DRAFT HIGH-RESOLUTION SITE CHARACTERIZATION REPORT

FORMER TIGER OIL SITE
2312 WEST NOB HILL BOULEVARD
YAKIMA, WASHINGTON
ECOLOGY FACILITY SITE ID NO. 469/CLEANUP SITE NO. 4919

Prepared for
CITY OF YAKIMA
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MAUL
FOSTER
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The material and data in this report were prepared under the supervision and direction of the undersigned.

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ACRONYMS AND ABBREVIATIONS

3-D	three-dimensional
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
C_{res}	residual LNAPL saturation concentrations
C_{sat}	LNAPL saturation concentrations
the City	City of Yakima, Washington
CH_4	methane
CO_2	carbon dioxide
COC	contaminant of concern
Columbia Technologies	Columbia Technologies LLC
CSM	conceptual site model
CUL	cleanup level
Ecology	Washington State Department of Ecology
EC	electrical conductivity
EPH	extractable petroleum hydrocarbons
FBI	Friedman & Bruya, Inc.
ft/day	feet per day
gal/ac/yr	gallons per acre per year
GWE	groundwater extraction
HPT	hydraulic profiling tool
HRSC	high-resolution site characterization
IDW	investigation-derived waste
IHS	indicator hazardous substance
IRA	interim remedial action
ITRC	Interstate Technology and Regulatory Council
LNAPL	light nonaqueous-phase liquid
MFA	Maul Foster & Alongi, Inc.
mg/kg	milligrams per kilogram
MiHpt	membrane interface probe-hydraulic profiling tool
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
New Tiger	Tiger Oil Corporation
NSZD	natural source zone depletion
NWTPH	Northwest Total Petroleum Hydrocarbons
O_2	oxygen
OIP	Optical Imaging Profiler
PID	photoionization detector
the Property	2312 West Nob Hill Boulevard, Yakima, Washington
QA/QC	quality assurance and quality control
the Site	Ecology Facility Site No. 469, Cleanup Site No. 4919
the technical team	Ecology, MFA, and Columbia Technologies

ACRONYMS AND ABBREVIATIONS (CONTINUED)

SVE	soil vapor extraction
TPH	total petroleum hydrocarbons
ug/L	micrograms per liter
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound
VPH	volatile petroleum hydrocarbons
WAC	Washington Administrative Code

1 INTRODUCTION

On behalf of the City of Yakima (the City), Maul Foster & Alongi, Inc. (MFA) has prepared this high-resolution site characterization (HRSC) report to present the results of the evaluation of the extent of residual light nonaqueous-phase liquid (LNAPL) and the extent of the dissolved-phase plume generated from the residual LNAPL at the former Tiger Oil facility, located at 2312 West Nob Hill Boulevard, Yakima, Washington (Washington State Department of Ecology [Ecology] Facility Site No. 469, Cleanup Site No. 4919). Throughout this report and consistent with Ecology's definition, the term "Property" is specific to the real property located at 2312 West Nob Hill Boulevard, and "Site" is specific to where contamination resulting from former operations at the Tiger Oil facility has come to lie, irrespective of property boundaries. A retail gasoline station was operated on the Property from 1978 until 2001; since that time no commercial activities have taken place on the Property. Several fuel releases at the Property during active facility operations resulted in adverse impacts to soil and groundwater at the Property as well as to the adjoining parcels to the east, south, and southeast. Remediation of the Site is being conducted under Amended Consent Decree No. 02-2-00956-22.

1.1 Regulatory Framework

This report presents a further assessment of the nature and extent of contamination at the Site. The HRSC was conducted in general accordance with guidance defined in the Washington State Model Toxics Control Act (MTCA) (Washington Administrative Code [WAC] 173-340-410).

1.2 Purpose and Objectives

The purpose of the HRSC is to characterize the nature and vertical and horizontal extent of residual LNAPL and the dissolved-phase plume at the Site in order to evaluate the LNAPL's transport and storage zones and determine the potential for mobility and/or fluid recovery, as well as to assess the potential efficacy of natural source zone depletion (NSZD) and monitored natural attenuation (MNA) as viable options for managing the remaining contamination at the Site.

The primary questions (or objectives) of the HRSC are:

- What is the extent of residual LNAPL at the Site?
- Is the LNAPL recoverable at this Site?
- What is the extent of the dissolved-phase petroleum impacts at the Site?
- What is the potential for NSZD and MNA at the Site?

The activities outlined in this report are intended to answer these questions. The methods are briefly outlined below and are described in more detail in subsequent sections. The approach utilizes multiple lines of evidence, including evaluation of previous data, use of HRSC techniques, and traditional laboratory analysis of discrete soil and groundwater samples.

1.3 HRSC Profiling Tools and Focused Areas

The U.S. Environmental Protection Agency (USEPA) defines HRSC as "strategies and techniques using scale-appropriate measurement and sample density to define contaminant distributions, and the physical context in which they reside, with greater certainty, supporting faster and more effective site cleanup." HRSC enables detailed evaluation of the heterogeneity of the subsurface and hydrogeologic conditions at the Site through real-time, rapid, and high-density data collection by various high-profiling tools, including the optical imaging profiler (OIP) via ultraviolet fluorescence, membrane interface probe-hydraulic profiling tool (MiHpt), and hydraulic profiling tool (HPT) (refer to Section 4). The HRSC also focused on hydrogeologic variables such as contaminant distribution, transport, and fate. The HPT mapped the residual LNAPL and the subsurface conditions in three dimensions. The generated three-dimensional (3-D), high-resolution graphical profiles were then compared to corresponding high-resolution vertical soil and groundwater and quantitative laboratory analyses.

MFA subcontracted with Columbia Technologies LLC (Columbia Technologies), of Rockville, Maryland, to perform the HRSC. The HRSC focused on the following areas:

- Geologic heterogeneity—evaluate the stratigraphy and lithologies of the subsurface conditions in conjunction with correlating contaminant data.
- Extent of LNAPL—advance borings using the OIP direct-sensing instrument at selected locations to evaluate the specific behavior of the LNAPL, including its viscosity, mobility, and dissolution in the subsurface. Identify the storage and transport zones of the LNAPL via the OIP surveys.
- Recoverability of LNAPL—analysis of transmissivity of soil through the HPT and the analytical measurement of percentage of LNAPL saturation and relative soil permeability in high-resolution soil samples.
- Extent of dissolved-phase plume—advance borings using the MiHpt to evaluate the aqueous and sorbed phases of the dissolved-phase plume.
- Dissolved-phase plume—evaluate the plume's core; plume stability; and characteristics, including its mass and biodegradation parameters.
- Potential for NSZD and MNA—collection and laboratory analysis of high-resolution groundwater samples from borings for geochemical parameters. Install and analyze the collected data from the carbon dioxide (CO_2) flux chambers. Install and evaluate monitoring data from soil vapor points monitoring wells.

1.4 HRSC Triad Data Collection

The HRSC Triad data collection approach involves systematic planning, dynamic work strategies, and real-time measurements technologies. Key factors of this approach include the following:

- Uses direct-sensing technologies to provide a high density of discrete measurements to determine spatial and matrix distribution of contaminants

- Targets collaborative sample analysis, where applicable
- Uses collaborative data sets from multiple direct-sensing instruments
- Uses real-time data management and interpretation to build and update the Site's conceptual site model during the field effort
- Enables real-time communication strategies
- Gathers high volume of HRSC data to capture, process, and format for stakeholder decision-making in field decisions

2 BACKGROUND AND PHYSICAL SETTING

The background and physical setting information summarized below for the Property has been obtained from previous investigations and interim remedial action (IRA) as well as from discussions with the City and Ecology.

2.1 Site Description

The Property's physical address is 2312 West Nob Hill Boulevard in Yakima, Washington (refer to Figure 2-1). The Property, a 0.52-acre, rectangular parcel (tax assessor parcel number 18132642051), is bordered by West Nob Hill Boulevard to the north, a Safeway Shopping Center parking lot to the east and southeast, the Xochimilco Mexican Restaurant to the east, the former One Love Smoke Shop to the south (now occupied by Barber HQ and 1 Up Games), and South 24th Avenue to the west (refer to Figure 2-2). The Property is currently vacant.

2.2 Site History

Until it was purchased by Tiger Oil Corporation (New Tiger) in 1987, the Property was operated by the Tiger Oil Company as a retail fuel station. New Tiger operated the Property as an Exxon-branded fuel station and convenience store from 1987 until 2001. All commercial operations ceased in 2001 and the Property has remained vacant since (TerraGraphics, 2013). The fuel station included four underground storage tanks (USTs) (one 20,000-gallon, two 10,000-gallon, and one 8,000-gallon tank) and associated product lines. The system was used for bulk petroleum storage and distribution.

In April 1981, volatilization of petroleum products in a drainage improvement district storm drain line adjacent to the Property resulted in an explosion and triggered an investigation by the City and Ecology to test the Property's UST system (Ecology, 2014). During the investigation, it was determined that a leak in the product line of the UST system had impacted the surrounding soil and groundwater at the Property and adjoining properties. The leak in the UST line was determined to be the source of the petroleum products found in the nearby drainage improvement district line. Ecology issued a Notice of Violation and Enforcement Order No. DE 82-517 to Tiger Oil Company, requiring recovery of LNAPL (i.e., free product) from the Site (Ecology, 2014).

It was estimated that approximately 20,000 gallons of petroleum-related product had been released from the Property's UST system in the early 1980s (Ecology, 2014). Several recovery wells had been installed by early 1983 at the Property and on adjacent parcels to the east and south. By March 1984, approximately 16,000 gallons of LNAPL had been extracted from the recovery wells (Kleinfelder, 1994).

In March 1990, Ecology issued EO No. DE 90-C140 to New Tiger and Federated Insurance, requiring site stabilization and a remedial investigation and feasibility study for the Site (Ecology, 2014). In 1991, a site hazard assessment was conducted, resulting in a hazard ranking of 1 (with 1 as the highest risk and 5 the lowest risk).

In August 1995, operation of soil vapor extraction (SVE) and groundwater extraction (GWE) systems began in order to collect LNAPL, impacted groundwater, and soil vapor on the Site, as well as to mitigate off-site migration of dissolved-phase gasoline-range total petroleum hydrocarbons (TPH) and LNAPL. However, the SVE and GWE systems were limited in scope and did not adequately target areas of LNAPL present on the Site. Ecology concluded that the SVE and GWE systems were not representative of final cleanup actions for the Site (Ecology, 2014).

In October 2004, New Tiger and Federated Insurance entered into a Consent Decree with Ecology requiring implementation of Ecology's 2004 Amended Cleanup Action Plan. In December 2004, the USTs and their associated piping, along with approximately 650 cubic yards of impacted soil around the UST system, were removed from the Site. Two trenches were dug in the vicinity of the USTs to determine the amount of LNAPL, if present, at the top of the water table at the Site. LNAPL was encountered, and an additional SVE system was installed to treat the impacted soil vapor at the Site. Appreciable LNAPL was encountered at monitoring wells MW-7 (2.34 feet thick, located east of the Property on the Xochimilco restaurant parking lot) and MW-11 (1.46 feet thick, located on the Property southeast of the former USTs—refer to Figure 2-2) during groundwater monitoring conducted in June 2013 (TerraGraphics, 2013).

The City purchased the Property in 2014 and entered into an Amended Consent Decree with Ecology to implement an Amended Cleanup Action Plan at the Site (Ecology, 2014).

Interim Remedial Action—2015

An IRA was completed at the Site in February and March 2015. The Site's indicator hazardous substances (IHSs) include gasoline-range TPH and petroleum-hydrocarbons-associated volatile organic compounds (VOCs,) including benzene, toluene, ethylbenzene, and xylenes (BTEX). Tasks completed during the IRA included the following:

- Demolition of the former convenience store
- Decommissioning of groundwater monitoring wells MW-8, MW-12, MW-15, KMW-20, and KMW-22
- Removal of subsurface piping of the former treatment system within the bounds of the IRA excavation, and demolition of the treatment system at the adjoining property

- Excavation and off-site disposal of contaminated soil:
  - Application of in situ treatment compounds Regenesis RegenOx® oxidizer and Regenesis Oxygen Release Compound Advanced® activator during backfill of the excavation
  - Installation of an infiltration gallery within the excavation footprint to provide the option for additional treatment compound injection should groundwater monitoring determine that the treatment application in the excavation area is not effective in fully attaining groundwater cleanup levels (CULs)
  - Backfill of the excavation with clean import fill and overburden from the excavation that was deemed appropriate for reuse, based on laboratory analysis
- Installation of three groundwater monitoring wells (YMW-1 through YMW-3) within the footprint of the excavation

Further information associated with the IRA is provided in the IRA completion report (MFA, 2015). Figure 2-3 presents the completed elements of IRA at the Site.

Semiannual Groundwater Monitoring Event—November 2018

The recently completed semiannual groundwater monitoring event was conducted in November 2018. Findings from this groundwater monitoring event included the following:

- The footprint of the thickest LNAPL remains in the same vicinity, i.e., involving MW-7 to KMW-10. LNAPL was also observed at MW-11 (0.01 foot) where previously LNAPL thicknesses had ranged from 0.55 to 0.01 foot. Similarly, LNAPL was also observed at MWG-3 (0.05 foot) where previously LNAPL thicknesses had ranged from 0.11 to 0.02 foot. Overall, LNAPL thicknesses at the Site have continued to decrease incrementally.
- The core of the dissolved-phase plume includes monitoring wells exhibiting the highest concentrations of gasoline-range TPH and BTEX constituents. These monitoring wells (YMW-1, YMW-2, YMW-3, MW-9, MW-13, and S-2) are located adjacent and/or downgradient of the area where residual petroleum-contaminated soil was not accessible (refer to Figures 2-3 and 2-4). Overall, it appears that the dissolved-phase plume, notably gasoline-range TPH and benzene, has stabilized and its lateral extent to the southeast has receded. Groundwater concentrations of gasoline-range TPH and benzene have decreased markedly (refer to Table 2-1).
- Sentry and dissolved-phase plume boundary wells, including KMW-14, KMW-15, MWG-2, and KMW-5, have had no MTCA Method A CUL exceedances, except for one benzene detection at KMW-14 during the November 2015 monitoring event (refer to Table 2-1).
- It appears that biodegradation of the dissolved-phase plume is ongoing, aerobic, and occurring sequentially, based on the trends of the primary terminal electron acceptors—dissolved oxygen (O_2) and nitrate (where $O_2$and then nitrate are being consumed and decreased by the use of microorganisms consuming petroleum contaminants), and increasing trends of by-products including manganese and ferrous iron coupled with an increase in the oxidation reduction potential (refer to Table 2-2). These trends are generally exhibited at MW-9, YMW-

1, YMW-2, and YMW-3. Additional data concerning other by-products indicative of natural attenuation, including sulfate and methane (CH_4) will further assist in the evaluation of the biodegradation process at the Site. Currently, accumulated data of these parameters are insufficient to further the evaluation.

- Geochemical parameters viewed in parallel with generally decreasing trends of the dissolved-phase plume concentrations (gasoline-range TPH and benzene) are also indicative of the continuing biodegradation at the Site.

2.3 Geology and Hydrogeology

The Site and vicinity have been mapped as eolian (windblown sediment) deposits. These deposits, approximately 20 feet thick, are underlain by the Thorp gravel, a moderately to highly weathered sand and gravel deposit, which has been logged to a depth of approximately 135 feet below ground surface (bgs) (Kleinfelder, 1992). The Site is underlain by fill to approximately 9 to 12 feet bgs, and by sandy clay to silty gravel below the fill to about 16 feet bgs, where gravel is present.

The matrix of the unconfined shallow aquifer appears to be interbedded sands and silts. The depth to groundwater is variable at the Site, ranging approximately from 9 to 13 feet bgs, and is influenced by seasonal fluctuations in the groundwater table due to local irrigation practices. The annual irrigation schedule is from April through September, which appears to impact the groundwater table, causing it to rise between 2 to 4 feet during that general period.

The direction of groundwater flow at the Site, based on the consecutive quarterly groundwater monitoring events completed from November 2015 through November 2018, is generally east-southeast. Figure 2-5 presents the groundwater potentiometric map drafted during the November 2018 semiannual groundwater event.

3 CURRENT LNAPL CONCEPTUAL SITE MODEL

The current conceptual site model (CSM) for residual LNAPL at the Site shows that the LNAPL is present primarily southeast of the Property (refer to Figure 2-4). This area is adjacent to and downgradient east-southeast of the area where the IRA was completed.

3.1 Residual LNAPL from Previous Investigations

During the November 2018 quarterly groundwater monitoring event, LNAPL was encountered in four monitoring wells, MW-11, MWG-3, KMW-10, and MW-7, at thicknesses of 0.01, 0.05, 0.37 and 0.20 foot, respectively. The footprint of the thickest LNAPL remains in the same vicinity, i.e., involving MW-7 to KMW-10. LNAPL was also observed at MW-11 (0.01 foot) where previously LNAPL thicknesses had ranged from 0.55 to 0.01 foot. Similarly, LNAPL was also observed at MWG-3 (0.05 foot) where previously LNAPL thicknesses had ranged from 0.11 to 0.02 foot. Overall, LNAPL thicknesses at the Site have continued to decrease incrementally.

Table 3-1 presents the depth to water, LNAPL, and associated groundwater elevations for the Site's network of monitoring wells.

3.2 Dissolved-Phase Groundwater Plume

Figure 3-1 presents the approximate extents of the dissolved-phase plume reported for the November 2018 semiannual groundwater monitoring event. Figures 3-1 and 3-2 show the extents of the November 2018 dissolved-phase plume as exhibited by the gasoline-range TPH and benzene isoconcentrations, respectively. Overall, the dissolved-phase plume appears to be receding, i.e., benzene concentration trends and partial gasoline-range TPH concentration trends within the plume have decreased, and there is a stable plume margin (refer to Table 2-1 and Figures 3-1 and 3-2).

4 HIGH-RESOLUTION SITE CHARACTERIZATION

From November 26 through December 7, 2018, the HRSC was conducted in general accordance with the methods and protocol described in the Interstate Technology and Regulatory Council (ITRC) guidelines for evaluating LNAPL remedial technologies (ITRC, 2009b) and MFA's HRSC work plan (MFA, 2018). The investigation involved the USEPA's Triad data collection HRSC approach as well as direct-sensing technologies (OIP, MiHpt, and HPT) to determine the spatial and matrix distribution of the contaminants of concern (COCs) and, through high-resolution soil and groundwater sampling and associated laboratory analysis, obtained qualitative data on the COCs. Real-time data analysis and interpretation of contaminant mass distribution and mass flux by phase and by the underlying soils stratigraphy enabled a greater degree of identification of the stable LNAPL and the lateral and vertical extent of the dissolved-phase plume.

4.1 HRSC Approach

The HRSC was intended to evaluate the geologic heterogeneity of the subsurface, determine the extent of residual LNAPL distribution, identify the pathways of the residual LNAPL, and evaluate the hydrostratigraphy for probable LNAPL transport and storage zones. This completed work also resulted in a macro-scale understanding of the residual LNAPL from its movement into and out of pore spaces (or monitoring wells) to potentially immobile LNAPL source zone areas. The HRSC was conducted with a systematic approach using multiple lines of evidence and incorporating the ITRC guidelines (ITRC, 2009a,b).

HRSC HPTs were coupled with direct-push drilling, using temporary soil borings, to enable collection of real-time physical and subsequent chemical data in the field. The profiling tools were modified for the collection of specific data relative to contaminant concentrations and the distribution of hydraulic conductivity and hydraulic head, as well as pH, specific conductance, dissolved O_2, and oxidation reduction potential.

The electrical conductivity (EC) probe, part of the HPT direct-sensing instrument, measures soil conductivity in milli-Siemens per meter. These data are used to characterize the Site's stratigraphy. The EC probe sends a known current through the soil and measures the voltage that is used to calculate the conductivity.

The HPT measures changes in the required pore entry pressure of the stratum, correlating with media permeability and allowing for vertical profiling of hydrostratigraphic information. The HPT delivers water to the subsurface through the probe head. A transducer in the probe measures the required injection pressure and hydrostatic pressure.

The dissolved-phase plume and stratigraphy, as well as migration pathways, are delineated when the EC and HPT are used in tandem.

The OIP uses in situ fluorescence spectroscopy to locate LNAPL and is dependent on the fluorescence from LNAPL and polyaromatic hydrocarbons partitioning. The data from OIP enable delineation, as well as qualitative analysis and recoverability evaluation, of the LNAPL.

The locations of the Site's monitoring wells, geologic logs, and associated groundwater analytical results from previous groundwater monitoring events were uploaded into Columbia Technologies' SmartData Solutions, a real-time decision support system that will integrate the results of recent groundwater analyses with the HRSC field findings. Using real-time information, initial HPT results were evaluated to adjust the proposed locations of investigations and depth of additional HPT soundings advanced to characterize the residual LNAPL source areas and areas of migration. The compiled data from each day are reviewed daily so that the HRSC progress can be evaluated and real-time decisions by the technical team (Ecology, MFA, and Columbia Technologies) can be based on the data being generated.

The HRSC approach uses multiple sampling methods in a prescribed sequence. The HRSC started with the OIP to investigate the residual LNAPL. When the OIP no longer detected residual LNAPL, then the MiHpt was utilized to map the residual and dissolved-phase plume. Typically, the residual phase of a gasoline spill contains many VOCs, such as BTEX compounds and naphthalene. These analytes were detected with the MiHpt. Multiple vertical profiles of the subsurface were conducted along multiple transects (refer to Figure 4-1) designated throughout the Site.

The 3-D data from OIP and MiHpt were visualized via Columbia Technologies' environmental visualization software, analyzed, and evaluated to guide specific locations for collecting high-resolution soil and groundwater samples for laboratory analysis. Cross sections of the Site were drafted using the 3-D high-resolution data. The Site's CSM was refined with additional high-resolution data throughout the fieldwork.

During the investigation, the data generated by the OIP and MiHpt logs were used to define the areas of highest response at the Site. The highest response locations were selected for high-resolution soil and/or groundwater sampling. The samples were collected at 1-foot intervals across the zones of highest response to profile the TPH distribution in the soil. If the response profiles were very narrow, the sample interval could be reduced to 6 inches.

Frequent online data reviews and discussions were conducted by the technical team at each Key Decision Point to ensure that the desired lines of evidence had been met and that the next steps in the work plan should be implemented.

Once the residual LNAPL mass was mapped and the dissolved-phase plume and the hydrostratigraphy assessed, then the task of evaluating the potential for NSZD began. High-resolution groundwater samples were collected upgradient, within the LNAPL mass, and downgradient for laboratory analysis of CH_4, CO_2, dissolved O_2, electron acceptors, and the contaminant mass to evaluate gradients across the Site. These collective data were evaluated for evidence of natural depletion at the Site and of NSZD's potential as a viable effective long-term management technology at the Site.

4.2 HRSC Direct-Sensing Equipment Quality Assurance and Quality Control

Columbia Technologies ensure the operations and quality assurance and quality control (QA/QC) of each direct-sensing instrument. Each of these instruments was operated in accordance with the manufacturer's standard operating procedures and the Standard Practice for Direct Push Technology for Volatile Contaminant Logging with the Membrane Interface Probe (American Society for Testing and Materials [ASTM] D7352-07). Prior to each survey sounding, performance testing for each direct-sensing instrument was conducted on each system before and after each survey sounding. The reviews also evaluated each instrument system for potential anomalies during the system operations. Additional details on the QA/QC HPT are provided in Columbia Technologies' HRSC Report (refer to Appendix A). Appendix A also provides the quality control procedures Columbia Technologies uses for direct-sensing technologies, including the OIP, MiHpt, and HPT.

4.3 Extent of Residual LNAPL Impact Investigation

The investigation to evaluate the extent of residual LNAPL impact was conducted using the OIP signatures. The OIP system delineates the extent of any residual petroleum hydrocarbons contained within the soil pore structure. Data verifying the presence and measured thicknesses of LNAPL from the November 2018 semiannual groundwater sampling event and previous groundwater monitoring events were instrumental to evaluating the locations for OIP direct-sensing. OIP borings were placed adjacent to monitoring wells where LNAPL has been documented to evaluate the presence and true depth interval of LNAPL. Figure 4-1 presents the locations of OIP surveys (OIP-01 through OIP-13) for investigating the residual LNAPL impacts. The observed OIP signatures at these locations were noted for delineation of LNAPL at the Site.

Three OIP surveys transects were conducted based on the compiled LNAPL measurements at monitoring wells from the previous quarterly groundwater monitoring events (refer to Figure 4-1). OIP toolings were advanced adjacent to these monitoring wells, or adjacent to monitoring wells where elevated dissolved-phase concentrations (above MTCA CULs) have been documented, to evaluate true LNAPL saturation. Based on the OIP observations at OIP-1 through OIP-10 and on real-time data interpretations, OIP-11 through OIP-13 were added to address potential data gaps (refer to Figure 4-1).

LNAPL was gathered from monitoring well KMW-10 for direct testing on the OIP before the probe was advanced through the ground. In addition, a sample of the LNAPL from KMW-10 was collected and submitted for analysis of extractable petroleum hydrocarbons (EPH) and volatile petroleum hydrocarbons (VPH).

Targeted high-resolution soil samples were collected after the signatures of OIP were reviewed and the data analyzed on site. The decision factors that triggered the locations of high-resolution soil sampling included the following:

- The investigated HRSC zones, which indicate the highest responses on the OIP, including responses from borings OIP-2, OIP-6, OIP-7, and OIP-10
- The zones with indications that residual LNAPL may be mobile

At these zones, the HRSC approach involves collecting one high-resolution soil sample per foot over the zone of highest OIP responses.

The OIP logs, provided in Columbia Technologies' HRSC report (refer to Appendix A), and sampling locations were presented on an interactive Columbia Technologies Web site after each location was finished, making data reviews for MFA and Ecology more comprehensive for all involved. Through its interactive graphical software, Columbia Technologies manipulated the OIP surveys to allow for multiple cross sections displaying the OIP responses across the Site to help the reviewers understand the LNAPL distribution and to guide the high-resolution soil sampling decisions.

The selected high-resolution soil samples were submitted for laboratory analysis of the following IHSs:

- Gasoline-range TPH
- BTEX

4.4 LNAPL Transmissivity Determination

The volume of LNAPL that is potentially mobile and recoverable is the amount that exists above the residual saturation. Residual saturation is defined by ITRC as the amount that exists both above and below the water saturated zone (ITRC, 2009b). LNAPL saturation is not uniform. It is controlled by soil heterogeneity. In order for LNAPL to enter a water-filled soil pore, pressure exerted by LNAPL must exceed the displacement soil pore entry pressure. A measurable LNAPL thickness in a monitoring well does not necessarily indicate that LNAPL is migrating (ITRC, 2018).

Since residual LNAPL thickness, observed during the OIP surveys, did not exceed 0.5 foot, LNAPL transmissivity was not determined using analytical measurement of percentage of LNAPL saturation and relative soil permeability.

LNAPL transmissivity is a more direct measure of LNAPL recoverability that factors in soil type heterogeneity and water levels. According to ITRC, an LNAPL transmissivity value of 0.8 square foot per day indicates that LNAPL is recoverable (ITRC, 2009b).

4.5 Extent of Dissolved-Phase Plume Investigation

The horizontal and vertical extents of the dissolved-phase plume were investigated using the MiHpt. Mature LNAPL likely will be present as a disassociated mass, with insufficient saturation for fluorescence with OIP, but will volatilize hydrocarbons when heated to 120-centigrade with the MiHpt. The MiHpt was also advanced along transects to define the extent of the dissolved-phase groundwater contamination and identify the transport pathways. The focus included gathering comprehensive data on the soil types and possible areas with higher or lower permeability to identify potential migration pathways for LNAPL and/or dissolved-phase petroleum hydrocarbons.

Figure 4-2 presents the locations for MiHpt soundings, which included the entire extent of the confirmed dissolved-phase plume to the distal end of the plume. Initially, three MiHpt surveys transects (transects A through C) were conducted based on the compiled groundwater analytical results from the quarterly groundwater monitoring events The MiHpt soundings were advanced adjacent to monitoring wells where LNAPL is present or where elevated gasoline-range TPH and/or BTEX concentrations measured in previous quarterly groundwater events have been sufficient to indicate that high levels of adsorbed or dissolved-phase petroleum hydrocarbons are present. The MiHpt detector responses served to characterize primary areas of impact and provide a baseline to interpret MiHpt response in potential areas of migration. Subsequent to the completion and real-time data analysis of transects A through C, transect D was added to ensure completeness of the HRSC of the lateral and vertical extents of the dissolved-phase plume.

The MiHpt logs, provided in Columbia Technologies' HRSC report (refer to Appendix A), and sampling locations were presented on an interactive Columbia Technologies Web site after each location was finished. Similar to the OIP surveys, Columbia Technologies manipulated the MiHpt surveys through its interactive graphical software to allow for multiple cross sections displaying the MiHpt responses across the Site to help reviewers understand the dissolved-phase plume distribution and to guide the high-resolution groundwater sampling decisions.

The selected high-resolution groundwater samples were submitted for laboratory analysis of the following IHSs:

- Gasoline-range TPH
- BTEX

These groundwater samples were also monitored and analyzed for the following geochemical parameters to evaluate the biodegradation processes at the Site:

- Nitrate
- Manganese
- Ferrous iron
- Sulfate
- CH_4
- Dissolved CO_2

The following typical groundwater quality parameters were also monitored:

- Dissolved O_2
- Oxygen reduction potential
- EC
- pH
- Temperature
- Turbidity

Appendix B provides the water field sampling data sheets, which recorded the above parameters for each high-resolution groundwater sampling activity.

4.5.1 Dissolved-Phase Plume Relative Hydraulic Conductivity Measurements

During the HPT surveys (refer to Figure 4-3), relative hydraulic conductivities of the targeted zones were also measured. Water was injected as the HPT tool was advanced. The pressure sensor measures responses of the soils to water injection, identifying the ability of the soils to transmit water. The measured data output includes EC, and injection flow and pressure. The hydraulic conductivity values are calculated by an HPT software using the injection flow and pressure data.

Table 4-1 presents the range of calculated estimated hydraulic conductivities for the targeted zones at the Site. Overall, the data indicated that the silts, sandy silts, and clayey silts units underlying the Site have low hydraulic conductivities, in the range of approximately 0.10 to 0.30 foot per day (ft/day), and would be classified as confining units. These confining units serve primarily as storage zones. In contrast, the fine- to coarse-grained sand units and gravel units that are interbedded with the confining units have hydraulic conductivities in the range of approximately 5 to 73 ft/day and indicate that these transport units enable the transportation of the gasoline-range TPH and associated VOCs through these zones. The estimated range of hydraulic conductivities at the Site was approximately 0.10 to 73 ft/day (refer to Table 4-1). Graphical presentations of the HPT surveys conducted by Columbia Technologies and the range of associated K values can be found in Appendix A.

4.6 Natural Source Zone Depletion Evaluation

NSZD is a combination of processes that reduce the mass of LNAPL in the subsurface. These processes include dissolution of LNAPL constituents into groundwater and volatilization of LNAPL constituents into the vadose zone. These LNAPL constituents can be biodegraded by microbial and/or enzymatic activity (ITRC, 2009a). Qualitative assessment of NSZD relies on the accumulation of evidence for the occurrence of mass redistribution from the source zone to groundwater and the vadose zone, and evidence that NSZD processes are occurring.

Evaluation of the LNAPL NSZD as a viable option for managing the remaining contamination at the Site was conducted in two approaches: one involving soil vapor points monitoring wells and the other involving CO_2 flux chambers.

4.6.1 Soil Vapor Points Monitoring Wells and Vapor Gradient Measurement

Characterization of current conditions in the vadose zone involved installation of soil vapor points monitoring wells at four locations to measure, at each location, three separate depths in the vadose zone. The depths targeted the shallow, medium, and deep zones above the LNAPL. The shallow soil vapor point depth was placed 1 foot bgs. The deep soil vapor point depth was placed above the LNAPL, and the medium soil vapor point was placed in between the shallow and deep zones. The locations of the soil vapor points monitoring wells were selected based on the OIP and MiHpt surveys observations. Their locations (SVP-01 through SVP-04) were adjacent to locales that had exhibited the highest responses for residual LNAPL (refer to Figure 4-4).

At each location, the three soil vapor points were nested into one soil vapor point monitoring well, each probe spaced laterally with approximately 1 foot between each point. Figure 4-5 shows the configuration of installation of the multiple soil vapor points monitoring wells, which involves installing three vapor points in a triangular formation using the direct-push drilling method.

The actual depth of each soil vapor point was determined by evaluating the OIP, MiHpt, and HPT data. For each location, a vapor screen (6 inches in length) was installed with Teflon tubing extended up to the ground surface and into a common monument, and with a polyvinyl chloride ball valve on each tube. Each Teflon tubing segment was labeled to identify each probe and its corresponding depth. Each cluster of vapor points was directed into a common 8-inch-by-12-inch, traffic-rated, flush monument.

Monitoring of the soil gas in the vadose zone, including CO_2, O_2, and CH_4, at multiple locations and multiple depths allows for the evaluation of soil vapor gradients, with results indicating whether NSZD is occurring. On December 5 and 6, 2018, MFA monitored the soil vapor from each tubing via a multi-gas meter pump. Table 4-2 presents the field monitoring of soil gas parameters (CO_2, O_2, and CH_4) for each location.

Overall, the soil vapor gradients indicate profiles of decreasing O_2, increasing CO_2, and/or increasing CH_4 concentrations with depth to the residual LNAPL (refer to Table 4-2 and Figure 4-6). These profile results indicate biodegradation. The thickness and density of the CH_4 affect the rate of biodegradation.

4.6.2 Carbon Dioxide Flux Chambers and Measurements

Additional NSZD evaluation involved CO_2 flux chambers, known as E-Flux chambers, and associated laboratory analyses to determine the contribution from natural degradation of the residual petroleum, following ITRC and American Petroleum Institute (API) guidances. The CO_2 data provide an estimate of the rate of natural depletion. These data are an essential component in showing that biodegradation is actually occurring.

To characterize current conditions in the vadose zone, five CO_2 flux chambers (EFLUX-01 through EFLUX-05) were installed at the Site (refer to Figure 4-4).

The passive CO_2 flux traps capture the CO_2 emanating from the soil surface over multiple days. The traps were field-deployed on December 5, 2019, and subsequently collected and capped on December 14, 2019. The traps were then shipped back to the vendor for laboratory analysis.

After the cross-sectional capture area and the deployment time had been established, the cumulative CO_2 mass released by the soil (and captured by the trap) was used to calculate the flux. The standard practice for passive flux traps is to analyze both total carbon and 14C (radiocarbon dating by atomic mass spectroscopy) to differentiate the contributions to the sample from modern CO_2 (background generated from natural organic matter in the soil) and fossil fuel CO_2 (generated from biodegradation of LNAPL contaminants) (ITRC, 2009a).

The initial measurement of the CO_2 flux measurement at the Site, 350 gallons per acre per year (gal/ac/yr), falls within the range of CO_2 flux measurements for facilities undergoing NSZD (refer to Figures 4-7 and 4-8). Analytical results for these CO_2 flux chambers are provided in the Columbia Technologies report (refer to Appendix A).

The NSZD measurement rates serve as a basis for assessing NSZD as a long-term site management strategy and remedy.

4.7 Potential Vapor Intrusion Concerns Evaluation

While a designated vapor intrusion evaluation was not conducted during the HRSC phase of site work, the accumulated data from groundwater monitoring events show the presence of residual LNAPL and elevated concentrations of TPH-gas and petroleum-fuel-associated VOCs (at concentrations above MTCA Method A CULs) at locations adjacent to existing buildings (including the Xochimilco Mexican Restaurant and the former One Love Smoke Shop) at the Site, indicating a high potential for vapor intrusion.

Additionally, indications of petroleum-hydrocarbons-associated VOCs, at depths less than 15 feet bgs and within approximately 30 feet laterally of the restaurant, were verified during the OIP and MiHpt surveys.

5 HIGH-RESOLUTION SAMPLING AND ANALYSIS

5.1 High-resolution Soil Sampling

Based on the findings from the OIP surveys, locations for high-resolution soil sampling were targeted. The designated depth for high-resolution soil sampling at each boring was determined by the highest OIP signatures at each depth interval. High-resolution soil cores were collected through the apparent LNAPL horizon. The targeted sampling intervals were selected based on the OIP observations and field screening via a photoionization detector (PID).

