Phase Hydrocarbons

Remediation of the dissolved-phase petroleum hydrocarbons is considered to occur as a direct benefit of LNAPL source zone depletion. Natural source zone depletion (NSZD) to be accomplished through volatilization, dissolution, biodegradation and sorption. As demonstrated above, these processes are occurring in the source zone and downgradient portions of the aquifer.

Benzene is the primary petroleum hydrocarbon in the dissolved-phase plume north of Winter Street. Benzene concentrations above its NR 140 Enforcement Standard are found from just north of Winter Street (monitor well MW-30D) to monitor well MW-41D, as described previously. The benzene plume appears be stable and primarily restricted to the "D-level" water-bearing zone, which was also found to have a higher hydraulic conductivity than the "S-zone" or the "DD-zone". The depth of occurrence of the dissolved-phase benzene and persistence of the extensive overlying silty-clay layer eliminates the vapor pathway to surficial receptors or discharge to St. Louis Bay. Exposure to dissolved-phase petroleum hydrocarbons through ingestion or inhalation from well water is eliminated due to provisions in the Real Estate Contract (July 19, 2000) that prohibit "water supply wells of any kind" [Section (ii)] and the availability of public water from the City of Superior.

Considering the isolation and depth of the dissolved-phase benzene plume, and the lack of exposure pathways to receptors, natural attenuation was the remedy considered for evaluation and implementation. To further substantiate and quantify natural attenuation, sampling events will continue to be conducted to evaluate trends in benzene concentrations temporally and spatially.

In addition, field parameters will be collected that will include field probe analysis of dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, pH, and specific conductivity, laboratory analysis of dissolved iron (Fe^{+2}), nitrate, and sulfate, and a field titration cell test for alkalinity. Alkalinity is included to allow for the determination of dissolved carbon dioxide, which is a diagnostic parameter verifying the degradation of hydrocarbons. The field parameters will be collected in addition to PVOC sample collection in 2019. This collection event will include all geochemical parameters, and will occur focus on "D level" wells aligned on or near an inferred groundwater flow path.

And finally, biodegradation potential will be evaluated by detecting and quantifying presence of the functional genes associated with both aerobic and anaerobic bacteria. Using a technique called quantitative polymerase chain reaction (qPCR) the genes indicative of specific bacteria active in biodegrading petroleum hydrocarbons and MTBE will be identified and quantified. The trade name for the laboratory technique specifically designed to identify aerobic and anaerobic bacteria that degrade petroleum hydrocarbons is QuantArray® - Petroleum, offered by Microbial Insights of Knoxville, Tennessee. Samples will be collected from upgradient and impacted monitor wells using the Bio-Trap® sampler or another appropriate sample-collection method. The specialized analysis will be performed by Microbial Insights (Knoxville, Tennessee).

For the field parameters and biodegradation evaluation, monitor wells for analysis include MW-30S, MW-30D, MWT-2S, MWT-2D, MWM-9RS, MWM-9RD, and MW-36S, MW-36D. Wells within these same well clusters may also be sampled to determine the change in geochemical parameters at different vertical delineations. Monitor wells MW-17, MW-52D, and MW-52DD will also be sampled to allow for a set of baseline parameters, as these wells have been consistently non-detect for benzene. Estimated costs for the field parameter sampling are as follows:

	Quantity	Unit Price	Estimated Subtotal
Dissolved iron (Fe^{+2}) lab analysis	11 wells	$7	$56
Nitrate lab analysis	11 wells	$14	$112
Sulfate lab analysis	11 wells	$14	$112
Bio-Trap® sampling	11 wells	$100	$1,100
QuantArray® - Petroleum analysis	11 wells	$750	$8,250
Alkalinity Titration Cells	1 x 30-test kit	$34.21	$34.21
YSI	1 day	$120/day	$120
Mobilization	280 miles	$0.58/mile	$162.40
Field Staffing	10 hours x 2 personnel	$85/hour	$1,700
Total			**$11,646.61**

Lab analysis estimates were obtained from Pace Analytical in Green Bay, WI. Bio-Trap® and QuantArray® analysis estimates were obtained from Microbial Insights (Knoxville, Tennessee). Alkalinity titration cell estimates were obtained from CHEMetrics catalog number K-9810. The YSI is owned by Antea Group and costs include unit pricing per day of usage.

The monitoring and sampling event will allow for the determination of which parameters are found at detectable levels, and which are beneficial to promoting degradation and found to be utilized in the degradation of petroleum hydrocarbons. One to two rounds of sampling will allow for the production of isoconcentration maps, and results will be compared to historical data. If results are favorable, site closure suitability and options will be evaluated at the end of the 2019 operating season.

REMARKS

The recommendations contained in this report represent Antea USA, Inc.'s professional opinions based upon the currently available information and are arrived at in accordance with currently accepted professional standards. This report is based upon a specific scope of work requested by the client. The contract between Antea USA, Inc. and its client outlines the scope of work, and only those tasks specifically authorized by that contract or outlined in this report were performed. This report is intended only for the use of Antea USA, Inc.'s client and anyone else specifically identified in writing by Antea USA, Inc. as a user of this report. Antea USA, Inc. will not and cannot be liable for unauthorized reliance by any other third party. Other than as contained in this paragraph, Antea USA, Inc. makes no expressed or implied warranty as to the contents of this report

Date: 3/14/19

Layne Kortbein
Staff Professional

I, Wayne Hutchinson, hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03 (1), Wis. Adm. Code, am registered in accordance with the requirements of ch. GHSS 2, Wis. Adm. Code, or licensed in accordance with the requirements of ch. GHSS 3, Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code.

Date: 3/14/19

Wayne Hutchinson, PG, PH
Senior Hydrogeologist

Professional Seal:

Reviewed by:

______________________________ Date: 3/14/19

Jonathan Zimdars
Consultant

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Figures

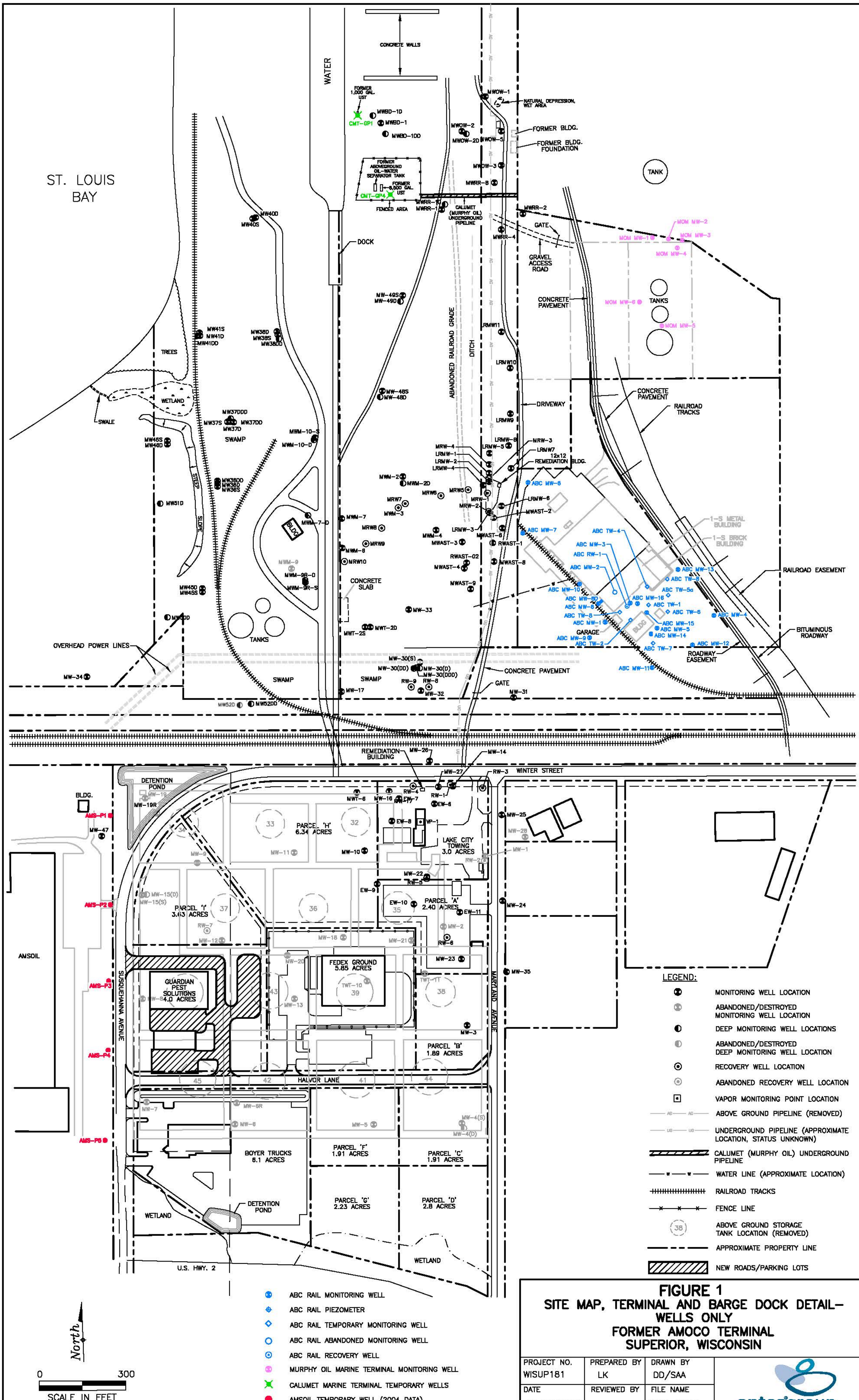
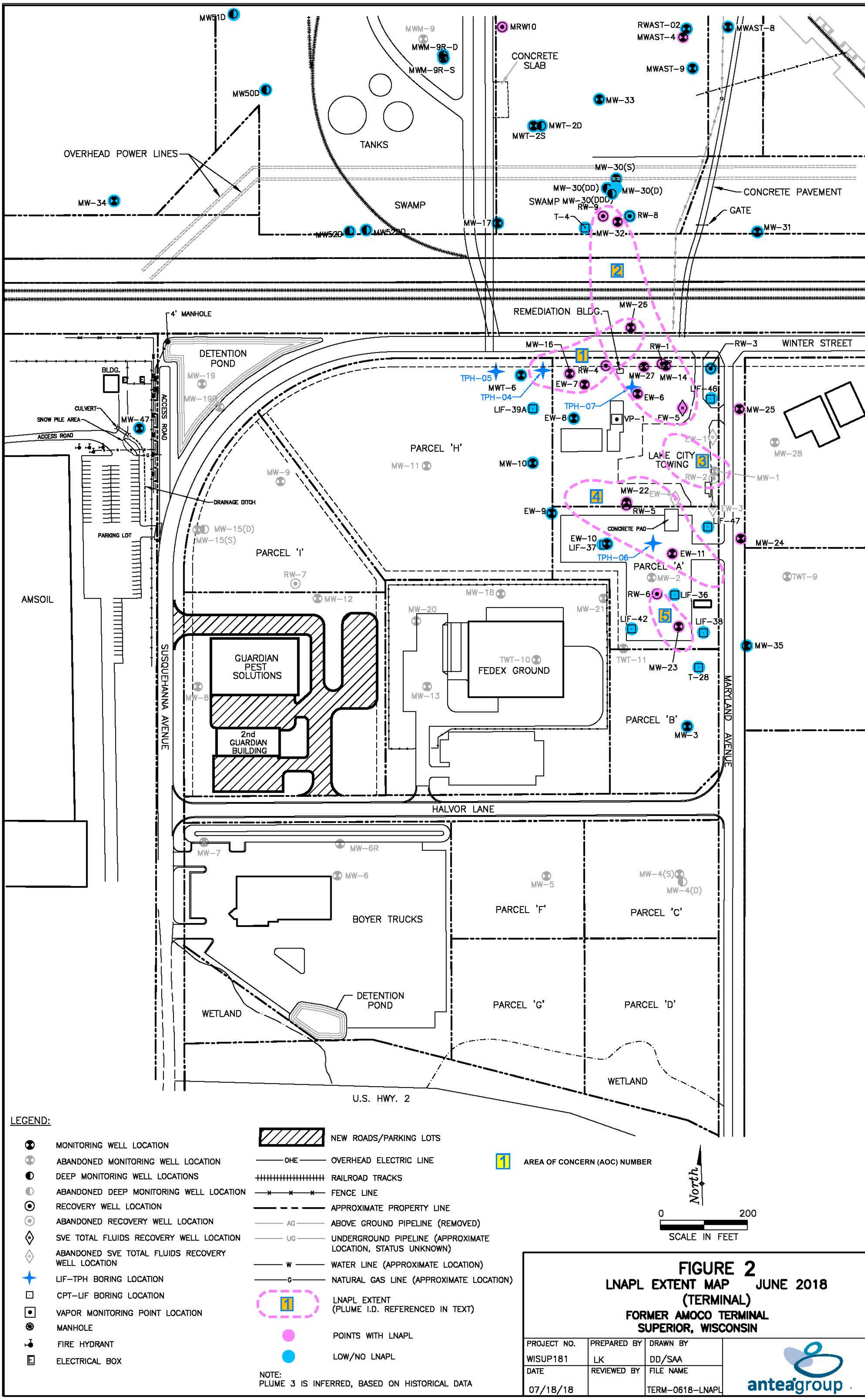
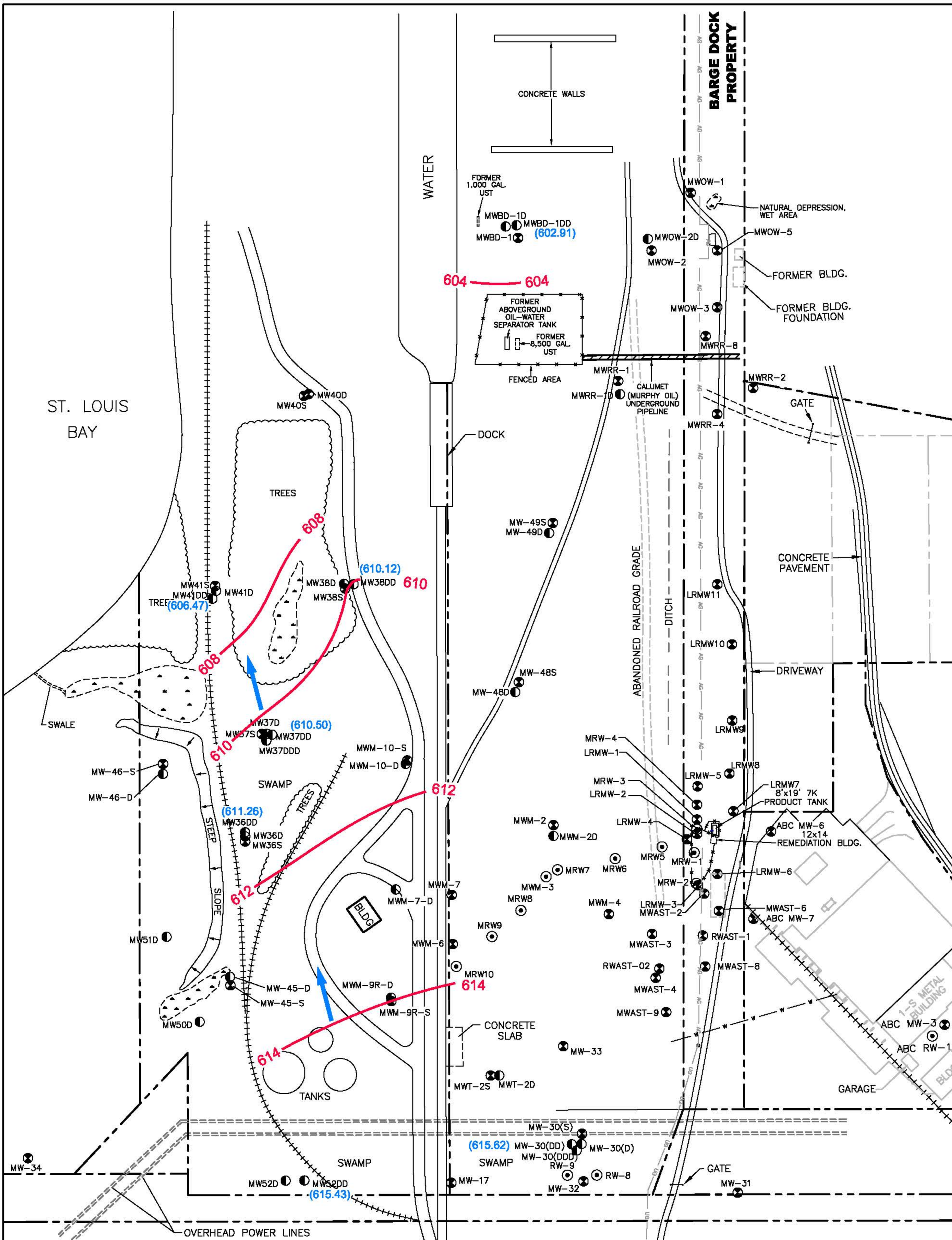