Using a direct-push drilling rig, all borings were continuously cored and logged for lithologic description and field screened with PID). Additionally, visual and olfactory observations of the soil were recorded.

Using a direct-push drilling rig, all borings were continuously cored and logged for lithologic description and field screened with a PID. Additionally, visual and olfactory observations of the soil were recorded. Selected soil samples from each boring were containerized and submitted for laboratory analysis.

All direct-push drilling fieldwork activities including samples collection, handling, and documentation followed the procedures outlined in the HRSC Work Plan (MFA, 2018).

In all, 13 OIP borings (OIP-01 through OIP-13—refer to Figure 4-1) were advanced. The locations of the selected high-resolution soil samples (refer to Figure 5-1) are as follows:

- OIP-02—located adjacent north of monitoring well KMW-10, where LNAPL (approximately 0.29 to 0.58 foot thick in 2016 through 2018—refer to Table 3-1) has been continuously documented. The OIP responses were highest from 10 to 23 feet bgs. Ten high-resolution soil samples were collected from this depth range (refer to Table 5-1).
- OIP-06—located adjacent east and downgradient of monitoring well YMW-1, where elevated concentrations of gasoline-range TPH in groundwater (ranging from 11,000 to 64,000 micrograms per liter [ug/L] in 2017 through 2018; refer to Table 2-1) have been documented. OIP responses were highest from 8.5 to 14 feet bgs. Five high-resolution soil samples were collected from this depth range (refer to Table 5-1).
- OIP-07—located southeast and downgradient of monitoring well YMW-2, where elevated concentrations of gasoline-range TPH in groundwater (ranging from 6,600 to 17,000 ug/L in 2017 through 2018; refer to Table 2-1) have been documented. OIP responses were highest from 14 to 21 feet bgs. Six high-resolution soil samples were collected from this depth range (refer to Table 5-1).
- OIP-10—located adjacent north of monitoring well MWG-3, where LNAPL (approximately 0.02 to 0.11 foot thick in 2016 through 2018—refer to Table 3-1) has been documented. The OIP responses were highest from 4 to 12 feet bgs. Nine high-resolution soil samples were collected from this depth range (refer to Table 5-1).

The interval of the targeted high-resolution soil samples ranged from 0.5 to 1 foot. The soil cores were collected through the apparent LNAPL horizon.

Borings were decommissioned with bentonite chips or with bentonite grout in accordance with WAC 173-160, Minimum Standards for Construction and Maintenance of Wells.

Investigation-derived waste (IDW) included soil cuttings, purged groundwater, decontamination fluids, and sampling debris. The IDW was stored in a designated area on the Property in drums approved by the Washington State Department of Transportation. The drums were labeled with their contents, the approximate volume of material, the date of collection, and the origin of the material. The drums will be disposed of at a regulated landfill pending characterization.

Under standard chain-of-custody procedures, the samples were submitted to Friedman & Bruya, Inc. laboratory (FBI) of Seattle, Washington, for analysis. The samples were analyzed for IHS by the following analytical methods:

- Gasoline-range TPH by the Northwest Total Petroleum Hydrocarbons (NWTPH) Method Gx
- BTEX by USEPA Method 8021B with USEPA 5035 sample preparation

All soil samples were submitted for standard turnaround times for the above-listed analytes.

5.1.1 High-resolution Soil Analytical Results

The laboratory analytical report for the high-resolution soil sampling is provided in Appendix C. Analytical data and the laboratory's internal QA/QC data were reviewed to assess whether they meet project-specific data quality objectives. This review was performed consistent with accepted USEPA procedures for evaluating laboratory analytical data and appropriate laboratory and method-specific guidelines (USEPA, 2004, 2008). A data validation memorandum summarizing data evaluation procedures, usability of data, and deviations from specific field and/or laboratory methods for the investigation data is presented in Appendix D. The data are considered acceptable for their intended use, with the appropriate data qualifiers assigned.

Table 5-1 summarizes the analytical results of high-resolution soil samples submitted for analysis. The results indicate the following:

- The impacted soils zone, from approximately 10 to 15 feet bgs, at the western area of the Site, as noted at OIP-2, OIP-6, and OIP-7, likely represents the smear zone of the TPH-gas-impacted subsurface.

- Because of an approximately 3-foot difference in elevation between the western area of the Site (i.e., the former Tiger Oil property and the parking area associated with the Xochimilco Mexican Restaurant) and the central-eastern area of the Site (i.e., the Safeway parking lot), the smear zone present in the central-eastern area was observed at approximately 4 to 11 feet bgs, as noted at OIP-10 (refer to Table 5-1).

5.2 High-resolution Groundwater Sampling

Based on the findings from the MiHpt surveys, locations for high-resolution groundwater sampling were targeted. The designated depth for high-resolution groundwater sampling at each boring was determined by the highest MiHpt signatures at each depth interval and the locales of interest in further identifying the boundaries of the lateral and vertical extents of the dissolved-phase plume. All borings were continuously cored using a direct-push drilling rig. Samples were prepared, handled, and documented per the procedures outlined in the HRSC work plan (MFA, 2018).

In all, 15 MiHpt borings (MiHpt-01 through MiHpt-15—refer to Figure 4-2) were advanced in the east and southeastern areas of the Site to evaluate the extent of the dissolved-phase plume. The locations of the selected high-resolution groundwater samples (refer to Figure 5-2) are as follows:

- MiHpt-03—located downgradient and southeast of monitoring wells MW-9 and MW-13 to evaluate the south-southeast boundary of the dissolved-phase plume and verify that the plume has attenuated in this area of the Site (refer to Table 2-1). Four high-resolution groundwater samples were collected from the depth range of 9 to 17 (refer to Table 5-2).
- MiHpt-05—located downgradient and southeast of monitoring well MWG-3, where high responses during the MiHpt surveys were observed, to evaluate the central area of the dissolved-phase plume. Three high-resolution groundwater samples were collected from the depth range of 9 to 18 (refer to Table 5-2).
- MiHpt-10—located downgradient and southeast of monitoring well S-2, where high responses during the MiHpt surveys were observed, to evaluate the northern lateral and vertical extents of the dissolved-phase plume. Three high-resolution groundwater samples were collected from the depth range of 10 to 18 (refer to Table 5-2).

The targeted high-resolution groundwater samples were collected from a 2-foot-interval range.

Under standard chain-of-custody procedures, the samples were submitted to FBI for analysis. The following analytical methods were used to analyze the samples for IHSs:

- Gasoline-range TPH by the NWTPH Method Gx
- BTEX by USEPA Method 8021B with USEPA 5035 sample preparation

The high-resolution groundwater samples were also analyzed for the following geochemical parameters to evaluate the biodegradation processes at the Site:

- Manganese by USEPA Method 6020
- Sulfate by USEPA Method 375.2
- CH_4 by RSK 175
- Dissolved CO_2 by ASTM D513-16

Ferrous iron and nitrate were measured in the field by the HACH Model IR-18C ferrous iron instrument and the YSI Professional Pro Plus instrument, respectively. Calibration of these instruments followed the procedures outlined in the HRSC work plan (MFA, 2018).

All groundwater samples were submitted for standard turnaround times for the above-listed analytes.

The high-resolution groundwater samples were field-monitored for the following groundwater quality parameters:

- Dissolved O_2
- Oxygen reduction potential

- EC
- pH
- Temperature
- Turbidity

An LNAPL product was collected from monitoring well KMW-10 and submitted for the following laboratory analyses:

- EPH by the EPH Method
- VPH by the VPH Method

The LNAPL was also sampled and tested on the OIP.

Custody of samples for all sampled media was tracked from point of origin through analysis and disposal, using a chain-of-custody form filled out with the appropriate sample and analytical information after samples were collected.

5.2.1 High-resolution Groundwater Analytical Results

The laboratory analytical report for the high-resolution groundwater sampling is provided in Appendix C. A data validation memorandum summarizing data evaluation procedures, usability of data, and deviations from specific field and/or laboratory methods for the investigation data is presented in Appendix D. The data are considered acceptable for their intended use, with the appropriate data qualifiers assigned

Table 5-2 summarizes the analytical results of high-resolution groundwater samples submitted for analysis. Overall, the results of a review of the high-resolution groundwater analytical results in concert with the quarterly/semiannual groundwater monitoring events analytical results indicate the following:

- The lateral and vertical extents of the dissolved-phase plume have been characterized.
- The dissolved-phase plume has diminished and attenuated downgradient and east-southeast from the source area.
- Groundwater analytical results from quarterly and semiannual groundwater monitoring events are representative of the attenuating dissolved-phase plume, in particular in the distal end of the plume.
- The central portion of the dissolved-phase plume, adjacent east-southeast of the petroleum-contaminated soil remedial action area to the southeast toward MiHpt-05/KMW-6 (refer to Figure 4-5), appears to represent the core area of the dissolved-phase plume, with elevated TPH-gas and benzene concentrations above their respective MTCA Method A CULs (refer to Tables 2-1 and 5-2).

5.2.2 LNAPL Analytical Results

Laboratory analysis of the LNAPL sample collected from KMW-10 indicates the following:

- The petroleum fractions by carbon range are indicative of a gasoline fuel, with the primary carbons ranging from carbons 5 to 12 both in the EPH and VPH ranges (refer to Table 5-3 and Appendix C).
- Some higher-ranging carbon chains, ranging from carbons 12 to 16 and minor components of carbons 16 to 21, are also identified. The presence of these higher carbon ranges is expected, as gasoline fuels will typically have materials that will boil past the carbons 12 range that are representative of the primary carbon chains for gasoline fuels (refer to Table 5-3).

6 REVISED LNAPL CONCEPTUAL SITE MODEL

The findings from the HRSC in tandem with high-resolution soil and groundwater sampling analytical results enabled correlation and a more rigorous understanding of the impacts/influences of the Site's stratigraphic and lithologic setting on contaminant mass distribution and flux. The HRSC allows for accurate identification and delineation of the LNAPL residual zone and dissolved-phase plume.

Upon completion of the HRSC fieldwork, Columbia Technologies and MFA presented the HRSC findings to the City and Ecology via an Internet webinar-based format. The LNAPL CSM was refined to reflect the findings from the HRSC and contaminant analytical data from the high-resolution soil and groundwater samples.

6.1 Residual LNAPL

The distribution of LNAPL, based on OIP surveys, is presented on Figure 6-1, which shows residual LNAPL adjacent to the Xochimilco Mexican Restaurant and the former One Love Smoke Shop. Soil remedial action could not remove the source and residual petroleum-contaminated soil near these buildings without undermining the integrity of the buildings' foundations. Residual LNAPL is also shown to be present southeast of the former Tiger Oil facility operations (refer to Figures 6-1 and 6-2).

LNAPL was encountered in pockets and lenses in the subsurface and was identified in confining units with thicknesses ranging from approximately 0.4 to 1.1 feet. The depths of these confining units/lenses were variable across the Site, ranging from approximately 8.5 to 13 feet bgs, 14.2 to 15.3 feet bgs, and 18.6 to 20 feet bgs. HRSC indicated the presence of three confining units within 8.5 to 13 feet bgs. Figure 6-3 illustrates the heterogeneous distribution of the LNAPL.

However, groundwater at the Site is unconfined (water table conditions) and was observed from approximately 10.5 to 15 feet bgs during the HRSC fieldwork as compared to a range of 8.3 to 13.6 feet bgs during the November 2018 groundwater event (refer to Table 3-1).

The residual LNAPL was encountered, as expected, at the capillary fringe (air-water interface) and also below the water table. The presence of submerged LNAPL likely indicates the following factors:

- Potentially voluminous historical releases of fuel that suppressed the water table and likely displaced groundwater and caused migration of the petroleum products laterally and vertically deeper into the saturated zone
- Fluctuations in the water table due to irrigation cycles
- Heterogeneity of the subsurface soils

Analytical results of the high-resolution soil samples indicate LNAPL saturation concentrations (C_{sat}). LNAPL was observed in small intervals (approximately 0.4 to 0.8 foot thick) in fine-grained lithologies. These units comprise silts, sandy silts, silty sand, and clayey silts stringers/lenses. HRSC indicate that LNAPL exist both as free-phase liquids and as residual liquids trapped by capillary forces above and below the water table. The presence of measured LNAPL thickness in monitoring wells is a poor indicator of the true thickness of LNAPL.

The residual LNAPL saturation concentrations (C_{res}) are screened against threshold concentrations that indicate whether LNAPL is mobile. The highest C_{sat} range from 1,100 to 2,900 milligrams per kilogram (mg/kg) (refer to Table 5-1 and Figure 6-2). In contrast, according to the API, the threshold for the potential for viable LNAPL recovery is for the C_{res} of the silt to fine- to coarse-grained sands to exhibit TPH-gas concentrations in the range of 3,387 to 10,000 mg/kg for gasoline fuels (API, 2000).

The compiled findings from the HRSC, including predominantly low ranges of hydraulic conductivity in various depths below the water table and dominant presence of heterogeneity and discontinuity of the subsurface conditions, indicate that LNAPL recoverability is unlikely or at least very low. Hence, attempts to extract LNAPL would not be a productive remedial option.

In addition to the OIP and HPT observations, HRSC quantitative data (including the level of saturation of LNAPL in the soil pores and the soils' relative K) indicate that the residual LNAPL is stable and not mobile.

6.2 Dissolved-Phase Groundwater Plume

Based on data analysis, trends of the groundwater quality concentrations from 2015 through 2018, and associated isoconcentration contours of TPH-gas and benzene (refer to Table 2-1 and Figures 3-1 and 3-2), the lateral and vertical extents of the Site's dissolved-phase plume indicate, overall, that the plume is receding, i.e., benzene concentration trends and partial gasoline-range TPH concentration trends within the plume have decreased, and there is a stable plume margin.

Findings from the MiHpt surveys and high-resolution groundwater samples analytical results have further confirmed the state of the dissolved-phase plume (refer to Figure 6-4).

Historical and recent groundwater potentiometric maps indicate a predominantly southeastern groundwater flow direction (refer to Figure 2-5). Findings from the HRSC confirm this groundwater migration pathway.

7 CONCLUSIONS AND RECOMMENDATIONS

The data amassed from the multiple lines of evidence conducted via HRSC provide a pathway for accurate data interpretation and correlation as well as integration of the qualitative with the quantitative data from contaminant laboratory analysis. The direct-sensing equipment enables 3-D spatial analysis of the residual LNAPL and dissolved-phase plume, the plume's mass concentrations and the stratigraphic heterogeneity influencing the contaminant distribution, and LNAPL mobility and immobility.

The Triad systematic planning and approach use a dynamic strategy for the HRSC of the subsurface and hydrogeologic conditions at the Site, resulting in technically defensible and supportive data from multiple lines of evidence to aid in the decision-making process for long-term remedial option and site management. Additionally, the systematic planning and real-time data interpretations with real-time communication strategies and discussions resulted in a comprehensive understanding of the Site, the residual LNAPL, the dissolved-phase plume, and the potential NSZD.

7.1 LNAPL Stability

The findings from HRSC indicate that the Site's thin and discontinuous confining units/lenses influence and impact the contaminant mass distribution and flux.

According to the USEPA, geologic heterogeneity controls mass distribution—about 80 percent of the plume-mass discharge occurs in about 10 percent of the cross-sectional area. The variability and low ranges of hydraulic conductivities associated with thin and discontinuous confining units underlying the Site is a primary factor in controlling the mobile and immobile phases of the LNAPL. Residual LNAPL, as exhibited in the OIP surveys, was observed from 8.5 to 15 feet bgs.

Analytical results from the high-resolution soil samples indicate C_{sat}. The highest C_{sat} range from 1,100 to 2,900 mg/kg. These results are below the C_{res} of 3,387 to 10,000 mg/kg for gasoline fuels, indicating nonmobile LNAPL.

The HRSC data indicate a stable, nonmobile residual LNAPL.

7.2 Hydrostratigraphy and Extents and Impacts of Dissolved-Phase Plume

HRSC allows for accurate identification and delineation of the hydrostratigraphy and dissolved-phase plume. The HPT data indicate zones of good hydraulic permeability, acting as transport zones, interbedded with discontinuous, thin, confining units that are serving as storage zones for petroleum hydrocarbons. The OIP, MiHpt, and HPT observations confirm previous geologic logs and geologic cross-sections of the Site that the underlying units are poorly connected.

Based on the combination of HRSC and groundwater quality analytical results, isoconcentrations indicate that the core of the dissolved-phase plume directly downgradient to the southeast of the former Tiger Oil operations area exhibits the highest concentrations of gasoline-range TPH and BTEX constituents. Overall, it appears that the dissolved-phase plume, notably gasoline-range TPH and benzene, has stabilized and that its lateral extent to the southeast has receded. Groundwater quality concentrations of gasoline-range TPH and benzene have decreased markedly.

7.3 Natural Source Zone Depletion

Overall, the soil vapor gradients indicate profiles of decreasing O_2, increasing CO_2, and/or increasing CH_4 concentrations with depth to the residual LNAPL. These indicate biodegradation. The initial measurement of the CO_2 flux measurement at the Site, 350 gal/ac/yr, falls within the range of CO_2 flux measurements for facilities undergoing NSZD.

7.4 Monitored Natural Attenuation

Geochemical parameters viewed in parallel with generally decreasing trends of the dissolved-phase plume concentrations (gasoline-range TPH and benzene) are also indicative of continuing biodegradation at the Site.

7.5 Potential Vapor Intrusion

There are concerns regarding soil vapors adversely impacting the adjoining parcels, including the adjoining restaurant and retail businesses to the northeast and south, respectively, of the Property. The responses of petroleum hydrocarbons on the OIP and MiHpt in the vadose zone, at depths less than 15 feet bgs and within approximately 30 feet of the Xochimilco Mexican Restaurant, exceed the initial screening levels for potential petroleum vapor intrusion into the buildings, per Ecology Guidance for Evaluating Soil Vapor Intrusion in Washington State: Investigation and Remedial Action. Further vapor intrusion evaluation is warranted.

LIMITATIONS

The services undertaken in completing this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our Client. This report is solely for the use and information of our Client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

The purpose of an environmental assessment is to reasonably evaluate the potential for or actual impact of past practices on a given site area. In performing an environmental assessment, it is understood that a balance must be struck between a reasonable inquiry into the environmental issues and an exhaustive analysis of each conceivable issue of potential concern. The following paragraphs discuss the assumptions and parameters under which such an opinion is rendered.

No investigation is thorough enough to exclude the presence of hazardous materials at a given site. If hazardous conditions have not been identified during the assessment, such a finding should not, therefore, be construed as a guarantee of the absence of such materials on the site.

Environmental conditions that cannot be identified by visual observation may exist at the site. Where subsurface work was performed, our professional opinions are based in part on interpretation of data from discrete sampling locations that may not represent actual conditions at unsampled locations.

Except where there is express concern of our client, or where specific environmental contaminants have been previously reported by others, naturally occurring toxic substances, potential environmental contaminants inside buildings, or contaminant concentrations that are not of current environmental concern may not be reflected in this document.

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TABLES

Table 2-1
Summary of Monitoring Wells Groundwater Analytical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	Collection Date	Indicator Hazardous Substances				
		Benzene	Ethylbenzene	Toluene	Xylenes[a]	Gasoline
Units		ug/L	ug/L	ug/L	ug/L	ug/L
MTCA Method A Cleanup Level (ug/L)		5	700	1,000	1,000	800[b]
KMW-5	05/27/2015	1 U	1 U	1 U	1 U	100 U
	02/02/2016	1 U	1 U	1 U	1 U	100 U
	05/09/2016	1 U	1 U	2 U	1 U	100 U
	07/25/2016	1 U	1 U	1 U	1 U	100 U
	11/07/2016	1 U	1 U	1 U	1 U	100 U
	02/14/2017	1 U	1 U	1 U	1 U	100 U
	05/08/2017	1 U	1 U	1 U	1 U	100 U
	08/16/2017	1 U	1 U	1 U	1 U	100 U
	11/06/2018	1 U	1 U	1 U	1 U	100 U
KMW-6	05/28/2015	**47**	**1.6**	1 U	1 U	100 U
	11/03/2015	**15**	**18**	**7.4**	**35.6**	**410**
	02/01/2016	**42**	**22**	4 U	**7.4**	100 U
	05/09/2016	**69**	**33**	3 U	**3**	**270**
	07/25/2016	**31**	**32**	**2**	**14**	**480**
	11/08/2016	**13**	**48**	1 U	**9.9**	**470**
	02/15/2017	**46**	**11**	1 U	**3.2**	**250**
	05/08/2017	**170**	**38**	**1.8**	**15.9**	**830**
	08/15/2017	**36**	**23**	4 U	**10.5**	**760**
	11/06/2018	**5.5**	**13**	1 U	**4.7**	**430**
KMW-7	05/29/2015	**8.4**	**14**	**2**	**88**	**620**
	11/02/2015	**13**	**21**	1 U	**5.6**	**350**
	02/03/2016	**47**	**41**	1 U	**2.6**	**610**
	05/10/2016	**25**	**21**	2.3 U	1 U	**250**
	07/26/2016	**3.1**	**1.5**	1 U	1 U	100 U
	11/09/2016	**5**	**6.3**	1 U	**3**	100 U
	02/14/2017	**12**	**30**	1 U	**5.1**	**200**
	05/09/2017	**110**	**150**	5 U	**196**	**1,800**
	08/16/2017	1 U	1 U	1 U	1 U	100 U
	11/08/2018	**1.3**	**8.3**	1 U	**3.3**	**120**
KMW-8	05/29/2015	1 U	1 U	1 U	1 U	100 U
KMW-10	05/29/2015	**830**	**1,200**	**4,000**	**6,400**	**81,000**

Table 2-1
Summary of Monitoring Wells Groundwater Analytical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	Collection Date	Indicator Hazardous Substances				
		Benzene	Ethylbenzene	Toluene	Xylenes[a]	Gasoline
Units		ug/L	ug/L	ug/L	ug/L	ug/L
MTCA Method A Cleanup Level (ug/L)		5	700	1,000	1,000	800[b]
KMW-14	05/28/2015	**1.9**	1 U	1 U	1 U	100 U
	11/03/2015	**5.5**	1 U	1 U	1 U	100 U
	02/02/2016	**3**	1 U	1 U	1 U	100 U
	05/09/2016	1 U	1 U	1.9 U	1 U	100 U
	07/25/2016	1 U	1 U	1 U	1 U	100 U
	11/07/2016	1 U	1 U	1 U	1 U	100 U
	02/15/2017	**1.2**	1 U	1 U	1 U	100 U
	05/08/2017	1 U	1 U	1 U	1 U	100 U
	08/15/2017	1 U	1 U	1 U	1 U	100 U
	11/06/2018	1 U	1 U	1 U	1 U	100 U
KMW-15	11/03/2015	1 U	1 U	1 U	1 U	100 U
	02/02/2016	1 U	1 U	1 U	1 U	100 U
	05/09/2016	1 U	1 U	1.1 U	1 U	100 U
	07/25/2016	1 U	1 U	1 U	1 U	100 U
	11/07/2016	1 U	1 U	1 U	1 U	100 U
	02/15/2017	1 U	1 U	1 U	1 U	100 U
	05/08/2017	1 U	1 U	1 U	1 U	100 U
	08/15/2017	1 U	1 U	1 U	1 U	100 U
	11/06/2018	1 U	1 U	1 U	1 U	100 U
KMW-16	05/28/2015	**60**	**9.6**	1 U	**5.1**	**280**
	11/03/2015	1 U	1 U	1 U	1 U	100 U
	02/02/2016	1 U	1 U	1 U	1 U	**200**
	05/09/2016	**7.6**	1 U	1 U	1 U	**200**
	07/25/2016	1 U	1 U	1 U	1 U	100 U
	11/07/2016	1 U	1 U	1 U	1 U	100 U
	05/08/2017	**2.9**	1 U	1 U	1 U	**160**
	08/15/2017	1 U	1 U	1 U	1 U	100 U
	11/06/2018	1 U	1 U	1 U	1 U	100 U
KMW-18	05/27/2015	1 U	1 U	1 U	1 U	100 U
KMW-24	05/29/2015	1 U	1 U	1 U	1 U	100 U
		1.7	1 U	1 U	1 U	100 U

Table 2-1
Summary of Monitoring Wells Groundwater Analytical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	Collection Date	Indicator Hazardous Substances				
		Benzene	Ethylbenzene	Toluene	Xylenes[a]	Gasoline
Units		ug/L	ug/L	ug/L	ug/L	ug/L
MTCA Method A Cleanup Level (ug/L)		5	700	1,000	1,000	800[b]
MW-9	05/28/2015	**1,200**	**740**	**1,900**	**2,780**	**28,000**
	11/03/2015	**1,800**	**720**	**1,400**	**2,240**	**18,000**
	02/02/2016	**1,800**	**850**	**1,500**	**2,670**	**19,000**
	05/10/2016	**1,500**	**960**	**1,700**	**2,810**	**26,000**
	07/26/2016	**1,400**	**1,300**	**2,100**	**3,600**	**26,000**
	11/08/2016	**810**	**1,300**	**1,300**	**3,300**	**21,000**
	02/15/2017	**390**	**1,300**	**960**	**3,200**	**21,000**
	05/09/2017	**300**	**990**	**760**	**2,270**	**15,000**
	08/16/2017	**380**	**860**	**460**	**1,800**	**17,000**
	11/07/2018	**67**	**1,200**	**220**	**1,850**	**16,000**
MW-10	11/02/2015	1 U	1 U	1 U	1 U	100 U
	02/03/2016	1 U	1 U	1 U	1 U	100 U
	05/10/2016	1 U	1 U	1 U	1 U	100 U
	07/26/2016	1 U	1 U	1 U	1 U	100 U
	11/07/2016	1 U	1 U	1 U	1 U	100 U
	02/14/2017	1 U	1 U	1 U	1 U	100 U
	05/09/2017	1 U	1 U	1 U	1 U	100 U
	08/16/2017	1 U	1 U	1 U	1 U	100 U
	11/08/2018	1 U	1 U	1 U	1 U	100 U
MW-11	07/26/2016	**110**	**1,400**	**150**	**15,900**	**67,000**
	11/08/2016	**93**	**1,800**	**110**	**12,490**	**52,000**
	05/09/2017	**57**	**1,900**	50 U	**11,100**	**54,000**
	08/16/2017	100 U	**1,500**	100 U	**8,500**	**90,000**
MW-13	05/28/2015	**32**	**1,500**	**510**	**12,500**	**92,000**
	08/16/2017	**6.5**	**340**	**23**	**870**	**19,000**
	11/07/2018	1 U	**69**	**2.2**	**100**	**4,300**
MWG-1	05/28/2015	1 U	1 U	1 U	1 U	100 U
MWG-2	02/03/2016	1 U	1 U	1 U	1 U	100 U
	05/09/2016	1 U	1 U	2.1 U	1 U	100 U
	07/26/2016	1 U	1 U	1 U	1 U	100 U
	11/07/2016	1 U	1 U	1 U	1 U	100 U
	02/14/2017	1 U	1 U	1 U	1 U	100 U
	05/09/2017	1 U	1 U	1 U	1 U	100 U
	08/14/2017	1 U	1 U	1 U	1 U	100 U
	11/06/2018	1 U	1 U	1 U	1 U	100 U

Table 2-1
Summary of Monitoring Wells Groundwater Analytical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	Collection Date	Indicator Hazardous Substances				
		Benzene	Ethylbenzene	Toluene	Xylenes[a]	Gasoline
Units		ug/L	ug/L	ug/L	ug/L	ug/L
MTCA Method A Cleanup Level (ug/L)		5	700	1,000	1,000	800[b]
MWG-3	05/28/2015	**3,300**	**2,700**	**710**	**8,000**	**64,000**
	08/14/2017	**1,100**	**1,100**	50 U	**2,570**	**27,000**
S-1	05/28/2015	1 U	**7.2**	1 U	**3.2**	**200**
S-2	05/27/2015	**1,300**	**200**	10 U	**56**	**1,600**
	11/07/2016	**3,000**	**570**	**35**	**337**	**3,700**
	02/14/2017	**2,800**	**530**	**21**	**274**	**3,900**
	05/08/2017	**3,300**	**710**	100 U	**560**	**14,000**
	08/14/2017	**2,400**	**500**	50 U	**395**	**5,400**
	11/08/2018	**1,800**	**510**	**28**	**248**	**4,300**
YMW-1	11/04/2015	**990**	**470**	**1,400**	**1,430**	**11,000**
	02/02/2016	**2,200**	**840**	**3,900**	**3,350**	**29,000**
	05/10/2016	**1,600**	**750**	**2,500**	**2,750**	**21,000**
	07/27/2016	**2,400**	**930**	**3,200**	**3,800**	**24,000**
	11/08/2016	**3,300**	**1,100**	**3,400**	**4,400**	**30,000**
	02/15/2017	**3,200**	**1,500**	**2,900**	**5,100**	**31,000**
	05/09/2017	**4,400**	**1,500**	**2,100**	**5,700**	**42,000**
	08/17/2017	**4,500**	**2,100**	**4,100**	**8,000**	**64,000**
	11/07/2018	**920**	**670**	**140**	**1,610**	**11,000**
YMW-2	11/04/2015	**72**	**150**	**130**	**770**	**3,700**
		76	**160**	**140**	**840**	**4,100**
	02/01/2016	**380**	**300**	**630**	**2,510**	**13,000**
		380	**310**	**650**	**2,630**	**13,000**
	05/10/2016	**240**	**180**	**570**	**1,070**	**6,600**
		240	**190**	**590**	**1,110**	**8,500**
	07/27/2016	**1,200**	**1,500**	**2,800**	**8,000**	**52,000**
		1,200	**1,500**	**2,800**	**8,200**	**53,000**
	11/08/2016	**180**	**1,000**	**230**	**3,210**	**23,000**
		190	**1,000**	**230**	**3,220**	**21,000**
	02/15/2017	**300**	**440**	**360**	**1,380**	**9,200**
		340	**500**	**420**	**1,530**	**11,000**
	05/09/2017	**380**	**330**	**150**	**810**	**6,700**
		370	**320**	**140**	**790**	**6,600**
	08/17/2017	**69**	**650**	**14**	**740**	**17,000**
		67	**630**	**13**	**730**	**17,000**
	11/07/2018	**39**	**380**	**8.8**	**189**	**9,300**

Table 2-1
Summary of Monitoring Wells Groundwater Analytical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	Collection Date	Indicator Hazardous Substances				
		Benzene	Ethylbenzene	Toluene	Xylenes[a]	Gasoline
Units		ug/L	ug/L	ug/L	ug/L	ug/L
MTCA Method A Cleanup Level (ug/L)		5	700	1,000	1,000	800[b]
YMW-3	02/01/2016	**3,100**	**1,200**	**1,800**	**5,700**	**31,000**
	05/10/2016	**2,000**	**980**	**1,100**	**3,210**	**23,000**
	07/26/2016	**2,000**	**1,400**	**2,100**	**5,100**	**33,000**
	11/09/2016	**2,800**	**2,200**	**4,500**	**9,000**	**48,000**
	02/15/2017	**990**	**2,400**	**3,600**	**8,200**	**47,000**
	05/09/2017	**900**	**1,900**	**1,100**	**4,200**	**33,000**
	08/16/2017	**810**	**1,800**	**1,300**	**7,300**	**52,000**
	11/08/2018	**75**	**1,800**	**450**	**5,800**	**38,000**
		80	**1,900**	**470**	**6,000**	**39,000**

NOTES:

Detected results are indicated by bold font.

Field duplicate collected when two values are shown for the same collection date for a single monitoring well location.

Shaded results indicate an exceedance of the MTCA Method A cleanup level.

MTCA = Model Toxics Control Act.

U = result was not detected at or above the reporting limit.

ug/L = micrograms per liter.

[a] Xylenes are the sum of m,p- and o-xylene. Non-detect results are summed at half of the reporting limit value. The highest reporting limit value is used when both results are non-detect.

[b] MTCA Method A cleanup level for gasoline with benzene present.

Table 2-2
Summary of Groundwater Geochemical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	Collection Date	Dissolved Oxygen[a] (mg/L)	Oxidation Reduction Potential[b] (mV)	Ferrous Iron (mg/L)	Manganese[c] (mg/L)	Methane (mg/L)	Nitrate (as N) (mg/L)	Sulfate (mg/L)
KMW-5	11/06/2018	3.75	37.6	0	1.1	0.001 U	3.2	26
KMW-6	11/06/2018	2.11	-43.4	0.25	1.3	0.23	2.2	19
KMW-7	11/08/2018	7.94	70	0	0.021	0.019	4.1	21
KMW-14	11/06/2018	0.73	-25.9	0.75	2.6	0.066	0.5	26
KMW-15	11/06/2018	5.49	30.1	0	0.029	0.0016	4.3	26
KMW-16	11/06/2018	0.54	-65.3	0.25	1.7	0.052	0.51	14
MW-9	02/15/2017	0.8	-34.8	2	3.8	--	0.05 U	5 U
	08/16/2017	2.28	-73.2	2.25	3.6	--	0.05 U	5 U
	11/07/2018	1.48	-82.3	3.5	4.4	1.4	0.081	5 U
MW-10	11/08/2018	22.98	115.7	0	0.019	0.001 U	5.7	24
MW-13	11/07/2018	2.5	-52.6	1.5	1.2	0.13	2.0	18
MWG-2	11/06/2018	5.34	48.2	--	0.032	0.0021	4.7	30
S-2	11/08/2018	0.89	-119.3	0.75	6.5	0.94	0.12	7.6
YMW-1	02/15/2017	0.56	-95	--	--	--	--	--
	08/17/2017	1.81	-109.1	0.75	3.3	--	0.05 U	5 U
	11/07/2018	0.35	-142.3	3.0	1.7	0.97	0.5	7.7
YMW-2	02/15/2017	0.83	-44.6	1	1.7	--	0.69	21
	08/17/2017	0.8	-107.1	0.25	0.96	--	0.05 U	16
	11/07/2018	0.83	-143.0	--	1.5	0.49	0.05 U	26
YMW-3	02/15/2017	0.34	-99.3	1.5	1.9	--	0.08	5 U
	08/16/2017	0.1	-169.1	--	--	--	--	--
	11/08/2018	0.67	-130.7	1.0	0.86	0.67	0.069	20 U

Table 2-2
Summary of Groundwater Geochemical Results
Former Tiger Oil Site
City of Yakima
Yakima, Washington

NOTES:

-- = not analyzed.

mg/L = milligrams per liter.

mV = millivolts.

N = nitrogen.

U = result is non-detect.

[a] Measured in the field, using a YSI meter and flow-through cell.

[b] Measured in the field, using a Hach test kit, Model IR-18C.

[c] Total manganese.

Table 3-1
Water Level Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	MP Elevation (feet, NAVD 88)	Measurement Date	LNAPL Thickness (feet)	Depth to Water (feet)	Depth to Water Corrected for Presence of LNAPL (feet)[b]	Groundwater Elevation (feet, NAVD 88)	Change in Groundwater Elevation Level (feet)[a]
KMW-5	1082.85	05/27/2015	--	9.11	NA	1073.74	--
		02/01/2016	--	8.78	NA	1074.07	0.33
		05/09/2016	--	8.72	NA	1074.13	0.06
		07/25/2016	--	8.10	NA	1074.75	0.62
		11/07/2016	--	8.35	NA	1074.5	-0.25
		02/14/2017	--	8.95	NA	1073.9	-0.6
		05/08/2017	--	8.51	NA	1074.34	0.44
		08/14/2017	--	7.64	NA	1075.21	0.87
		11/06/2018	--	8.62	NA	1074.23	-0.98
KMW-6	1083.58	05/28/2015	--	8.82	NA	1074.76	--
		11/03/2015	--	8.43	NA	1075.15	0.39
		02/01/2016	--	8.45	NA	1075.13	-0.02
		05/09/2016	--	8.36	NA	1075.22	0.09
		07/25/2016	--	7.71	NA	1075.87	0.65
		11/07/2016	--	7.94	NA	1075.64	-0.23
		02/15/2017	--	8.65	NA	1074.93	-0.71
		05/08/2017	--	8.06	NA	1075.52	0.59
		08/14/2017	--	7.18	NA	1076.40	0.88
		11/06/2018	--	8.30	NA	1075.28	-1.12
KMW-7	1091.96	05/29/2015	--	13.47	NA	1078.49	--
		11/02/2015	--	12.64	NA	1079.32	0.83
		02/01/2016	--	12.85	NA	1079.11	-0.21
		05/09/2016	--	12.69	NA	1079.27	0.16
		07/25/2016	--	11.98	NA	1079.98	0.71
		11/07/2016	--	12.09	NA	1079.87	-0.11
		02/14/2017	--	13.10	NA	1078.86	-1.01
		05/08/2017	--	12.30	NA	1079.66	0.80
		08/14/2017	--	11.40	NA	1080.56	0.90
		11/06/2018	--	12.45	NA	1079.51	-1.05
KMW-8	1092.11	05/29/2015	--	13.48	NA	1078.63	--
KMW-10[c]	1090.63	05/29/2015	--	13.10	NA	1077.53	--
		07/25/2016	0.43	12.25	11.93	1078.70	--
		11/07/2016	0.58	12.50	12.07	1078.57	-0.14
		02/15/2017	0.40	13.30	13.00	1077.63	-0.93
		05/08/2017	0.32	12.51	12.27	1078.36	0.73
		08/14/2017	0.29	11.48	11.26	1079.37	1.01
		11/06/2018	0.37	12.70	12.42	1078.21	-1.16

Table 3-1
Water Level Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	MP Elevation (feet, NAVD 88)	Measurement Date	LNAPL Thickness (feet)	Depth to Water (feet)	Depth to Water Corrected for Presence of LNAPL (feet)[b]	Groundwater Elevation (feet, NAVD 88)	Change in Groundwater Elevation Level (feet)[a]
KMW-14	1082.40	05/28/2015	--	12.66	NA	1069.74	--
		11/03/2015	--	12.37	NA	1070.03	0.29
		02/01/2016	--	12.27	NA	1070.13	0.10
		05/09/2016	--	12.29	NA	1070.11	-0.02
		07/25/2016	--	11.86	NA	1070.54	0.43
		11/07/2016	--	11.98	NA	1070.42	-0.12
		02/15/2017	--	12.62	NA	1069.78	-0.64
		05/08/2017	--	12.02	NA	1070.38	0.60
		08/14/2017	--	11.38	NA	1071.02	0.64
		11/06/2018	--	12.22	NA	1070.18	-0.84
KMW-15	1083.54	11/03/2015	--	10.90	NA	1072.64	--
		02/01/2016	--	10.86	NA	1072.68	0.04
		05/09/2016	--	10.88	NA	1072.66	-0.02
		07/25/2016	--	10.36	NA	1073.18	0.52
		11/07/2016	--	10.51	NA	1073.03	-0.15
		02/15/2017	--	11.14	NA	1072.40	-0.63
		05/08/2017	--	10.56	NA	1072.98	0.58
		08/14/2017	--	9.84	NA	1073.70	0.72
		11/06/2018	--	10.73	NA	1072.81	-0.89
KMW-16	1083.27	05/28/2015	--	11.05	NA	1072.22	--
		11/03/2015	--	10.67	NA	1072.60	0.38
		02/02/2016	--	10.67	NA	1072.60	0.00
		05/09/2016	--	10.66	NA	1072.61	0.01
		07/25/2016	--	10.14	NA	1073.13	0.52
		11/07/2016	--	10.27	NA	1073.00	-0.13
		2/15/2017[d]	--	--	--	--	--
		05/08/2017	--	10.31	NA	1072.96	--
		08/15/2017	--	9.58	NA	1073.69	0.73
		11/06/2018	--	10.47	NA	1072.80	-0.89
KMW-18	1085.34	05/27/2015	--	9.70	NA	1075.64	--
KMW-24	1087.47	05/29/2015	--	10.25	NA	1077.22	--

Table 3-1
Water Level Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	MP Elevation (feet, NAVD 88)	Measurement Date	LNAPL Thickness (feet)	Depth to Water (feet)	Depth to Water Corrected for Presence of LNAPL (feet)[b]	Groundwater Elevation (feet, NAVD 88)	Change in Groundwater Elevation Level (feet)[a]
MW-7	1090.30	05/29/2015	1.44	13.78	12.70	1077.60	--
		11/04/2015	0.29	12.20	11.98	1078.32	0.72
		02/01/2016	0.29	12.30	12.08	1078.22	-0.10
		05/09/2016	0.32	12.21	11.97	1078.33	0.11
		07/25/2016	0.30	11.50	11.28	1079.03	0.69
		11/07/2016	0.28	11.58	11.37	1078.93	-0.09
		02/15/2017	0.27	12.42	12.22	1078.08	-0.85
		05/08/2017	0.18	11.77	11.64	1078.67	0.58
		08/14/2017	0.21	10.55	10.39	1079.91	1.24
		11/06/2018	0.20	11.95	11.80	1078.50	-1.41
MW-9	1091.48	05/28/2015	--	14.20	NA	1077.28	--
		11/03/2015	--	13.98	NA	1077.50	0.22
		02/01/2016	--	14.21	NA	1077.27	-0.23
		05/09/2016	--	14.11	NA	1077.37	0.10
		07/25/2016	--	13.43	NA	1078.05	0.68
		11/07/2016	--	13.59	NA	1077.89	-0.16
		02/15/2017	--	14.45	NA	1077.03	-0.86
		05/08/2017	--	13.74	NA	1077.74	0.71
		08/14/2017	--	12.78	NA	1078.70	0.96
		11/06/2018	--	13.95	NA	1077.53	-1.17
MW-10	1092.11	05/29/2015	--	13.19	NA	1078.92	--
		11/02/2015	--	12.36	NA	1079.75	0.83
		02/01/2016	--	12.54	NA	1079.57	-0.18
		05/09/2016	--	12.35	NA	1079.76	0.19
		07/25/2016	--	11.60	NA	1080.51	0.75
		11/07/2016	--	11.70	NA	1080.41	-0.10
		02/14/2017	--	12.71	NA	1079.40	-1.01
		05/08/2017	--	11.96	NA	1080.15	0.75
		08/14/2017	--	11.00	NA	1081.11	0.96
		11/06/2018	--	12.10	NA	1080.01	-1.10

Table 3-1
Water Level Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	MP Elevation (feet, NAVD 88)	Measurement Date	LNAPL Thickness (feet)	Depth to Water (feet)	Depth to Water Corrected for Presence of LNAPL (feet)[b]	Groundwater Elevation (feet, NAVD 88)	Change in Groundwater Elevation Level (feet)[a]
MW-11	1091.68	05/29/2015	0.55	14.51	14.10	1077.58	--
		11/04/2015	0.01	13.35	13.34	1078.34	0.76
		02/01/2016	0.10	13.52	13.45	1078.24	-0.10
		05/09/2016	0.10	13.41	13.34	1078.35	0.11
		07/25/2016	--	12.62	NA	1079.06	0.72
		11/07/2016	--	12.70	NA	1078.98	-0.08
		02/14/2017	0.01	13.70	13.69	1077.99	-0.99
		05/08/2017	--	12.93	NA	1078.75	0.76
		08/14/2017	--	11.95	NA	1079.73	0.98
		11/06/2018	0.01	13.05	13.04	1078.64	-1.09
MW-13	1091.27	05/28/2015	--	10.10	NA	1081.17	--
		11/04/2015	0.20	14.03	13.88	1077.39	-3.78
		02/01/2016	0.21	14.10	13.94	1077.33	-0.06
		05/09/2016	0.18	13.98	13.85	1077.43	0.10
		07/25/2016	0.02	13.12	13.11	1078.17	0.74
		11/07/2016	0.05	13.30	13.26	1078.01	-0.16
		02/14/2017	0.04	14.19	14.16	1077.11	-0.90
		05/08/2017	0.04	13.48	13.45	1077.82	0.71
		08/14/2017	--	12.45	NA	1078.82	1.00
		11/06/2018	--	13.60	NA	1077.67	-1.15
MWG-1	1083.98	05/28/2015	--	9.71	NA	1074.27	--
MWG-2	1085.47	02/01/2016	--	8.90	NA	1076.57	--
		05/09/2016	--	8.78	NA	1076.69	0.12
		07/25/2016	--	8.10	NA	1077.37	0.68
		11/07/2016	--	8.32	NA	1077.15	-0.22
		02/14/2017	--	9.15	NA	1076.32	-0.83
		05/08/2017	--	8.46	NA	1077.01	0.69
		08/14/2017	--	7.47	NA	1078.00	0.99
		11/06/2018	--	8.60	NA	1076.87	-1.13

Table 3-1
Water Level Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	MP Elevation (feet, NAVD 88)	Measurement Date	LNAPL Thickness (feet)	Depth to Water (feet)	Depth to Water Corrected for Presence of LNAPL (feet)[b]	Groundwater Elevation (feet, NAVD 88)	Change in Groundwater Elevation Level (feet)[a]
MWG-3	1084.15	05/28/2015	--	7.60	NA	1076.55	--
		11/03/2015	0.06	7.10	7.06	1077.10	0.54
		02/01/2016	0.08	7.10	7.04	1077.11	0.02
		05/09/2016	0.04	7.00	6.97	1077.18	0.07
		07/25/2016	0.05	6.40	6.36	1077.79	0.61
		11/07/2016	0.11	6.61	6.53	1077.62	-0.16
		02/14/2017	0.02	7.27	7.26	1076.90	-0.73
		05/08/2017	0.03	6.68	6.66	1077.49	0.60
		08/14/2017	--	5.81	NA	1078.34	0.85
		11/06/2018	0.05	6.90	NA	1077.25	-1.09
S-1	1088.82	05/28/2015	--	11.79	NA	1077.03	--
S-2	1085.74	05/27/2015	--	8.73	NA	1077.01	--
		11/07/2016	--	7.67	NA	1078.07	--
		02/14/2017	--	8.41	NA	1077.33	-0.74
		05/08/2017	--	7.88	NA	1077.86	0.53
		08/14/2017	--	7.02	NA	1078.72	0.86
		11/06/2018	--	8.10	NA	1077.64	-1.08
YMW-1	1089.05	05/29/2015	--	12.00	NA	1077.05	--
		11/04/2015	--	11.40	NA	1077.65	0.60
		02/01/2016	--	11.49	NA	1077.56	-0.09
		05/09/2016	--	11.36	NA	1077.69	0.13
		07/25/2016	--	10.69	NA	1078.36	0.67
		11/07/2016	--	10.79	NA	1078.26	-0.10
		02/15/2017	--	11.65	NA	1077.40	-0.86
		05/08/2017	--	11.01	NA	1078.04	0.64
		08/14/2017	--	10.03	NA	1079.02	0.98
		11/06/2018	--	11.25	NA	1077.80	-1.22
YMW-2	1090.86	05/29/2015	--	13.73	NA	1077.13	--
		11/04/2015	--	13.10	NA	1077.76	0.63
		02/01/2016	--	13.17	NA	1077.69	-0.07
		05/09/2016	--	13.08	NA	1077.78	0.09
		07/25/2016	--	12.30	NA	1078.56	0.78
		11/07/2016	--	12.44	NA	1078.42	-0.14
		02/15/2017	--	13.36	NA	1077.50	-0.92
		05/08/2017	--	12.65	NA	1078.21	0.71
		08/14/2017	--	11.12	NA	1079.74	1.53
		11/06/2018	--	12.90	NA	1077.96	-1.78

Table 3-1
Water Level Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

Location	MP Elevation (feet, NAVD 88)	Measurement Date	LNAPL Thickness (feet)	Depth to Water (feet)	Depth to Water Corrected for Presence of LNAPL (feet)[b]	Groundwater Elevation (feet, NAVD 88)	Change in Groundwater Elevation Level (feet)[a]
YMW-3	1089.53	05/29/2015	--	12.28	NA	1077.25	--
		11/04/2015	0.06	11.68	11.64	1077.90	0.64
		02/01/2016	--	11.75	NA	1077.78	-0.12
		05/09/2016	--	11.62	NA	1077.91	0.13
		07/25/2016	--	10.92	NA	1078.61	0.70
		11/07/2016	--	11.05	NA	1078.48	-0.13
		02/15/2017	--	11.90	NA	1077.63	-0.85
		05/08/2017	--	11.21	NA	1078.32	0.69
		08/14/2017	--	10.18	NA	1079.35	1.03
		11/06/2018	--	11.42	NA	1078.11	-1.24

NOTES:

-- = no measurable LNAPL thickness present.

LNAPL = light nonaqueous-phase liquid.

MP = measuring point.

NA = not applicable.

NAVD 88 = North American Vertical Datum of 1988.

[a] Change in water level is relative to two most recent sampling events.

[b] Water level corrected for presence of LNAPL, using assumed product density of 0.75 gram per cubic centimeter (American Petroleum Institute).

[c] Monitoring well KMW-10 is included in monitoring well network only for evaluating presence of LNAPL and depth to water.

[d] Monitoring well KMW-16 was not sampled due to inaccessibility from snow pile.

Table 4-1
Summary of Estimated Hydraulic Conductivities
Hydraulic Profiling Tool Surveys
Former Tiger Oil Site
City of Yakima
Yakima, Washington

MiHPT BORING	DATE	DEPTH OF TARGETED ZONE (ft bgs)	DEPTH TO GROUNDWATER (ft bgs)	ESTIMATED K (ft/day)	LITHOLOGIC UNITS[a]
HPT-01	11/28/2018	11.90 - 18.20	15.00	0.10 - 58	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-02.MHP	11/28/2018	7.5 - 16.75	10.50	0.10 - 25	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand
MiHPT-03.MHP	11/28/2018	8.75 - 16.1	12.50	0.10 - 56	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-04.MHP	11/28/2018	8.60 - 17.20	11.25	0.10 - 20	silts, sandy silts, silty sands, clayey sands, to fine- to coarse-grained sand
MiHPT-05-MHP	11/28/2018	8.30 - 16.85	14.50	0.10 - 53	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-06.MHP	11/28/2018	8.40 - 16.45	13.00	0.10 - 47	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand
MiHPT-07.MHP	11/29/2018	9.10 - 16.85	10.50	0.10 - 53	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-09.MHP	11/29/2018	10.65 - 19.20	11.25	0.10 - 55	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-10.MHP	11/29/2018	9.30 - 18.15	13.00	0.10 - 73	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-11.MHP	11/29/2018	11.20 - 21.00	14.50	0.10 - 44	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand
MiHPT-12.MHP	11/29/2018	10.85 - 21.35	19.00	0.10 - 67	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand and gravel
MiHPT-13.MHP	11/30/2018	8.55 - 16.85	11.50	0.10 - 25	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand

Table 4-1
Summary of Estimated Hydraulic Conductivities
Hydraulic Profiling Tool Surveys
Former Tiger Oil Site
City of Yakima
Yakima, Washington

MiHPT BORING	DATE	DEPTH OF TARGETED ZONE (ft bgs)	DEPTH TO GROUNDWATER (ft bgs)	ESTIMATED K (ft/day)	LITHOLOGIC UNITS[a]
MiHPT-14.MHP	11/30/2018	7.70 - 14.80	11.00	0.10 - 30	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand
MiHPT-15.MHP	11/30/2018	9.60 - 17.10	14.50	0.10 - 38	silts, sandy silts, silty sands, clayey silts, to fine- to coarse-grained sand

NOTES:

bgs = below ground surface.

ft = feet.

K = hydraulic conductivity.

MiHPT = membrane interface probe-hydraulic profiling tool.

[a] Estimated K ranges of lithologic units obtained from Domenico and Schwartz, 1990. Physical and Chemical Hydrogeology.

Table 4-2
Soil Vapor Points Monitoring Wells Monitoring Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

SVP MW	DATE	TIME	CH_4 (%)	CO_2 (%)	O_2 (%)	COMMENTS
SVP-01-shallow	12/06/2018	1102	0.8	1.5	20.0	shallow vapor probe depth at 1 ft bgs
	12/06/2018	1104	0.8	1.5	20.0	
	12/06/2018	1106	0.8	1.5	20.0	
SVP-01-medium	12/06/2018	1054	0.8	2.9	17.9	medium vapor probe depth at 4 ft bgs
	12/06/2018	1056	0.8	2.8	17.9	
	12/06/2018	1100	0.8	2.8	18.0	
SVP-01-deep	12/06/2018	1110	0.8	3.1	18.2	deep vapor probe depth at 8 ft bgs
	12/06/2018	1112	0.8	3.0	18.3	
SVP-02-shallow	12/05/2018	1600	1.0	5.8	13.8	shallow vapor probe depth: 1 ft bgs
	12/05/2018	1603	1.0	6.7	12.5	
	12/05/2018	1604	0.9	7.0	12.1	
	12/05/2018	1605	1.0	7.0	12.1	
SVP-02-medium	12/05/2018	1606	0.9	10.7	6.3	medium vapor probe depth at 5 ft bgs
	12/05/2018	1607	0.9	10.6	6.3	
	12/05/2018	1608	0.9	10.6	6.1	
	12/05/2018	1609	0.9	10.6	6.5	
SVP-02-deep	12/05/2018	1611	1.1	11.7	11.4	deep vapor probe depth at 9 ft bgs
	12/05/2018	1612	1.3	15.7	11.0	
SVP-03-shallow	12/05/2018	1627	0.9	0.5	16.8	shallow vapor probe depth: 1 ft bgs
	12/05/2018	1628	0.9	0.5	16.9	
	12/05/2018	1629	0.9	0.5	17.1	
	12/05/2018	1630	0.9	0.5	17.2	
SVP-03-medium	12/05/2018	1631	0.9	1.8	17.4	medium vapor probe depth at 4.5 ft bgs
	12/05/2018	1632	0.9	2.1	17.1	
SVP-03-deep	12/05/2018	1633	0.9	2.4	20.4	deep vapor probe depth at 9 ft bgs
	12/05/2018	1634	0.9	2.3	20.6	

Table 4-2
Soil Vapor Points Monitoring Wells Monitoring Data
Former Tiger Oil Site
City of Yakima
Yakima, Washington

SVP MW	DATE	TIME	CH_4 (%)	CO_2 (%)	O_2 (%)	COMMENTS
SVP-04-shallow	12/05/2018	1615	1.0	0.4	15.6	shallow vapor probe depth: 1 ft bgs
	12/05/2018	1616	1.0	0.4	15.9	
	12/05/2018	1617	1.0	0.4	16.2	
	12/05/2018	1618	1.0	0.4	16.5	
SVP-04-medium	12/05/2018	1619	0.9	9.4	2.7	medium vapor probe depth at 4 ft bgs
	12/05/2018	1620	0.9	8.2	2.8	
	12/05/2018	1621	0.9	8.8	3.0	
	12/05/2018	1622	0.9	8.6	3.4	
SVP-04-deep	12/06/2018	1115	13.2	6.7	11.0	deep vapor probe depth at 7 ft bgs
	12/06/2018	1117	12.1	6.3	11.4	
	12/06/2018	1119	11.9	6.3	11.4	

NOTES:

bgs = below ground surface.

CH_4 = methane.

CO_2 = carbon dioxide.

ft = feet.

MW = monitoring well.

O_2 = oxygen.

SVP = soil vapor probe.

Table 5-1
Summary of High-Resolution Soil Analytical Results—OIP
Former Tiger Oil High Resolution Site Characterization
City of Yakima
Yakima, Washington

Location:	MTCA A	DSS-OIP2										DSS-OIP6				
Sample Name:		DSS-OIP2-10.0	DSS-OIP2-11.0	DSS-OIP2-12.0	DSS-OIP2-14.0	DSS-OIP2-15.0	DSS-OIP2-19.0	DSS-OIP2-20.0	DSS-OIP2-21.0	DSS-OIP2-22.0	DSS-OIP2-23.0	DSS-OIP6-8.5	DSS-OIP6-9.0	DSS-OIP6-10.0	DSS-OIP6-13.0	DSS-OIP6-14.0
Collection Date:		12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/03/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018
Collection Depth (ft bgs):		10	11	12	14	15	19	20	21	22	23	8.5	9	10	13	14
VOCs (mg/kg)																
Benzene	0.03	0.02 U	**0.086**	**1.2**	**1.8**	**0.78**	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	**0.073**	**7.7**	**0.37**
Ethylbenzene	6	**2.3**	**1.7**	**33**	**20**	**17**	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	**0.12**	**0.12**	**0.45**	**31**	**0.37**
Toluene	7	**0.032**	**0.14**	**3.5**	**4**	**2**	**0.028**	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	**0.14**	**52**	**1.1**
Xylenes (total)	9	**4.1**	**6.8**	**170**	**100**	**40**	0.06 U	0.06 U	**0.14**	0.06 U	0.06 U	**0.25**	**0.18**	**1.4**	**170**	**2.3**
TPH (mg/kg)																
Gasoline-Range Hydrocarbons	30	**530**	**240**	**2100**	**1300**	**960**	5 U	5 U	5 U	5 U	5 U	**11**	**9.8**	**69**	**1700**	**29**

Table 5-1
Summary of High-Resolution Soil Analytical Results—OIP
Former Tiger Oil High Resolution Site Characterization
City of Yakima
Yakima, Washington

Location:	MTCA A	DSS-OIP7						DSS-OIP10								
Sample Name:		DSS-OIP7-14.0	DSS-OIP7-15.0	DSS-OIP7-16.0	DSS-OIP7-19.0	DSS-OIP7-20.0	DSS-OIP7-21.0	DSS-OIP10-4.0	DSS-OIP10-5.0	DSS-OIP10-6.0	DSS-OIP10-7.0	DSS-OIP10-8.0	DSS-OIP10-9.0	DSS-OIP10-10.0	DSS-OIP10-11.0	DSS-OIP10-12.0
Collection Date:		12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018	12/04/2018
Collection Depth (ft bgs):		14	15	16	19	20	21	4	5	6	7	8	9	10	11	12
VOCs (mg/kg)																
Benzene	0.03	**0.75**	**0.11**	0.02 U	0.02 U	**0.08**	0.02 U	**0.33**	**8.2**	**1.4**	**4.3**	**2.4**	**6.5**	**0.14**	**2**	0.02 U
Ethylbenzene	6	**17**	**1.3**	**0.18**	**0.43**	**1.3**	**0.073**	**2.8**	**53**	**8.9**	**15**	**14**	**46**	**0.16**	**13**	**0.09**
Toluene	7	**8.3**	**1.5**	**0.042**	**0.044**	**0.071**	**0.032**	**0.31**	**11**	**2.8**	**8.1**	**5.3**	**18**	0.02 U	**4**	**0.041**
Xylenes (total)	9	**92**	**7.3**	**1**	**0.64**	**2.1**	**0.31**	**14**	**220**	**32**	**74**	**57**	**250**	**0.19**	**66**	**0.51**
TPH (mg/kg)																
Gasoline-Range Hydrocarbons	30	**1100**	**90**	5 U	**6.5**	**23**	**6**	**140**	**2900**	**670**	**930**	**930**	**2600**	**8.6**	**830**	**9.5**

Table 5-1
Summary of High Resolution Soil Analytical Results—OIP
Former Tiger Oil High Resolution Site Characterization
City of Yakima
Yakima, Washington

NOTES:
Detected results are shown in bold font.
Shading indicates cleanup level exceedance. Non-detect results were not evaluated for exceedances.
ft bgs = feet below ground surface.
mg/kg = milligrams per kilogram.
MTCA A = Model Toxics Control Act Method A, unrestricted land use.
OIP = Optical Imaging Profiler.
TPH = total petroleum hydrocarbons.
U = result not detected at or above method reporting limit.
VOC = volatile organic compound.

Table 5-2
Summary of High Resolution Groundwater Analytical Results—MiHpt
Former Tiger Oil High Resolution Site Characterization
City of Yakima
Yakima, Washington

Location:	MTCA A	DSW-MiHpt-03				DSW-MiHpt-05			DSW-MiHpt-10		
Sample Name:		DSW-MiHpt03-10.0	DSW-MiHpt03-11.0	DSW-MiHpt03-12-14	DSW-MiHpt03-15-17	DSW-MiHpt05-9-11	DSW-MiHpt05-12-14	DSW-MiHpt05-16-18	DSW-MiHpt10-10-12	DSW-MiHpt10-13-15	DSW-MiHpt10-16-18
Collection Date:		12/04/2018	12/04/2018	12/05/2018	12/05/2018	12/05/2018	12/05/2018	12/05/2018	12/05/2018	12/05/2018	12/05/2018
Collection Depth (ft bgs):		9 - 10	10 - 11	12 - 14	15 - 17	9 - 11	12 - 14	16 - 18	10 - 12	13 - 15	16 - 18
Total Metals (ug/L)											
Manganese	NV	**2910**	**834**	**278**	**220**	**1210**	**2310**	**349**	**1640**	**65.1**	**23**
VOCs (ug/L)											
Benzene	5	**2.9**	1 U	1 U	1 U	**5.5**	**25**	1 U	1 U	1 U	1 U
Ethylbenzene	700	**10**	1 U	1 U	1 U	**89**	**29**	1 U	1 U	1 U	1 U
Toluene	1000	**2.6**	1 U	1 U	1 U	**4.5**	**1.6**	1 U	1 U	1 U	1 U
Xylenes (total)	1000	**3.8**	3 U	**5.8**	3 U	**34**	3 U	3 U	3 U	3 U	3 U
TPH (ug/L)											
Gasoline-Range Hydrocarbons	800	**360**	100 U	100 U	100 U	**1800**	**760**	100 U	100 U	100 U	100 U
Attenuation Factors (ug/L)											
Carbon Dioxide	NV	**549000**	**384000**	**374000**	**365000**	**500000**	**446000**	**506000**	**601000**	**458000**	**425000**
Sulfate	NV	**14900**	**28400**	**32600**	**31900**	**16700**	**15600**	**25700**	**36400**	**30400**	**31000**
Methane	NV	**31**	5 U	5 U	5 U	**140**	**240**	5 U	**20**	**8.1**	5 U

NOTES:
Detected results are shown in bold font.
Shading indicates cleanup level exceedance. Non-detect results were not evaluated for exceedances.
ft bgs = feet below ground surface.
MiHpt = Membrane Interface Probe-Hydraulic Profiling Tool.
MTCA A = Model Toxics Control Act Method A.
NV = no value.
TPH = total petroleum hydrocarbons.
U = result not detected at or above method reporting limit.
ug/L = micrograms per liter.
VOC = volatile organic compound.

Table 5-3
Summary of LNAPL Analytical Results
Former Tiger Oil High Resolution Site Characterization
City of Yakima
Yakima, Washington

Location: Sample Name: Collection Date:	KMW-10 KMW10-LNAPL 12/04/2018
EPH (mg/kg)	
C8-C10 Aliphatic	**229000 J-**
C10-C12 Aliphatic	**171000**
C12-C16 Aliphatic	**87000**
C16-C21 Aliphatic	**684**
C21-C34 Aliphatic	200 U
C8-C10 Aromatic	**21900 J-**
C10-C12 Aromatic	**36600**
C12-C16 Aromatic	**45500**
C16-C21 Aromatic	**1440**
C21-C34 Aromatic	200 U
VPH (mg/kg)	
C5-C6 Aliphatic	**1320**
C6-C8 Aliphatic	**19400 J**
C8-C10 Aliphatic	**104000**
C10-C12 Aliphatic	**96200**
C8-C10 Aromatic	**344000**
C10-C12 Aromatic	**202000**
C12-C13 Aromatic	**83200**
Benzene	**68.5**
Ethylbenzene	**8670**
m,p-Xylene	**75800**
Methyl tert-butyl ether	43.1 U
Naphthalene	**12900 J**
o-Xylene	**30500**
Toluene	**3360**

NOTES:

Detected results are shown in bold font.

EPH = extractable petroleum hydrocarbon.

J = The result is estimated.

J- = The result is estimated with a low bias.

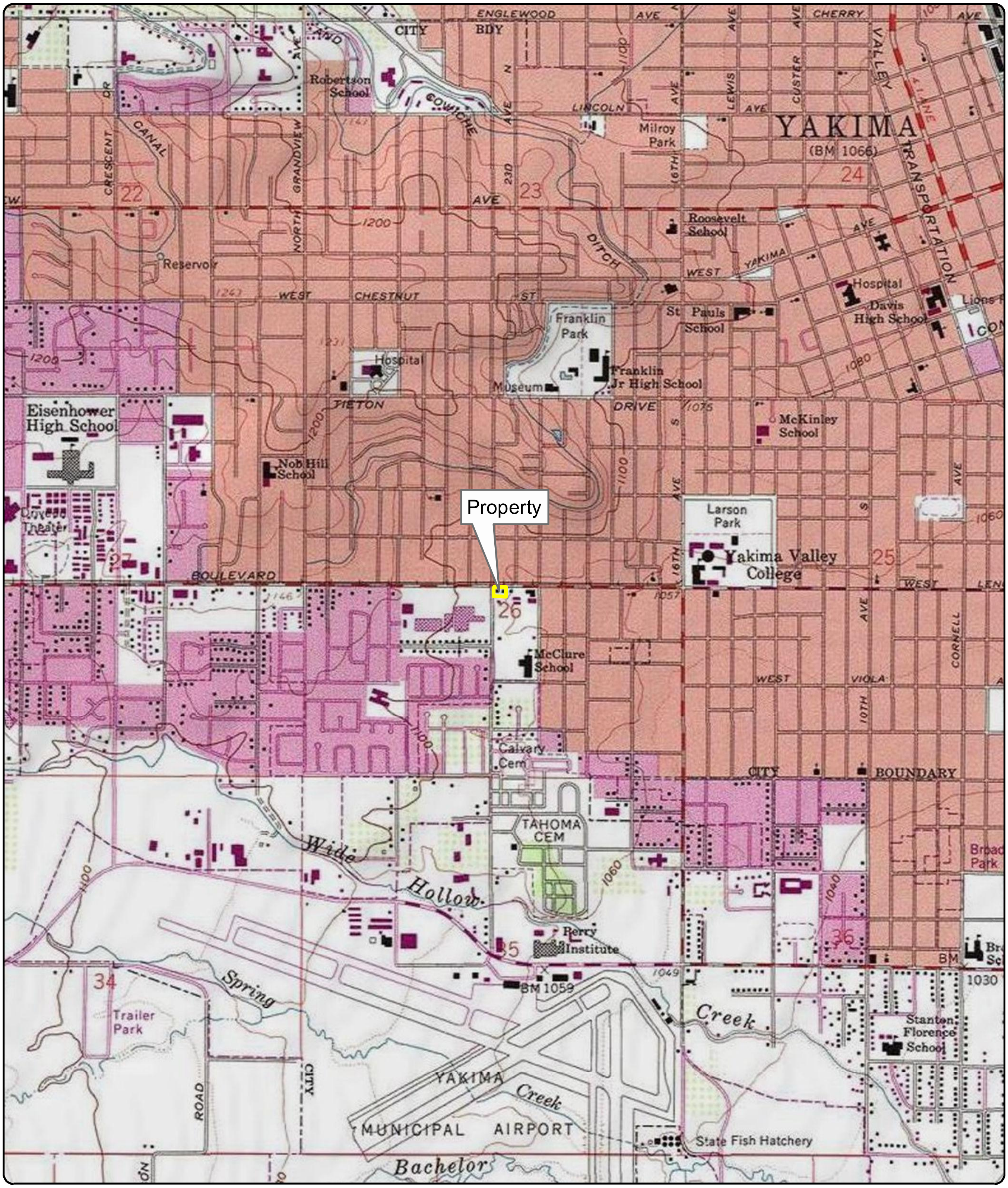
LNAPL = light nonaqueous-phase liquid.

mg/kg = milligrams per kilogram.

U = The result is not detected at or above method reporting limit.

VPH = volatile petroleum hydrocarbon.

FIGURES



Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig1_Site Location.mxd

Print Date: 4/22/2019

Approved By: yvan

Produced By: jputnam

Project: 0818.02.01-01

Source: Taxlots obtained from City of Yakima GIS,
US Geological Survey (1990) 7.5-minute
topographic quadrangle: Yakima West
Section 26, Township 13 North, Range 18 East

Legend

▢ Property Boundary (approximate)

Figure 2-1
Site Location

Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

0 1,000 2,000
Feet

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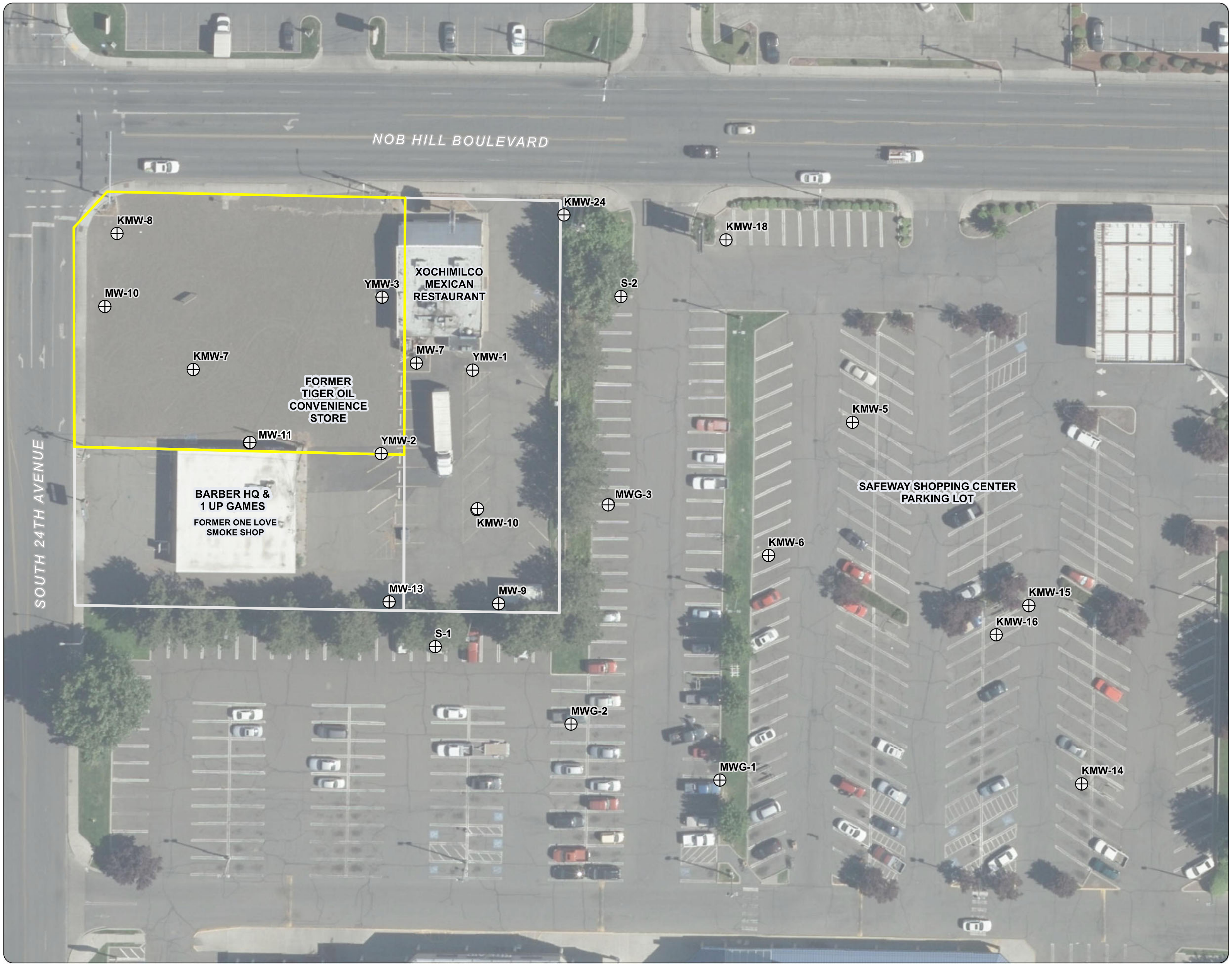
Figure 2-2
Site Features

Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington



Legend

- ⊕ Monitoring Well
- 🟨 Former Tiger Oil Property Boundary
- ⬜ Adjacent Taxlot Boundaries

0 25 50
Feet

Source: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA.