FIGURE 1
SITE MAP, TERMINAL AND BARGE DOCK DETAIL– WELLS ONLY
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUP181	LK	DD/SAA
DATE	REVIEWED BY	FILE NAME
07/18/2018		2018-300B

anteagroup


MW51D
MRW10
MWM-9
MWM-9R-D
MWM-9R-S
RWAST-02
MWAST-4
MWAST-8
MWAST-9
CONCRETE SLAB
MW50D
MW-33
TANKS
MWT-2D
MWT-2S
OVERHEAD POWER LINES
MW-30(S)
MW-30(DD)
MW-30(D)
SWAMP MW-30(DDD)
CONCRETE PAVEMENT
MW-34
SWAMP
RW-9
RW-8
GATE
T-4
MW-17
MW-32
MW-31
MW52D
MW52DD
REMEDIATION BLDG.
MW-26
4' MANHOLE
DETENTION POND
MW-16
RW-1
RW-3
WINTER STREET
TPH-05
RW-4
MW-27
MW-14
BLDG.
MW-19
MWT-6
EW-7
TPH-04
EW-6
LIF-46
MW-25
MW-19R
LIF-39A
TPH-07
CULVERT
SNOW PILE AREA
MW-47
ACCESS ROAD
EW-8
VP-1
EW-5
ACCESS ROAD
EW-1
MW-28
PARCEL 'H'
LAKE CITY TOWING
MW-11
MW-10
RW-2
MW-1
MW-9
MW-22
EW-4
DRAINAGE DITCH
RW-5
EW-3
EW-9
LIF-47
CONCRETE PAD
PARKING LOT
MW-15(D)
MW-15(S)
EW-10
LIF-37
MW-24
EW-11
TPH-06
PARCEL 'I'
PARCEL 'A'
RW-7
MW-2
TWT-9
AMSOIL
MW-12
MW-18
RW-6
LIF-36
MW-20
MW-21
LIF-42
LIF-38
GUARDIAN PEST SOLUTIONS
MW-35
TWT-10
FEDEX GROUND
TWT-11
MW-23
T-28
SUSQUEHANNA AVENUE
MW-8
MW-13
MARYLAND AVENUE
PARCEL 'B'
MW-3
2nd GUARDIAN BUILDING
HALVOR LANE
MW-7
MW-6R
MW-6
MW-5
MW-4(S)
MW-4(D)
BOYER TRUCKS
PARCEL 'F'
PARCEL 'C'
DETENTION POND
WETLAND
PARCEL 'G'
PARCEL 'D'
WETLAND
U.S. HWY. 2
LEGEND:
MONITORING WELL LOCATION
ABANDONED MONITORING WELL LOCATION
DEEP MONITORING WELL LOCATIONS
ABANDONED DEEP MONITORING WELL LOCATION
RECOVERY WELL LOCATION
ABANDONED RECOVERY WELL LOCATION
SVE TOTAL FLUIDS RECOVERY WELL LOCATION
ABANDONED SVE TOTAL FLUIDS RECOVERY WELL LOCATION
LIF-TPH BORING LOCATION
CPT-LIF BORING LOCATION
VAPOR MONITORING POINT LOCATION
MANHOLE
FIRE HYDRANT
ELECTRICAL BOX
NEW ROADS/PARKING LOTS
OHE
OVERHEAD ELECTRIC LINE
RAILROAD TRACKS
FENCE LINE
APPROXIMATE PROPERTY LINE
AG
ABOVE GROUND PIPELINE (REMOVED)
UG
UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
W
WATER LINE (APPROXIMATE LOCATION)
G
NATURAL GAS LINE (APPROXIMATE LOCATION)
LNAPL EXTENT (PLUME I.D. REFERENCED IN TEXT)
POINTS WITH LNAPL
LOW/NO LNAPL
NOTE:
PLUME 3 IS INFERRED, BASED ON HISTORICAL DATA
AREA OF CONCERN (AOC) NUMBER
North
0
200
SCALE IN FEET
FIGURE 2
LNAPL EXTENT MAP JUNE 2018
(TERMINAL)
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN
PROJECT NO.
WISUP181
PREPARED BY
LK
DRAWN BY
DD/SAA
DATE
07/18/18
REVIEWED BY
FILE NAME
TERM-0618-LNAPL
anteagroup



LEGEND:

- MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- NATURAL DEPRESSION, WET AREA
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- CALUMET (MURPHY OIL) UNDERGROUND PIPELINE
- W — WATER LINE (APPROXIMATE LOCATION)
- GRAVEL ACCESS ROAD
- RAILROAD TRACKS
- FENCE LINE
- APPROXIMATE PROPERTY LINE
- (615.43) GROUNDWATER ELEVATION (NO LNAPL IN WELL)
- 612 GROUNDWATER CONTOUR LINE
- INFERRED GROUNDWATER FLOW DIRECTION

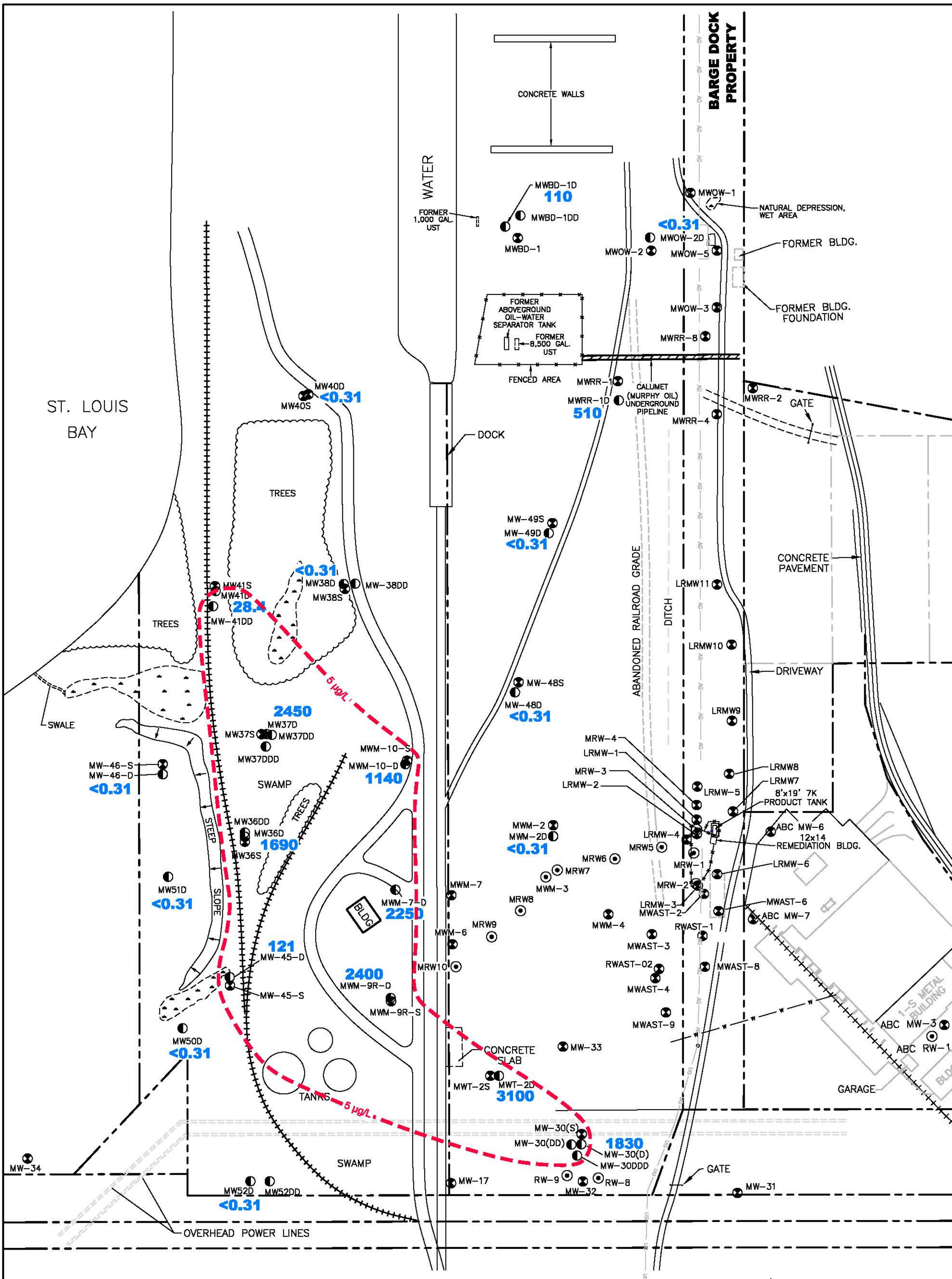
FIGURE 3

GROUNDWATER CONTOUR MAP –OCTOBER 8, 2018
DD LEVEL WELLS (BARGE DOCK)

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUP181	LK	DD/SAA/DR
DATE	REVIEWED BY	FILE NAME
10/19/2018		BD-1018-GWS

anteagroup



LEGEND:

- MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- NATURAL DEPRESSION, WET AREA
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- CALUMET (MURPHY OIL) UNDERGROUND PIPELINE
- W — WATER LINE (APPROXIMATE LOCATION)
- GRAVEL ACCESS ROAD
- RAILROAD TRACKS
- X — FENCE LINE
- APPROXIMATE PROPERTY LINE

1830 BENZENE CONCENTRATION µg/L (OCTOBER 2017) (ES = 5 µg/L)

5 µg/L — INFERRED HORIZONTAL EXTENT OF BENZENE CONTAMINATION EXCEEDING THE NR 140 ES

FIGURE 4
DISSOLVED PHASE BENZENE CONCENTRATIONS– BARGE DOCK (DEEP WELLS) OCTOBER 2018
FORMER AMOCO TERMINAL SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUP181	LK	DD/DR
DATE	REVIEWED BY	FILE NAME
10/26/18		BD-1018-BENZ

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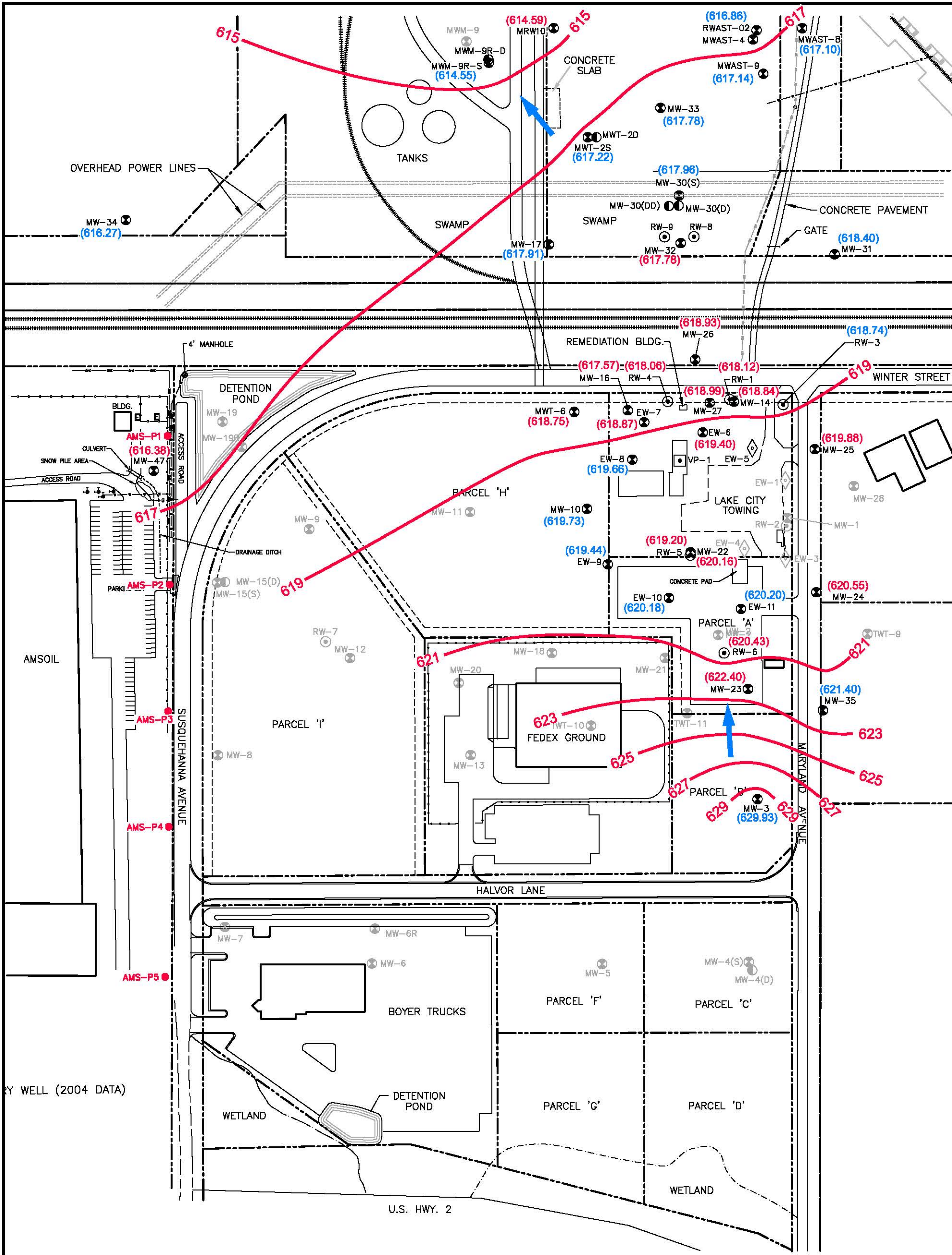


LEGEND:

- MONITORING WELL LOCATION
- ABANDONED MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- ABANDONED DEEP MONITORING WELL LOCATION
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- ABANDONED SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- VAPOR MONITORING POINT LOCATION
- MANHOLE
- FIRE HYDRANT
- ELECTRICAL BOX
- OHE — OVERHEAD ELECTRIC LINE
- RAILROAD TRACKS
- FENCE LINE
- APPROXIMATE PROPERTY LINE
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- W — WATER LINE (APPROXIMATE LOCATION)
- G — NATURAL GAS LINE (APPROXIMATE LOCATION)
- (619.73) GROUNDWATER ELEVATION (NO FREE PRODUCT IN WELL)
- (620.16) GROUNDWATER ELEVATION (CORRECTED FOR FREE PRODUCT IN WELL)
- 619 GROUNDWATER CONTOUR LINE
- INFERRED GROUNDWATER FLOW DIRECTION