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Project: 0818.02.01-01 Produced By: mjosef Approved By: mstringer Print Date: 3/26/2019 Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig2_Site Features v2.mxd

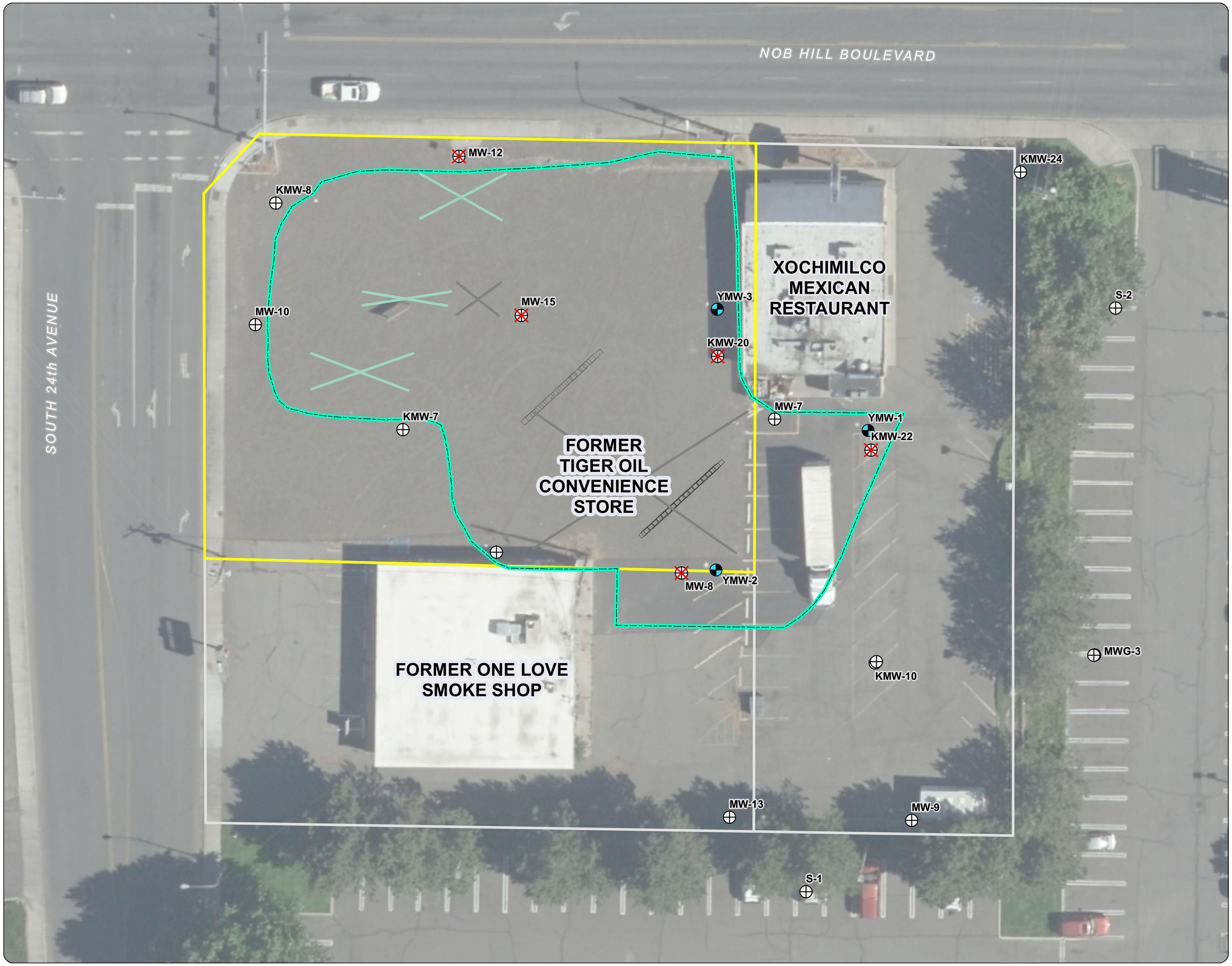

Figure 2-3
Remedial Action Elements Completed

Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ⊗ Decommissioned Monitoring Well
- ⊕ Monitoring Well
- ● Monitoring Well Installed on May 26, 2015
- ▭ Infiltration Gallery for Supplemental Bioremediation
- 🟩 Interim Remedial Action Area (May 2015)
- 🟨 Former Tiger Oil Property Boundary
- ✕ Building Demolished
- ✕ Cement Pad Demolished

0 15 30
Feet

Source: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA.

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Project: 0818.02.01-01 Produced By: mjosef Approved By: Print Date: 3/26/2019 Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig4_Remedial Action Elements Completed.mxd

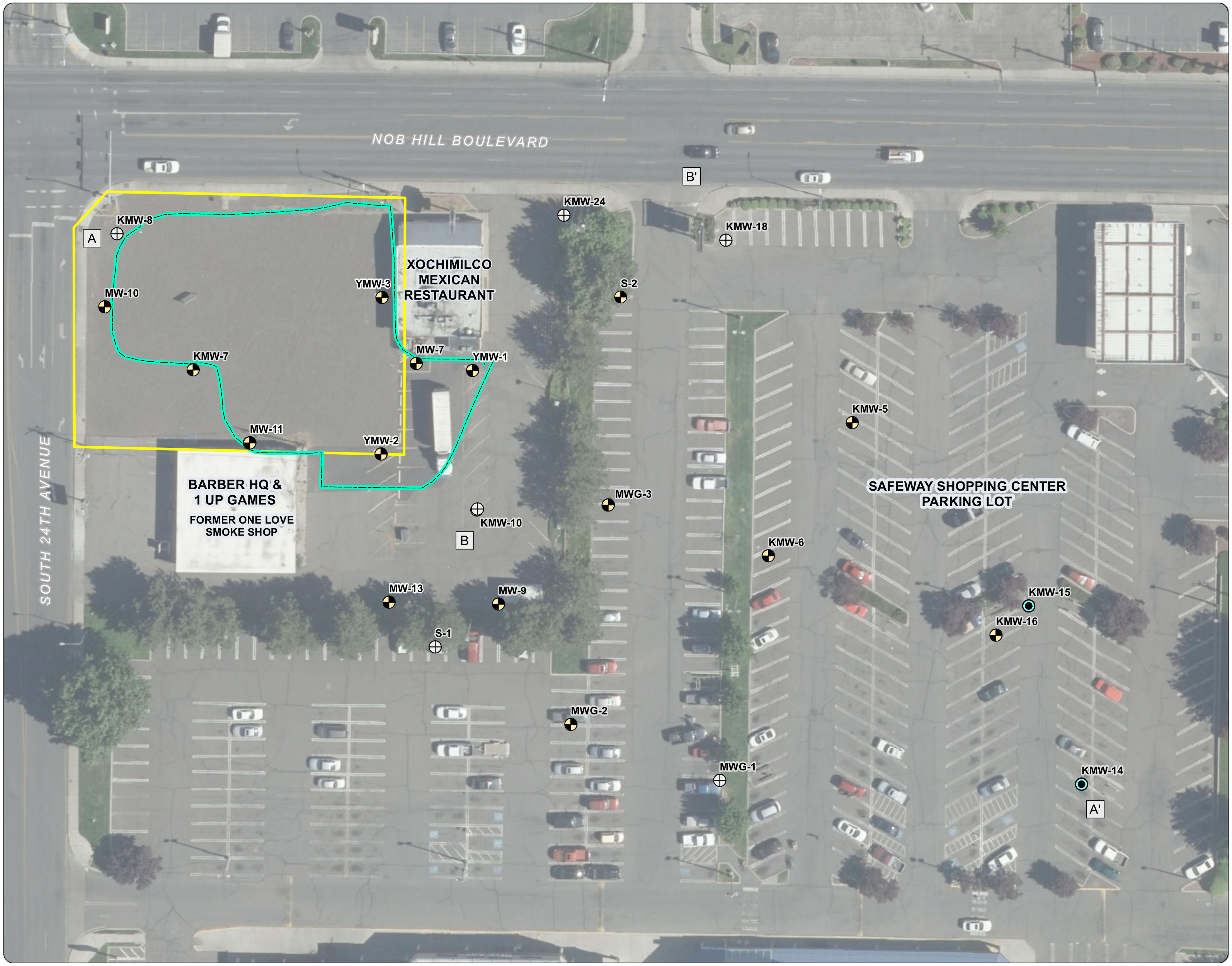

Figure 2-4
Groundwater Monitoring Well Network

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ⊕ Monitoring Network Well
- ⊕ Monitoring Well
- ◉ Sentry Monitoring Well
- ▭ Interim Remedial Action Area (May 2015)
- ▭ Former Tiger Oil Property Boundary

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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Project: 0818.02.01-06 Produced By: jputnam Approved By: Print Date: 4/22/2019 Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig2_GW Monitoring Well Network_Update.mxd

Figure 2-5
Groundwater Potentiometric Map
November 2018

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ● Monitoring Network Well
- ↘ Groundwater Flow Direction
- — Groundwater Elevation Contour (1 ft., NAVD 88)
- ▭ Former Tiger Oil Property Boundary

0 25 50
Feet

Source:
Aerial photograph obtained from Esri ArcGIS Online.

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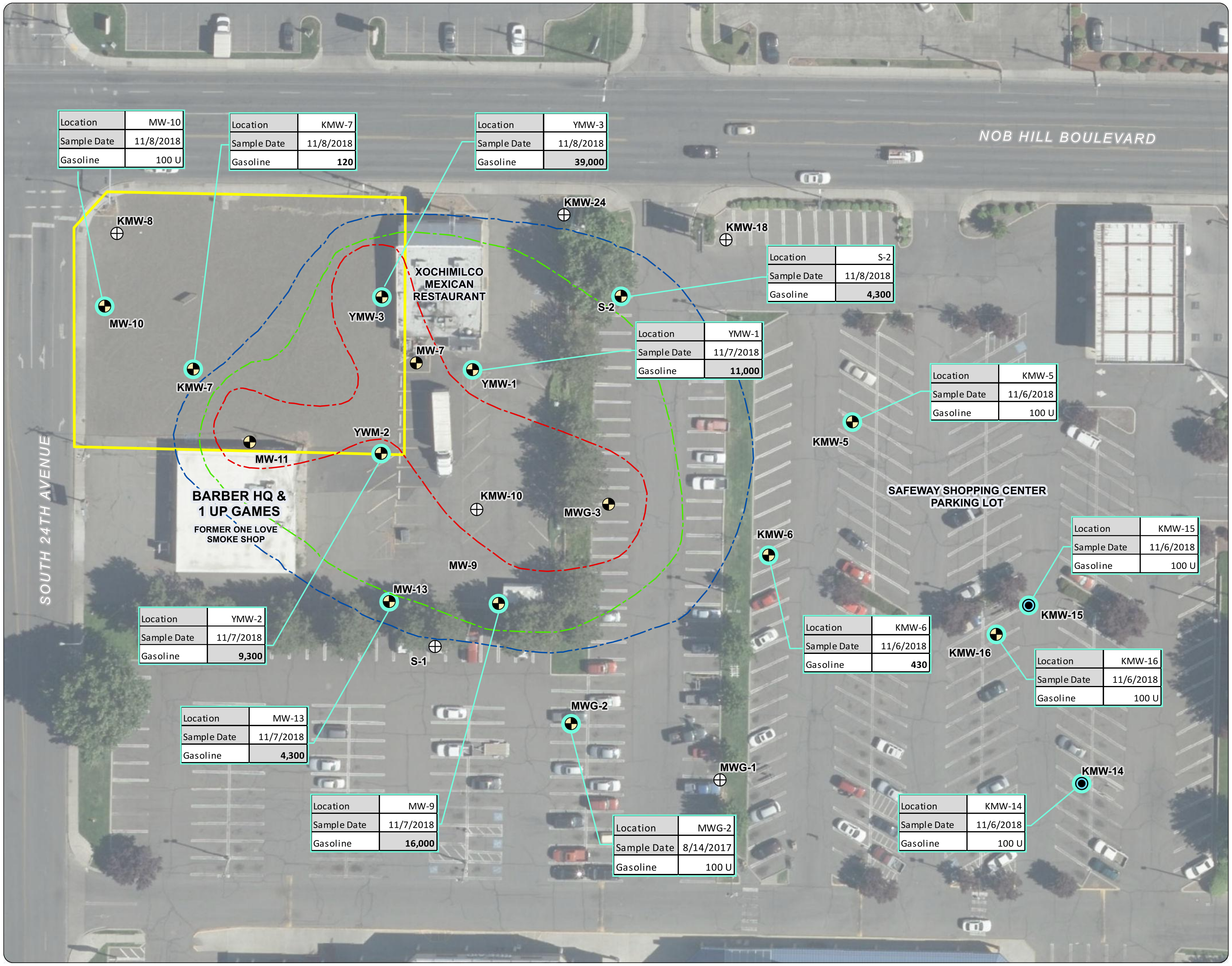
Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig2-5_GW Elevation Contour 201811.mxd
Print Date: 4/22/2019
Approved By: mstringer
Produced By: jputnam
Project: 0818.02.01

Figure 3-1
Gasoline-Range TPH Isoconcentration Contours - November 2018

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington



Legend

Approximate Gasoline-Range TPH Isoconcentration

- 800 ug/L contour
- 5,000 ug/L contour
- 20,000 ug/L contour

- Monitoring Network Well
- Monitoring Well
- Sentry Monitoring Well
- Sample Collected
- Former Tiger Oil Property Boundary

Notes:
1. Monitoring Network Wells containing LNAPL were not sampled.
2. Shaded and bolded result values indicate exceedance of MTCA Method A cleanup level of 800 ug/L.
3. The highest value of a field duplicate is shown.
4. LNAPL = light nonaqueous-phase liquid
5. MTCA = Model Toxics Control Act
6. TPH = total petroleum hydrocarbons
7. U = result was not detected at or above the reporting limit.
8. ug/L = micrograms per liter

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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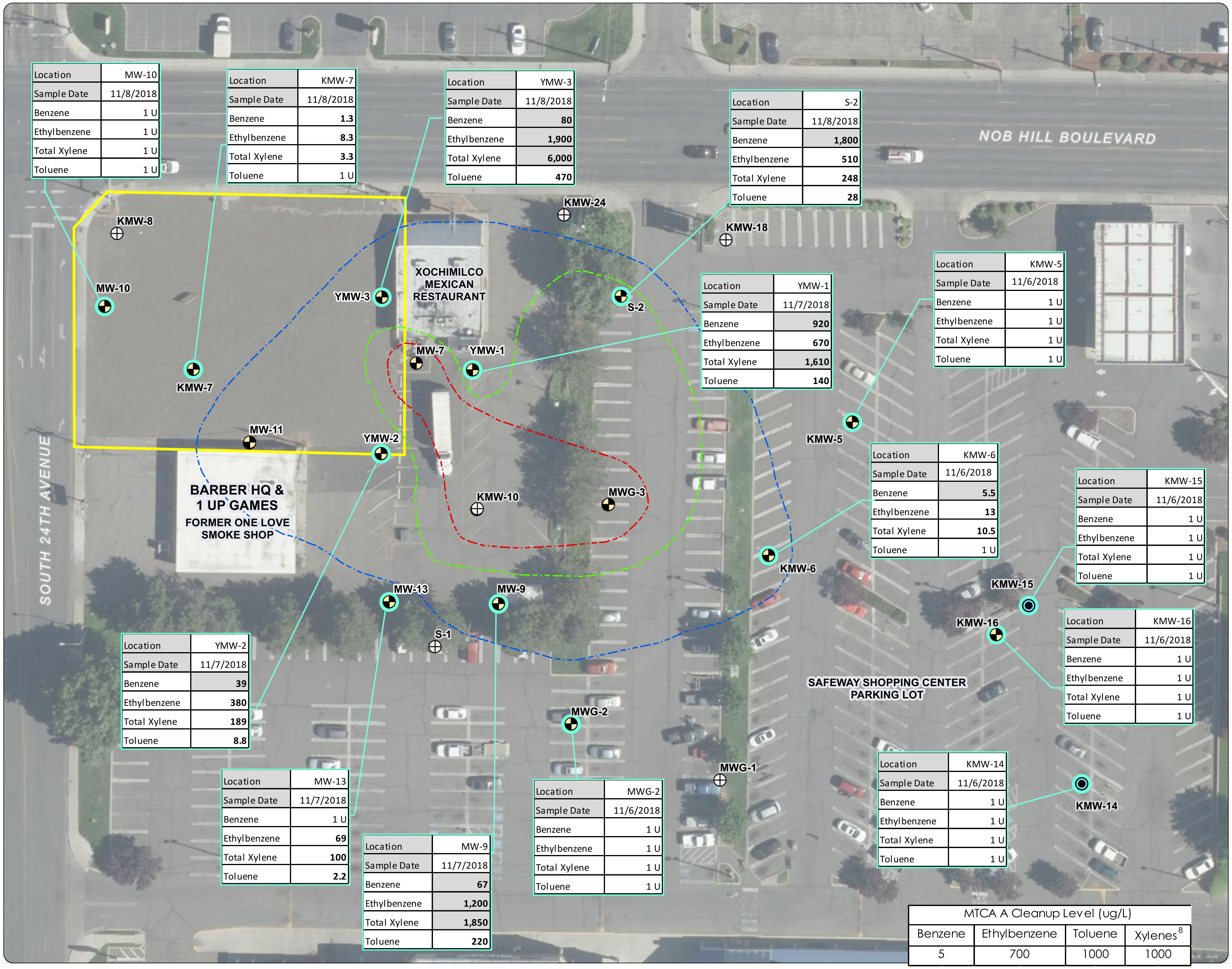
Project: 0818.02.01-06 Produced By: aguse Approved By: yvan Print Date: 4/22/2019 Path: X:\0818.02 City of Yakima\Projects\Quarterly GW Monitoring\Fig6_GasolineConcentration_201811_.mxd

Figure 3-2
Benzene Isoconcentration Contours – November 2018

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington



Location	MW-10
Sample Date	11/8/2018
Benzene	1 U
Ethylbenzene	1 U
Total Xylene	1 U
Toluene	1 U

Location	KMW-7
Sample Date	11/8/2018
Benzene	1.3
Ethylbenzene	8.3
Total Xylene	3.3
Toluene	1 U

Location	YMW-3
Sample Date	11/8/2018
Benzene	**80**
Ethylbenzene	**1,900**
Total Xylene	**6,000**
Toluene	470

Location	S-2
Sample Date	11/8/2018
Benzene	**1,800**
Ethylbenzene	510
Total Xylene	248
Toluene	28

Location	YMW-1
Sample Date	11/7/2018
Benzene	**920**
Ethylbenzene	670
Total Xylene	**1,610**
Toluene	140

Location	KMW-5
Sample Date	11/6/2018
Benzene	1 U
Ethylbenzene	1 U
Total Xylene	1 U
Toluene	1 U

Location	KMW-6
Sample Date	11/6/2018
Benzene	**5.5**
Ethylbenzene	13
Total Xylene	10.5
Toluene	1 U

Location	KMW-15
Sample Date	11/6/2018
Benzene	1 U
Ethylbenzene	1 U
Total Xylene	1 U
Toluene	1 U

Location	KMW-16
Sample Date	11/6/2018
Benzene	1 U
Ethylbenzene	1 U
Total Xylene	1 U
Toluene	1 U

Location	YMW-2
Sample Date	11/7/2018
Benzene	**39**
Ethylbenzene	380
Total Xylene	189
Toluene	8.8

Location	MW-13
Sample Date	11/7/2018
Benzene	1 U
Ethylbenzene	69
Total Xylene	100
Toluene	2.2

Location	MW-9
Sample Date	11/7/2018
Benzene	**67**
Ethylbenzene	**1,200**
Total Xylene	**1,850**
Toluene	220

Location	MWG-2
Sample Date	11/6/2018
Benzene	1 U
Ethylbenzene	1 U
Total Xylene	1 U
Toluene	1 U

Location	KMW-14
Sample Date	11/6/2018
Benzene	1 U
Ethylbenzene	1 U
Total Xylene	1 U
Toluene	1 U

MTCA A Cleanup Level (ug/L)			
Benzene	Ethylbenzene	Toluene	Xylenes[8]
5	700	1000	1000

Legend

Approximate Benzene Isoconcentration

-·-·-	5 ug/L contour
-·-·-	1,000 ug/L contour
-·-·-	10,000 ug/L contour
◐	Monitoring Network Well
⊕	Monitoring Well
◉	Sentry Monitoring Well
●	Sample Collected
☐	Former Tiger Oil Property

0 25 50
Feet

Notes:
1. Monitoring Network Wells containing LNAPL were not sampled.
2. Shaded and bolded result values indicate exceedance of the MTCA Method A cleanup level.
3. LNAPL = light nonaqueous-phase liquid
4. MTCA = Model Toxics Control Act
5. U = result was not detected at or above the reporting limit.
6. ug/L = micrograms per liter
7. Xylenes = the sum of m,p- and o-xylene. Non-detect results are summed at half of the non-detect value. The highest non-detect value is used when both results are non-detect.

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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Project: 0818.02.01-06 Produced By: aguse Approved By: yvan Print Date: 4/22/2019 Path: X:\0818.02 City of Yakima\Projects\Quarterly GW Monitoring\Fig7_BTEXConcentration_201811.mxd

Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig4_1_Residual_LNAPL_Impact_Investigation.mxd

Print Date: 4/26/2019

Approved By:

Produced By: aguse

Project: 0818.02.01-06

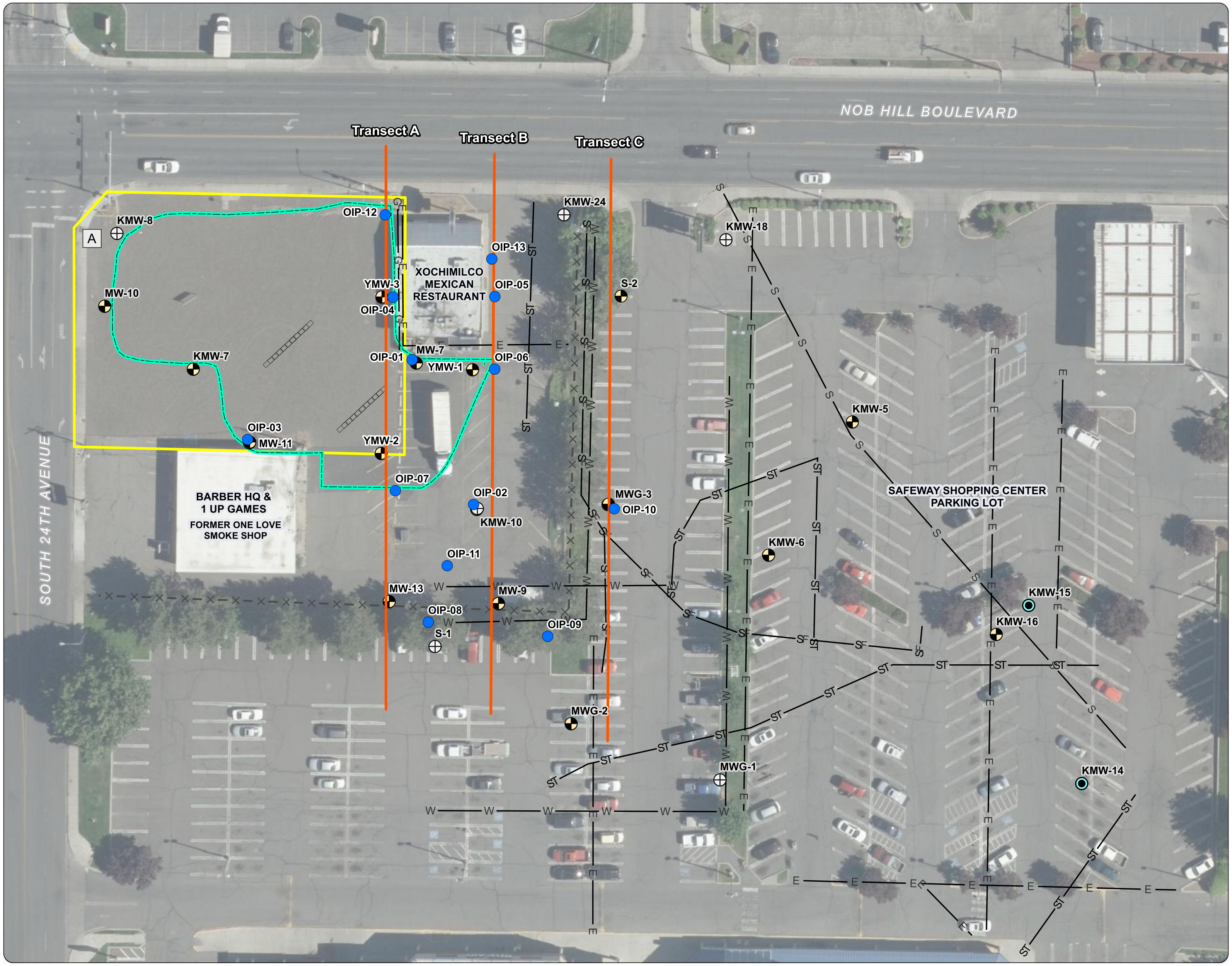

Figure 4-1
Residual LNAPL Impact Investigation -- OIP

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ● OIP Locations
- ◐ Monitoring Network Well
- ⊕ Monitoring Well
- ◉ Sentry Monitoring Well
- — OIP Transect
- ▭ Interim Remedial Action Area (May 2015)
- ▭ Former Tiger Oil Property Boundary
- ▨ Infiltration Gallery for Supplemental Bioremediation

Notes:
LNAPL = light non-aqueous phase liquid.
OIP = Optical Imaging Profiler.
PHC = petroleum hydrocarbon carbons.

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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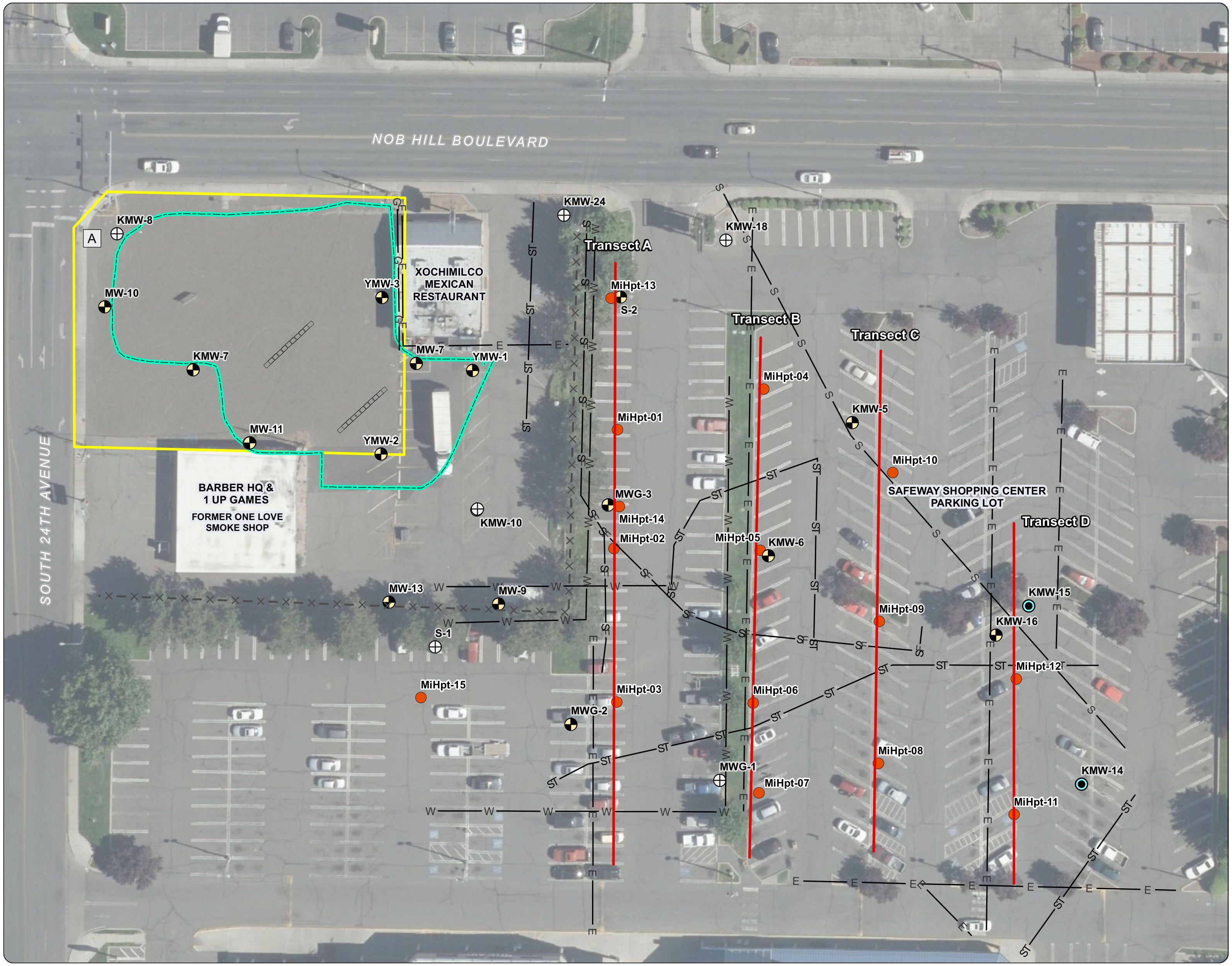

Figure 4-2
Dissolved Phase
Plume Investigation -- MiHpt

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ● MiHpt Location
- ◐ Monitoring Network Well
- ⊕ Monitoring Well
- ◉ Sentry Monitoring Well
- — MiHpt Transect
- ▭ Interim Remedial Action Area (May 2015)
- ▭ Former Tiger Oil Property Boundary
- ▭ Infiltration Gallery for Supplemental Bioremediation

Note:
Advance MiHpt soundings along transects to define the extent of the dissolved phase groundwater contamination and identify the primary transport pathways.
MiHpt = Membrane Interface Probe-Hydraulic Profiling Tool.
Soil and/or groundwater samples will be collected at each proposed MiHpt location.

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig4_2_Groundwater_Plume_Investigation_MiHpt.mxd

Print Date: 4/22/2019

Approved By:

Produced By: jputnam

Project: 0818.02.01-06

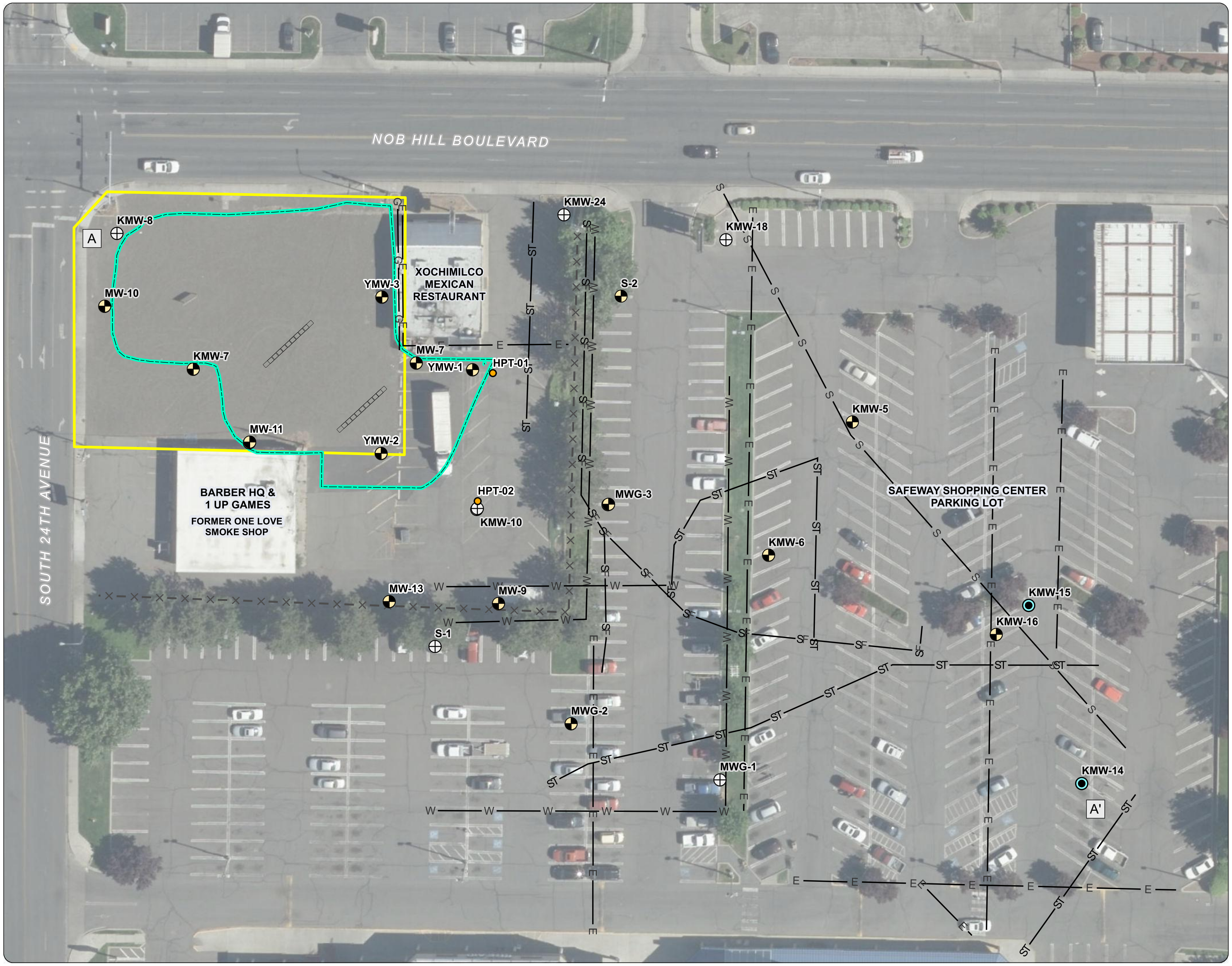

Figure 4-3
Subsurface Permeability Invesigation - HPT Locations

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ● HPT Location
- ◐ Monitoring Network Well
- ⊕ Monitoring Well
- ◉ Sentry Monitoring Well
- ▭ Interim Remedial Action Area (May 2015)
- ▭ Former Tiger Oil Property Boundary
- ▭ Infiltration Gallery for Supplemental Bioremediation

Notes:
HPT = Hydraulic Profiling Tool

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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Project: 0818.02.01-06 Produced By: aguse Approved By: Print Date: 4/26/2019 Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig4_3_Subsurface_Permeability_Investigation_Hpt_for_Report.mxd

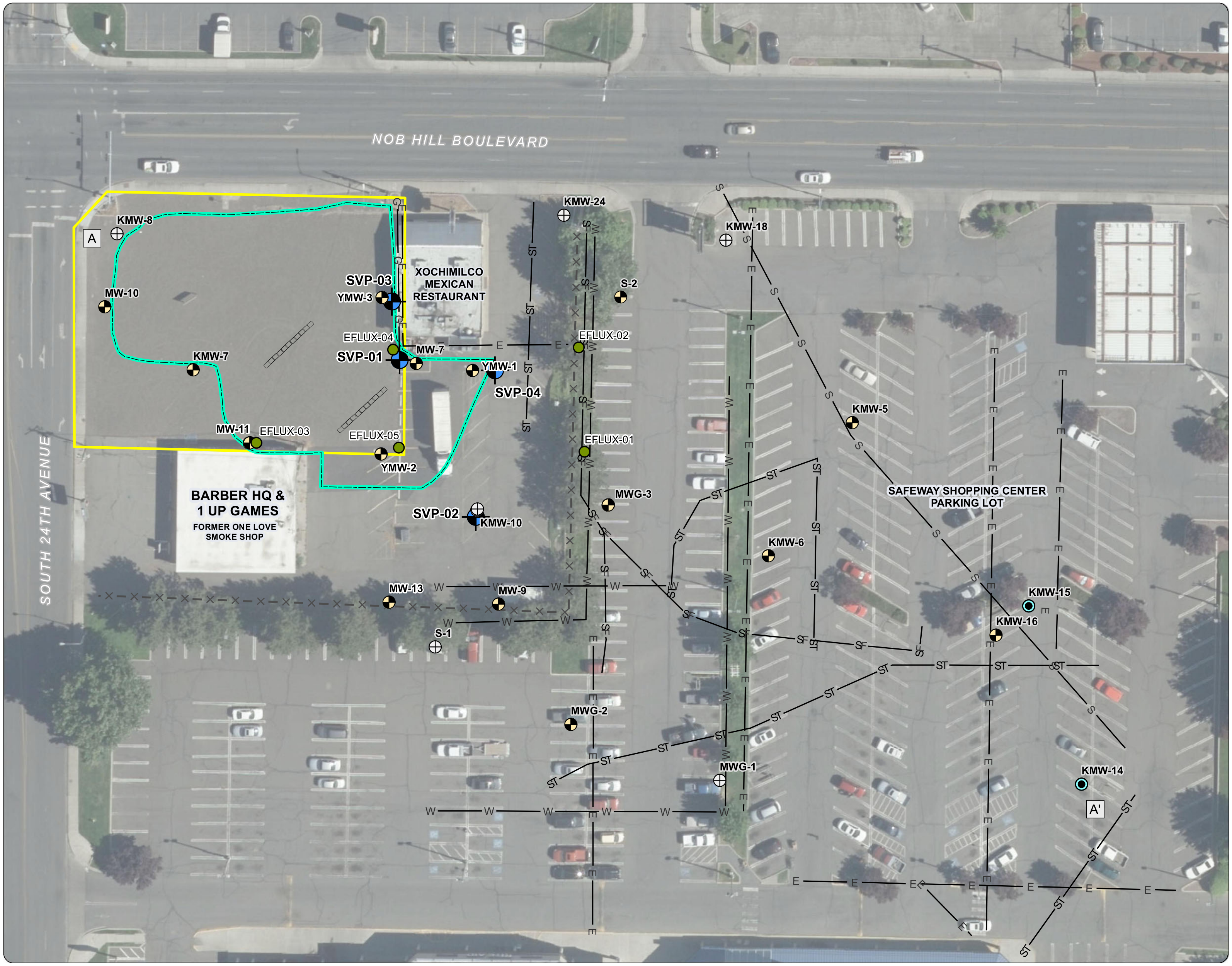

Figure 4-4
Natural Source Zone Depletion Investigation

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

- ● Monitoring Network Well
- ⊕ Monitoring Well
- ◉ Sentry Monitoring Well
- 🟩 Interim Remedial Action Area (May 2015)
- 🟨 Former Tiger Oil Property Boundary
- ▭ Infiltration Gallery for Supplemental Bioremediation
- ● Carbon Dioxide Flux Chamber
- ⊕ Soil Vapor Probe Monitoring Well (Comprised of 1 shallow, medium, and deep probe)

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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Path: X:\0818.02 City of Yakima\Projects\GW Monitoring Plan\Fig4_6_Natural_Source_Zone_Depletion_Investigation_for_Report.mxd
Print Date: 4/22/2019
Approved By:
Produced By: jputnam
Project: 0818.02.01-06

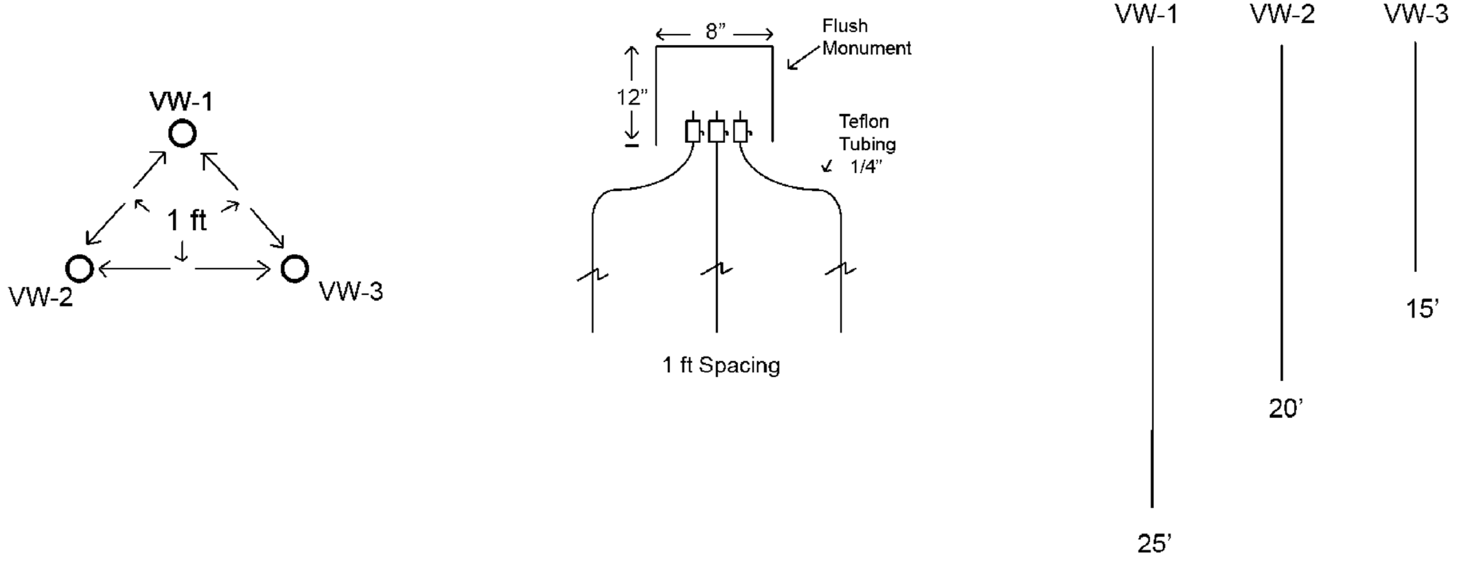

Figure 4-5
Multiple Vapor Point Monitoring Wells Configuration

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

For each location a vapor screen (6" length is the most common) is installed with Teflon tubing extended up to the surface and into a common monument with a PVC ball valve on each tube. The Teflon tubing is labeled to identify each each probe and its corresponding depth.