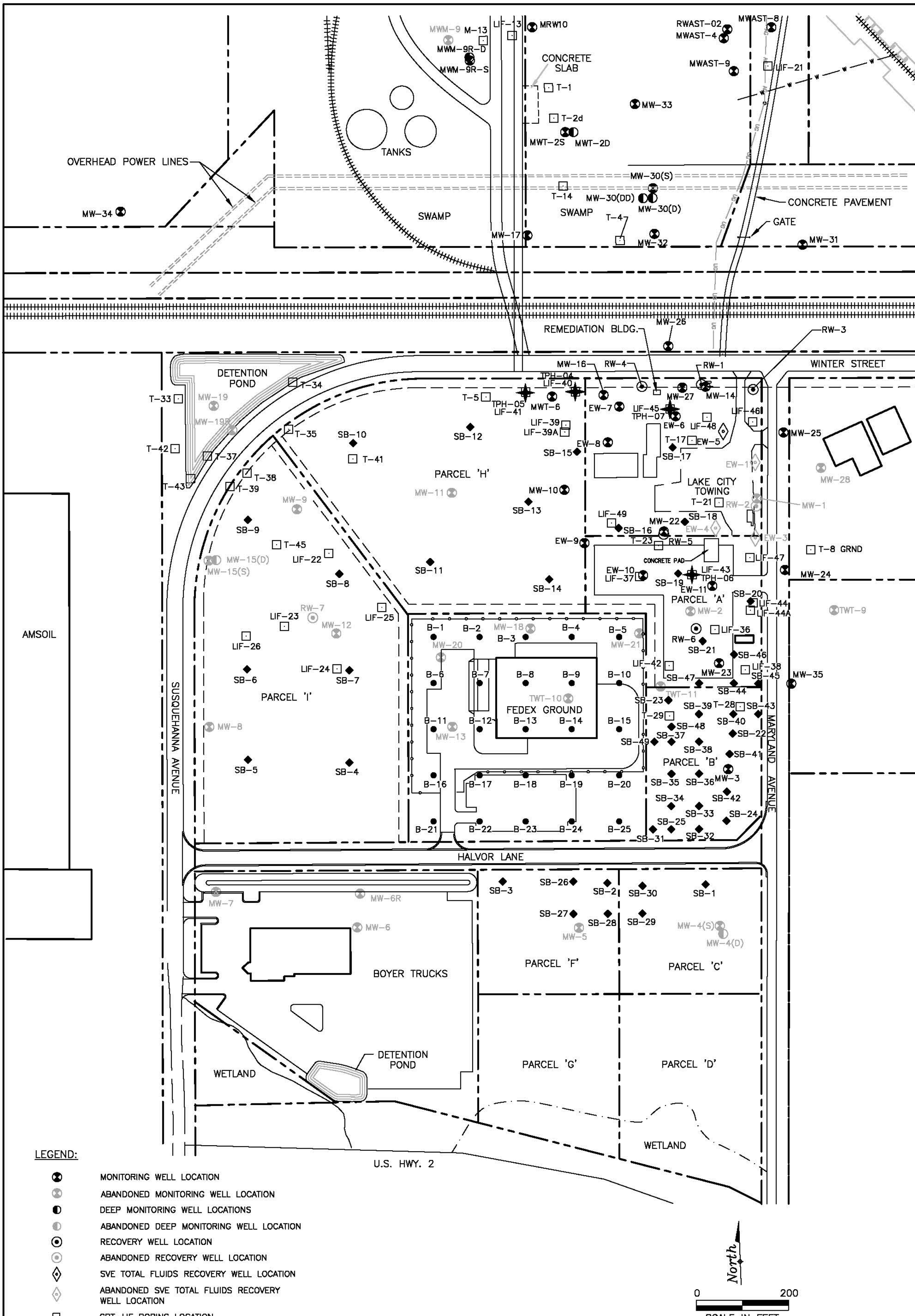
FIGURE 5

GROUNDWATER CONTOUR MAP – OCTOBER 3, 2016 SHALLOW WELLS (TERMINAL)

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPER161	TK	DD
DATE	REVIEWED BY	FILE NAME
12/21/16		TERM-1016-GW

anteagroup



LEGEND:

- MONITORING WELL LOCATION
- ABANDONED MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- ABANDONED DEEP MONITORING WELL LOCATION
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- ABANDONED SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- CPT-LIF BORING LOCATION
- LIF-TPH BORING LOCATION
- SOIL SAMPLING LOCATION
- HAND AUGER SAMPLING LOCATION
- RAILROAD TRACKS
- FENCE LINE
- APPROXIMATE PROPERTY LINE
- ABOVE GROUND PIPELINE (REMOVED)
- UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- WATER LINE (APPROXIMATE LOCATION)

FIGURE 6
SITE MAP, TERMINAL DETAIL

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPER141	AT	DD
DATE	REVIEWED BY	FILE NAME
01/07/15		Superior–Sur21

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SGS-29	10/25/07 5'	10/25/07 14'
PID	2.4	0
OXY	20.1	20.5
LEL	2	0.4
CO2	0.1	0.1
METH	0.1	0.2
B	<42	NS
T	<20	NS
E	470	NS
MP-X	740	NS
O-X	460	NS
GRO	50000	NS

SGS-21	10/24/07 5'
PID	3.4
OXY	19.7
LEL	2
CO2	0.3
METH	0.1
B	NS
T	NS
E	NS
MP-X	NS
O-X	NS
GRO	NS

SGS-19	12/7/06 5'	12/7/06 17'
PID	49.9	NS
OXY	21.4	NS
LEL	0	NS
CO2	0	NS
METH	0	NS
B	3100	NS
T	20000	NS
E	9300	NS
MP-X	12000	NS
O-X	4600	NS
GRO	620000	NS

SGS-18	12/7/06 5'	12/7/06 17'
PID	NS	0
OXY	NS	21.6
LEL	NS	0
CO2	NS	0
METH	NS	0
B	NS	6400
T	NS	7300
E	NS	7200
MP-X	NS	12000
O-X	NS	6200
GRO	NS	1700000

SGS-17	12/7/06 5'	12/7/06 17'
PID	1.2	0
OXY	22.2	21.5
LEL	0	0
CO2	0	0
METH	0	0
B	<40	220
T	80	190
E	<40	90
MP-X	<135	<180
O-X	<20	<110
GRO	7700	14000

SGS-6	9/21/06 5'	9/21/06 17'
PID	8	32
OXY	20	19.6
LEL	0	0
CO2	0.4	0.4
METH	0	0
B	650	1000
T	3300	720
E	4900	1600
MP-X	14000	3000
O-X	1800	350
GRO	190000	90000

SGS-5	9/20/06 5'	9/20/06 17'
PID	1.7	0
OXY	20	19.6
LEL	0	4
CO2	0.3	0.3
METH	0	2
B	270	9500
T	1300	2400
E	420	1100
MP-X	1100	1700
O-X	520	400
GRO	96000	110000

SGS-4	9/20/06 5'	9/20/06 17'
PID	41	355
OXY	19.6	9.5
LEL	0	>100
CO2	1.7	13.9
METH	0	>100
B	90	72000
T	390	170000
E	430	34000
MP-X	1100	100000
O-X	330	44000
GRO	63000	18000000

SGS3	9/20/06 5'	9/20/06 17'
PID	12.7	361
OXY	16.9	0.8
LEL	0	>100
CO2	2.4	20.8
METH	0	>100
B	<40	<4000
T	250	<120000
E	450	<4000
MP-X	960	25000
O-X	620	<2000
GRO	55000	8000000

SGS-2	9/19/06 5'	9/19/06 17'
PID	450	424
OXY	10.1	18
LEL	43.6	100
CO2	9.9	1.2
METH	22.5	15
B	<40000	<4000
T	<42000	<4200
E	<40000	<4000
MP-X	<70000	<7000
O-X	<20000	<2000
GRO	15000000	2600000

SGS-22	10/24/07 5'	10/24/07 14'
PID	NS	0
OXY	19.4	19.4
LEL	0	0
CO2	0.6	0.4
METH	0	0
B	NS	NS
T	NS	NS
E	NS	NS
MP-X	NS	NS
O-X	NS	NS
GRO	NS	NS

SGS-28	10/25/07 5'	10/25/07 14'
PID	0	152
OXY	20	0.9
LEL	0	>100
CO2	0.1	8.2
METH	0	132
B	56	<4200
T	150	<2000
E	120	44000
MP-X	270	72000
O-X	100	44000
GRO	13000	26000000

SGS-23	10/25/07 5'	10/25/07 17'
PID	0	0
OXY	20.6	20.1
LEL	4	2
CO2	0	0
METH	0.2	0.1
B	<42	210
T	<20	860
E	190	580
MP-X	340	920
O-X	75	530
GRO	19000	45000

SGS-24	10/25/07 5'	10/25/07 17'
PID	0	2.5
OXY	20.2	19.9
LEL	0	0
CO2	0.1	0.1
METH	0	0
B	NS	160
T	NS	470
E	NS	180
MP-X	NS	420
O-X	NS	180
GRO	NS	6800

SGS-25	10/25/07 5'	10/25/07 17'
PID	13.4	0
OXY	20.3	20.4
LEL	4	4
CO2	0	0
METH	0.2	0.2
B	<42	<42
T	<20	<20
E	7500	500
MP-X	10000	780
O-X	6100	470
GRO	750000	56000

SGS-26	10/25/07 5'	10/25/07 17'
PID	0	0
OXY	20.3	20.6
LEL	2	4
CO2	0	0
METH	0.1	0.2
B	<42	<42
T	290	<20
E	210	100
MP-X	360	<250
O-X	120	82
GRO	18000	13000

SGS-1	9/19/06 5'	9/19/06 17'
PID	1.4	1.4
OXY	20.3	20.2
LEL	0	0
CO2	1.2	1.2
METH	0	0
B	<40	NS
T	<42	NS
E	<40	NS
MP-X	<70	NS
O-X	<20	NS
GRO	1500	NS

SGS-9	9/21/06 5'	9/21/06 17'
PID	NS	330
OXY	18.9	0
LEL	4	>100
CO2	1	19.7
METH	0.3	100
B	NA	87000
T	NA	76000
E	NA	<8000
MP-X	NA	<14000
O-X	NA	<4000
GRO	NA	17000000

SGS-12	12/6/06 5'	12/6/06 17'
PID	16.4	23.1
OXY	20.9	20.2
LEL	0	50
CO2	0	0.2
METH	0	2.3
B	5400	130000
T	3600	240000
E	1400	42000
MP-X	3000	110000
O-X	1400	53000
GRO	120000	8500000

SGS-11	12/6/06 5'	12/6/06 17'
PID	0	279
OXY	22.5	17.0
LEL	0	208
CO2	0	3.2
METH	0	10.7
B	590	18000
T	300	59000
E	480	7800
MP-X	670	39000
O-X	510	14000
GRO	25000	570000

SGS-10	9/21/06 5'	9/21/06 17'
PID	NS	350
OXY	NS	16.7
LEL	NS	490
CO2	NS	13.6
METH	NS	39
B	NS	3600
T	NS	<42
E	NS	10000
MP-X	NS	18000
O-X	NS	7700
GRO	NS	2000000

SGS-8	9/21/06 5'	9/21/06 16'
PID	NS	350
OXY	19.6	0.6
LEL	0	>100
CO2	0.4	16.7
METH	0	>100
B	NS	250000
T	NS	400000
E	NS	60000
MP-X	NS	120000
O-X	NS	40000
GRO	NS	51000000

SGS-27	10/25/07 5'	10/25/07 17'
PID	2.4	0
OXY	10.1	19.7
LEL	0	0
CO2	2.8	0.1
METH	0	0
B	<42	<42
T	200	200
E	67	79
MP-X	150	220
O-X	93	113
GRO	<700	<700

SGS-20	10/24/07 5'	10/24/07 17'
PID	9	0
OXY	19.5	4.8
LEL	8	2
CO2	0.2	11.1
METH	0.4	0.2
B	NS	NS
T	NS	NS
E	NS	NS
MP-X	NS	NS
O-X	NS	NS
GRO	NS	NS

SGS-16	12/7/06 5'	12/7/06 17'
PID	NS	0
OXY	NS	22.0
LEL	NS	0
CO2	NS	0
METH	NS	0
B	NS	130
T	NS	250
E	NS	150
MP-X	NS	250
O-X	NS	150
GRO	NS	15000

SGS-15	12/7/06 5'	12/7/06 17'
PID	0	2
OXY	22.0	22.1
LEL	0	0
CO2	0	0
METH	0	0
B	130	170
T	250	230
E	300	110
MP-X	440	210
O-X	400	130
GRO	30000	18000

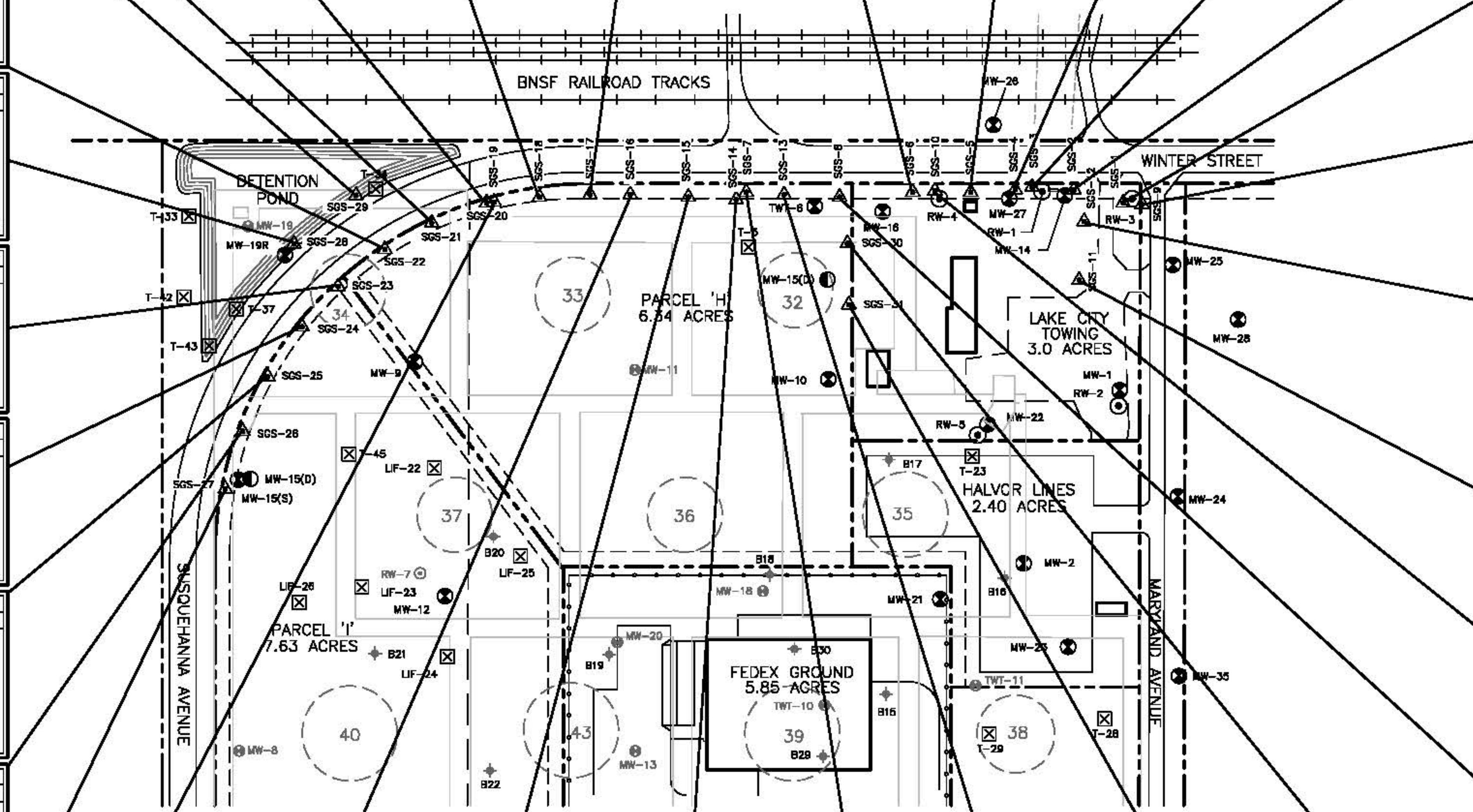
SGS-14	12/7/06 5'	12/7/06 17'
PID	NS	42.6
OXY	NS	19.5
LEL	NS	20
CO2	NS	0.9
METH	NS	0.9
B	NS	1800
T	NS	1800
E	NS	1600
MP-X	NS	2000
O-X	NS	1300
GRO	NS	260000

SGS-7	9/21/06 5'	9/21/06 17'
PID	NA	345
OXY	19.1	1.2
LEL	0	>100
CO2	0.6	13.1
METH	0	>100
B	NS	260000
T	NS	690000
E	NS	65000
MP-X	NS	130000
O-X	NS	45000
GRO	NS	45000000

SGS13	12/7/06 5'	12/7/06 17'
PID	1.2	25.5
OXY	22.1	17.9
LEL	0	300
CO2	0	2
METH	0	14.3
B	320	29000
T	<42	76000
E	<40	30000
MP-X	<70	<14000
O-X	<20	<4000
GRO	NA	4400000

SGS-31	10/24/07 5'	10/24/07 17'
PID	3.1	411
OXY	19.8	0.3
LEL	0	34
CO2	0.1	13.4
METH	0	96
B	<42	<4200
T	230	<2000
E	57	250000
MP-X	150	380000
O-X	85	38000
GRO	<700	29000000

SGS-30	10/24/07 5'	10/24/07 17'
PID	1.9	439
OXY	20.9	3.9
LEL	6	69
CO2	0	9.7
METH	0.2	>134
B	<42	<42000
T	<20	<20000
E	680	160000
MP-X	1000	240000
O-X	970	<56000
GRO	68000	39000000



LEGEND:

- SOIL GAS SURVEY POINTS
- MONITORING WELL
- ABANDONED MONITORING WELL
- DEEP MONITORING WELL
- RECOVERY WELL
- ABANDONED RECOVERY WELL
- SOIL BORING LOCATION
- CPT–LIF BORING LOCATION

ANALYTICAL:

9/19/06 = SAMPLE DATE
17' = SAMPLE DEPTH (FEET)

PID = PHOTOIONIZATION DETECTOR (ppm)
OXY = OXYGEN (%)
LEL = LOWER EXPLOSIVE LIMIT (%)
CO2 = CARBON DIOXIDE (%)
METH = METHANE (%)
B = BENZENE (ug/m3)
T = TOLUENE (ug/m3)
E = ETHYLBENZENE (ug/m3)
MP–X = M&P XYLENE (ug/m3)
O–X = O XYLENE (ug/m3)
GRO = GASOLINE RANGE ORGANICS (ug/m3)

(ppm) = PARTS PER MILLION
(%) = PER CENT
(ug/m3) = MICROGRAMS PER CUBIC METER

NA = NOT ANALYZED FOR INDICATED PARAMETER
NS = SAMPLE NOT COLLECTED AT INDICATED DEPTH

North

0 200
SCALE IN FEET

FIGURE 7
SOIL GAS SURVEY RESULTS MAP
SUPERIOR TERMINAL
VINJE INDUSTRIAL PARK AREA
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
004060A091	NJ	DD
DATE	REVIEWED BY	FILE NAME
9/25/09		Superior–S4

anteagroup

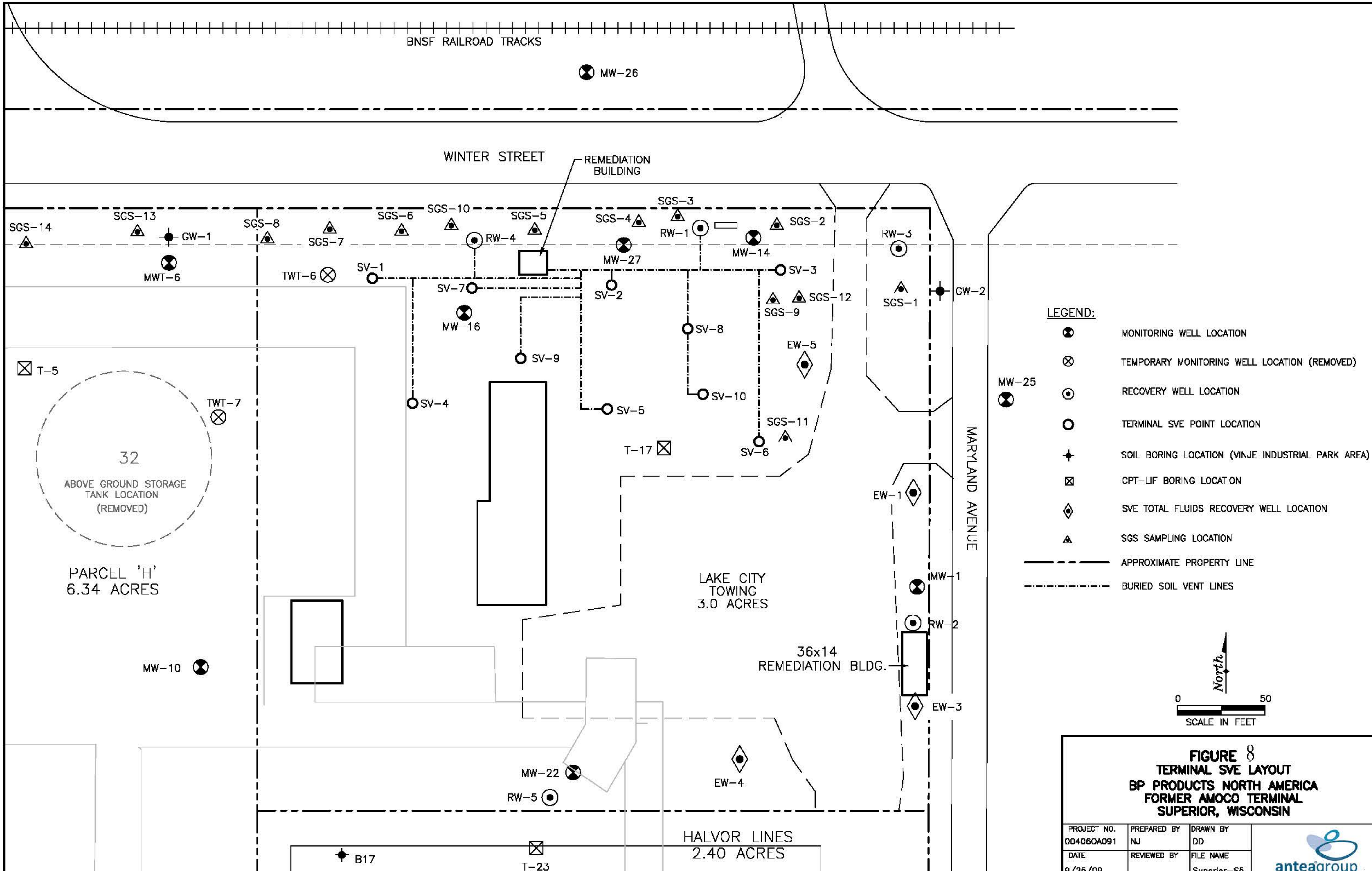
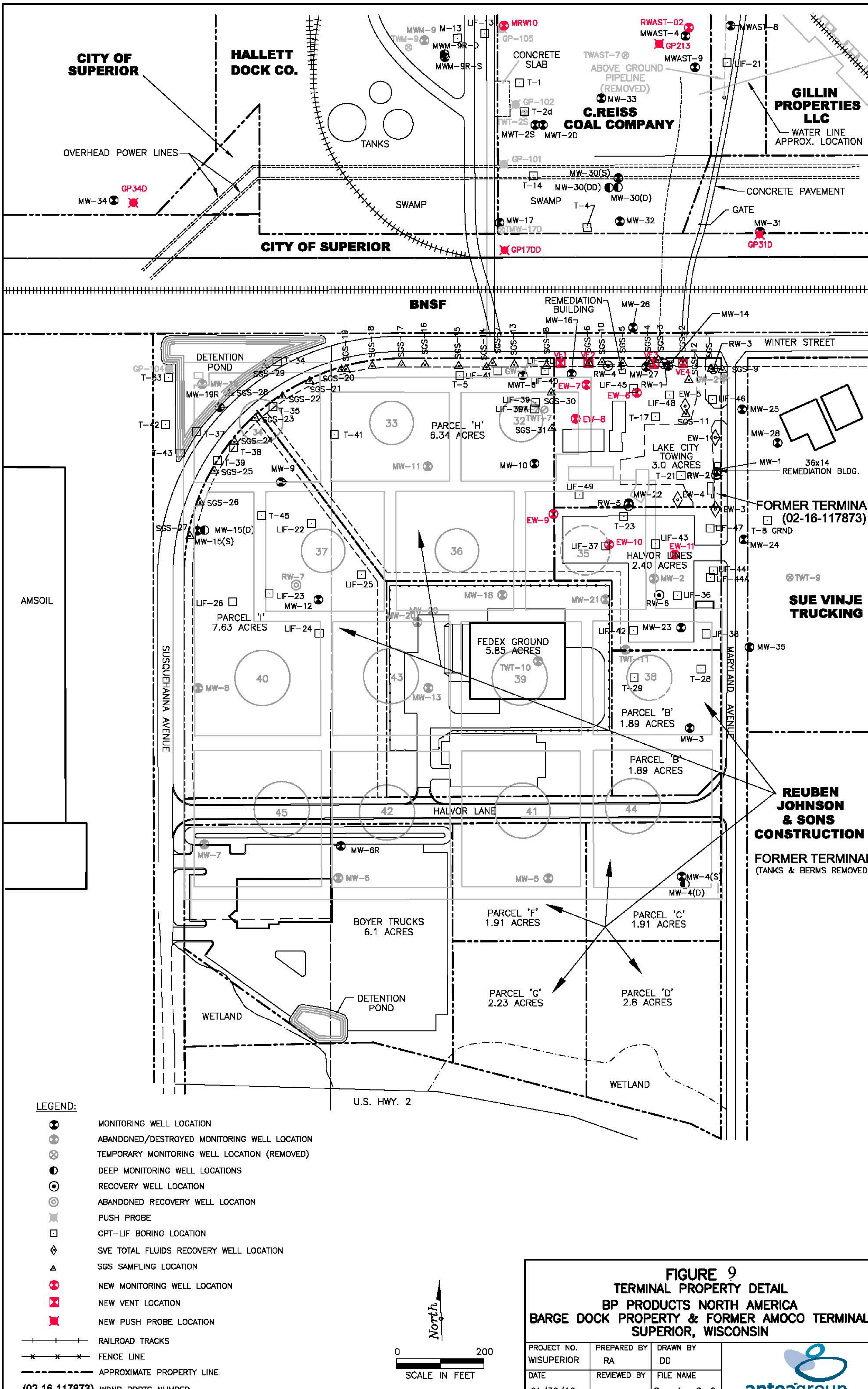


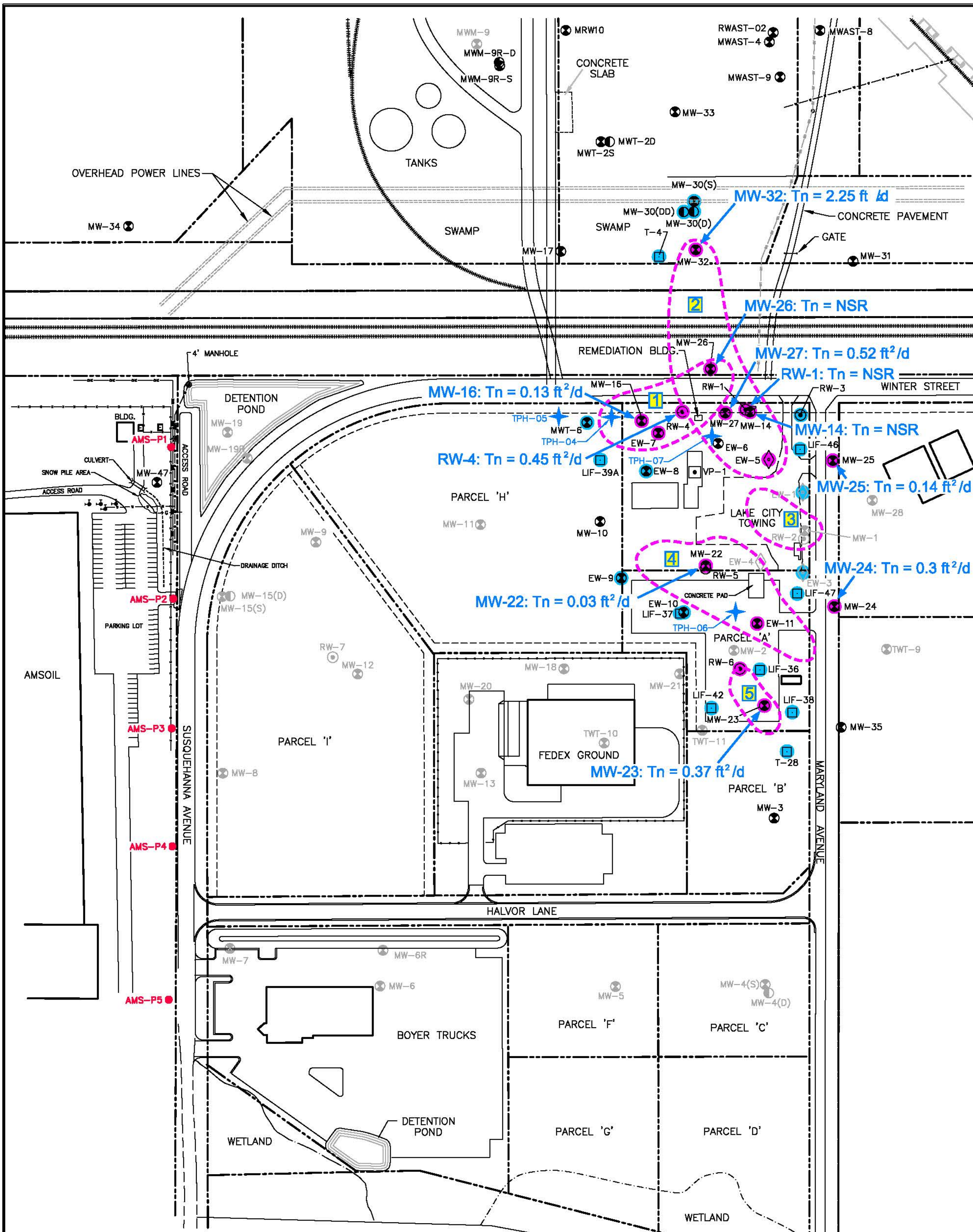
FIGURE 8
TERMINAL SVE LAYOUT
BP PRODUCTS NORTH AMERICA
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
00406OA091	NJ	DD
DATE	REVIEWED BY	FILE NAME
9/25/09		Superior-S5

anteagroup



CITY OF SUPERIOR
HALLETT DOCK CO.
C.REISS COAL COMPANY
GILLIN PROPERTIES LLC
WATER LINE APPROX. LOCATION
OVERHEAD POWER LINES
TANKS
CONCRETE SLAB
ABOVE GROUND PIPELINE (REMOVED)
SWAMP
CONCRETE PAVEMENT
GATE
CITY OF SUPERIOR
BNSF
REMEDIATION BUILDING
WINTER STREET
DETENTION POND
PARCEL 'H' 6.34 ACRES
LAKE CITY TOWING 3.0 ACRES
36x14 REMEDIATION BLDG.
FORMER TERMINAL (02-16-117873)
HALVOR LINES 2.40 ACRES
SUE VINJE TRUCKING
AMSOIL
PARCEL 'I' 7.63 ACRES
FEDEX GROUND 5.85 ACRES
PARCEL 'B' 1.89 ACRES
PARCEL 'B' 1.89 ACRES
SUSQUEHANNA AVENUE
MARYLAND AVENUE
HALVOR LANE
REUBEN JOHNSON & SONS CONSTRUCTION
FORMER TERMINAL (TANKS & BERMS REMOVED)
BOYER TRUCKS 6.1 ACRES
PARCEL 'F' 1.91 ACRES
PARCEL 'C' 1.91 ACRES
PARCEL 'G' 2.23 ACRES
PARCEL 'D' 2.8 ACRES
DETENTION POND
WETLAND
WETLAND
U.S. HWY. 2
LEGEND:
MONITORING WELL LOCATION
ABANDONED/DESTROYED MONITORING WELL LOCATION
TEMPORARY MONITORING WELL LOCATION (REMOVED)
DEEP MONITORING WELL LOCATIONS
RECOVERY WELL LOCATION
ABANDONED RECOVERY WELL LOCATION
PUSH PROBE
CPT-LIF BORING LOCATION
SVE TOTAL FLUIDS RECOVERY WELL LOCATION
SGS SAMPLING LOCATION
NEW MONITORING WELL LOCATION
NEW VENT LOCATION
NEW PUSH PROBE LOCATION
RAILROAD TRACKS
FENCE LINE
APPROXIMATE PROPERTY LINE
(02-16-117873) WDNR BRRTS NUMBER
North
0 200
SCALE IN FEET
FIGURE 9
TERMINAL PROPERTY DETAIL
BP PRODUCTS NORTH AMERICA
BARGE DOCK PROPERTY & FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN
PROJECT NO. WISUPERIOR
PREPARED BY RA
DRAWN BY DD
DATE 01/30/12
REVIEWED BY
FILE NAME Superior-Sur2
anteagroup



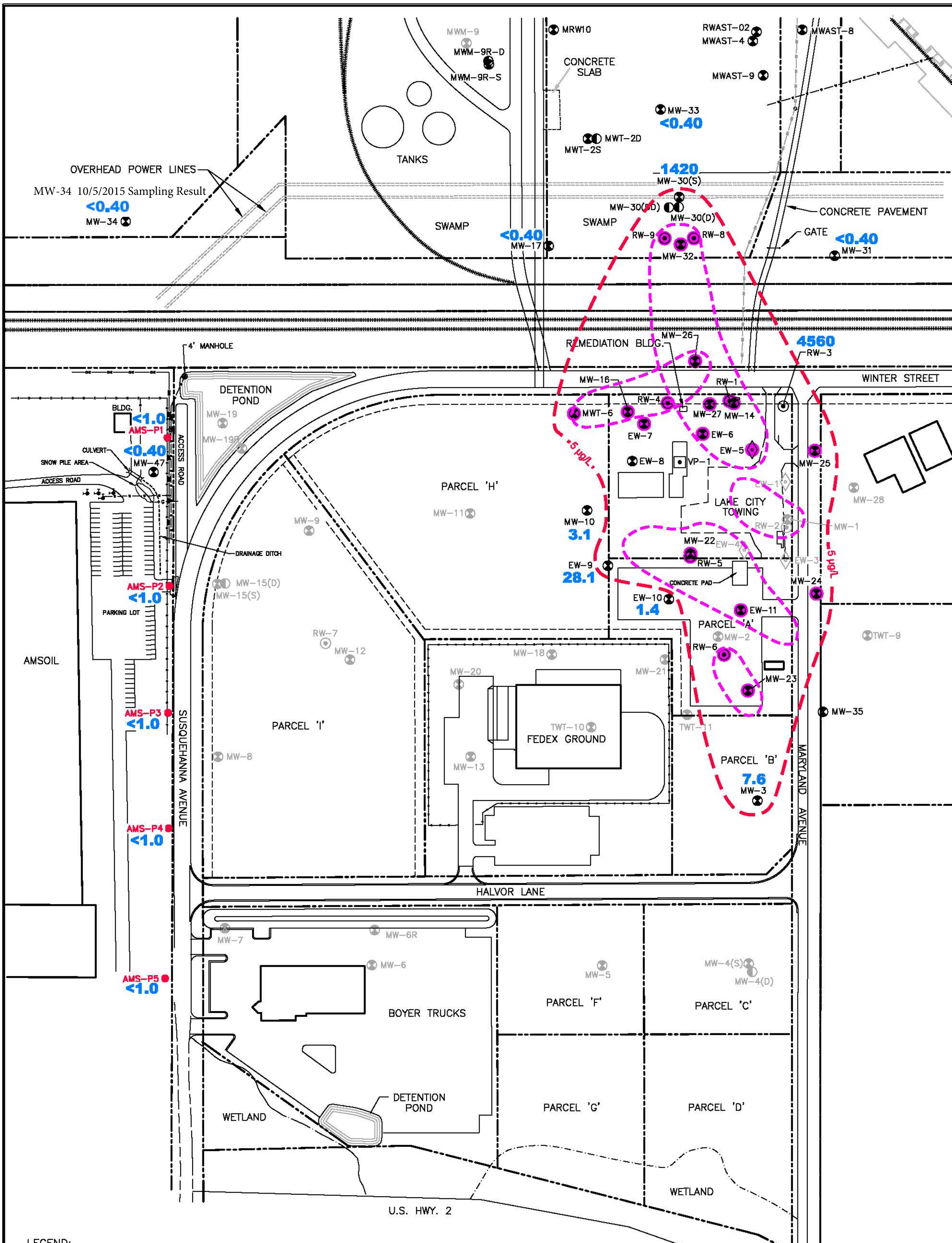
LEGEND:

- MONITORING WELL LOCATION
- ABANDONED MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- ABANDONED DEEP MONITORING WELL LOCATION
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- ABANDONED SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- VAPOR MONITORING POINT LOCATION
- LIF-TPH BORING LOCATION
- CPT-LIF BORING LOCATION
- MANHOLE
- FIRE HYDRANT
- ELECTRICAL BOX
- APPROXIMATE PROPERTY LINE
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- W — WATER LINE (APPROXIMATE LOCATION)
- G — NATURAL GAS LINE (APPROXIMATE LOCATION)
- OHE — OVERHEAD ELECTRIC LINE
- RAILROAD TRACKS
- FENCE LINE
- 1 — LNAPL EXTENT (PLUME I.D. REFERENCED IN TEXT)
- POINTS WITH LNAPL
- LOW IMPACT POINTS
- NSR — NO SIGNIFICANT RECHARGE
- AMSOIL TEMPORARY WELL (2004 DATA)

FIGURE 10
LNAPL EXTENT MAP – MAY 2015 (TERMINAL)
FORMER AMOCO TERMINAL SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPER161	TK	DD
DATE	REVIEWED BY	FILE NAME
11/17/16		TERM-0515-LNAPL

antea group



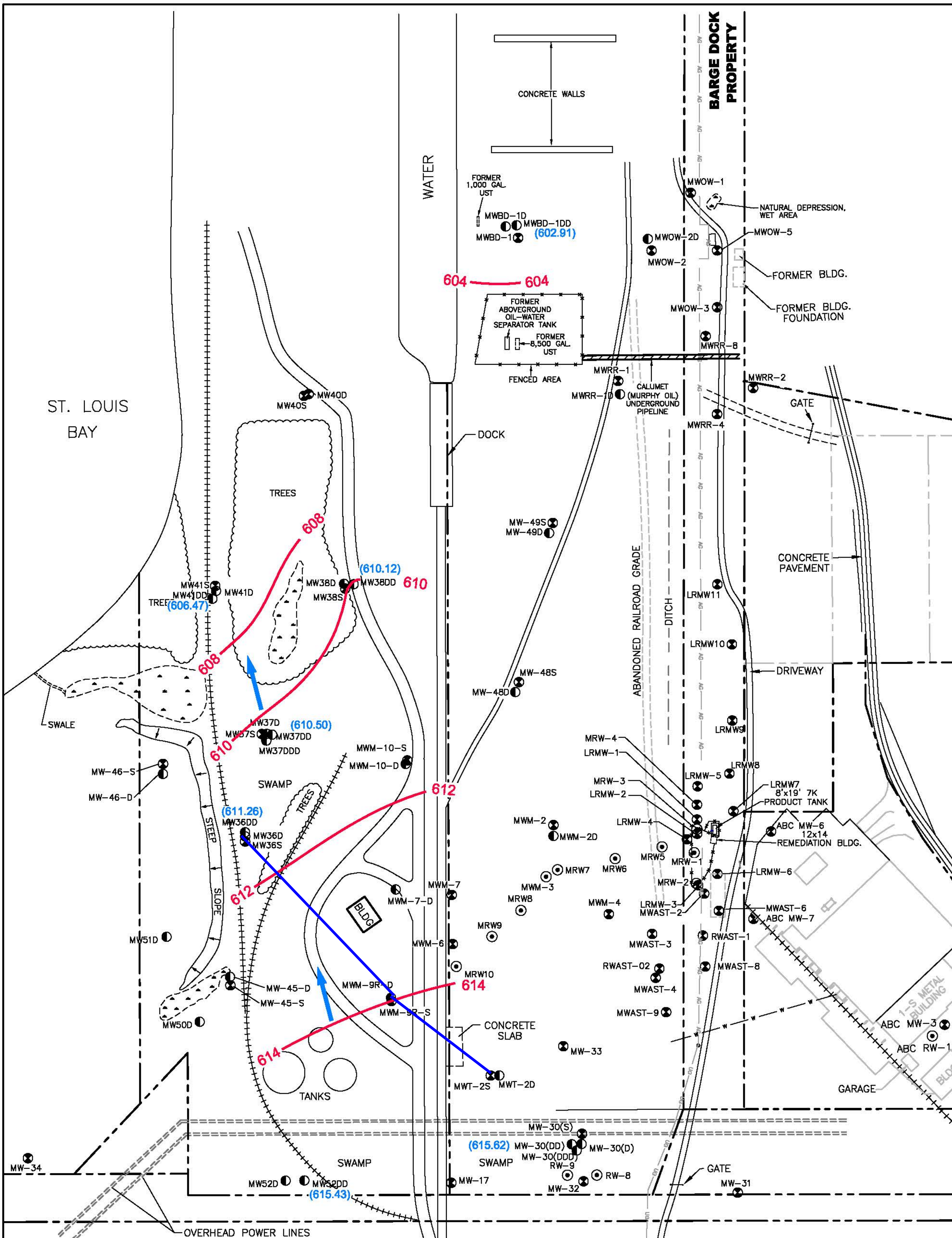
LEGEND:

- MONITORING WELL LOCATION
- ABANDONED MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- ABANDONED DEEP MONITORING WELL LOCATION
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- ABANDONED SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- VAPOR MONITORING POINT LOCATION
- MANHOLE
- FIRE HYDRANT
- ELECTRICAL BOX
- OHE — OVERHEAD ELECTRIC LINE
- RAILROAD TRACKS
- FENCE LINE
- APPROXIMATE PROPERTY LINE
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- W — WATER LINE (APPROXIMATE LOCATION)
- G — NATURAL GAS LINE (APPROXIMATE LOCATION)
- POINTS WITH LNAPL
- LNAPL EXTENT
- 28.1 BENZENE CONCENTRATION µg/L (OCTOBER 2016) (ES = 5 ug/L)
- 5 µg/L HORIZONTAL EXTENT OF CONTAMINATION EXCEEDING THE NR 140 ES
- AMSOIL TEMPORARY WELL (2004 DATA)

FIGURE 11
DISSOLVED PHASE BENZENE CONCENTRATIONS OCTOBER 2016 SHALLOW WELLS (TERMINAL) FORMER AMOCO TERMINAL SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPER161	TK	DD
DATE	REVIEWED BY	FILE NAME
12/21/16		TERM-1016-BENZ

anteagroup



LEGEND:

- MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- NATURAL DEPRESSION, WET AREA
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- CALUMET (MURPHY OIL) UNDERGROUND PIPELINE
- W — WATER LINE (APPROXIMATE LOCATION)
- GRAVEL ACCESS ROAD
- RAILROAD TRACKS
- FENCE LINE
- APPROXIMATE PROPERTY LINE
- (615.43) GROUNDWATER ELEVATION (NO LNAPL IN WELL)
- 612 GROUNDWATER CONTOUR LINE
- INFERRED GROUNDWATER FLOW DIRECTION

= Inferred Flow Path Wells

North

0 200
SCALE IN FEET

FIGURE 12
GROUNDWATER CONTOUR MAP –OCTOBER 8, 2018 DD LEVEL WELLS (BARGE DOCK)

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUP181	LK	DD/SAA/DR
DATE	REVIEWED BY	FILE NAME
10/19/2018		BD-1018-GWS

anteagroup

Figure 13a

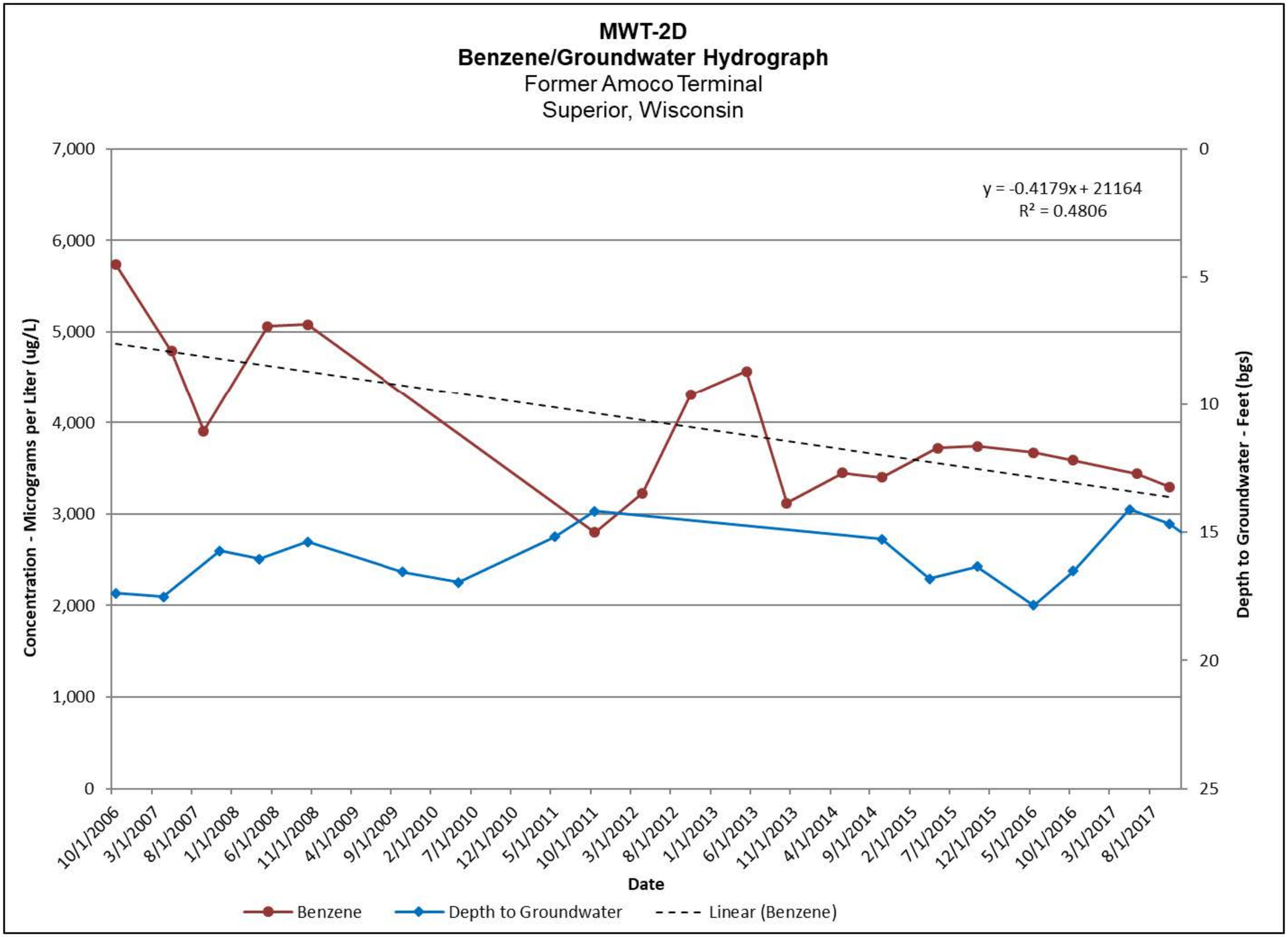
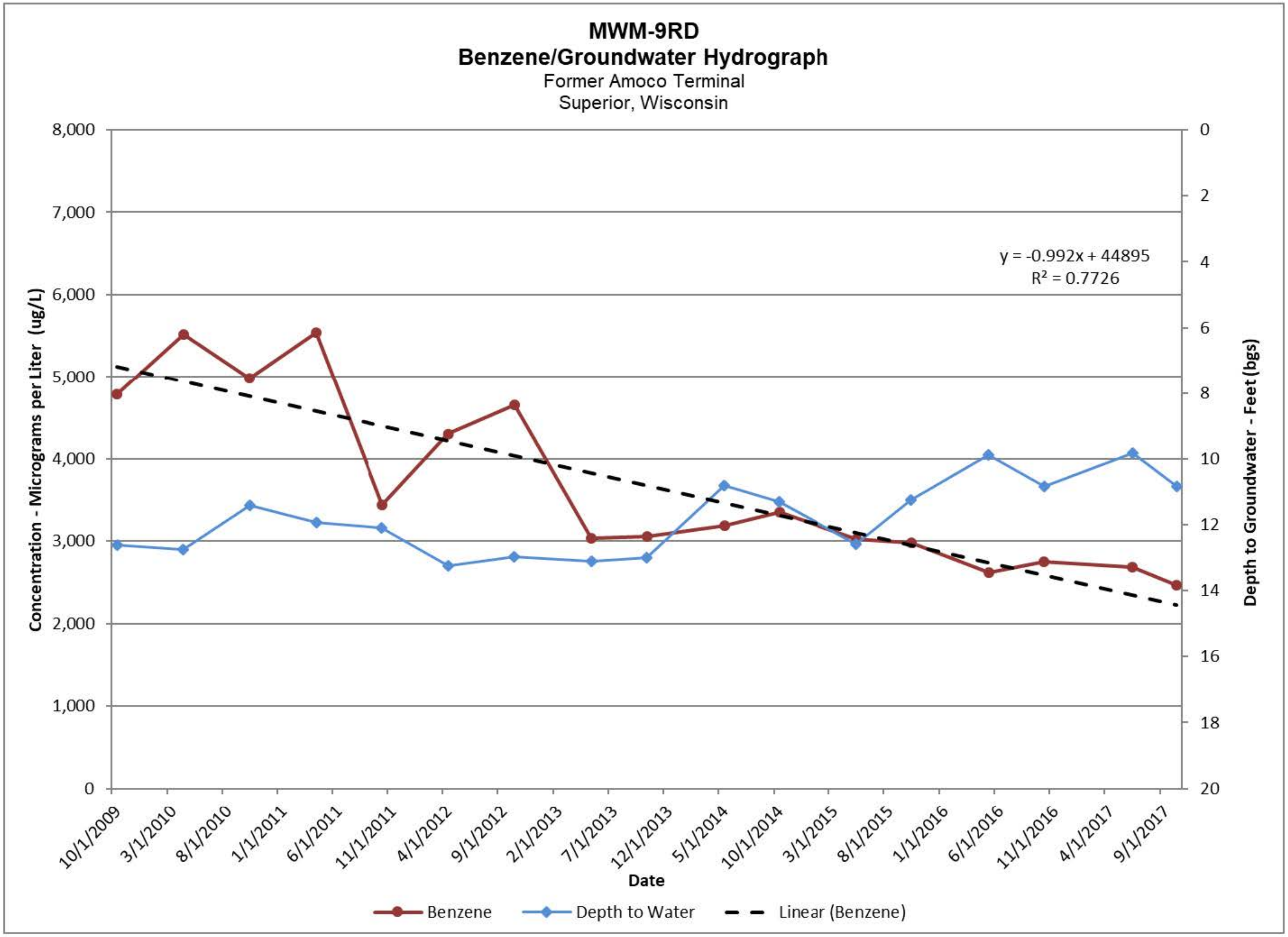
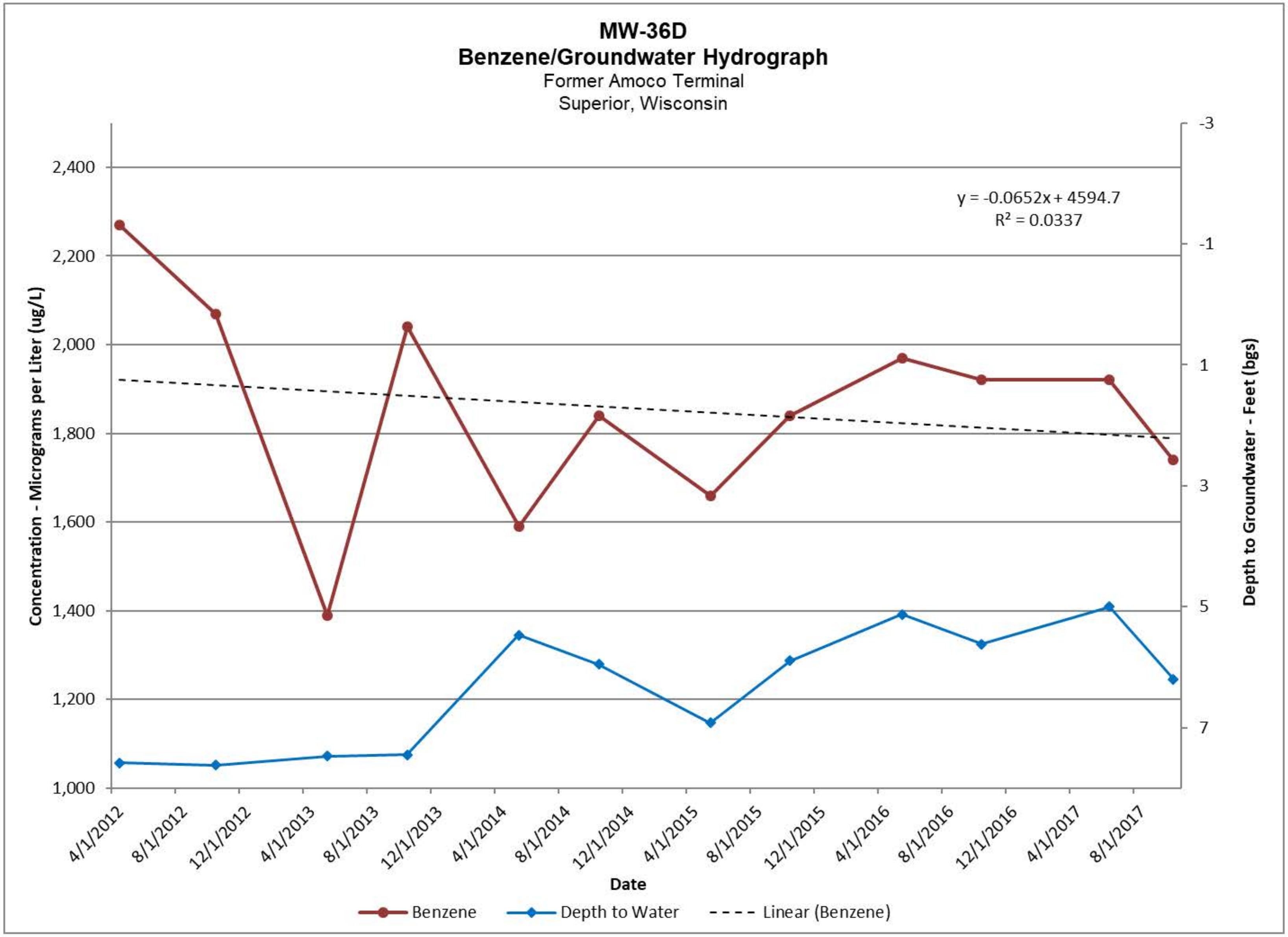