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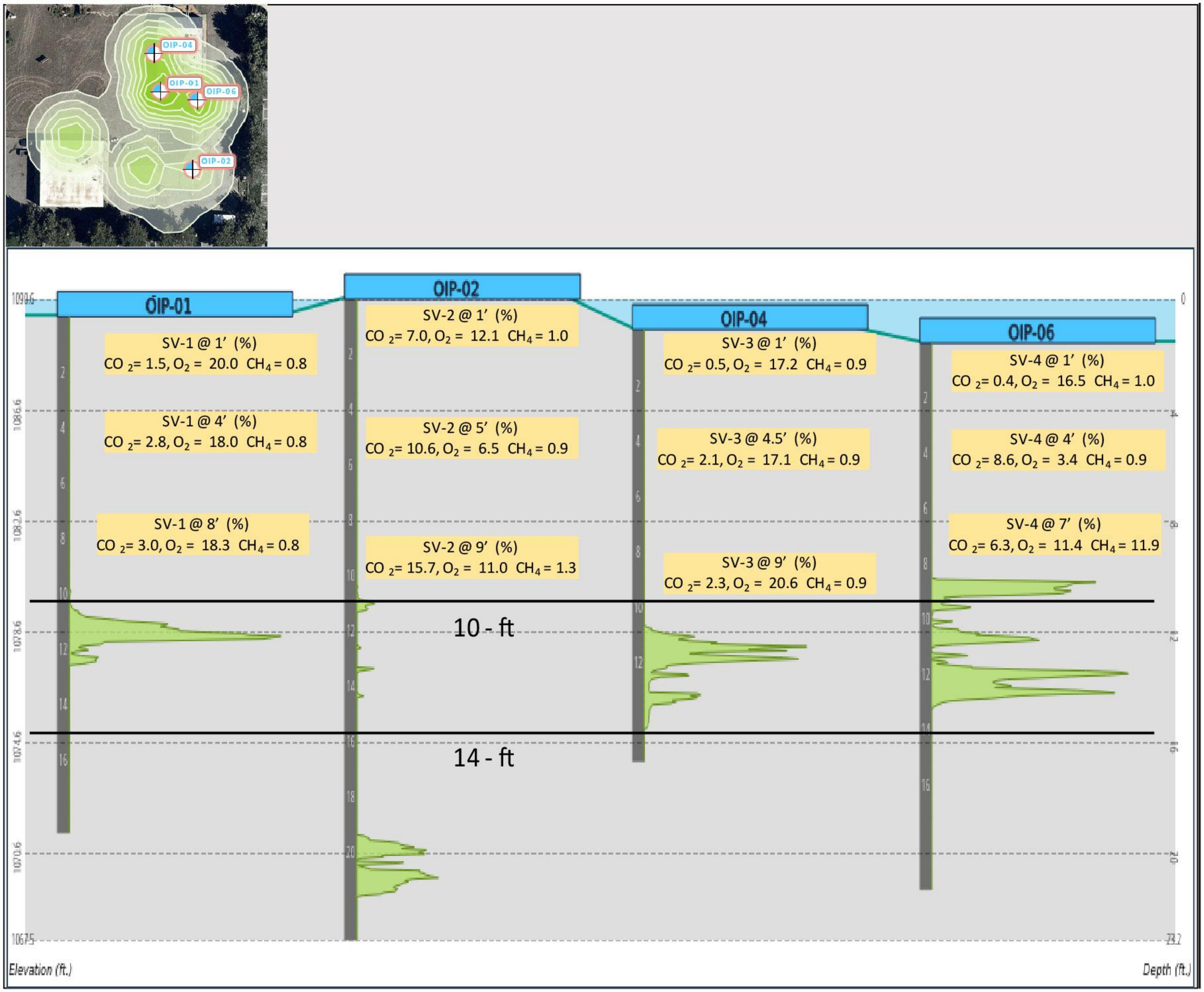

Figure 4-6
Soil Vapor Gradients

City of Yakima
Former Tiger Oil
2312 West Nob Hill Boulevard
Yakima, Washington

Notes:
% = percentage.
CH4 = methane.
CO2 = carbon dioxide.
ft = feet.
O2 = oxygen.
OIP = Optical Imaging Profiler.
SV = soil vapor point monitoring well.

Source: Columbia Technologies, LLC.

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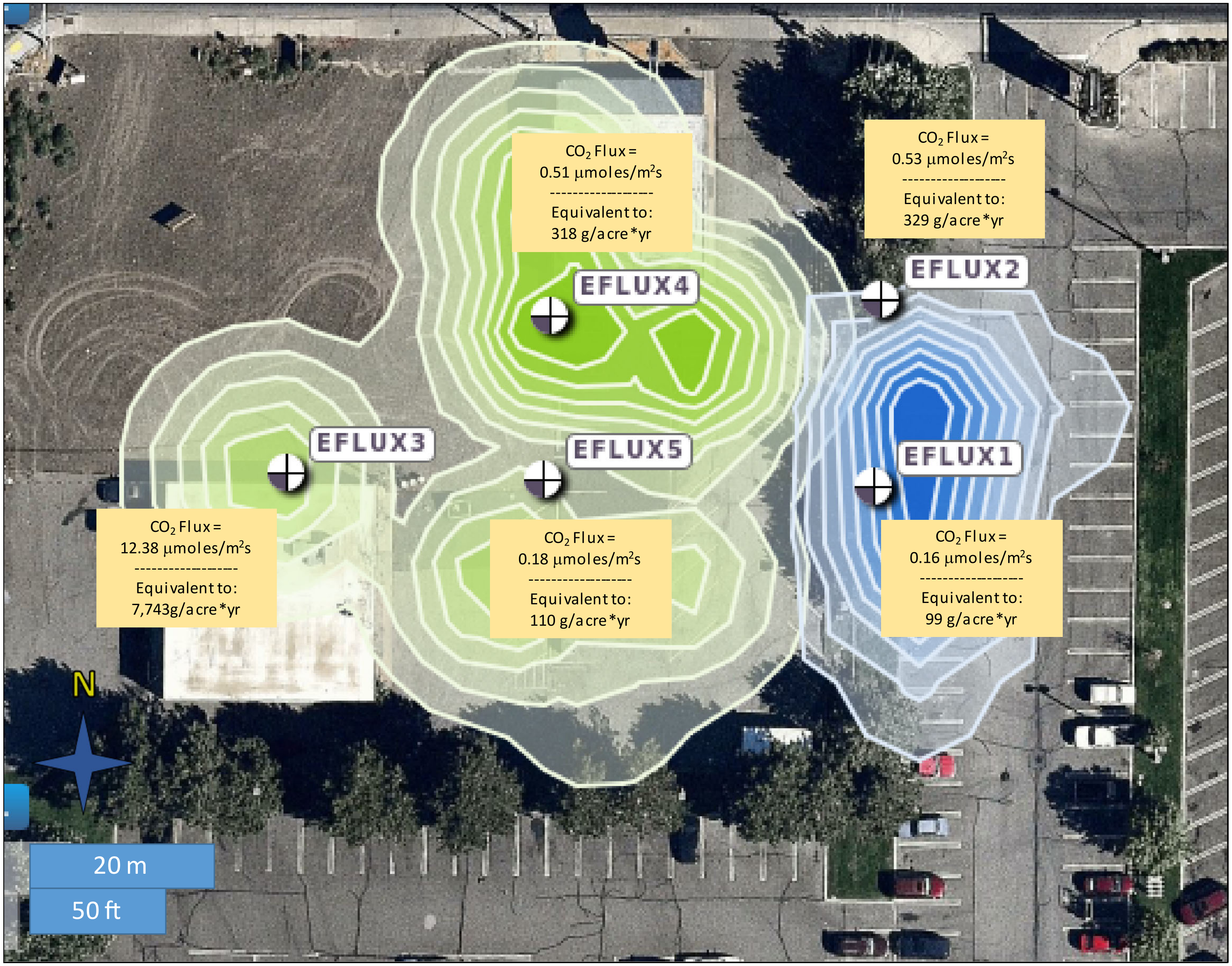
Figure 4-7
Carbon Dioxide Flux Results

City of Yakima
Former Tiger Oil
2312 West Nob Hill Boulevard
Yakima, Washington



Notes:
CO_2 = carbon dioxide.
ft = feet.
g/acre yr = gallons per acre per year.
m = meter.
umoles/m2s = micromoles per square meter per second.

Source: Columbia Technologies, LLC.

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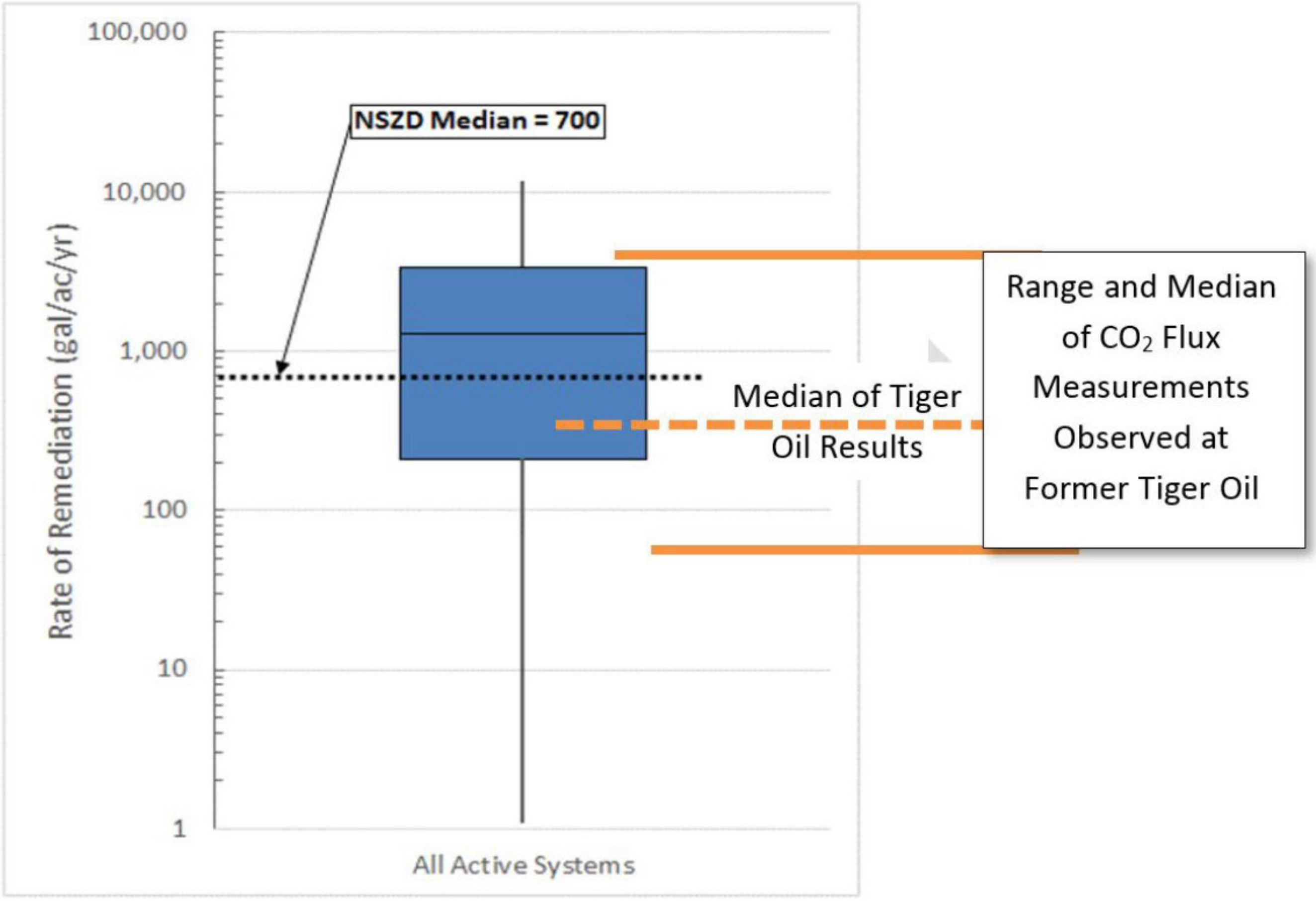
Figure 4-8
Comparison Plot of NSZD to Remediation Rates of Active Remediation Systems

City of Yakima
Former Tiger Oil
2312 West Nob Hill Boulevard
Yakima, Washington



Notes:
CO_2= carbon dioxide.
gal/ac/yr = gallon per acre per year.
NSZD = natural source zone depletion.

Source: Columbia Technologies, LLC.

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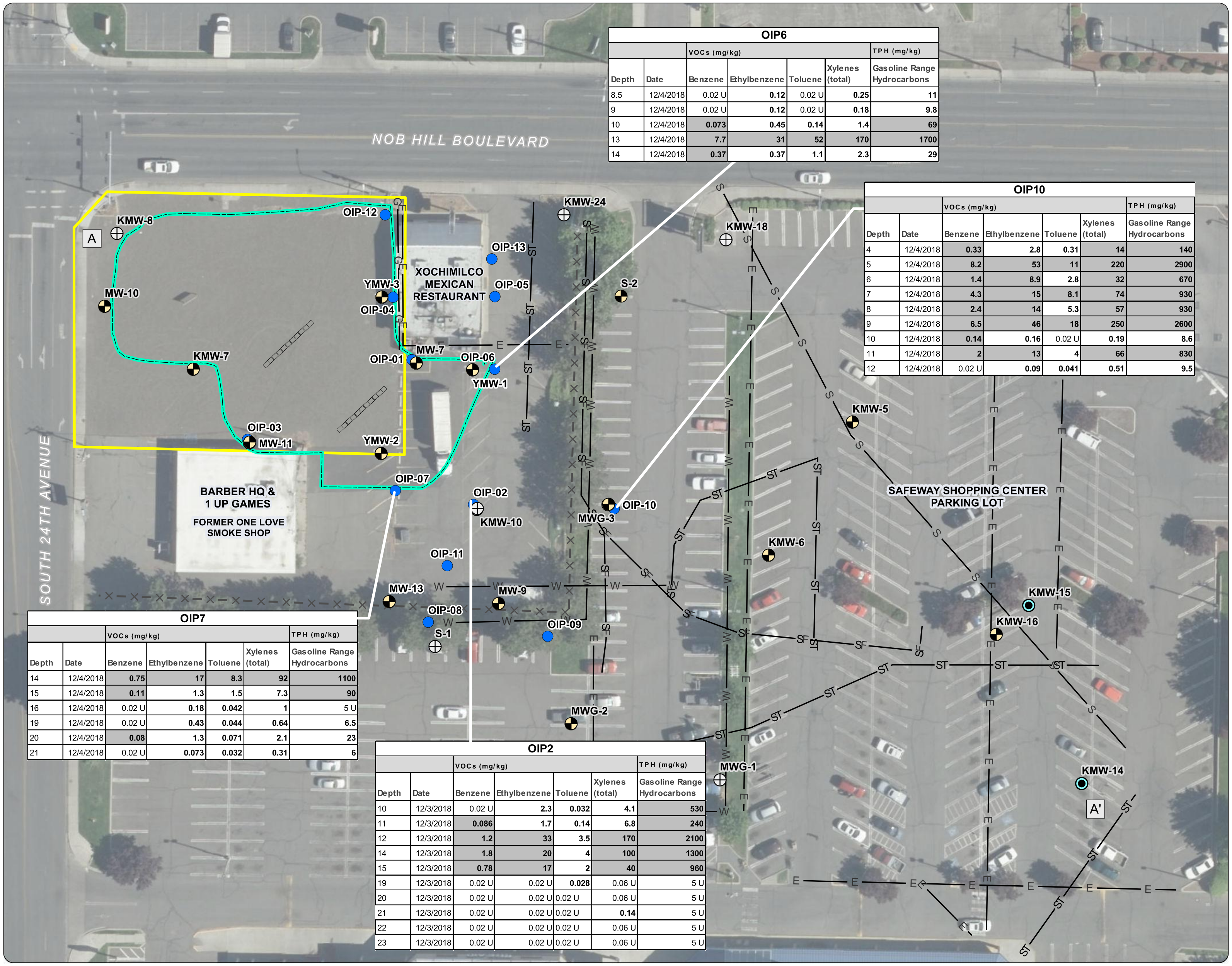
Figure 5-1
High-Resolution Soil Sampling - OIP

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington



OIP6

		VOCs (mg/kg)				TPH (mg/kg)
Depth	Date	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons
8.5	12/4/2018	0.02 U	**0.12**	0.02 U	**0.25**	**11**
9	12/4/2018	0.02 U	**0.12**	0.02 U	**0.18**	**9.8**
10	12/4/2018	**0.073**	**0.45**	**0.14**	**1.4**	**69**
13	12/4/2018	**7.7**	**31**	**52**	**170**	**1700**
14	12/4/2018	**0.37**	**0.37**	**1.1**	**2.3**	**29**

OIP10

		VOCs (mg/kg)				TPH (mg/kg)
Depth	Date	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons
4	12/4/2018	**0.33**	**2.8**	**0.31**	**14**	**140**
5	12/4/2018	**8.2**	**53**	**11**	**220**	**2900**
6	12/4/2018	**1.4**	**8.9**	**2.8**	**32**	**670**
7	12/4/2018	**4.3**	**15**	**8.1**	**74**	**930**
8	12/4/2018	**2.4**	**14**	**5.3**	**57**	**930**
9	12/4/2018	**6.5**	**46**	**18**	**250**	**2600**
10	12/4/2018	**0.14**	**0.16**	0.02 U	**0.19**	**8.6**
11	12/4/2018	**2**	**13**	**4**	**66**	**830**
12	12/4/2018	0.02 U	**0.09**	**0.041**	**0.51**	**9.5**

OIP7

		VOCs (mg/kg)				TPH (mg/kg)
Depth	Date	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons
14	12/4/2018	**0.75**	**17**	**8.3**	**92**	**1100**
15	12/4/2018	**0.11**	**1.3**	**1.5**	**7.3**	**90**
16	12/4/2018	0.02 U	**0.18**	**0.042**	**1**	5 U
19	12/4/2018	0.02 U	**0.43**	**0.044**	**0.64**	**6.5**
20	12/4/2018	**0.08**	**1.3**	**0.071**	**2.1**	**23**
21	12/4/2018	0.02 U	**0.073**	**0.032**	**0.31**	**6**

OIP2

		VOCs (mg/kg)				TPH (mg/kg)
Depth	Date	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons
10	12/3/2018	0.02 U	**2.3**	**0.032**	**4.1**	**530**
11	12/3/2018	**0.086**	**1.7**	**0.14**	**6.8**	**240**
12	12/3/2018	**1.2**	**33**	**3.5**	**170**	**2100**
14	12/3/2018	**1.8**	**20**	**4**	**100**	**1300**
15	12/3/2018	**0.78**	**17**	**2**	**40**	**960**
19	12/3/2018	0.02 U	0.02 U	**0.028**	0.06 U	5 U
20	12/3/2018	0.02 U	0.02 U	0.02 U	0.06 U	5 U
21	12/3/2018	0.02 U	0.02 U	0.02 U	**0.14**	5 U
22	12/3/2018	0.02 U	0.02 U	0.02 U	0.06 U	5 U
23	12/3/2018	0.02 U	0.02 U	0.02 U	0.06 U	5 U

Legend

●	OIP Locations
◕	Monitoring Network Well
⊕	Monitoring Well
◉	Sentry Monitoring Well
🟩	Interim Remedial Action Area (May 2015)
🟨	Former Tiger Oil Property Boundary
▭	Infiltration Gallery for Supplemental Bioremediation

MTCA A CUL (mg/kg)	
Benzene	0.03
Ethylbenzene	6
Toluene	7
Xylenes (total)	9
Gasoline Range Hydrocarbons	30

Notes:
Shading within the table indicates CUL exceedance.
CUL = cleanup level.
LNAPL = light non-aqueous phase liquid.
mg/kg = milligram per kilogram.
OIP = Optical Imaging Profiler.
TPH = total petroleum hydrocarbons.
U = result is not detected at or above method reporting limit.
VOC = volatile organic compound.

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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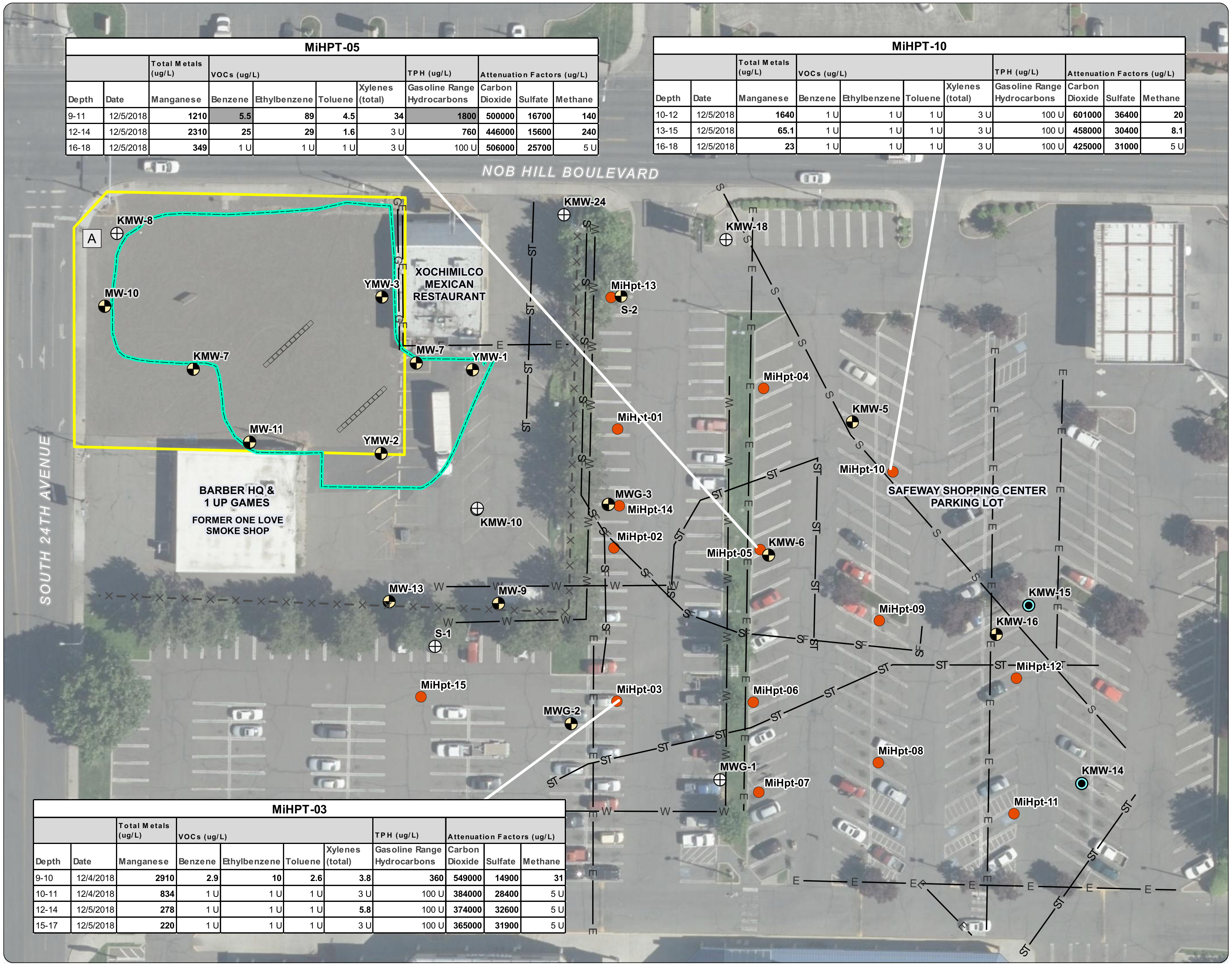

MiHPT-05

		Total Metals (ug/L)	VOCs (ug/L)				TPH (ug/L)	Attenuation Factors (ug/L)		
Depth	Date	Manganese	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons	Carbon Dioxide	Sulfate	Methane
9-11	12/5/2018	**1210**	**5.5**	**89**	**4.5**	**34**	**1800**	**500000**	**16700**	**140**
12-14	12/5/2018	**2310**	**25**	**29**	**1.6**	3 U	**760**	**446000**	**15600**	**240**
16-18	12/5/2018	**349**	1 U	1 U	1 U	3 U	100 U	**506000**	**25700**	5 U

MiHPT-10

		Total Metals (ug/L)	VOCs (ug/L)				TPH (ug/L)	Attenuation Factors (ug/L)		
Depth	Date	Manganese	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons	Carbon Dioxide	Sulfate	Methane
10-12	12/5/2018	**1640**	1 U	1 U	1 U	3 U	100 U	**601000**	**36400**	**20**
13-15	12/5/2018	**65.1**	1 U	1 U	1 U	3 U	100 U	**458000**	**30400**	**8.1**
16-18	12/5/2018	**23**	1 U	1 U	1 U	3 U	100 U	**425000**	**31000**	5 U

MiHPT-03

		Total Metals (ug/L)	VOCs (ug/L)				TPH (ug/L)	Attenuation Factors (ug/L)		
Depth	Date	Manganese	Benzene	Ethylbenzene	Toluene	Xylenes (total)	Gasoline Range Hydrocarbons	Carbon Dioxide	Sulfate	Methane
9-10	12/4/2018	**2910**	**2.9**	**10**	**2.6**	**3.8**	**360**	**549000**	**14900**	**31**
10-11	12/4/2018	**834**	1 U	1 U	1 U	3 U	100 U	**384000**	**28400**	5 U
12-14	12/5/2018	**278**	1 U	1 U	1 U	**5.8**	100 U	**374000**	**32600**	5 U
15-17	12/5/2018	**220**	1 U	1 U	1 U	3 U	100 U	**365000**	**31900**	5 U

Figure 5-2
High-Resolution Groundwater Sampling - MiHpt

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Legend

●	MiHpt Location
◐	Monitoring Network Well
⊕	Monitoring Well
◉	Sentry Monitoring Well
🟩	Interim Remedial Action Area (May 2015)
🟨	Former Tiger Oil Property Boundary
▭	Infiltration Gallery for Supplemental Bioremediation

MTCA A CUL (ug/L)	
Manganese	
Benzene	0.03
Ethylbenzene	6
Toluene	7
Xylenes (total)	9
Gasoline Range Hydrocarbons	30
Carbon Dioxide	
Sulfate	
Methane	

Notes:
Depth shown in feet.
Detected results are shown in bold font.
Shading indicates cleanup level exceedance. Non-detect results were not evaluated for exceedances.
MiHpt = Membrane Interface Probe-Hydraulic Profiling Tool.
MTCA = Model Toxics Control Act.
TPH = total petroleum hydrocarbons.
ug/L = microgram per liter.
U = the result is not detected at or above method reporting limit.
VOC = volatile organic compound.

0 25 50
Feet

Sources: Aerial photograph obtained from Esri ArcGIS Online; Infiltration Gallery delineated by Maul Foster & Alongi, Inc.; stormwater line and taxlot boundaries obtained from City of Yakima; all other features obtained from PLSA Engineering & Surveying.

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Figure 6-1
LNAPL Aerial Distribution on OIP

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Notes:
ft = feet.
LNAPL = light non-aqueous phase liquid.
m = meter.
MIP = Membrane Interface Probe.
OIP = Optical Imaging Profiler.
XSD = halogen specific detector.

Source: Columbia Technologies, LLC.

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Figure 6-2
LNAPL Response on OIP and MIP

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Residual Saturation Screening Values (API Bulletin No. 9, 2000)				
LNAPL	Soil	C_{Sat}	C_{Res}	S_r
Type	Type	mg/kg	mg/kg	cm^3/cm^3
Gasoline	M-C Sand	143	3,387	0.02
Gasoline	M-F Sand	215	5,833	0.03
Gasoline	Silt – F Sand	387	10,000	0.05
Middle Distillates	M-C Sand	5	7,742	0.04
Middle Distillates	M-F Sand	9	13,333	0.06
Middle Distillates	Silt – F Sand	18	22,857	0.1

Notes:
API = American Petroleum Institute.
cm3 = cubic centimeter.
Cres = residual NAPL concentration in soil.
Csat = soil saturation limit for the NAPL mixture, total concentration (mg/kg).
F = fine grained sand.
ft = feet.
LNAPL = light non-aqueous phase liquid.
m = meter.
mg/kg = milligrams per kilogram.
M - C = medium to coarse grained sand.
M - F = medum to fine grained sand.
MIP = Membrane Interface Probe.
NAPL = non-aqueous phase liquid.
No. = number.
OIP = Optical Imaging Profiler.
St = fraction of non-aqueous phase filled void.
TPH = total petroleum hydrocarbons.

Source: Columbia Technologies, LLC.

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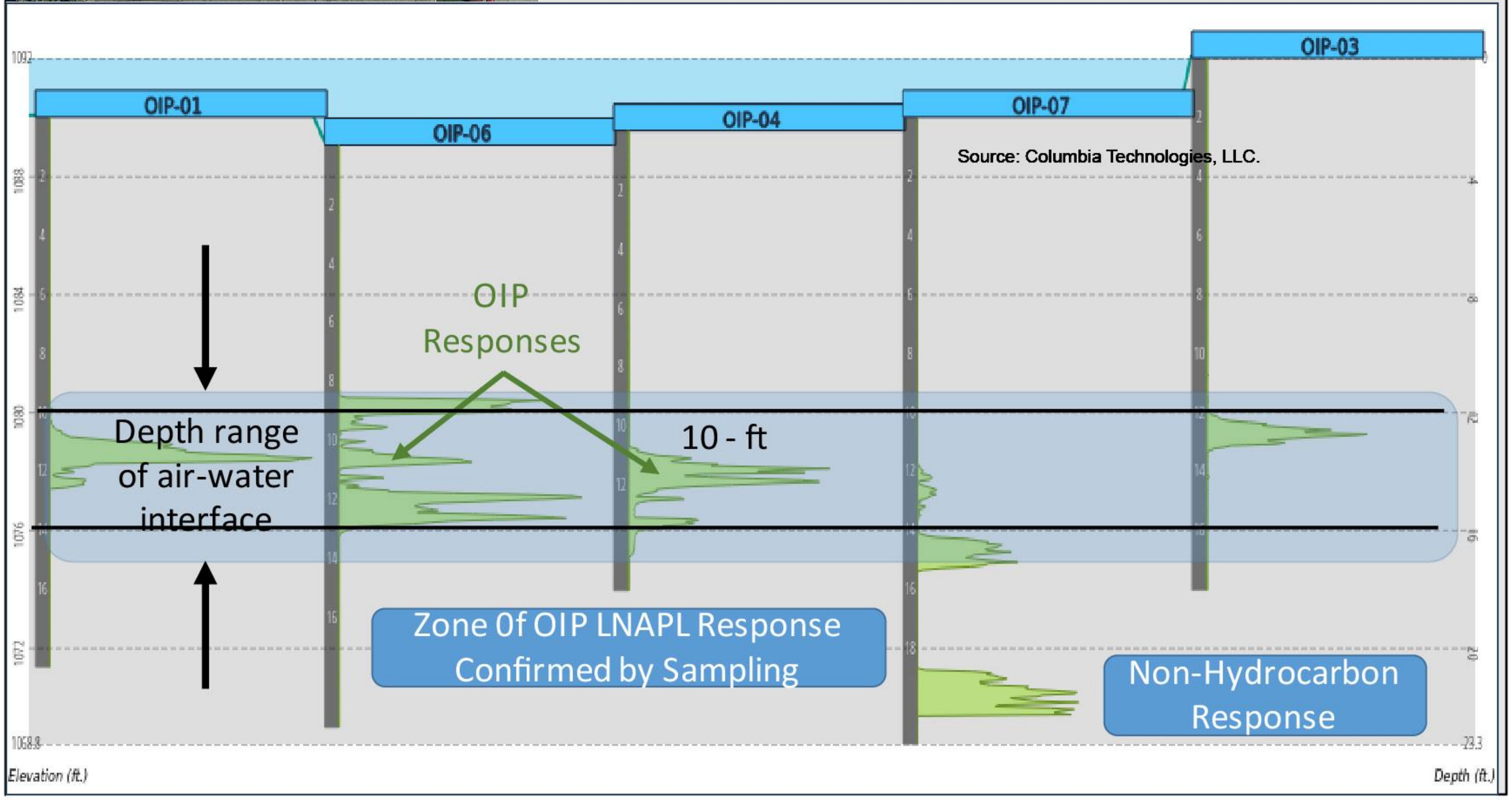

Source: Columbia Technologies, LLC.