MWT-2D
Benzene/Groundwater Hydrograph
Former Amoco Terminal
Superior, Wisconsin
y = -0.4179x + 21164
R² = 0.4806
Concentration - Micrograms per Liter (ug/L)
Depth to Groundwater - Feet (bgs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
5
10
15
20
25
10/1/2006
3/1/2007
8/1/2007
1/1/2008
6/1/2008
11/1/2008
4/1/2009
9/1/2009
2/1/2010
7/1/2010
12/1/2010
5/1/2011
10/1/2011
3/1/2012
8/1/2012
1/1/2013
6/1/2013
11/1/2013
4/1/2014
9/1/2014
2/1/2015
7/1/2015
12/1/2015
5/1/2016
10/1/2016
3/1/2017
8/1/2017
Date
Benzene
Depth to Groundwater
Linear (Benzene)

Figure 13b



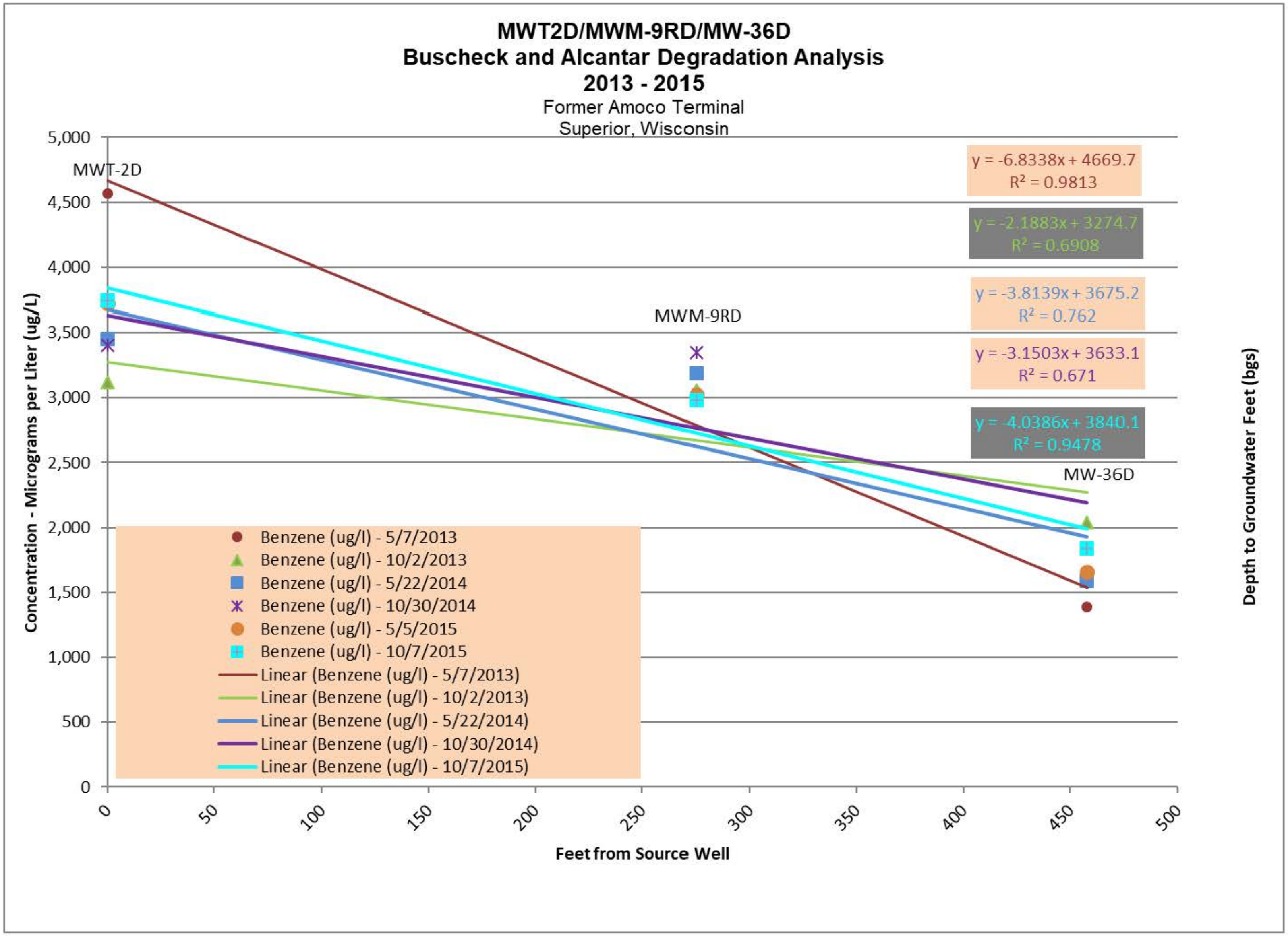
MWM-9RD
Benzene/Groundwater Hydrograph
Former Amoco Terminal
Superior, Wisconsin
Concentration - Micrograms per Liter (ug/L)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Depth to Groundwater - Feet (bgs)
0
2
4
6
8
10
12
14
16
18
20
y = -0.992x + 44895
R² = 0.7726
10/1/2009
3/1/2010
8/1/2010
1/1/2011
6/1/2011
11/1/2011
4/1/2012
9/1/2012
2/1/2013
7/1/2013
12/1/2013
5/1/2014
10/1/2014
3/1/2015
8/1/2015
1/1/2016
6/1/2016
11/1/2016
4/1/2017
9/1/2017
Date
Benzene
Depth to Water
Linear (Benzene)

Figure 13c



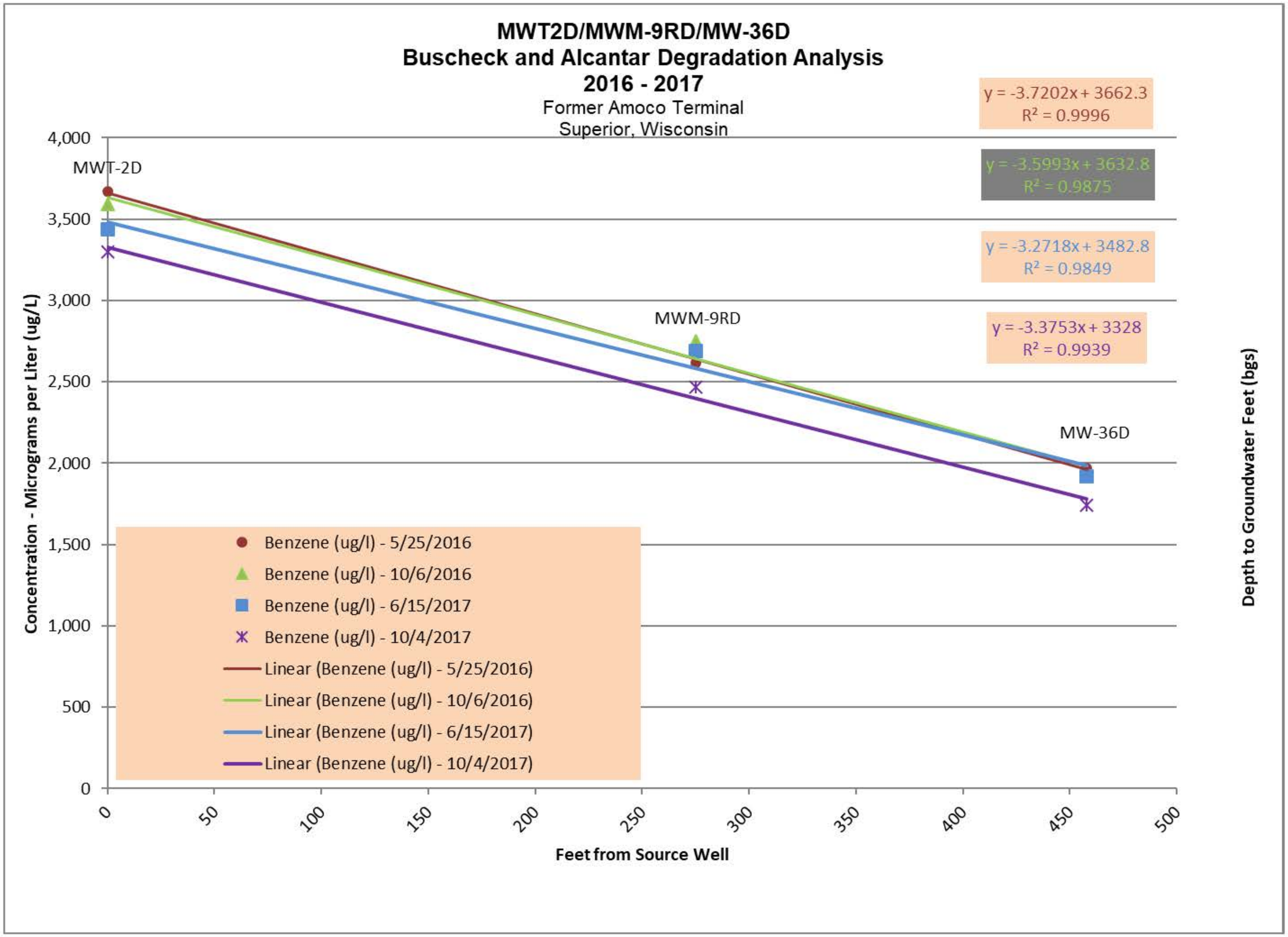
MW-36D
Benzene/Groundwater Hydrograph
Former Amoco Terminal
Superior, Wisconsin
y = -0.0652x + 4594.7
R² = 0.0337
Concentration - Micrograms per Liter (ug/L)
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
Depth to Groundwater - Feet (bgs)
-3
-1
1
3
5
7
4/1/2012
8/1/2012
12/1/2012
4/1/2013
8/1/2013
12/1/2013
4/1/2014
8/1/2014
12/1/2014
4/1/2015
8/1/2015
12/1/2015
4/1/2016
8/1/2016
12/1/2016
4/1/2017
8/1/2017
Date
Benzene
Depth to Water
Linear (Benzene)

Figure 14a



MWT2D/MWM-9RD/MW-36D
Buscheck and Alcantar Degradation Analysis
2013 - 2015
Former Amoco Terminal
Superior, Wisconsin
MWT-2D
MWM-9RD
MW-36D
y = -6.8338x + 4669.7
R² = 0.9813
y = -2.1883x + 3274.7
R² = 0.6908
y = -3.8139x + 3675.2
R² = 0.762
y = -3.1503x + 3633.1
R² = 0.671
y = -4.0386x + 3840.1
R² = 0.9478
Benzene (ug/l) - 5/7/2013
Benzene (ug/l) - 10/2/2013
Benzene (ug/l) - 5/22/2014
Benzene (ug/l) - 10/30/2014
Benzene (ug/l) - 5/5/2015
Benzene (ug/l) - 10/7/2015
Linear (Benzene (ug/l) - 5/7/2013)
Linear (Benzene (ug/l) - 10/2/2013)
Linear (Benzene (ug/l) - 5/22/2014)
Linear (Benzene (ug/l) - 10/30/2014)
Linear (Benzene (ug/l) - 10/7/2015)
Concentration - Micrograms per Liter (ug/L)
Depth to Groundwater Feet (bgs)
Feet from Source Well
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
0
50
100
150
200
250
300
350
400
450
500

Figure 14b


MWT2D/MWM-9RD/MW-36D
Buscheck and Alcantar Degradation Analysis
2016 - 2017
Former Amoco Terminal
Superior, Wisconsin
y = -3.7202x + 3662.3
R² = 0.9996
y = -3.5993x + 3632.8
R² = 0.9875
y = -3.2718x + 3482.8
R² = 0.9849
y = -3.3753x + 3328
R² = 0.9939
MWT-2D
MWM-9RD
MW-36D
Concentration - Micrograms per Liter (ug/L)
Depth to Groundwater Feet (bgs)
Feet from Source Well
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
50
100
150
200
250
300
350
400
450
500
Benzene (ug/l) - 5/25/2016
Benzene (ug/l) - 10/6/2016
Benzene (ug/l) - 6/15/2017
Benzene (ug/l) - 10/4/2017
Linear (Benzene (ug/l) - 5/25/2016)
Linear (Benzene (ug/l) - 10/6/2016)
Linear (Benzene (ug/l) - 6/15/2017)
Linear (Benzene (ug/l) - 10/4/2017)