Figure 6-3
LNAPL Vertical Distribution on OIP

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washington

Notes:
ft = feet.
LNAPL = light non-aqueous phase liquid.
OIP = Optical Imaging Profiler.

Source: Columbia Technologies, LLC.

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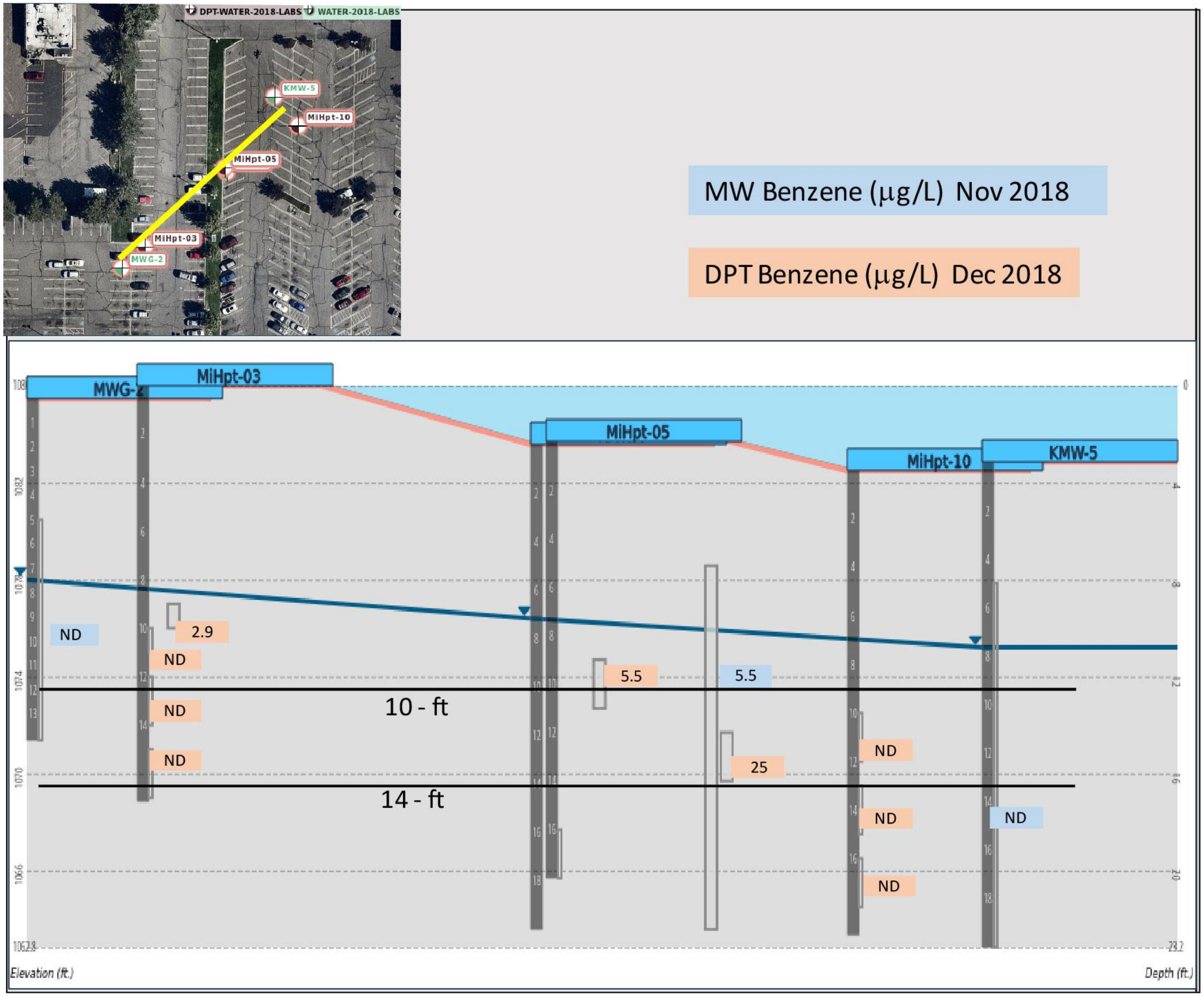

Figure 6-4
Monitoring Wells vs High Resolution Groundwater Sample Results

City of Yakima
Former Tiger Oil Site
2312 West Nob Hill Boulevard
Yakima, Washinton

▼ Depth to groundwater

Notes:
DPT = direct push technology.
ft = feet.
MW = monitoring well.
ND = non-detectable concentration.
MiHpt = Membrane Interface Probe and Hydraulic Profiling Tool.
ug/L = micrograms per liter.

Source: Columbia Technologies, LLC.

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APPENDIX A

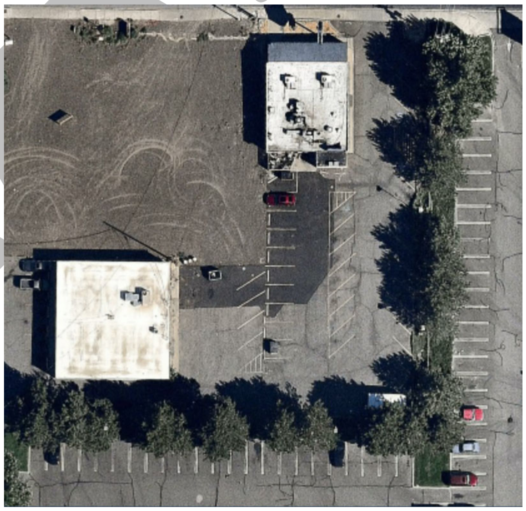
COLUMBIA TECHNOLOGIES HRSC REPORT

Prepared for:

Maul Foster & Alongi, Inc.
2815 2nd Avenue, Suite 540
Seattle, WA

High-Resolution Light Non-Aqueous Phase Liquid (LNAPL) Conceptual Site Model Assessment, Former Tiger Oil, Yakima, WA
December 2018

WA Department of Ecology Facility Site No. 469
Cleanup Site No. 4919
CT Project Number 3578-2017-04



Submitted by:

COLUMBIA Technologies
Rockville, Maryland

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For more information on COLUMBIA Technologies, SmartData Solutions®, and LNAPL assessment tools and protocols visit http://www.columbiatechnologies.com or call 1-888-344-2704.

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Appendix B: Interpretation of Qualitative Direct Sensing Data

Appendix C: Quality Control Procedures

Appendix D: MiHpt Logs (Individual Scale)

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Appendix F: OIP® Logs

Appendix G: MIP Quality Control performance Test Results

Appendix H: CO2 Flux and NSZD Rate Results

Conversion Factors

Inch/Ounce/Pound/PSI to International System of Units

Multiply	By	To obtain
	Length	
Inch (in.)	2.54	Centimeter (cm)
Inch (in.)	25.4	Millimeter (mm)
Foot (ft.)	0.3048	Meter (m)
	Volume	
Ounce (oz.)	29.6	Milliliters (ml)
Gallon (gal)	3.8	Liters (L)
	Pressure	
Pounds per Square Inch (psi)	6.89	Kilopascals (kPa)
	Hydraulic Conductivity	
Feet per day (ft/day)	0.0003527	Centimeters per second (cm/sec)

Temperature in degrees Celsius (°C) is converted to degrees Fahrenheit (°F) as

(°F) = (1.8 x (°C)) + 32

Datum

Horizontal and vertical coordinates are referenced from the World Geodetic System 1984 [EPSG:4326].

Supplemental Information

Electrical conductivity (EC) is provided in millisiemens per meter (mS/meter).

Concentrations of chemical constituents in water are provided in either milligrams per liter (mg/L) or micrograms per liter (μg/L).

Concentrations of chemical constituents in soil are provided in either milligrams per kilogram (mg/kg) or micrograms per kilogram (μg/kg).

Concentrations of chemical constituents in vapor are provided in either milligrams per cubic meter (mg/m^3) or micrograms per cubic meter ($\mu g/m^3$).

High-Resolution Light Non-Aqueous Phase Liquid (LNAPL) Conceptual Site Model Assessment, Former Tiger Oil, Yakima, WA

December 2018

Summary

COLUMBIA Technologies, LLC, in collaboration with **Maul Foster and Alongi (MFA)**, conducted a high-resolution assessment of the Former Tiger Oil site, 2312 West Nob Hill Boulevard, Yakima, Washington (the Site) during the period of 26 November through 03 December 2018.

The primary assessment objectives were to fully characterize the extent physical characteristics of the remaining LNAPL sources and investigate potential preferential pathways for any possible LNAPL migration from the site. Information from this assessment can be used to aid in the monetization of further LNAPL management, the selection of remedial alternatives and aid in the effective design and installation of a remediation system.

Additional objectives include:

- Evaluate the actual LNAPL transmissivity within the soil matrices to determine the potential for mobility and/or fluid recovery.
- Evaluate the pathway or pathways of groundwater flow from the site to the adjacent properties and the measure the amount of mass flow through those pathways.
- Evaluate the potential efficacy of Natural Source Zone Depletion as a viable option for managing the remaining contamination on the site.
- Evaluate any potential petroleum vapor intrusion to the present or future building structures at the site.

To accomplish these objectives, a High-Resolution Site Characterization (HRSC) was conducted and an updated LNAPL Conceptual Site Model (LCSM) was developed in accordance with the guidelines of the Interstate Technology and Regulatory Council (ITRC), *LNAPL-3: LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies* *(2018)*.

The updated LCSM presented herein is based on high-resolution direct sensing measurements made by **COLUMBIA Technologies** and pertinent historic site data provided by **MFA**.

The locations of monitoring wells impacted by petroleum hydrocarbons (PHCs) at concentrations indicative of LNAPL are presented in **Figure 5** (see end of report).

The direct sensing data employed for this assessment are comprised of the Optical Imagine Profiler (OIP®), and the combined Membrane Interface Probe (MIP) and Hydraulic Profiling Tool (HPT) measurements. This combined tool is referred to as a MiHpt. Direct sensing logs are presented in **Appendices D, E,** and **F**.

Direct sensing survey stations are shown in **Figures 6 and 7**. Direct sensing survey locations consist of the following:

- Thirteen (13) OIP® borings
- Fifteen (15) MiHpt borings

These direct-sensing stations were initially located at the Site adjacent to existing monitoring wells exhibition elevated concentrations of petroleum hydrocarbons (PHCs). Subsequent locations were added where needed to more completely define the LNAPL footprint.

The OIP® technology was used to delineate residual LNAPL phase PHCs. The direct sensing technology was changed to MiHpt as the OIP® responses diminished east and south of the site. The MiHpt survey continued east and south to evaluate the dissolved phase plume migration off of the site.

Multiple lines of evidence developed through this HRSC indicate a residual LNAPL east of the site in the parking lot behind the Xochimilco Restaurant.

OIP® responses generally occur in a zone ranging from eight to fifteen (8 to 15) feet below ground surface (BGS), depending on the location. The highest responses occur west and south of the Xochimilco Restaurant and may indicate that further LNAPL resides beneath the restaurant.

MiHpt data indicates that dissolved phase impacts diminish with distance to the east and southeast of the site. Groundwater data from monitoring wells and discrete interval sampling confirm this trend.

High resolution soil samples were collected across the depth interval of elevated OIP® and MiHpt responses at four (4) locations with the responses of greatest magnitude and thickest impact within the observed footprint. The gasoline-range concentrations fall below screening values that would indicate potential mobility or and recoverability according to API guidelines (Reference A).

CO2 Flux analysis indicates that Natural Source Zone Depletion is occurring at a rate of at least 100 gallons/acre/year with a mean depletion rate of 325 gallons/acre/year. This rate is of the same order of magnitude as more aggressive active remediation systems.

Groundwater sampling results confirm natural attenuation of the residual LNAPL body. Aerobic conditions are present upgradient of the LNAPL changing to anaerobic conditions within the footprint of the residual LNAPL. These conditions are marked by a negative oxygen reduction potential (ORP) and the presence of elevated methane levels in soil gas.

Aerobic conditions are reestablished downgradient of the LNAPL body most likely by the influx of oxygenated water and reduced LNAPL mass.

Introduction

Background and Current Conceptual Site Model

The Former Tiger Oil site is located at, **2312** West Nob Hill Boulevard, Yakima, Washington. Monitoring wells in the vicinity of the site continue to exhibit concentration levels of BTEX compounds above guidelines established by the Washington Department of Ecology. Previous excavation and amendment activities have not mitigated these concentrations sufficiently.

Background provided by MFA

“*The Property was operated by the Tiger Oil Company as a retail fuel station until it was purchased by Tiger Oil Corporation (New Tiger) in 1987. New Tiger operated an Exxon-branded fuel station and convenience store at the Property from 1987 until 2001. All commercial operations ceased in 2001 and the Property has since remained vacant. The fuel station comprised four underground storage tanks (USTs) (one 20,000-gallon, two 10,000-gallon, and one 8,000-gallon tank) and associated product lines. The system was used for bulk petroleum storage and distribution.*

In April 1981, volatilization of petroleum products in a drainage improvement district (DID) storm drain line adjacent to the Property resulted in an explosion and triggered an investigation by the City and Ecology to test the Property’s UST system. During the investigation, it was determined that a leak in the product line of the UST system had impacted the surrounding soil and groundwater at the Property and adjoining properties. The leak in the UST line was determined to be the source of the petroleum products found in the nearby DID line. Ecology issued a Notice of Violation and Enforcement Order, No. DE 82-517, to Tiger Oil Company, requiring recovery of free product from the Site.

It was estimated that, in the early 1980s, approximately 20,000 gallons of petroleum-related product was released from the Property’s UST system. Several recovery wells were installed by early 1983 at the Property and on adjacent parcels to the east and south. By March 1984, approximately 16,000 gallons of free product had been extracted from the recovery wells.

In March 1990, Ecology issued Enforcement Order No. DE 90-C140 to New Tiger and Federated Insurance, requiring site stabilization and a remedial investigation and feasibility study for the Site. In 1991, a site hazard assessment was conducted, resulting in a hazard ranking of 1 (with 1 as the highest risk and 5 the lowest risk).

In August 1995, soil vapor extraction (SVE) and groundwater extraction (GWE) systems began operation to collect free product (i.e., gasoline that has not dissolved into groundwater), and *impacted groundwater and soil vapor on the Site as well as to mitigate off-site migration of dissolved-phase gasoline-range total petroleum hydrocarbons (TPH) and free product. However, the SVE and GWE systems were limited in scope and did not adequately target areas of free product present on the Site. Ecology concluded that the SVE and GWE systems were not representative of final cleanup actions for the Site.*

In October 2004, New Tiger and Federated Insurance entered into a Consent Decree with Ecology requiring implementation of Ecology's 2004 amended CAP. In December 2004, the USTs and their associated piping, along with approximately 650 cubic yards of impacted soil around the UST system, were removed from the Site. Two trenches were excavated in the vicinity of the USTs to determine the amount of free product, if present, at the top of the water table at the Site. Free product was encountered, and an additional SVE system was installed to treat the impacted soil vapor at the Site.

Appreciable free product was encountered at monitoring wells MW-7 (at 2.34 feet thick, located adjacent east of the Property on the former Xochimilco restaurant parking lot) and MW-11 (at 1.46 feet thick, located adjacent southeast of the former USTs on the Property) during a groundwater monitoring event in June 2013."

Project Objectives

The primary assessment objectives are to fully characterize the remaining LNAPL sources and investigate potential preferential pathways for LNAPL migration from the site. Information from this assessment can be used to aid in the selection of remedial alternatives and aid in the effective design and installation of a remediation system.

Additional objectives include:

- Evaluate the actual LNAPL transmissivity within the soil matrices to determine the potential for mobility and/or fluid recovery.
- Evaluate the pathway or pathways of groundwater flow from the site to the adjacent properties and the measure the amount of mass flow through those pathways.
- Evaluate the potential efficacy of Natural Source Zone Depletion as a viable option for managing the remaining contamination on the site.
- Evaluate any potential petroleum vapor intrusion to the present or future building structures remaining on the site.

Methods, Assumptions, and Procedures

This High-Resolution Site Characterization (HRSC) was conducted in accordance with the guidelines of the Interstate Technology and Regulatory Council (ITRC), *LNAPL-3: LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies (2018)*.

Planning for this High-Resolution Site Characterization (HRSC) involved a review of available site documentation to develop an understanding of the existing Conceptual Site model (CSM) and indications of residual LNAPL impacts, and to assess the performance of remedial efforts implemented to date.

Locations of monitoring wells were mapped along with the results of recent groundwater analyses and a high-resolution assessment work plan was developed.

Optical Imaging Profiler (OIP®)

Utilizing OIP®, the vertical distribution and relative concentrations of LNAPL in the subsurface can be discerned at the centimeter scale. Initial OIP® stations were advanced in proximity to selected monitoring wells with known residual phase petroleum hydrocarbons or dissolved phase concentrations of benzene or BTEX indicative of LNAPL. These first lines of evidence enabled the team to characterize the presence and depth interval of LNAPL at the impacted locations. The observed response of the OIP® system at these locations then served as a reference for complete delineation of LNAPL present at the site.

The remaining OIP® stations were planned to be advanced at selected locations stepping out from the responses discovered during the initial borings to establish lateral boundaries to the LNAPL mass and confirm stability.

Membrane Interface Probe-Hydraulic Profiling Tool (MiHpt)

COLUMBIA Technologies employed two primary chemical detectors on the MIP for this assessment: A Photo-Ionization Detector (PID) and a Flame-Ionization Detector. The PID provides sensitivity to aromatic compounds (BTEX). The FID is a general detector useful for confirmation of high concentrations of organic compounds, including those not measured by the PID. Together, the two detectors provide a reliable measurement for the presence of residual petroleum LNAPL combined with concentrated adsorbed, dissolved, and vapor phase PHCs.

COLUMBIA Technologies employed the Hydraulic Profiling Tool (HPT) with the Electrical Conductivity (EC) system to evaluate subsurface hydrostratigraphy in the area of the release. The HPT identifies soil intervals exhibiting higher hydraulic permeability or heterogeneities that infer preferential pathways for the movement of LNAPL or dissolved-phase contaminants, and lower permeability layers that often serve as storage zones for residual hydrocarbons.

The HPT pressure logs record changes in hydraulic pressure measured directly as water is pumped into the formation at a constant rate. These logs reveal the variability and relative hydraulic conductivity of the soil.

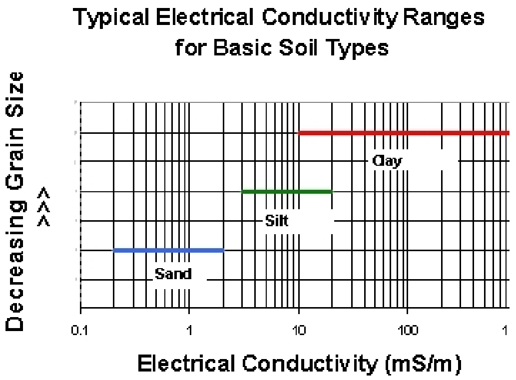
The combined membrane Interface Probe and Hydraulic Profiling tool is known as the MiHpt Probe. This probe also contains an Electrical Conductivity dipole array that measures the electrical conductivity (EC) of soil and groundwater is mounted on the tip of the MIP probe.

EC measurements identify changes in the soil's electrical conductivity that can be related to changes in stratigraphy, providing insight into contaminant pathways when viewed in relation to chemical detector response.

Low EC values generally indicate coarse-grained materials (sand and gravel), while higher EC values usually indicate elevated clay content, although water chemistry and other site-specific factors influence EC response as well.

General conductivity ranges for basic soil types are presented in **Table 1** below (Geoprobe, 2015).

Table 1



Verification of LNAPL Plume Stability Using High-Resolution Discrete Soil Sampling

Guided by the results of the OIP® and MiHpt surveys, **COLUMBIA** recommended high-resolution (1-foot interval) saturated soil sample at locations across the vertical intervals of most continuous and highest responses. Samples were selected to provide a statistically significant profile across the zones of response.

Saturated soil cores were collected using a direct-push Geoprobe Macrocore soil sampler, which collects cores in acetate liners. Discrete soil samples were collected using Terracore devices. Samples transferred to 40-ml Volatile Organic Analysis (VOA) vials and placed in coolers with ice for overnight shipment to a laboratory. Soil samples were sent for laboratory analysis for Gasoline Range Organics (GRO), Diesel Range Organics (DRO) or both, depending on the site history. Sample results are compared to screening concentrations in API Bulletin 9 for potential product mobility and recoverability and to establish plume stability.

Delineation of Dissolved Phase Contamination Using High-Resolution Discrete Groundwater Sampling

To delineate the vertical and horizontal extent of dissolved phase contamination discrete-interval water samples were collected based on the information in the MiHpt logs at the site. Sample locations and intervals are chosen based on both the range of MIP-PID detector responses and in zones of higher hydraulic permeability determined from the HPT pressure profiles.

Sampling was achieved by advancing a Geoprobe SP-16 sample tool to the desired depth, then pulling back the outer rods to expose a desired length of stainless-steel screen at the desired depth interval. Water samples were then be collected using a peristaltic pump through passing through a flow cell measuring physical properties of the groundwater.

Water samples were collected in the appropriate containers for the analysis desired, such as preserved 40-ml VOAs for EPA Method 8260 for volatile organic compounds (VOCs). Sample containers were placed in a cooler with ice for shipment to a laboratory for analysis. BTEX by 8260 and TPH-GRO.

Determination of Natural Source Zone Degradation

Verification of LNAPL Degradation Using Groundwater Sampling

In addition to changes in VOC concentrations, further verification of LNAPL degradation in the saturated zone can be determined by measuring physical and geochemical groundwater parameters. Measurements of pH, Oxidation-Reduction Potential (ORP), temperature, and dissolved oxygen determine the degree and where in the LNAPL footprint degradation is occurring and whether by aerobic or anaerobic processes. Measurement of electron receptor concentrations including nitrate, ferric iron, and sulfate, provide an understanding of both the availability of receptors and the degree of anaerobic natural degradation in the saturated zone. Refer to Figure XX below.

The assessment team used three lines of measurement, one upgradient and two downgradient of the LNAPL mass to monitor for natural degradation in the saturated zone. A combination of groundwater samples from both the existing monitoring well network and discrete groundwater sampling described above were used to complete this evaluation.

The groundwater monitoring well network was sampled for geochemical parameters in November 2018. The results from selected wells are provide in

Figure 19 and demonstrate the residual LNAPL is undergoing anaerobic degration

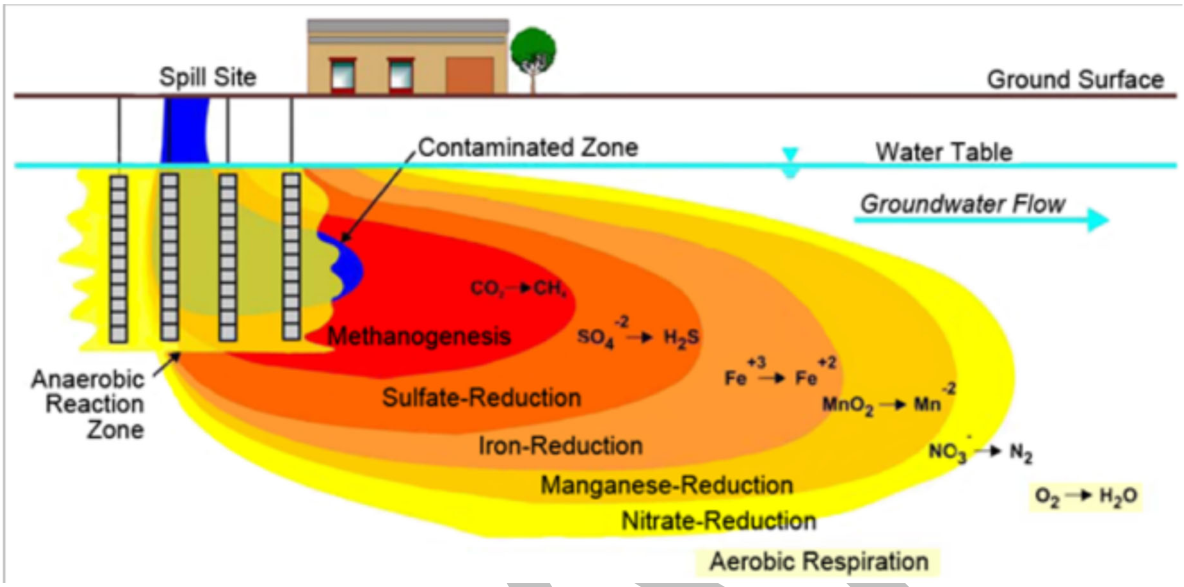


Figure 1 - LNAPL Degradation Under Anaerobic Conditions

Verification of LNAPL Degradation Using Vapor Sampling in the Vadose

Vapor phase related processes natural source zone degradation of petroleum have been determined to be a major contributor to hydrocarbon mass reduction. Infiltration of oxygen from the surface combining with methane created as a byproduct of anaerobic degradation produces a mass and flux of carbon dioxide directly related to the natural degradation of the hydrocarbon mass.

API Publication 4784 provides for three methods for the Quantification of Vapor Phase-related Natural Source Zone Depletion (NSZD) Processes. The technical team chose to use two methods: The Vapor Gradient Measurement and the Passive Carbon Dioxide Flux Chamber Measurements in order to confirm and quantify the rate of vapor phase-related NSZD at the site.

Vapor Gradient Measurement

Vapor gradients above the LNAPL plume can provide additional information on subsurface processes occurring at petroleum contaminated sites. Measurement profiles of the CO_2, oxygen, and methane concentrations at several depth intervals reveals the concentration gradient for those compounds as depth decreases from the top of the plume to the ground surface.

For this project, nested multi-depth vapor wells were installed at four (4) locations with three screened sampling intervals between one (1) and nine (9) feet below grade. The wells were sampled using a multiple parameter landfill gas field instrument. The sampling results are provided in **Figure 20**.

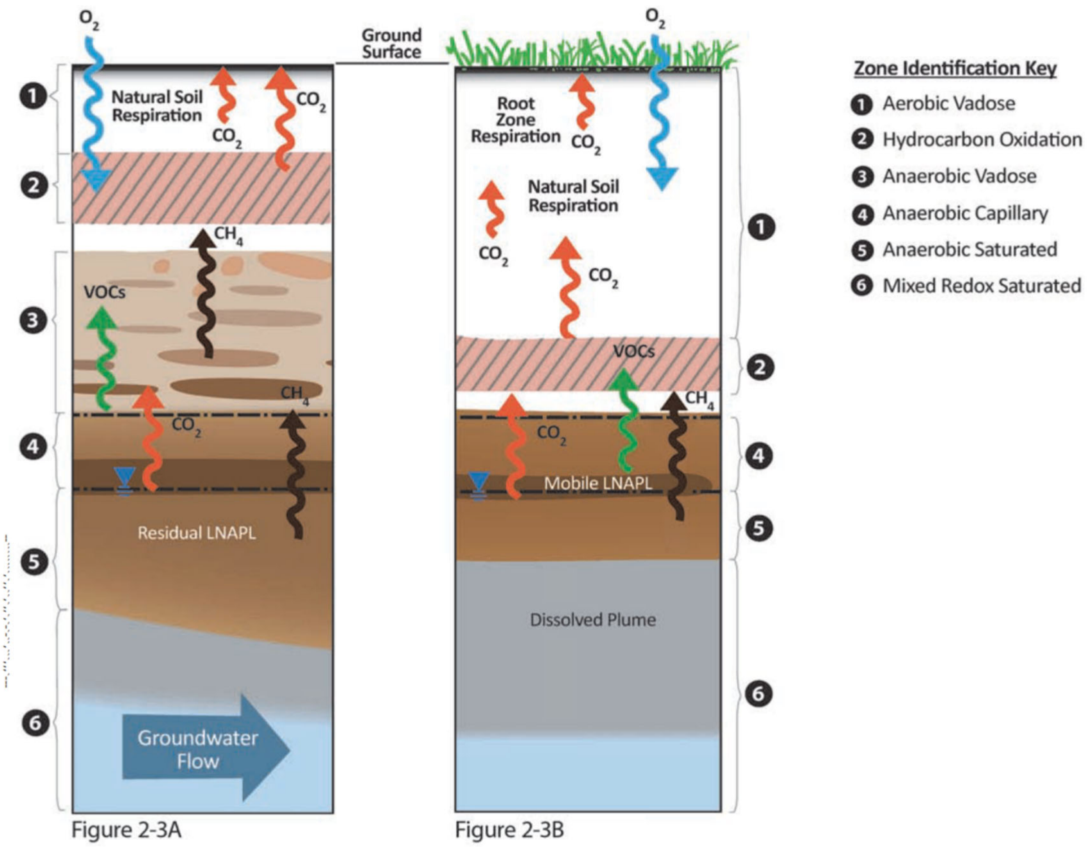


Figure 2-3A

Figure 2-3B

Figure 2 – Conceptualization of Vapor Phase-related NSZD Processes (a) with and (b) without Hydrocarbon Impacts in the Vadose Zone[1]

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[1] Managing Risk at LNAPL Sites, API Bulletin No. 18 2nd Edition, May 2018

Passive Carbon Dioxide Flux Chamber Measurement

Carbon Dioxide (CO_2) Flux is a useful tool to determine that Natural Source Zone Depletion (NSZD) is occurring at a site. To measure CO_2 Flux, passive flux chambers were placed at five (5) locations above the established LNAPL footprint. The collectors are sorbent traps, or chambers, which collect CO2 over a period ranging from several days to several weeks depending on site characteristics. These are installed at the ground surface, in areas with no impermeable cover (such as asphalt). Following exposure, the traps are collected, sealed, and sent to a laboratory for analysis. Biogenic CO_2 is separated from petroleum-generated CO_2 by carbon-14 analysis. A complete description of the process is included in **Appendix H**.

Results and Discussion

Hydrostratigraphy

High HPT pressure and low system flow is indicative of low permeability soils. Higher permeability is manifested by low hydraulic pressure and normal system flow.

HPT data identified a vertical profile of soils exhibiting good hydraulic permeability or transport zones, interbedded with one or two lower permeability soils. The two lower permeability zones were approximately eight (8) to ten (10) feet and twelve (12) and sixteen (16) feet bgs. These lower permeability zones exhibited elevated MIP response indicating they were acting as storage zones for PHCs.

Depth to groundwater at the site has been reported as seasonally variable ranging in depth between eight (8) and thirteen (13) bgs.

LNAPL Stability

Reference (O) provides a comprehensive update of the current science and understanding of LNAPL distribution in the subsurface and how it changes over time.

The residual LNAPL was identified primary at or below the air-water interface and exhibited the characteristics of a discontinuous (residual), non-wetting material present primarily in thin finer-grained soils acting as storage zones. (See **Figure 3** below)

In order to map the extent of the residual LNAPL mass, the initial OIP® locations were placed adjacent to the monitoring wells with the greatest impact. OIP® logs advanced at the site reveal evidence of residual-phase gasoline LNAPL at depth intervals ranging from 8.5 to 15 feet below ground surface (bgs).

Additional, OIP® locations were then placed south and east of the residual source area to determine the lateral extent of the LNAPL. Further delineation to the west and north were not accessible because of the backfill in the tank excavation to the west and a roadway to the north. As a result, the response measured by the OIP® is generally located east of the site at the rear of the Xochimilco restaurant. Additional LNAPL may be located under the excavated portion of the site and under the restaurant.

Figure 4 presents the LNAPL footprint in a plan view as detected by OIP®. The vertical distribution of the LNAPL at the five (5) locations with the greatest magnitude of OIP® response are presented in **Figure 8.**

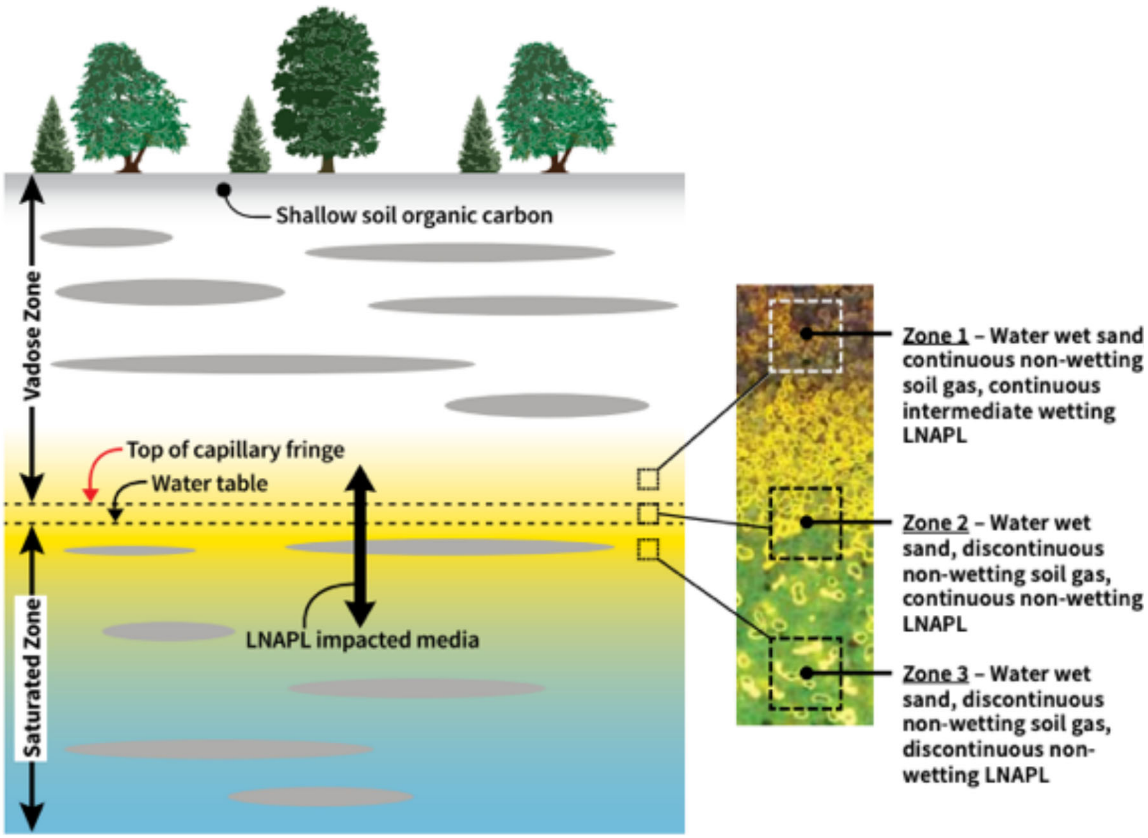

Figure 3 LNAPL Distribution in the Subsurface[2]

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[2] Managing Risk at LNAPL Sites, API Bulletin No. 18 2nd Edition, May 2018

High-Resolution Soil Sampling to Verify Plume Stability and Direct Sensing Results

Guided by the OIP® and MiHpt logs, **COLUMBIA and MFA** collected high-resolution discrete soil samples across the zone of greatest response at four (4) stations: OIP-02, OIP-06, OIP-07, and OIP-10.

The soil samples locations and maximum concentrations are displayed in **Figure 10**.

Figures 11 through 14 present the OIP® logs and the corresponding concentration of total petroleum hydrocarbon (TPH) for gasoline range organics (GRO) measured in discrete soil samples taken at each location in a vertical profile.

The results of laboratory analyses of the discrete soil samples are tabulated in **Table 2** below.

These results imply that the overall LNAPL footprint is stable on a macro-scale. On a localized scale, however, LNAPL movement into and out of pore spaces (or monitoring wells) may persist, largely due to fluctuations in hydraulic conditions. That is, LNAPL may continue to exhibit micro-scale mobility within an LNAPL zone that is stable on a macro-scale.

The API screening values were developed for use in making conservative estimates of NAPL mobility, based on residual NAPL concentrations and residual NAPL saturation in unsaturated soils. The use of these values to screen for NAPL mobility presumes homogeneous soils and soil properties, which is never the case. Inherent geologic variability, macro-pores, and fractures will greatly affect the mobility and movement of NAPL. These factors must be recognized when these screening values are applied.

Concentrations above LNAPL saturation concentrations (C_{sat}) are indicative of the presence of LNAPL. Residual LNAPL saturation concentrations (C_{res}) are used as a screening limit below which LNAPL is presumed to be immobile.

The results for TPH GRO fall below the concentrations necessary for product mobility according to API guidelines[3].

This condition of concentrations below the threshold required for LNAPL mobility with result in inefficient or ineffective hydraulic product recovery using methods such as hydraulic recovering or high-vacuum extraction.

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[3] API Soil & Groundwater Research Bulletin No. 9., Brost et al., June 2000. *Non-Aqueous Phase Liquid (NAPL) Mobility Limits in Soil*.

Residual Saturation Screening Values (API Bulletin No. 9, 2000)

LNAPL	Soil	C_{Sat}	C_{Res}	S_r
Type	Type	mg/kg	mg/kg	cm^3/cm^3
Gasoline	M-C Sand	143	3,387	0.02
Gasoline	M-F Sand	215	5,833	0.03
Gasoline	Silt – F Sand	387	10,000	0.05
Middle Distillates	M-C Sand	5	7,742	0.04
Middle Distillates	M-F Sand	9	13,333	0.06
Middle Distillates	Silt – F Sand	18	22,857	0.1

Discrete Soil Sample Results for Former Tiger Oil (mg/kg)

Sample ID	Depth	TPH - GRO
DSS-OIP-02	10	**530**
DSS-OIP-02	11	**240**
DSS-OIP-02	12	**2,100**
DSS-OIP-02	14	**1,300**
DSS-OIP-02	15	**960**
DSS-OIP-02	19	ND (<5.0)
DSS-OIP-02	20	ND (<5.0)
DSS-OIP-02	21	ND (<5.0)
DSS-OIP-02	22	ND (<5.0)
DSS-OIP-02	23	ND (<5.0)
DSS-OIP-06	8.5	11
DSS-OIP-06	9	9.8
DSS-OIP-06	10	69
DSS-OIP-06	13	**1700**
DSS-OIP-06	14	29
DSS-OIP-07	14	**1,100**
DSS-OIP-07	15	90
DSS-OIP-07	16	ND (<5.0)
DSS-OIP-07	19	6.5
DSS-OIP-07	20	23
DSS-OIP-07	21	6.0
DSS-OIP-10	4	**140**
DSS-OIP-10	5	**2,900**
DSS-OIP-10	6	**670**
DSS-OIP-10	7	**930**
DSS-OIP-10	8	**930**
DSS-OIP-10	9	**2,600**
DSS-OIP-10	10	8.6
DSS-OIP-10	11	**830**
DSS-OIP-10	12	9.5

Table 2:
Comparison of Measured TPH Concentrations to
API Residual Saturation Screening Values for NAPL Mobility

Dissolved-Phase Distribution

Lateral Extent of and Pathways for Groundwater Contamination

Once the extent of the LNAPL mass was determined using the OIP® technology MiHpt technology was next advanced to profile lower concentration, typically less than 1000 mg/kg, residual phase LNAPL and dissolved petroleum hydrocarbons (PHCs) down to less than 100 μg/L.

MiHpt logs reveal an area of residual PHCs in the area east of the site, diminishing with distance from the source. **Figure 10** shows the footprint on significant dissolved phase contamination identified with the MIP-PID technology plotted downgradient of the footprint for residual LNAPL initially identified with the OIP® technology.

Groundwater sampling was conducted across three zones related to the identified residual LNAPL mass. These three zones were:

- upgradient of the LNAPL body by sampling existing monitoring wells,
- immediately downgradient of the LNAPL mass to identify migration pathways by using multiple high-resolution discrete groundwater samples, and
- further downgradient to optimally verify the total extent of groundwater contamination by sampling existing monitoring wells.

Results from the water sampling are presented in **Table 3** below.

The direct-sensing logs generated for this assessment are presented in **Appendices D, E** and **F**.

Table 3
Discrete Groundwater Sampling Results

Discrete Water Sample Results for Hydrocarbons at the Former Tiger Oil Site (μ/L)						
Sample ID	Depth (ft)	Benzene	Toluene	Ethylbenzene	Xylenes	TPH-GRO
DSW-MiHpt-03	10 - 12	**2.9**	**2.6**	**10**	**3.8**	**360**
	11 – 13	1 U	1 U	1 U	3 U	100 U
	12 – 14	1 U	1 U	1 U	**5.8**	100 U
	15 – 17	1 U	1 U	1 U	3 U	100 U
DSW-MiHpt-05	09 - 11	**5.5**	**4.5**	**89**	**34**	**1800**
	12 – 14	**25**	**1.6**	**29**	3 U	760
	16 – 18	1 U	1 U	1 U	3 U	100 U
DSW-MiHpt-10	10 - 12	1 U	1 U	1 U	3 U	100 U
	13 – 15	1 U	1 U	1 U	3 U	100 U
	16 – 18	1 U	1 U	1 U	3 U	100 U

Saturated Zone Natural Degradation Processes

The assessment team used three lines of measurement, one upgradient and two downgradient of the LNAPL mass to monitor for natural degradation in the saturated zone. A combination of groundwater samples from both the existing monitoring well network and discrete groundwater sampling described above were used to complete this evaluation.

The results of this evaluation are presented in **Figure 19**.

Natural Source Zone Depletion

Vapor Phase Degradation in the Vadose Zone

In reference (M), Palaia describes that "after a subsurface release, the mass of petroleum hydrocarbon light non-aqueous phase liquid (LNAPL) is degraded by the intrinsic processes of volatilization, dissolution, and biodegradation. These collective processes have been termed natural source zone depletion (NSZD). Recent published literature indicates that NSZD is significant and may contribute to NAPL pool stability."

Vapor Gradient Measurement

For this project, nested multi-depth vapor wells were installed at four (4) locations with three screened sampling intervals between one (1) and nine (9) feet below grade. The wells were sampled using a landfill gas field instrument. The sampling results are provided in **Figure 20**.

These data indicate the expected infiltration of oxygen from the surface with concentration decreasing with depth, increasing concentrations of carbon dioxide with depth, and a small increase in methane noted closest to the air-water interface. These data are characteristic of degradation associated with a hydrocarbon impact below the air-water interface and without any residual hydrocarbon impact in the vadose zone.

Passive Carbon Dioxide Flux Chamber Measurement

The initial measurements of CO_2 flux measurements completed during this field investigation fall within range of measurements compiled and reported by Palaia in reference (M) as shown in **Figure 4** below.

"[Palaia's] study reported NSZD data reported for eleven diverse sites collected between 2011 and 2015. The sites include urban and rural areas with predominantly pervious, but variable ground cover over consolidated and unconsolidated subsurface soil types. The sites had various sizes, sources, types, and ages of petroleum releases.

Sitewide, geospatially averaged NSZD rates were generally observed within an order-of- magnitude ranging between 300 to 5,600 gal/ac/yr. The lowest rate was measured at a site in Alberta with natural gas liquid LNAPL in sedimentary bedrock. The highest rate was measured at a semi-arid site in Colorado with weathered diesel in a sand.

Palaia demonstrates that the NSZD rates measured using CO_2 efflux methods are significant and reasonable as compared to reported mass removal rates from the active remediation systems studied herein. The theoretical and actual measured NSZD rates fell within the range of active remediation mass removal rates and prove that the methods of CO_2 efflux monitoring are producing reasonable results.

Understanding site-specific rates of NSZD is not only useful to refine the conceptual site model, but also to help support remedy decision-making. *The value of the NSZD measurements grow when it is included with trend charts that show decreasing LNAPL transmissivity and groundwater contaminant concentrations.”*[4]

For all sites including the Former Tiger Oil site a quantitative measurement of actual LNAPL depletion is highly dependent on plume geometry, constituents, and data density. Complete degradation of the LNAPL mass by natural processes can be expected to take decades. This preliminary screening data should be considered in relationship to desired outcomes, other potential remedial alternatives, desired time frames, and cost.

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[4] Proceedings 7th International Contaminated Site Remediation Conference, Crown Melbourne 2017, A Comparison of Natural Source Zone Depletion And Active Remediation Rates, T. Palaia,, Sep 2017

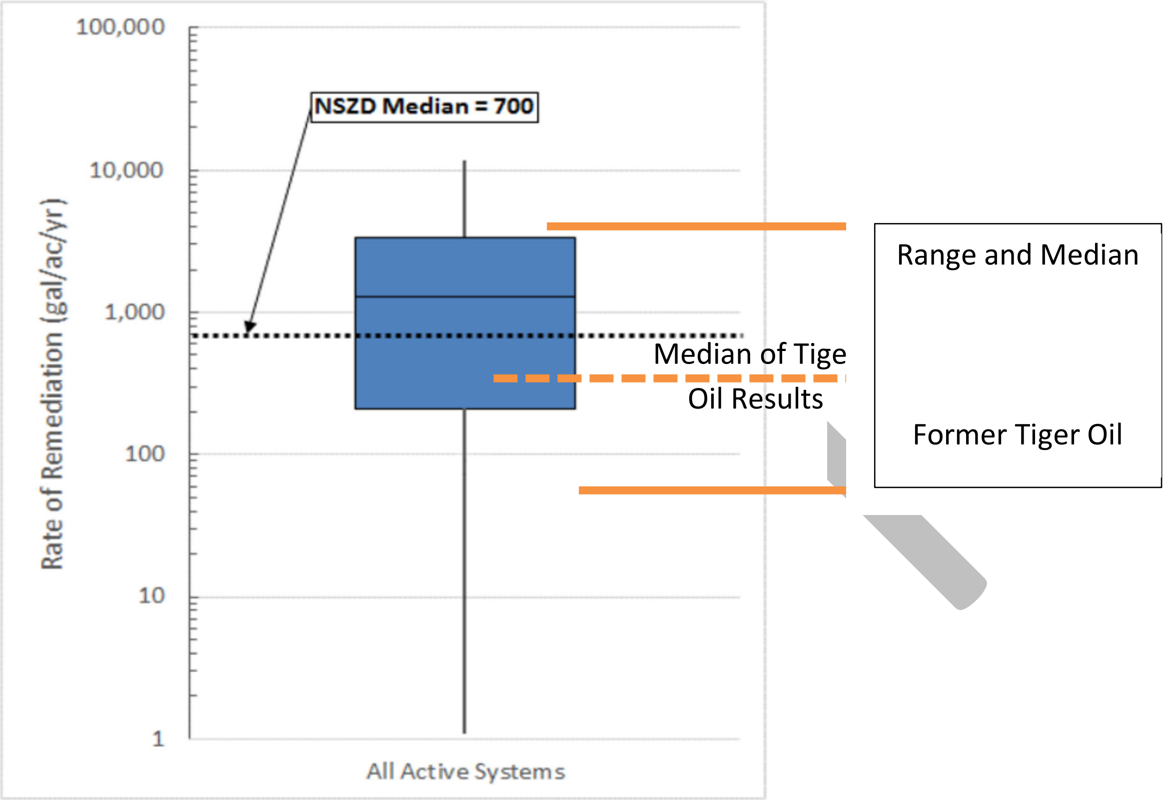

Figure 4 Box Plot of Remediation rates of active remediation systems[5]

Alignment of Monitoring Wells

Current screened intervals on monitoring wells are accurately placed vertically for measuring hydrocarbon constituents and geochemical parameters at and adjacent to the site

Possible Evidence of Petroleum Vapor

PHC response in the vadose zone, at depths less than 15-ft bgs and within 30-ft. of the Xochimilco Restaurant. These criteria exceed the initial screening levels for possible petroleum vapor intrusion to the building per ITRC guidelines. Additional investigation would be required to determine if petroleum vapor intrusion is in fact a risk at the occupied building.

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[5] Proceedings 7th International Contaminated Site Remediation Conference, Crown Melbourne 2017, A Comparison of Natural Source Zone Depletion And Active Remediation Rates, T. Palaia,, Sep 2017

Quality Control and Data Anomalies

Each direct sensing instrument was operated in accordance with the manufacturer’s standard operating procedures and the *Standard Practice for Direct Push Technology for Volatile Contaminant Logging with the Membrane Interface Probe (MIP)* ASTM STANDARD D7352 – 07.

Performance testing was performed on each system prior to and following each survey sounding. These procedures are outlined in **Appendix C.**

A QC review of the OIP® and MiHpt logs for this project did not reveal any anomalies in the operation or either system that would have resulted in a lack of detection of petroleum LNAPL.

TPH GRO results in the lower 20 to 22-ft interval of OIP-02 were reported as non-detect by the laboratory, indicating the response was a false positive with respect to TPH-GRO. Possible sources of false fluorescence could be natural minerals or some chemicals used during prior remediation efforts. A similar response in the same lower depth interval was observed in OIP-07.

Conclusions

1. This high-resolution assessment of the Former Tiger Oil site confirmed residual LNAPL based on multiple lines of evidence that include OIP® response, MIP-PID and MIP-FID response, elevated BTEX concentrations in groundwater monitoring well analyses, and high-resolution soil sampling.
2. Residual petroleum extends east and south of the site into the adjacent parking lots.
3. The highest MIP direct sensing responses occurred east of the site and diminished with distance further east indicating the dissolved phase contamination dissipated within the boundaries of the survey.
4. Current screened intervals on monitoring wells appear to be adequate for measuring groundwater constituents at and adjacent to the site.
5. TPH-GRO concentrations in the discrete soil samples indicate that the residual mass does not exceed the screening criteria for mobility and is therefore stable.
6. CO2 Flux analysis indicates that Natural Source Zone Depletion is occurring at a rate of at least 100 gallons/acre/year with a mean depletion rate of 325 gallons/acre/year. This rate is of the same order of magnitude as more aggressive active remediation systems.
7. Vapor phase and groundwater geochemical parameters confirm the anaerobic degradation of the residual LNAPL mass.
8.

Recommendations

This report is intended to provide an improved LNAPL Conceptual Site Model (LCSM) In order to further evaluate and monetize the long-term management of LNAPL at the site. The reader is encouraged to consult the Interstate Technology and Regulatory Council (ITRC) interactive web-based document *LNAPL-3: LNAPL Site Management: LCSM Evolution, Decision Process, and Remedial Technologies* (2018) for viable technical options for LNAPL management going forward.

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O. Managing Risk at LNAPL Sites, API Bulletin No. 18 2nd Edition, May 2018

APPENDIX A - Direct Sensing Equipment Description

Optical Imaging Profiler (OIP®) Equipment Description

The OIP® system utilized for this investigation is the latest generation developed by Geoprobe Systems. The OIP® system uses a high-energy Light Emitting Diode (LED) to produce an ultraviolet light source for the detection of polycyclic aromatic hydrocarbons (PAHs).

The OIP® system employs an excitation beam of light from an LED at 275 nanometers (nm). Any residual phase PAHs present in the soil matrix will absorb and then release this photon energy in the form of fluorescence.

This fluorescence is captured via a UV camera in the probe. Individual OIP® logs consist of a primary graph of fluorescence as a % of the optical image recorded by the UV camera. Visible light images can also be captured if desired. The camera records the UV images at a rate of 30 frames per second.

OIP® screening is performed by pushing or hammering the OIP® probe into the soil at the target rate of two centimeters per second (0.8 inches per second). As the OIP® is advanced, the fluorescence in each frame is captured and analyzed and displayed in real-time as a function of depth.

OIP® system data is presented as a percentage of the optical window showing fluorescence. OIP® system performance is checked using know compounds such as diesel, motor oil, and gasoline. Site specific products may be used as an additional performance check

Any fluorescence response is normally indicative of residual phase petroleum hydrocarbons, though some naturally occurring materials such as limestone will also fluoresce to a lesser and more monochromatic degree.

MiHpt Equipment Description

The combined membrane Interface Probe and Hydraulic Profiling tool is known as the MiHpt Probe. This probe also contains an Electrical Conductivity dipole. The MiHpt probe is approximately 24 inches in length and 1.5-inches in diameter. The probe is driven into the ground at the nominal rate of 12 inches per minute using direct push technology (DPT) system Geoprobe or equivalent.

Geoprobe Systems developed the MIP/EC probe® that contains two separate systems: the soil EC tool and the MIP. EC, MIP chemical response, MIP operating parameters, the rate of push speed and temperature are collected by the MIP/EC Field Instrument and displayed continuously in real-time during each push of the probe.

EC: Soil electrical conductivity, the inverse of soil resistivity, is measured using a dipole arrangement. In this process, an alternating electrical current is transmitted through the soil from the center, isolated pin of the probe. This current is then passed back to the probe body. The voltage response of the imposed current to the soil is measured across these same two points. Conductivity is measured in Siemens/meter, and due to the low conductivity of earth materials, the EC probe uses millisiemens/meter (mS/m). The probe is reasonably accurate in the range of 5 to 400 mS/m.

The electrical properties of soil vary by geological setting. Therefore, conductivity measurements will vary both in magnitude and the relative change from one soil type to another in each geological setting. In general, at a given location, lower conductivity values are characteristic of larger particles such as cobbles and sands, while higher conductivities are characteristic of finer sized particles such as finer sand, silts, and clays. Observed conductivities significantly higher than 400 mS/m are indicative of ionic materials other than soil. Examples include saltwater intrusion, the presence of ionic chemicals from storage or injection, or potentially soil mixtures with metallic compounds.

MIP: The MIP portion of the probe is used to create high-resolution, real-time profiles of subsurface volatile organic compounds (VOCs). The operating principle is based on heating the soil and/or water around a semi-permeable polymer membrane to 121 degrees Celsius (ºC), which allows VOCs to partition across this membrane.

The MIP can be used in saturated or unsaturated soils, as water does not pass through the membrane. Nitrogen is used as an inert carrier gas and travels from a surface supply down a transfer tubing which sweeps across the back of the membrane and returns any captured VOCs to the installed detectors at the surface. It takes approximately 60 seconds for the nitrogen gas stream to travel through 150 feet of inert tubing and reach the detectors.

COLUMBIA Technologies utilizes two chemical detectors on the MIP for this work: a Photo Ionization Detector (PID) and a Flame Ionization Detector (FID) mounted on a laboratory grade gas chromatograph (GC). The output signal from the detectors is captured by the MIP/EC data logging system installed on a laptop computer.

The PID detector consists of a special ultraviolet (UV) lamp mounted on a thermostatically controlled, low volume, flow-through cell. The temperature is adjustable from ambient temperature to 250 ºC. The 10.6-electron volt (eV) UV lamp emits energy at a wavelength of 120 nm, which is sufficient to ionize most aromatics such as BTEX and many other molecules such as hydrogen sulfide (H_2S), hexane, and ethanol whose ionization potentials are less than 10.6 eV.

The PID also emits a response for chlorinated compounds containing double-bonded carbons (e.g. halogenated ethylenes), such as trichloroethylene (TCE) and tetrachloroethylene (PCE). Methanol and water, which have ionization potentials greater than 10.6 eV, do not respond on the PID. Given that the PID is non-destructive, it is often run first in series with other detectors for multiple analyses from a single injection.

The FID utilizes a hydrogen flame to combust compounds in the carrier gas. The FID responds linearly over several orders of magnitude, and the response is very stable from day to day. This detector responds to any molecule with a carbon-hydrogen bond, but poorly to compounds such as H_2S, carbon tetrachloride, or ammonia. The carrier gas effluent from the GC column is mixed with hydrogen and burned. This combustion ionizes the analyte molecules. A collector electrode attracts the negative ions to the electrometer amplifier, producing an analog signal, which is directed to the data system input.

HPT Equipment Description

The HPT probe is approximately 24 inches in length and 1.5-inches in diameter. The probe is driven into the ground at the nominal rate of 12 inches per minute using a DPT rig.

The HPT probe was developed by Geoprobe Systems® and contains two separate systems: soil EC and the HPT. EC, HPT parameters, and temperature are collected by the HPT Field Instrument and displayed continuously in real-time during each push of the probe.

EC: Soil electrical conductivity, the inverse of soil resistivity, is measured using a Werner array arrangement. In this process, an electrical current is transmitted through the soil from two electrodes on the probe body. This current is then passed back to the probe, and the voltage response of the imposed current to the soil is measured across these points. Conductivity is measured in Siemens/meter, and due to the low conductivity of earth materials, the EC probe uses mS/m. The probe is reasonably accurate in the range of 5 to 400 mS/m.

The electrical properties of soil vary by geological setting. Therefore, conductivity measurements will vary both in magnitude and the relative change from one soil type to another in each geological setting. In general, at a given location, lower conductivity values are characteristic of larger particles such as cobbles and sands, while higher conductivities are characteristic of finer sized particles such as finer sand, silts, and clays. Observed conductivities significantly higher than 400 mS/m are indicative of ionic materials other than soil. Examples include saltwater intrusion, the presence of ionic chemicals from storage or injection, or potentially soil mixtures with metallic compounds.

HPT: The HPT portion of the system is used to create high-resolution, real-time profiles of soil hydraulic properties, which can be used to infer permeability and hydraulic conductivity. The HPT system consists of a controller, a pump, a transfer line (trunkline) which is pre-strung through the DPT rods, a pressure transducer, a permeable screen, and a field computer.

HPT screening is performed simultaneously with the EC logging. As the tool is advanced, water is pumped through the trunkline and passes into the soil through the permeable screen. The flow is regulated as to be as constant as possible. The pressure required to inject the constant flow of water into the soil, known as the HPT pressure, is monitored by the pressure transducer and recorded on the field computer in pounds per square inch (psi) versus depth. The flow rate of the water into the soil formation is also measured and recorded in milliliters per minute (mL/min) versus depth.

Static pressure measurements (dissipation tests) can also be made by stopping at discrete intervals, allowing users to determine the static water level. The dissipation test provides an estimate of the static water level, based on the hydraulic head imposed on the probe at rest as compared to the pressure measured at the surface prior to starting each location push. Dissipation tests are best to run in coarse-grained materials (sands and gravels) to assure that the local ambient hydrostatic pressure is measured quickly and accurately.

To perform a dissipation test, the HPT probe is advanced to a depth below the water table and the water flow is stopped. The pressure dissipation (reduction of pressure gradient caused by forcibly pumping water into the formation) is monitored until a stable value is observed. The dissipation usually takes the shape of a curve approaching an inflection point or stable value. The stable value is then used for the hydraulic pressure at that depth and can be used to estimate static water depth. The HPT software can also provide an estimate of K (a value used in hydrogeologic calculations) to provide an interpretation of the hydraulic permeability of the formation.

Depth in feet is measured and recorded using a precision potentiometer with a 100-inch linear range. The potentiometer is mounted on the mast of the DPT rig and a counter-weight anchored to the foot of the rig. Measurements are recorded on the down stroke of the mast, as the tooling string is pushed into the ground, and is accurate within 1/10th of an inch. The reference elevation (depth) reported for each individual boring is established by setting the data logger to zero feet with the sensing window of the downhole probe aligned with the ground surface.

True boring elevations can be established with the addition of survey data if provided for in the scope of work.

APPENDIX B – Interpretation of Qualitative Direct Sensing Data

General OIP® Log Interpretation

Each OIP® log contains 2 graphs of data. The first log is Electrical Conductivity (EC), and the second is Percent Fluorescence. The Y-axis on both graphs is depth.

Individual OIP® logs consist of a primary graph of total fluorescence versus depth, an information box and up to five waveform “callouts”. In the primary fluorescence graph, depth is plotted on the Y-axis and the combined total fluorescence intensity of the four monitored wavelengths is plotted on the X-axis. Total fluorescence intensity is presented as a percentage of the RE standard. Given that various PAHs fluoresce at differing intensities, there are several compounds that fluoresce brighter than the RE standard; therefore, the total %RE can exceed 100. Total fluorescence intensity is typically proportional to concentration and responds linearly as concentration increases.

While the magnitude of response of a LIF system may be indicative of the amount of contamination present, the system response should be considered only qualitative and not quantitative. The depth of the response is highly accurate and may be relied upon to guide additional data gathering such as soil and/or groundwater sampling. Furthermore, the depth of the response in one boring location does provide a reliable indicator of a potential source(s) of contamination, particularly when compared to results from adjacent boring locations.

Waveform callouts are presented along with the left-hand side of the primary graph. These callouts present the fluorescence intensity of each of the monitored wavelengths on the Y-axis [in microvolts (µV)] and the duration of fluorescence of each wavelength on the X-axis. No scale is given along the X-axis, however; it is a consistent 320 nanoseconds wide. The four peaks are due to the fluorescence at the four monitored wavelengths called channels. Each channel is assigned a color. Various NAPLs will have a unique waveform signature based on the relative amplitude of the four channels and/or the broadening of one or more of the channels. Callouts are selected by the operator and typically correspond to peaks on the primary graph.

The fill color of the response on the primary graph is based on the relative contribution of each of the four channels’ area versus the total waveform area. This allows the viewer to discern different substances at different each depth interval based on the fill color.

General MIP/EC Log Interpretation

Each MIP/EC log includes four separate graphs of data. The Y-axis on all graphs is depth. The first two graphs are displays of measures of chemical detector response: PID and FID measured in µV. These graphs are a linear scale and provide a relative comparison of total detector response between boring locations. The third graph displays the HPT pressure in psi and flow rate measured in mL/min. In general, higher HPT pressure readings and lower flow rates indicate lower soil permeability, while lower HPT pressure readings and higher flow rate readings indicate higher soil permeability. The fourth graph displays the EC, measured in mS/m. Small soil conductivity values are indicative of coarser grained particles, such as sands and silty sands, and larger soil conductivities are indicative of finer-grained particles, such as clays and silty clays.

General HPT Log Interpretation

Each HPT log, presented on an individual scale, includes three separate graphs of data. The Y axis on all graphs is depth. The first graph displays HPT pressure in psi and flow rate measured in mL/min. In general, higher HPT pressure readings and lower flow rates indicate lower soil permeability, while lower HPT pressure readings and higher flow rate readings indicate higher soil permeability. The second graph shows estimated K value, in feet/day, indicating the hydraulic permeability of the formation. The static groundwater level is also displayed on the graphs. The third graph displays the EC, measured in mS/m. Lower soil conductivities are indicative of coarser grained particles, such as sands and silty sands, and higher soil conductivities are indicative of finer grained particles, such as clays and silty clays.

The HPT pressure and electrical conductivity can be used to identify hydraulic permeable layers, confining units and preferential migration pathways. This information is useful for creating contaminate fate and transport models, selecting monitoring well location and screen intervals, and targeting zones for remedial injections.

Interpreting OIP® and Comparison to Laboratory Analyses

Generalized correlation between OIP® and laboratory analytical results can be inferred but cannot be viewed as a linear comparison. OIP® response and laboratory results are collected, analyzed and reported in different units and by different procedures, so correlation is not an exact one-to-one comparison. The OIP® uses a process where a 2D soil surface is exposed to excitation light, and any fluorescent light emitted is analyzed at the ground surface. Soil and groundwater results involve the collection of a soil core, extraction of sub-sample at the surface, and then transporting them to a laboratory for extraction and analysis. These processes are different by definition.

Interpreting MIP Results and Comparison to Laboratory Analyses

A typically configured MIP system is effective at profiling the relative distribution of certain VOCs and relative soil types versus depth. The typical MIP system will detect VOCs with boiling points of 121 ºC or less; with vapor pressures above approximately 0.14 psi; and with non-polar hydrophobic compound structures. The sensitivity or in-situ detection level of a MIP system is dependent on many different factors. **COLUMBIA Technologies**' systems and protocols are standardized to provide reliable and comparable detection and logging of chlorinated VOCs (CVOCs) on the order of 200 ppb in-situ concentrations. Petroleum based VOCs are reliably logged at 1 ppm in-situ concentrations. Each of **COLUMBIA Technologies**' MIP system configurations is performance tested prior to use and if requested, MIP systems may be specially configured for atypical compounds of concern (COCs) and site conditions.

An understanding of the principles of operation and performance of the configured MIP detectors is essential to properly interpret the MIP log results. For example, a CVOC with an ionization potential greater than 10.6 eV will respond on the XSD detector but not on the PID equipped with a 10.6 eV lamp. A hydrophilic compound such as an alcohol or ketone will normally be scrubbed out of the MIP gas stream by the MIP Membrane and the installed dryer and never reach the detectors. Properly configuring and testing the MIP system for the site-specific COCs prior to use can overcome each shortfall in detector or system performance. Additionally, the in-field performance tests performed before and after each boring are critical to monitor the performance of the MIP system from the membrane through to the data logging system.

Generalized correlations between MIP response and laboratory sample results can be inferred but cannot be viewed as a linear comparison. MIP response and laboratory results are collected, analyzed and reported in different units and by different procedures, so correlation is not an exact one-to-one comparison. For example, not all VOCs present and analyzed in laboratory instruments with compound separation are detected and measured by a typical MIP system. The MIP process uses a membrane extraction process from a heated zone of varying subsurface matrix of soil, water, and/or vapor. Soil and groundwater results involve the collection of a sample, extraction of sub-sample at the surface, and then transporting them to a laboratory for further extraction and analysis. These two processes are different by definition.

Unusual or invalid responses on the MIP system can result from malfunctions such as carrier or makeup gas leakage, gas flow blockage, heater failure, and carryover of water vapor or excessive chemical saturation. Each MIP detector will respond differently to each of these malfunctions. The most common cause of false positive responses for CVOCs is water carryover or blockage of carrier gas flow. The most common causes of false negative are improperly adjusted gas flows or leakage and inoperative detectors. **COLUMBIA Technologies**' field geochemists are trained to recognize these problems and to take the appropriate corrective action in the field.

APPENDIX C – Quality Control Procedures

System Quality Control Checks

Direct sensing technologies such as MIP, OIP®, and LIF provide qualitative or semi-quantitative direct contact measurements of conditions in the soil, water, and vapor matrix of the subsurface. Correct performance response of the instruments is determined using standards or mixtures of known values or concentrations. Before and after each measurement run, the instruments are tested with these known standards to ensure their response is within an acceptable range.

The nature of direct-sensing technology is different than a typical laboratory analysis. In the lab, a known volume of a known concentration is introduced to the system, the compounds are separated chromatographically, and the response for each individual compound is recorded. This process is highly reproducible, and precise standards exist for laboratory control limits.

These performance tests of direct sensing instruments are not calibrations, per se. While the instrument response can be expected to be linear for a single chemical compound or in the known matrix conditions of the performance test standards, matrix conditions and chemical mixtures will be highly variable throughout the measurement run in subsurface.

In MIP, for instance, subsurface compounds diffuse across the MIP membrane, enter the carrier gas stream, and are transported directly to the GC. There is no chromatographic separation, just total response with depth.

Several other factors affect direct-sensing responses.

For LIF and OIP®, these factors include:

- Soil grain size
- Interferences from fluorescent minerals such as limestones
- Contaminant types
- Degree of saturation
- System performance

For MIP, these factors include:

- The diffusion rate across the MIP membrane. This differs for every compound, based on:
  - Vapor pressure
  - Solubility
  - Interactions with other compounds
  - Membrane age and wear
- Ambient temperature
- Temperature of the subsurface
- Soil conditions (Clays provide a higher response than sands, due to increased back-pressure at the membrane)
- Detector response for each compound
- System performance

For these reasons, a "calibration" is not possible. The variables within compounds of interest, mixtures of compounds, and subsurface conditions cannot be standardized. However, system performance can. Therefore, COLUMBIA Technologies implements protocols to test and evaluate system performance to produce the highest quality data in the industry. The results of these performance tests are maintained with each project file and available upon request.

LIF/UVOST® System Performance Tests

As a quality control check, the LIF/UVOST® system response is evaluated prior to and upon completion of each LIF/UVOST® screening location. This evaluation is completed using a Reference Emitter (RE) that consists of a blend of NAPL and produces a consistent fluorescence response over the four wavelengths monitored by the LIF/UVOST® system. Collected data is then presented as a percentage of the RE. Using the same RE at each location and site allows normalization of data collected over several locations, sites, or screening events. The RE standard is provided by the manufacturer, Dakota Technologies, and is the same for all LIF/UVOST® systems currently in operation.

In addition to obtaining a baseline RE for each location, the background reading of the LIF/UVOST® system is electronically recorded prior to insertion into the soil. This background reading is required to be less than 0.5% of RE prior to the start of any testing. The background during tool advancement typically stays at or below the surface background reading – giving confidence that any increases in fluorescence are "true" readings and not fluctuations or variations in background.

MIP System Performance Tests

System response is checked via Performance Tests with known compounds at known concentrations to verify that the system is responding to an acceptable level. On the recommendation of the manufacturer, Geoprobe Systems, this minimum acceptable response level is established as five (5) times the standard deviation of the baseline noise level for each detector.

These tests vary, mostly due to ambient temperature and the age of the membrane. So, rather than looking for a specific response factor, the system is monitored for an acceptable response. When the response is not acceptable, the system is investigated, and corrective actions are implemented as necessary.

COLUMBIA Technologies performs several levels of MIP system evaluation for each project:

- Pre-Mobilization 5-Point

Response Check

- Site Arrival 5-Point Response Check
- Pre-log Midpoint Response Check
- Post-Log Midpoint Response Check

For 5-point response tests, the system is evaluated at 0.10, 0.50, 1.0, 5.0, and 10.0 ppm to check response across 3 orders of magnitude of concentrations. For sites with expected petroleum contamination the system is checked using Toluene. For sites where chlorinated VOCs are expected, the system is checked using Trichloroethene (TCE). Site -specific compounds may be used where appropriate.

As an ongoing quality control check, the MIP system response is evaluated using a 1.0 ppm performance test solution prior to and upon completion of each MIP location. The resulting response values are recorded and compared to the results of the 5-point performance tests. When the response tests fall below 25% of the baseline value, corrective action must be taken.

Low-Level MIP System performance Test

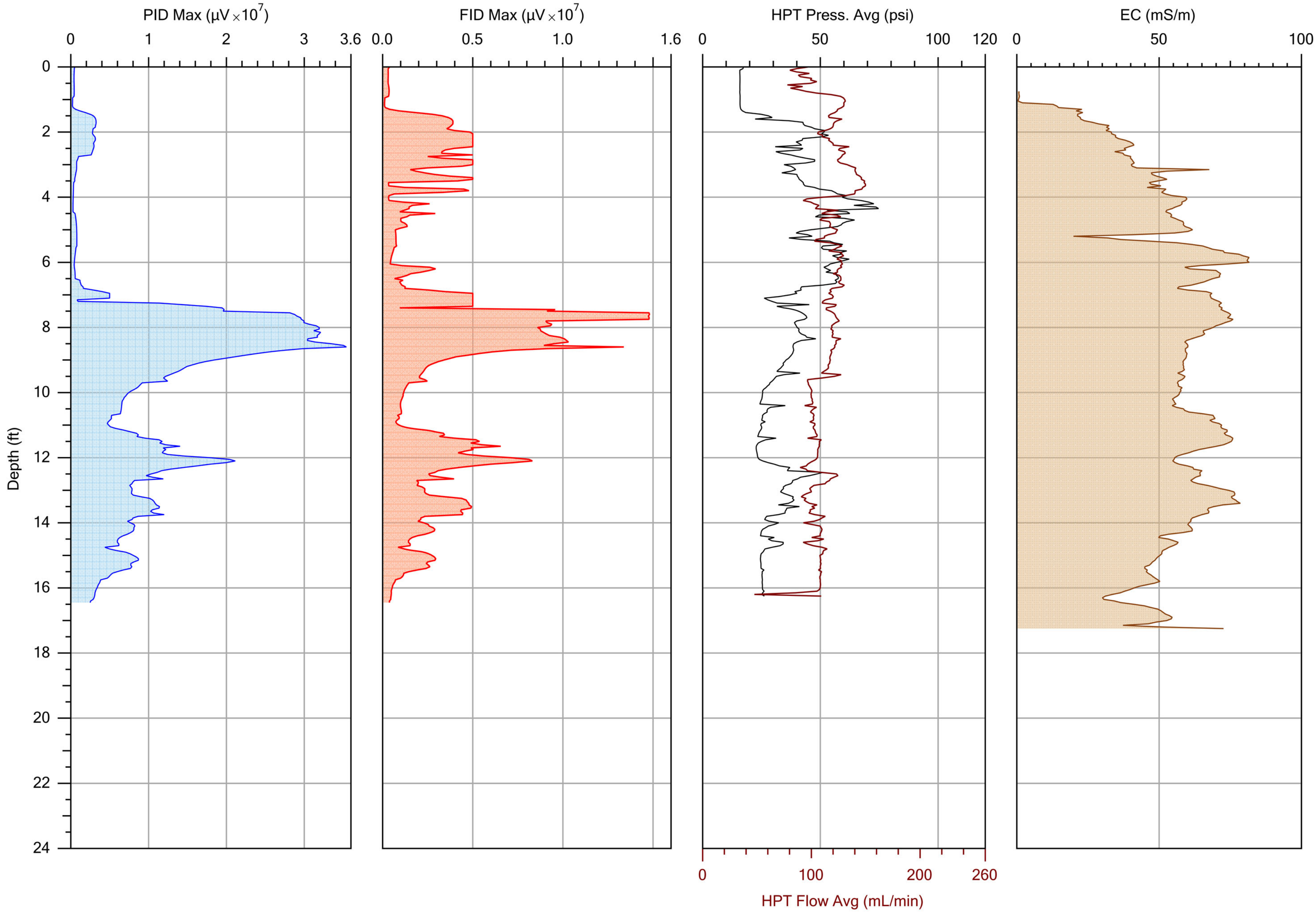
The Low-Level system is evaluated using a similar 5-point response test. The test concentrations are 10, 50, 100, 500, and 1,000 ppb, using Toluene of TCE as appropriate. Ongoing Response tests are performed using a 100 ppb solution.