Tables

Table 1 - LNAPL Volume Calculations AOCs 1-5

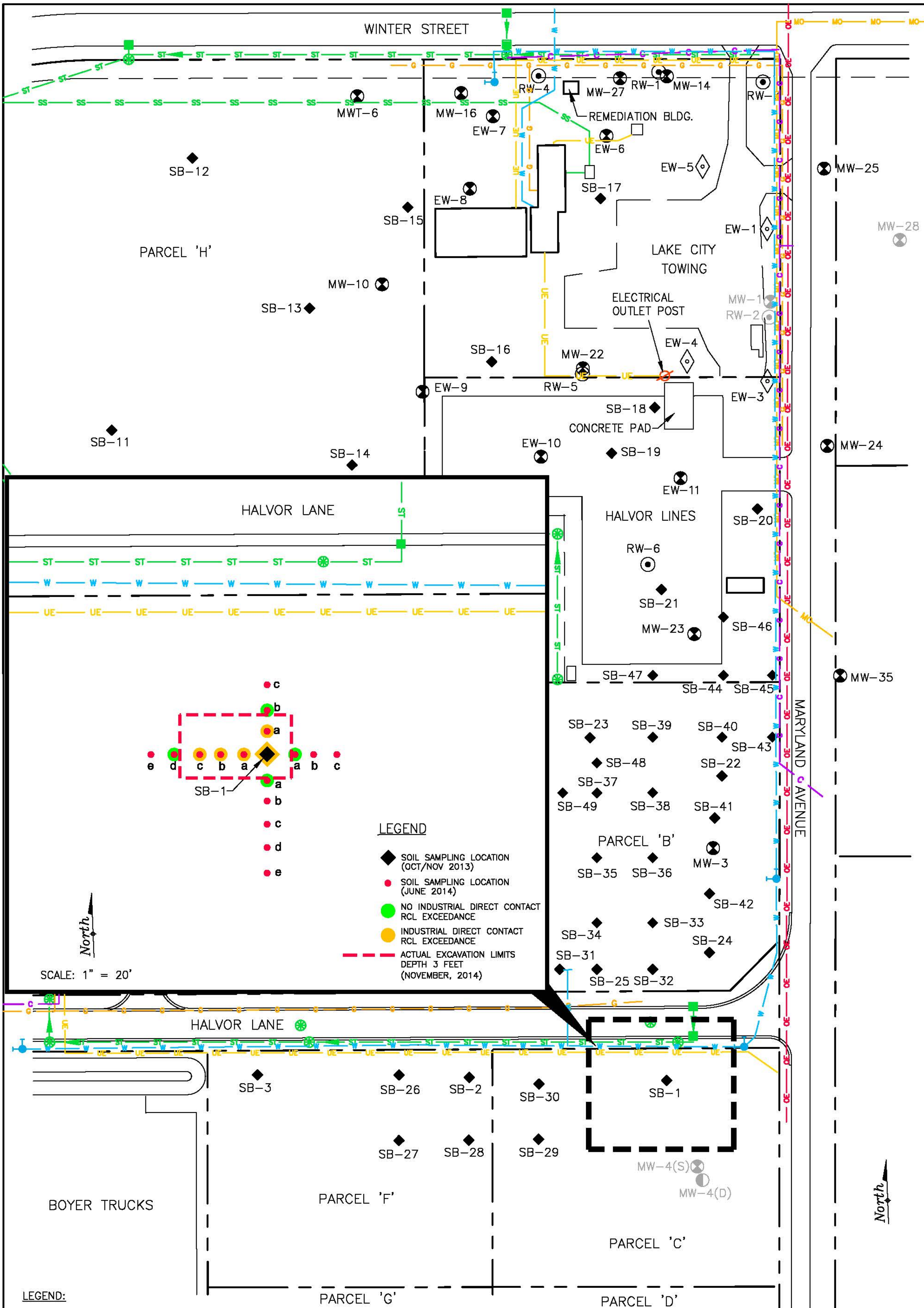
Table 1
Terminal LNAPL Volume Calculations

Well	Easting	Northing	OSV	
EW-07	1436415	576360.7	0.045884411	Calculated from LNAPL thickness in well
MW-16	1436280	576448.6	2.786010373	Calculated from LNAPL thickness in well
MW-26	1436426	576549.9	0.004658912	Calculated from LNAPL thickness in well
RW-4	1436362	576465.1	0.05353876	Calculated from LNAPL thickness in well
TPH-04			0.024168332	Calculated from TPH to OSV Analysis
EW-05	1436567	576390.1	4.44668E-07	Calculated from LNAPL thickness in well
EW-06	1436529	576337.9	0.003956826	Calculated from LNAPL thickness in well
MW-14	1436501	576459	0.026333235	Calculated from LNAPL thickness in well
MW-27	1436450	576457.5	0.026333235	Calculated from LNAPL thickness in well
MW-32	1436388	576745	0.008058479	Calculated from LNAPL thickness in well
RW-1	1436499	576474.9	0.652444311	Calculated from LNAPL thickness in well
TPH-07			0.142404793	Calculated from TPH to OSV Analysis
T-21A	1436537	576243.8	0.09	
MW-1	1436602	576210.1	3.77862E-06	Calculated from LNAPL thickness in well
RW-2	1436615	576226.4	7.05779E-05	Calculated from LNAPL thickness in well
EW-04	1436525	576151.4	0.187975267	Calculated from LNAPL thickness in well
EW-11	1436602	575963.9	0.020766798	Calculated from LNAPL thickness in well
MW-22	1436398	576147.5	0.00961313	Calculated from LNAPL thickness in well
RW-5	1436425	576151.2	7.78178E-05	Calculated from LNAPL thickness in well
TPH-06			0.019	Calculated from TPH to OSV Analysis
MW-23	1436504	575857.5	0.014577254	Calculated from LNAPL thickness in well
RW-6	1436362	576465.1	0.010228835	Calculated from LNAPL thickness in well

	AOC 1	AOC 2	AOC 3	AOC 4	AOC 5	TOTALS
Geomean (OSV in feet)	0.059892	0.006739	0.000288457	0.008888602	0.012211	
Plume Area (sq. ft)	16214	66682	12222	44646	8303	148,067 sq. ft
	0.37	1.53	0.28	1.02	0.19	3.40 acres
LNAPL Vol. (cu. ft)	971	449	4	397	101	1,922 cu. ft
LNAPL Vol. (gallons)	7264	3362	26	2968	758	14,378 gallons

Appendix A

Soil Delineation Locations



LEGEND:

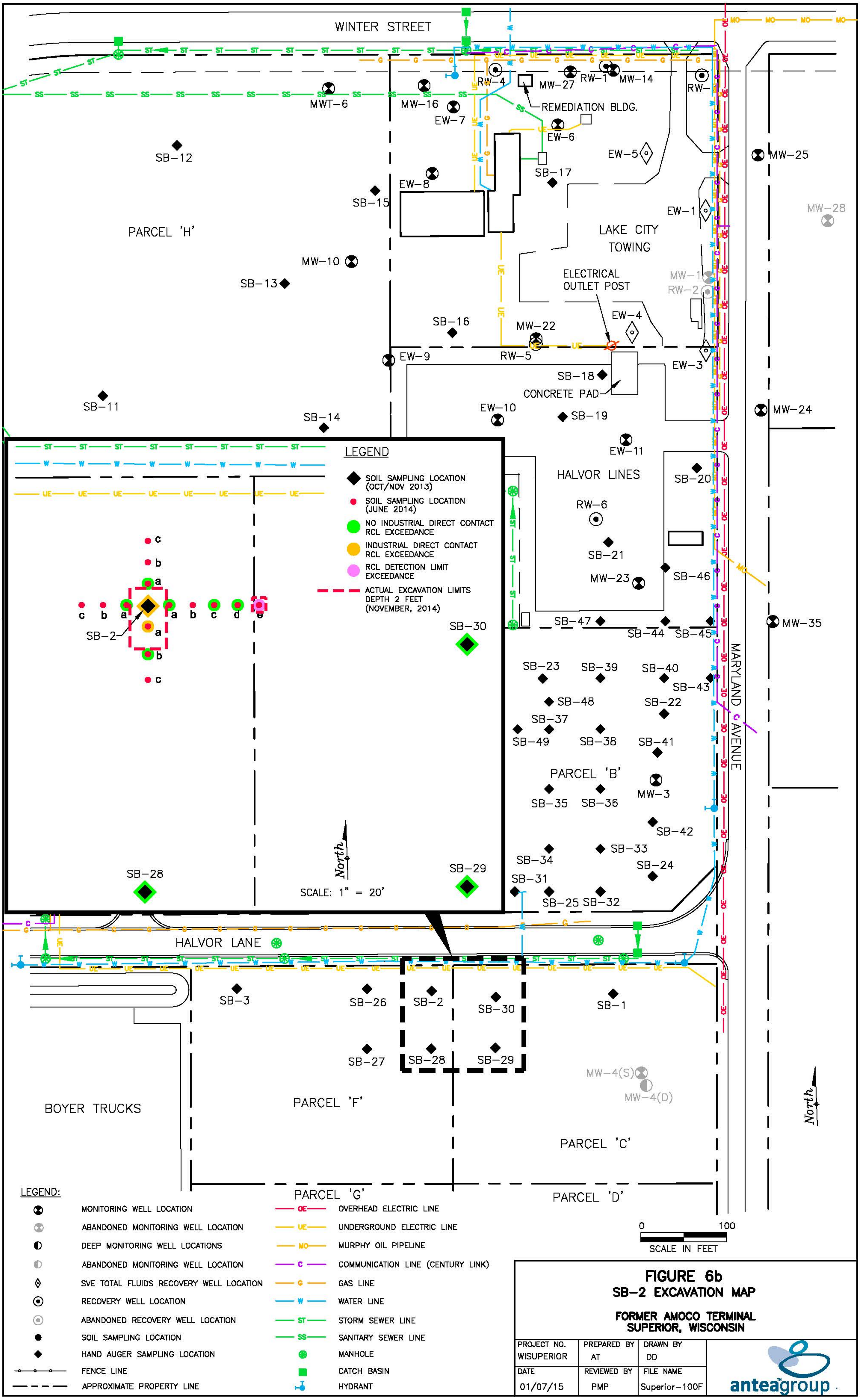
	MONITORING WELL LOCATION	OE	OVERHEAD ELECTRIC LINE
	ABANDONED MONITORING WELL LOCATION	UE	UNDERGROUND ELECTRIC LINE
	DEEP MONITORING WELL LOCATIONS	MO	MURPHY OIL PIPELINE
	ABANDONED MONITORING WELL LOCATION	C	COMMUNICATION LINE (CENTURY LINK)
	SVE TOTAL FLUIDS RECOVERY WELL LOCATION	G	GAS LINE
	RECOVERY WELL LOCATION	W	WATER LINE
	ABANDONED RECOVERY WELL LOCATION	ST	STORM SEWER LINE
	SOIL SAMPLING LOCATION	SS	SANITARY SEWER LINE
	HAND AUGER SAMPLING LOCATION		MANHOLE
	FENCE LINE		CATCH BASIN
	APPROXIMATE PROPERTY LINE		HYDRANT

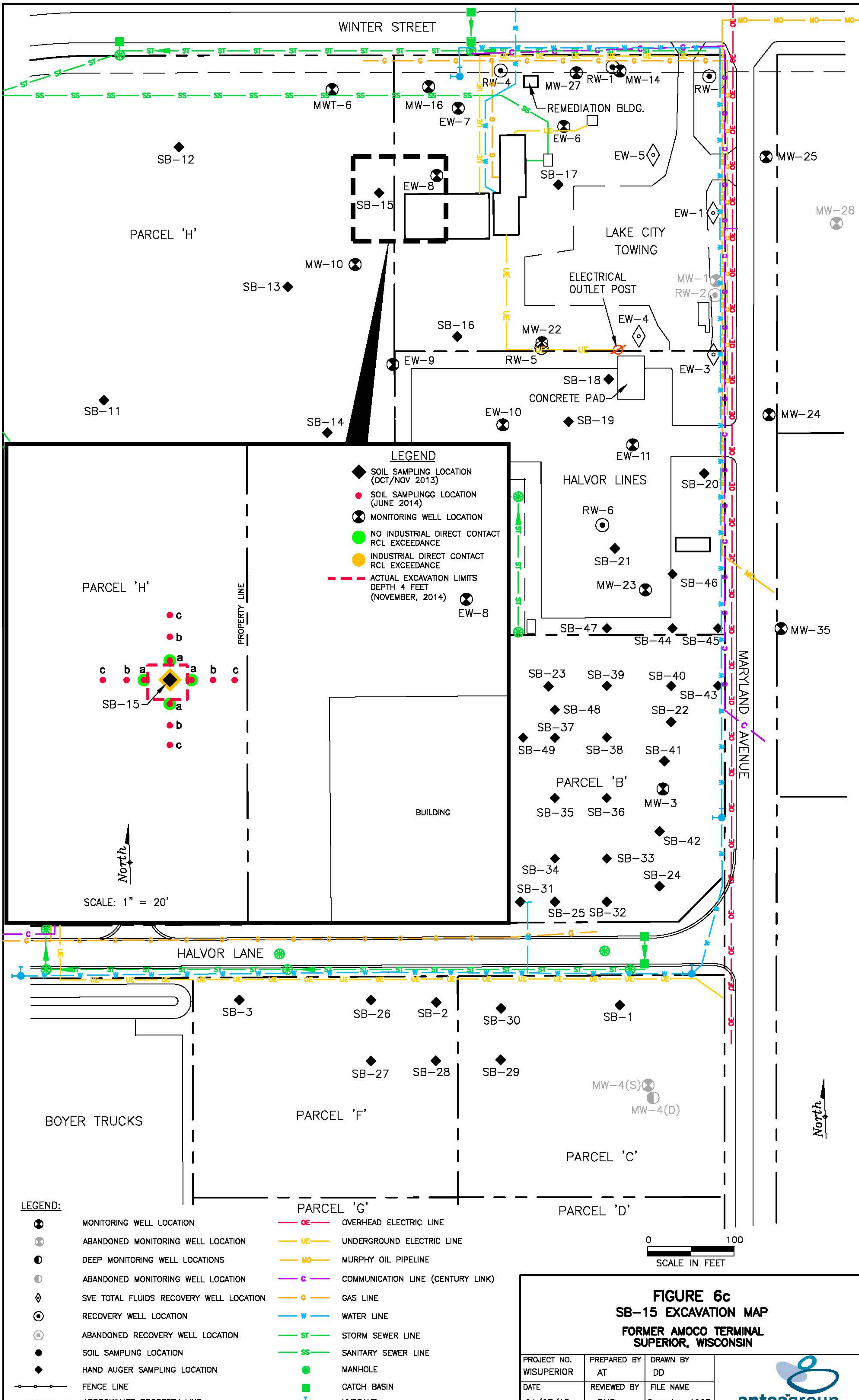
FIGURE 6a
SB-1 EXCAVATION MAP

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPERIOR	AT	DD
DATE	REVIEWED BY	FILE NAME
01/07/15	PMP	Superior-100F

anteagroup


WINTER STREET
HALVOR LANE
MARYLAND AVENUE
PARCEL 'H'
PARCEL 'B'
PARCEL 'F'
PARCEL 'C'
PARCEL 'G'
PARCEL 'D'
BOYER TRUCKS
LAKE CITY TOWING
HALVOR LINES
REMEDIATION BLDG.
ELECTRICAL OUTLET POST
CONCRETE PAD
MWT-6
MW-16
MW-27
RW-1
MW-14
RW-4
EW-7
EW-6
EW-5
MW-25
SB-12
SB-17
EW-8
SB-15
MW-28
EW-1
MW-10
SB-13
MW-1
RW-2
EW-4
SB-16
MW-22
EW-9
RW-5
EW-3
SB-18
SB-11
SB-14
EW-10
SB-19
MW-24
EW-11
SB-20
RW-6
SB-21
MW-23
SB-46
MW-35
SB-47
SB-44
SB-45
SB-23
SB-39
SB-40
SB-43
SB-48
SB-22
SB-37
SB-49
SB-38
SB-41
MW-3
SB-35
SB-36
SB-42
SB-34
SB-33
SB-24
SB-31
SB-25
SB-32
SB-3
SB-26
SB-2
SB-30
SB-1
SB-27
SB-28
SB-29
MW-4(S)
MW-4(D)
LEGEND
SOIL SAMPLING LOCATION (OCT/NOV 2013)
SOIL SAMPLING LOCATION (JUNE 2014)
NO INDUSTRIAL DIRECT CONTACT RCL EXCEEDANCE
INDUSTRIAL DIRECT CONTACT RCL EXCEEDANCE
RCL DETECTION LIMIT EXCEEDANCE
ACTUAL EXCAVATION LIMITS DEPTH 2 FEET (NOVEMBER, 2014)
North
SCALE: 1" = 20'
LEGEND:
MONITORING WELL LOCATION
ABANDONED MONITORING WELL LOCATION
DEEP MONITORING WELL LOCATIONS
ABANDONED MONITORING WELL LOCATION
SVE TOTAL FLUIDS RECOVERY WELL LOCATION
RECOVERY WELL LOCATION
ABANDONED RECOVERY WELL LOCATION
SOIL SAMPLING LOCATION
HAND AUGER SAMPLING LOCATION
FENCE LINE
APPROXIMATE PROPERTY LINE
OVERHEAD ELECTRIC LINE
UNDERGROUND ELECTRIC LINE
MURPHY OIL PIPELINE
COMMUNICATION LINE (CENTURY LINK)
GAS LINE
WATER LINE
STORM SEWER LINE
SANITARY SEWER LINE
MANHOLE
CATCH BASIN
HYDRANT
0 100
SCALE IN FEET
FIGURE 6b
SB-2 EXCAVATION MAP
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN
PROJECT NO. WISUPERIOR
PREPARED BY AT
DRAWN BY DD
DATE 01/07/15
REVIEWED BY PMP
FILE NAME Superior-100F
anteagroup



WINTER STREET
MWT-6
MW-16
EW-7
RW-4
MW-27
RW-1
MW-14
RW-
REMEDIATION BLDG.
EW-6
EW-5
MW-25
SB-12
SB-17
EW-8
SB-15
EW-1
MW-28
PARCEL 'H'
LAKE CITY TOWING
MW-10
SB-13
ELECTRICAL OUTLET POST
MW-1
RW-2
EW-4
SB-16
MW-22
EW-9
RW-5
EW-3
SB-18
CONCRETE PAD
SB-11
EW-10
SB-19
MW-24
SB-14
EW-11
HALVOR LINES
SB-20
RW-6
SB-21
MW-23
SB-46
MW-35
SB-47
SB-44
SB-45
SB-23
SB-39
SB-40
SB-43
SB-48
SB-22
SB-37
SB-49
SB-38
SB-41
MARYLAND AVENUE
PARCEL 'B'
MW-3
SB-35
SB-36
SB-42
SB-34
SB-33
SB-24
SB-31
SB-25
SB-32
LEGEND
SOIL SAMPLING LOCATION (OCT/NOV 2013)
SOIL SAMPLINGG LOCATION (JUNE 2014)
MONITORING WELL LOCATION
NO INDUSTRIAL DIRECT CONTACT RCL EXCEEDANCE
INDUSTRIAL DIRECT CONTACT RCL EXCEEDANCE
ACTUAL EXCAVATION LIMITS DEPTH 4 FEET (NOVEMBER, 2014)
EW-8
PARCEL 'H'
PROPERTY LINE
SB-15
BUILDING
North
SCALE: 1" = 20'
HALVOR LANE
SB-3
SB-26
SB-2
SB-30
SB-1
SB-27
SB-28
SB-29
MW-4(S)
MW-4(D)
BOYER TRUCKS
PARCEL 'F'
PARCEL 'C'
PARCEL 'G'
PARCEL 'D'
North
0
100
SCALE IN FEET
LEGEND:
MONITORING WELL LOCATION
ABANDONED MONITORING WELL LOCATION
DEEP MONITORING WELL LOCATIONS
ABANDONED MONITORING WELL LOCATION
SVE TOTAL FLUIDS RECOVERY WELL LOCATION
RECOVERY WELL LOCATION
ABANDONED RECOVERY WELL LOCATION
SOIL SAMPLING LOCATION
HAND AUGER SAMPLING LOCATION
FENCE LINE
APPROXIMATE PROPERTY LINE
OVERHEAD ELECTRIC LINE
UNDERGROUND ELECTRIC LINE
MURPHY OIL PIPELINE
COMMUNICATION LINE (CENTURY LINK)
GAS LINE
WATER LINE
STORM SEWER LINE
SANITARY SEWER LINE
MANHOLE
CATCH BASIN
HYDRANT
FIGURE 6c
SB-15 EXCAVATION MAP
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN
PROJECT NO. WISUPERIOR
PREPARED BY AT
DRAWN BY DD
DATE 01/07/15
REVIEWED BY PMP
FILE NAME Superior-100F
anteagroup

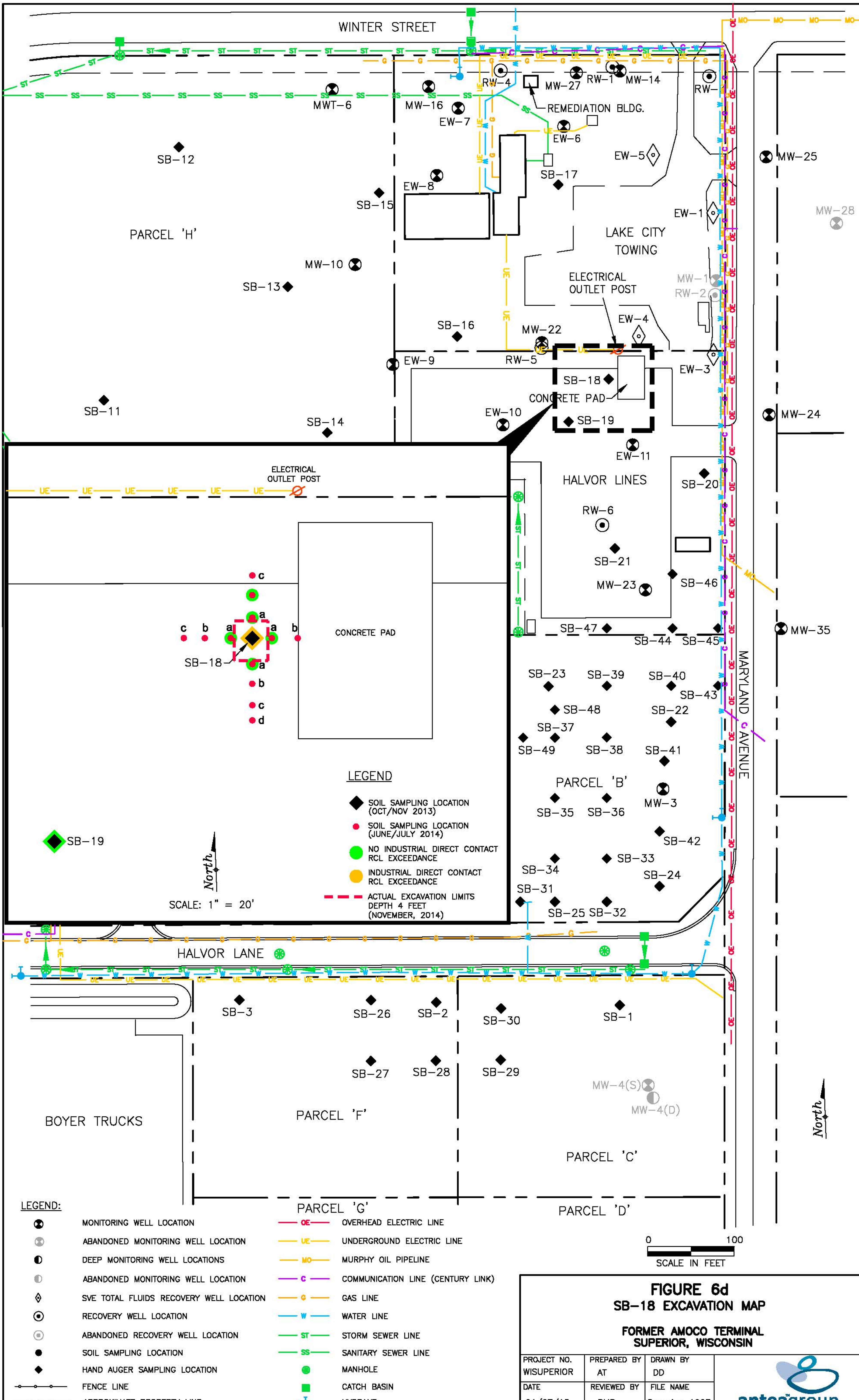


FIGURE 6d
SB-18 EXCAVATION MAP

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPERIOR	AT	DD
DATE	REVIEWED BY	FILE NAME
01/07/15	PMP	Superior-100F

anteagroup

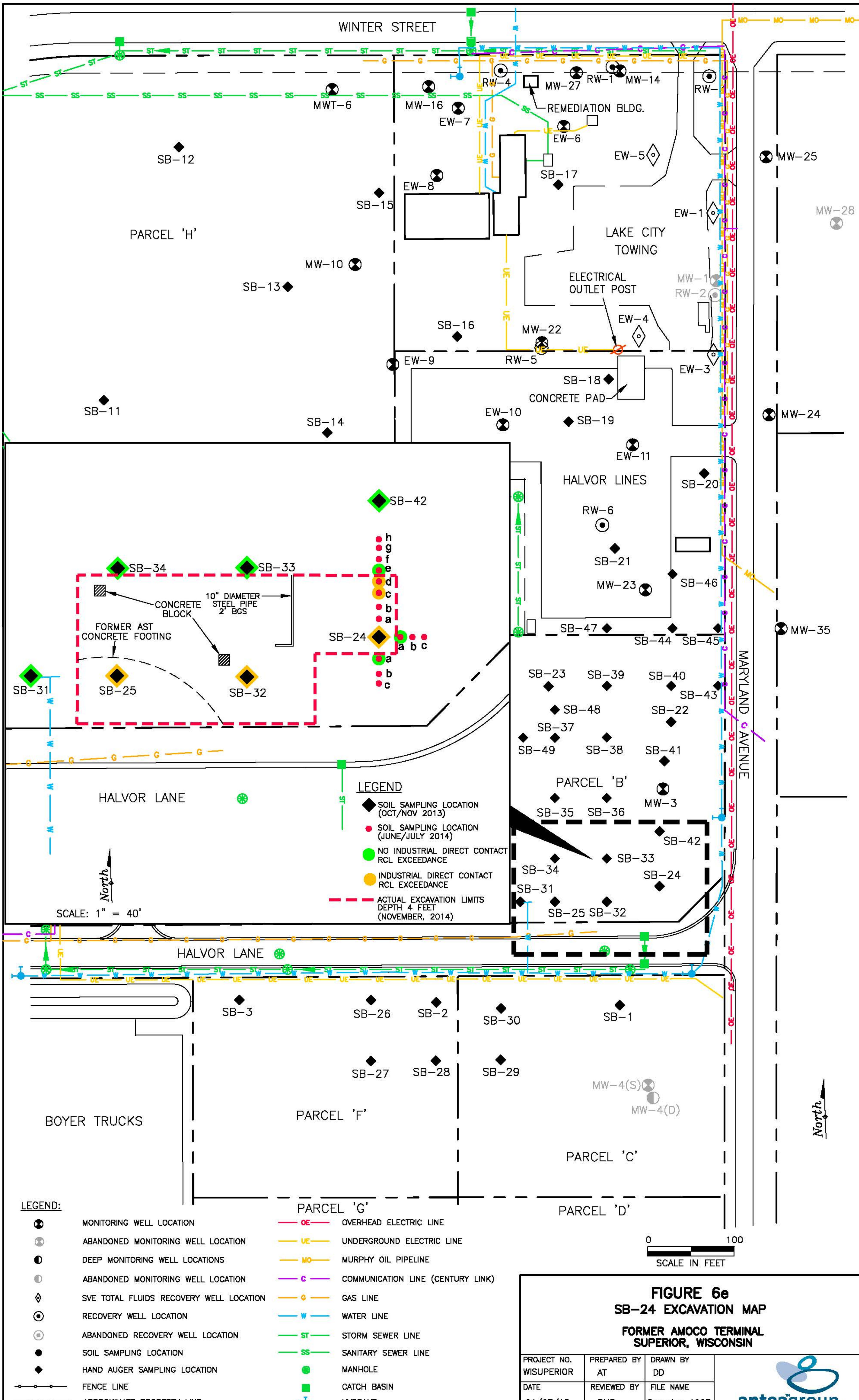


FIGURE 6e
SB-24 EXCAVATION MAP

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPERIOR	AT	DD
DATE	REVIEWED BY	FILE NAME
01/07/15	PMP	Superior-100F

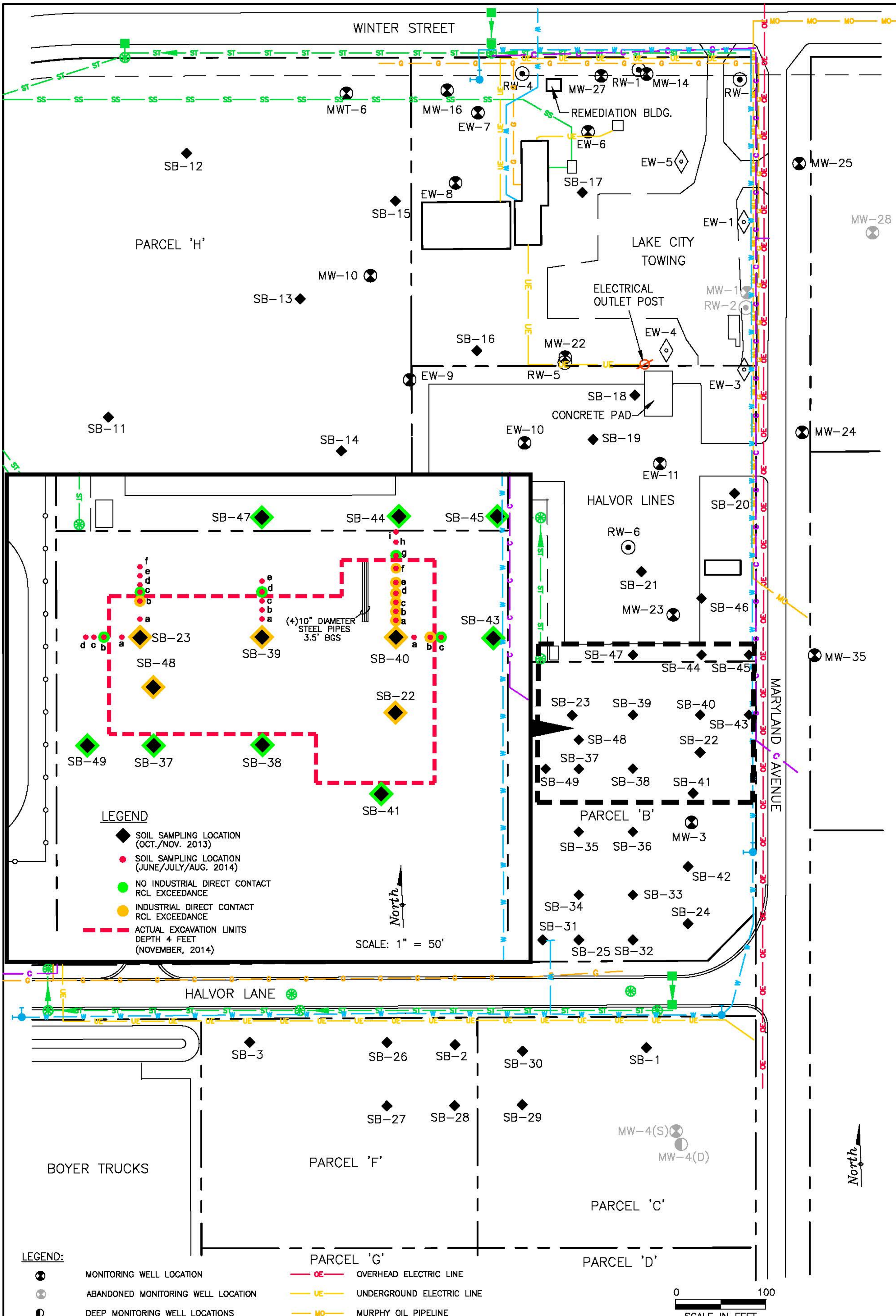


FIGURE 6f

SB-23, SB-39 & SB-40 EXCAVATION MAP

FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUPERIOR	AT	DD
DATE	REVIEWED BY	FILE NAME
01/07/15	PMP	Superior-100F

anteagroup