HPT System Performance Test

The EC dipole is evaluated using a brass and stainless-steel test jig, resulting in known values of 55 and 290 millisiemens (mS). Results must fall within 10% of the expected values; otherwise corrective action must be performed.

The HPT pressure and flow sensors are also evaluated using static (no flow) and dynamic (flow at approximately 150 milliliters per minute) hydraulic pressure measurements at two different head elevations, 6.0 inches apart. The difference for each test must be 0.2 psi, +/- 10%; otherwise corrective action must be performed.

APPENDIX D – Data Logs for Membrane Interface Probe/EC with Hydraulic Profile Tool (MiHpt) – Individual Scale



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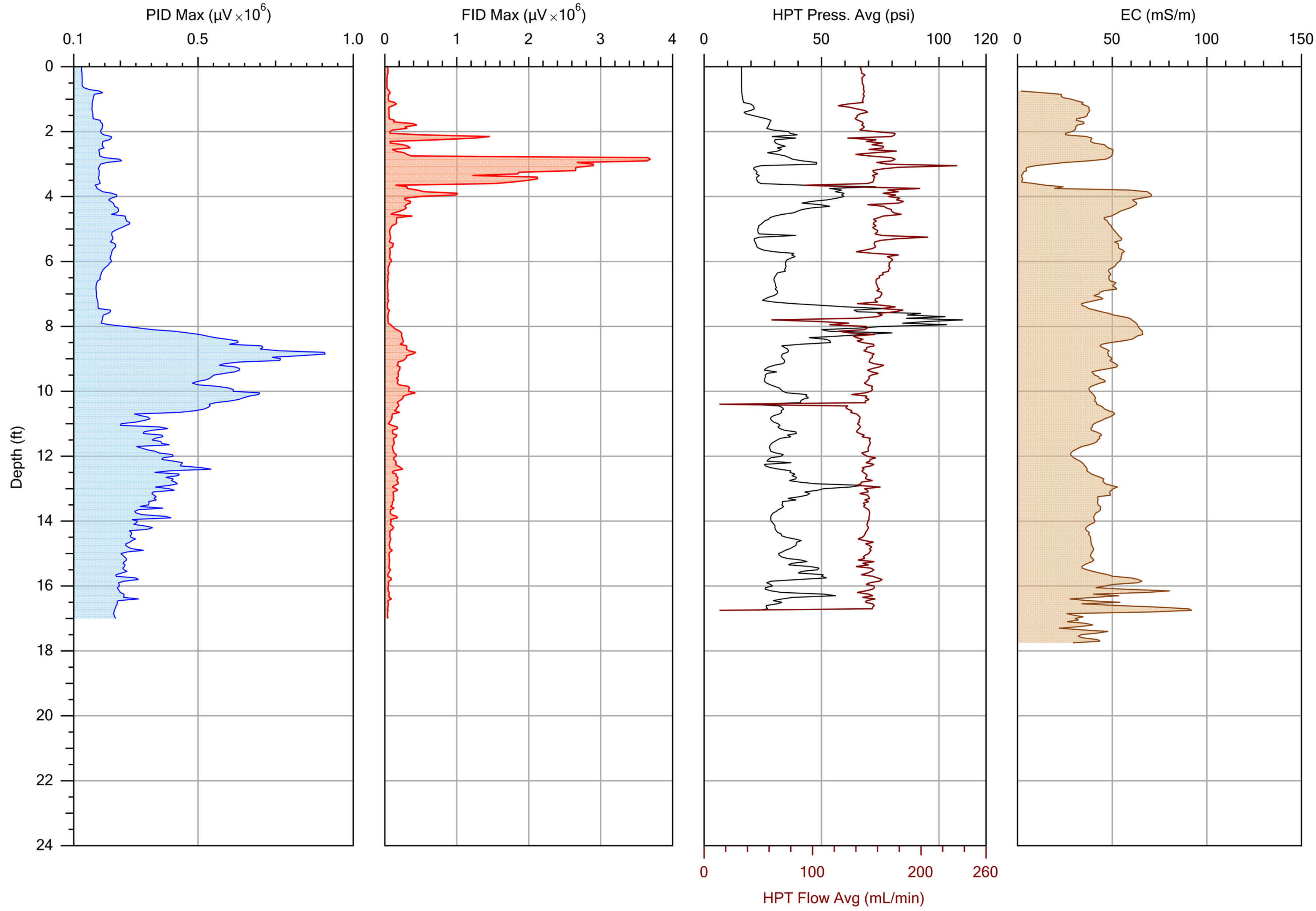
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA



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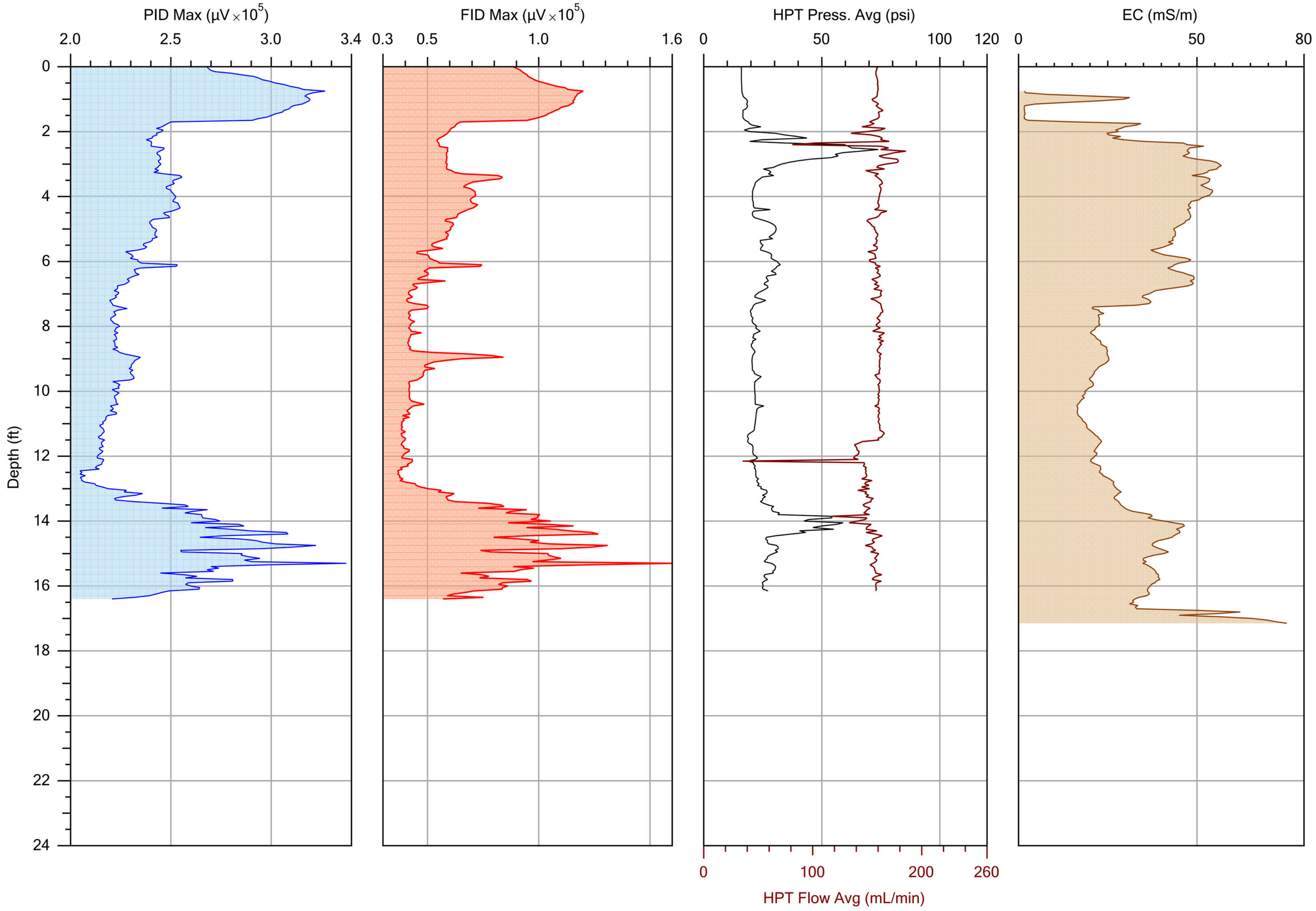

COLUMBIA TECHNOLOGIES

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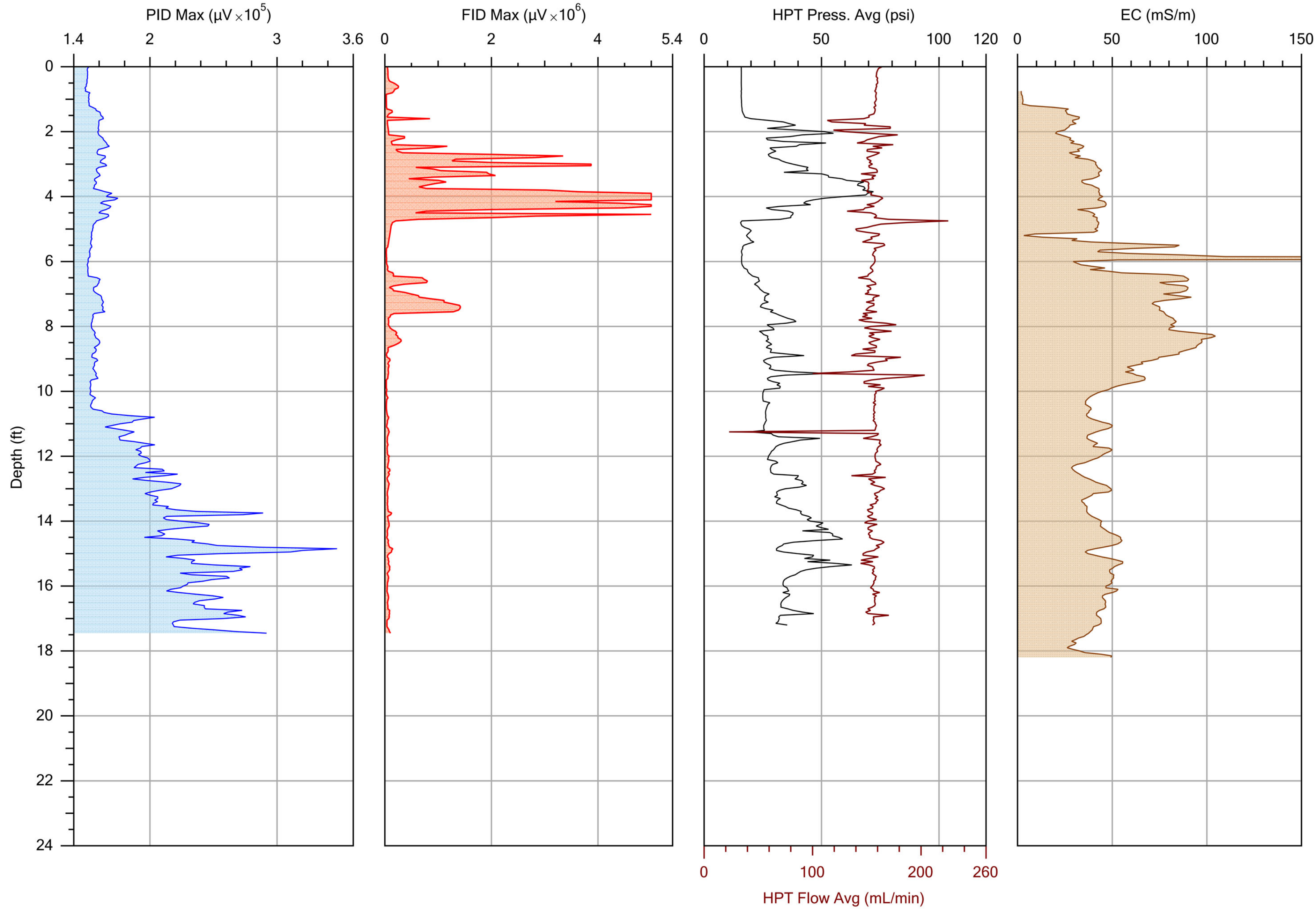

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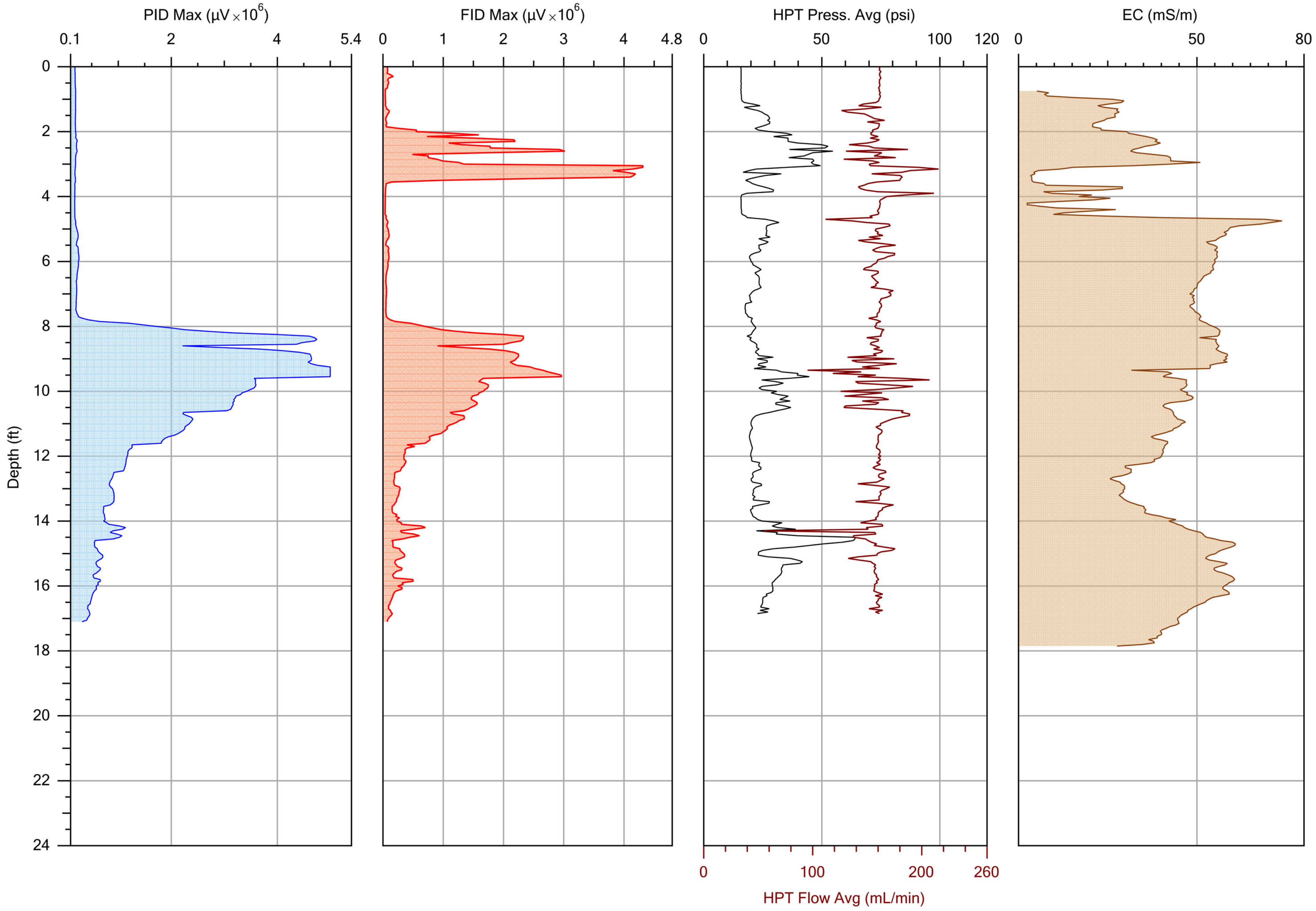

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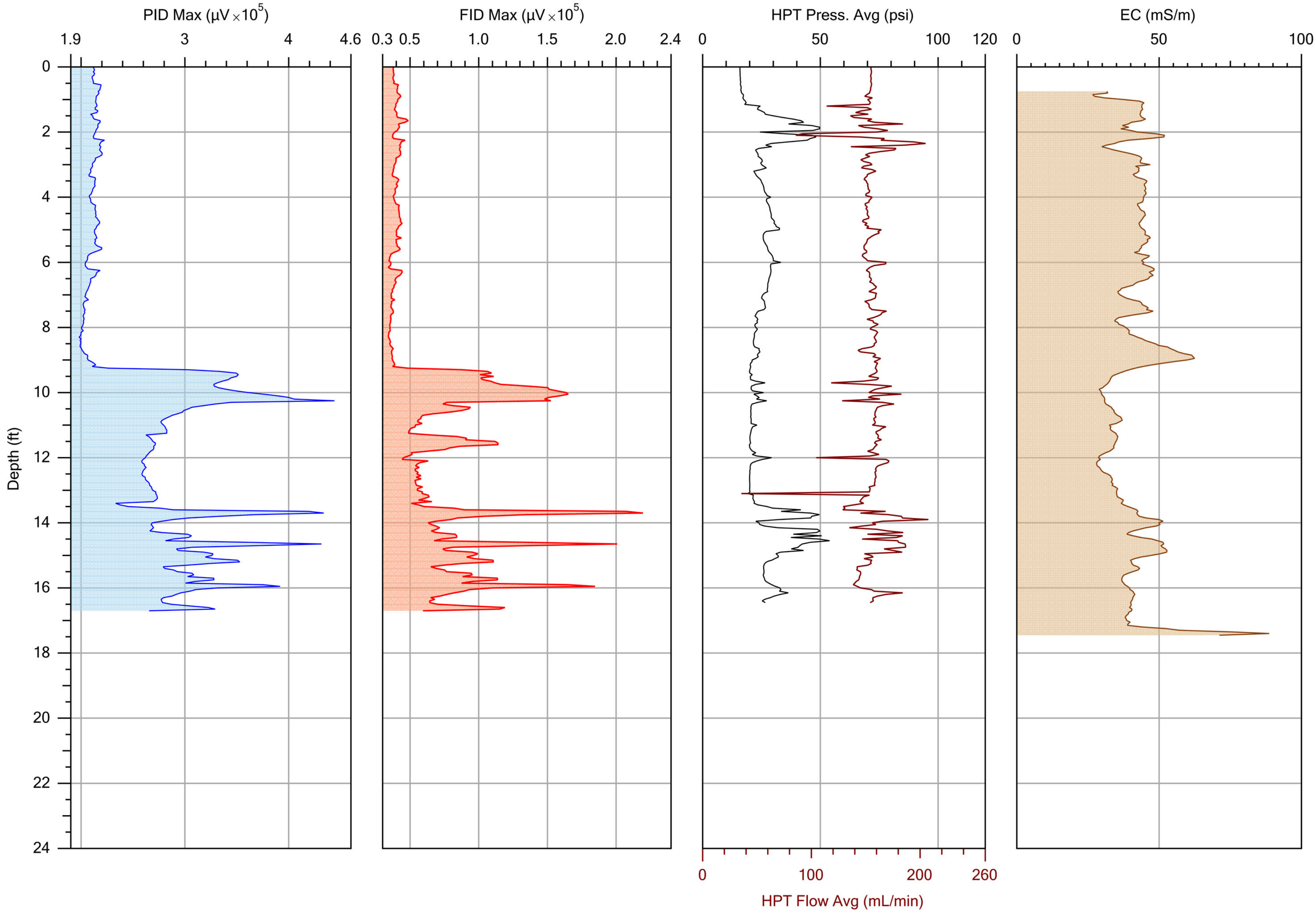

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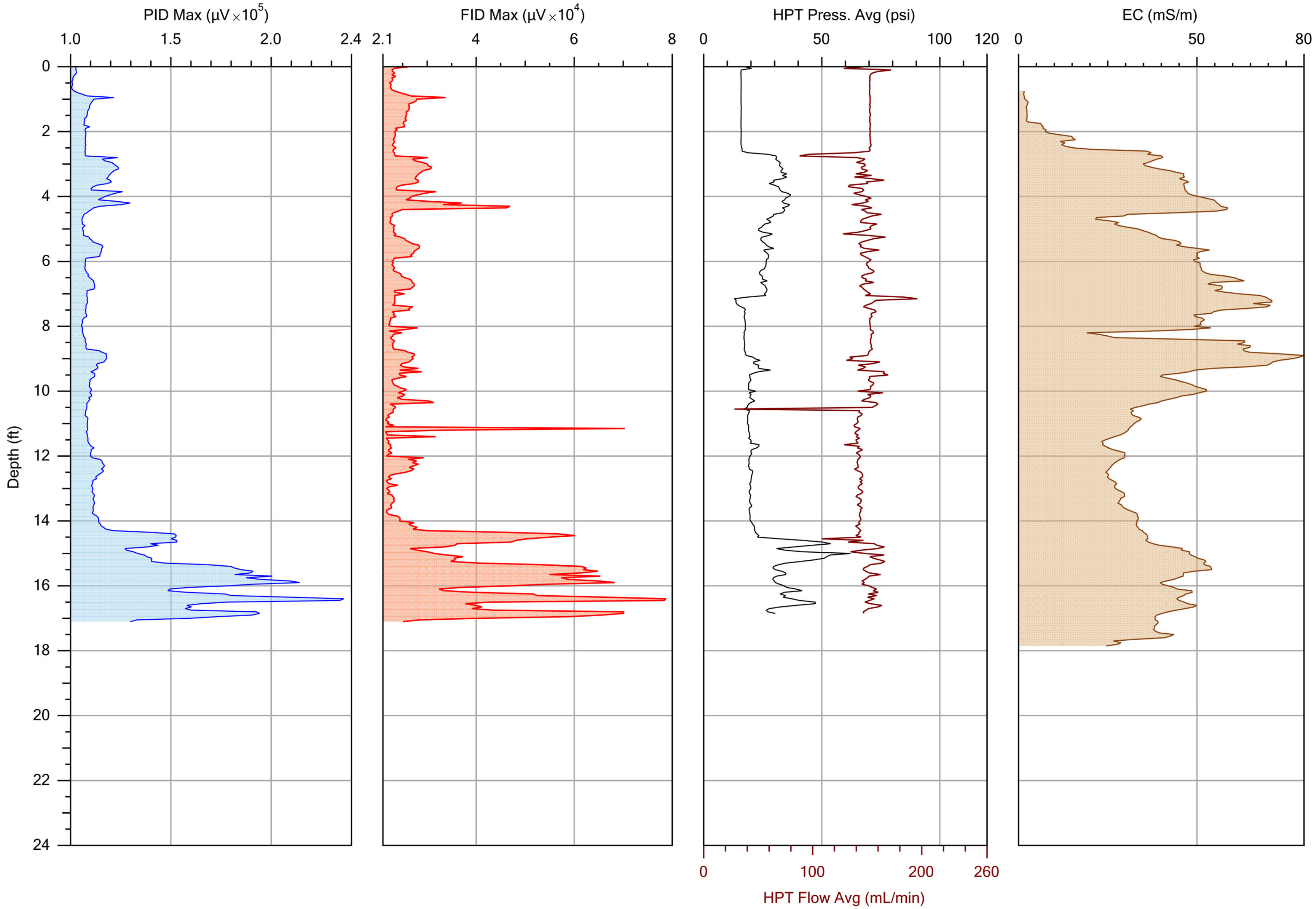

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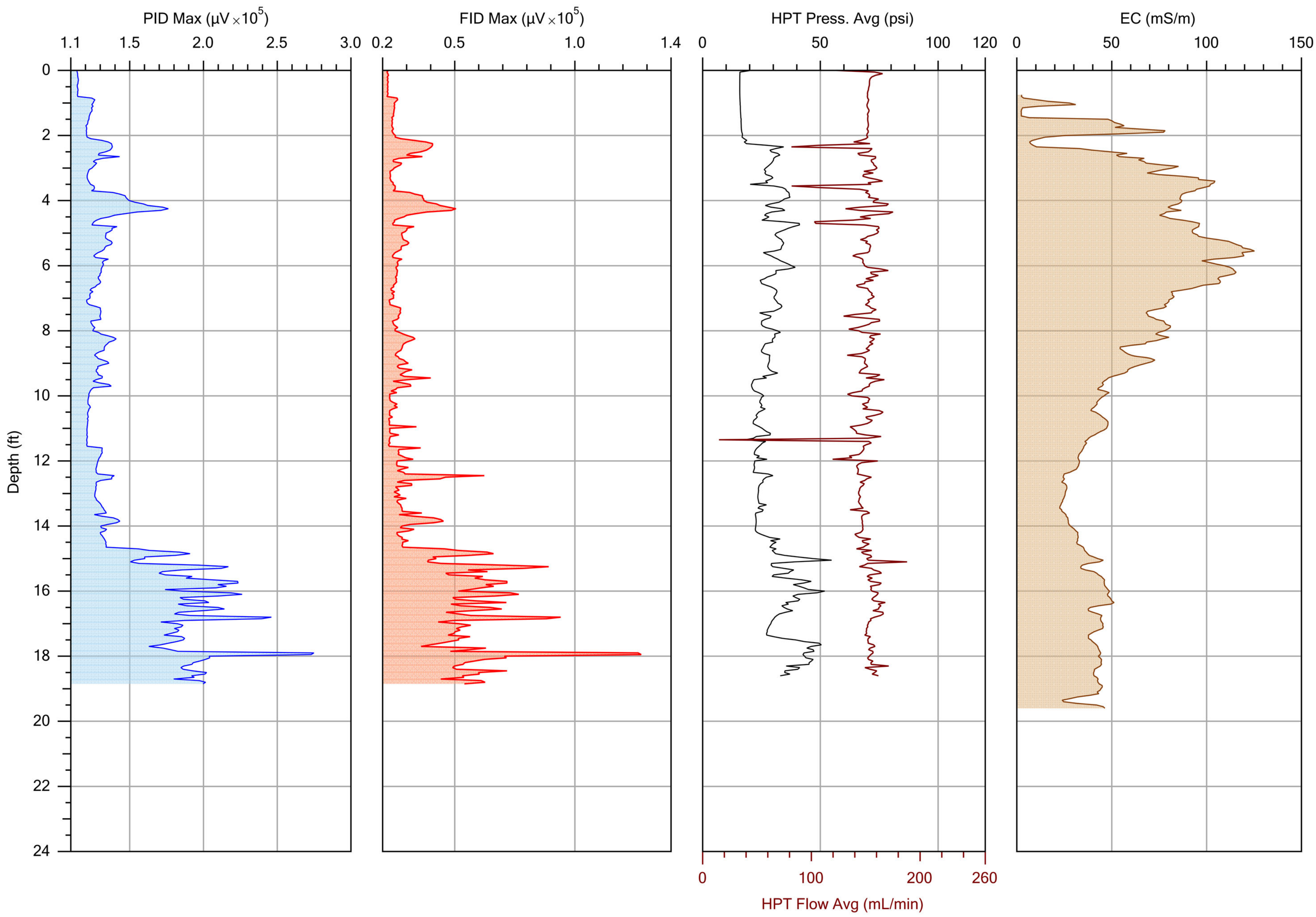

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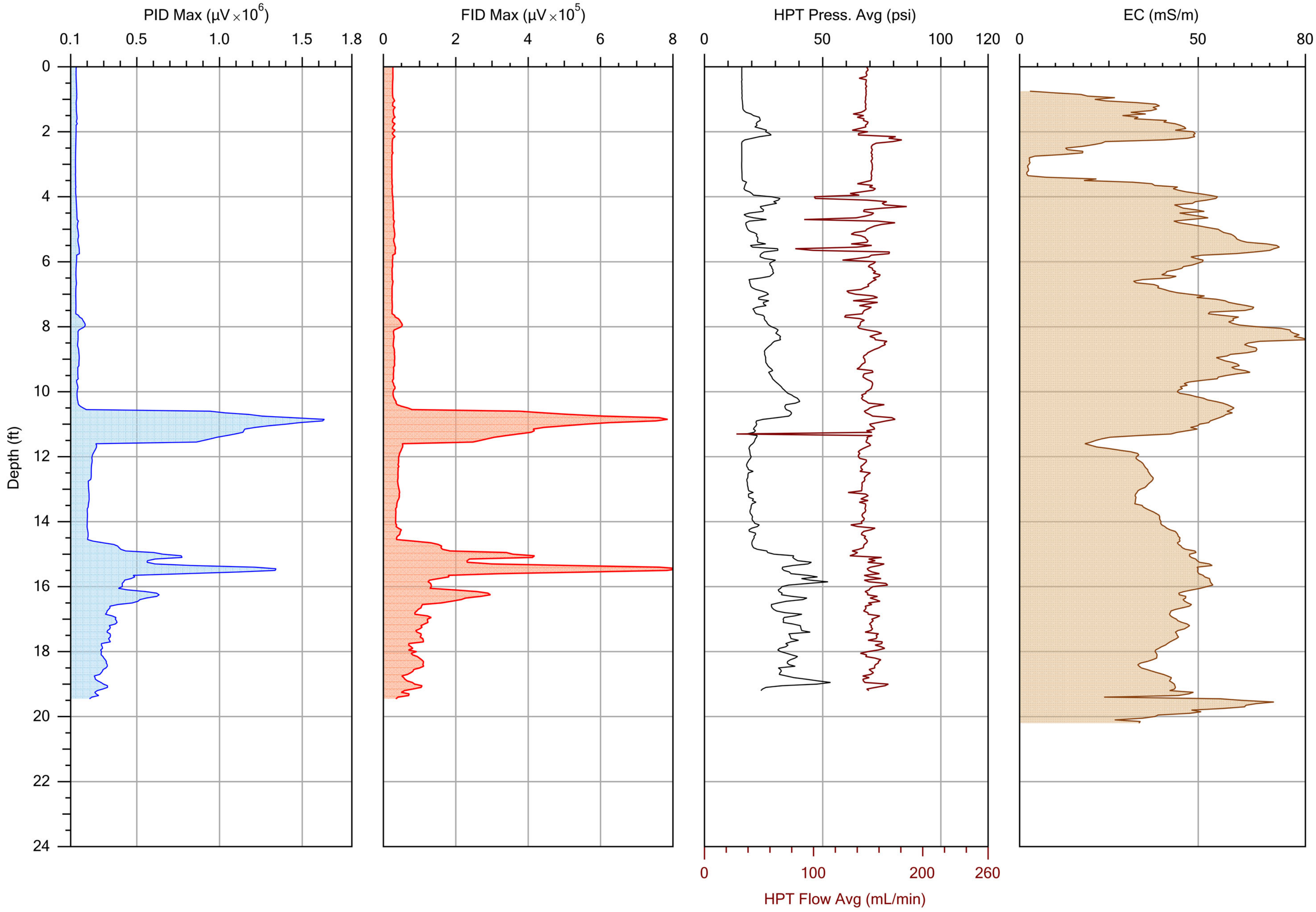

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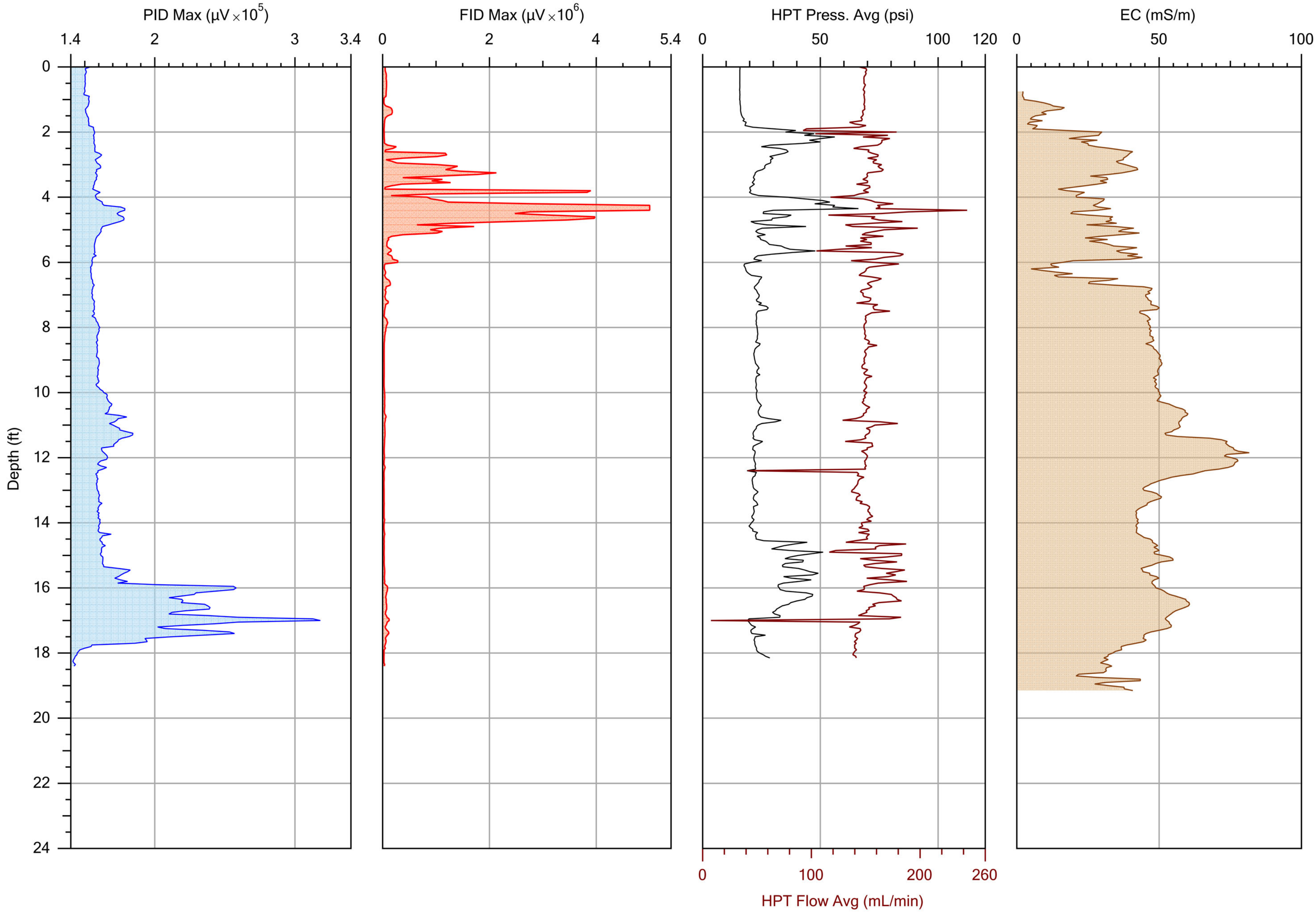

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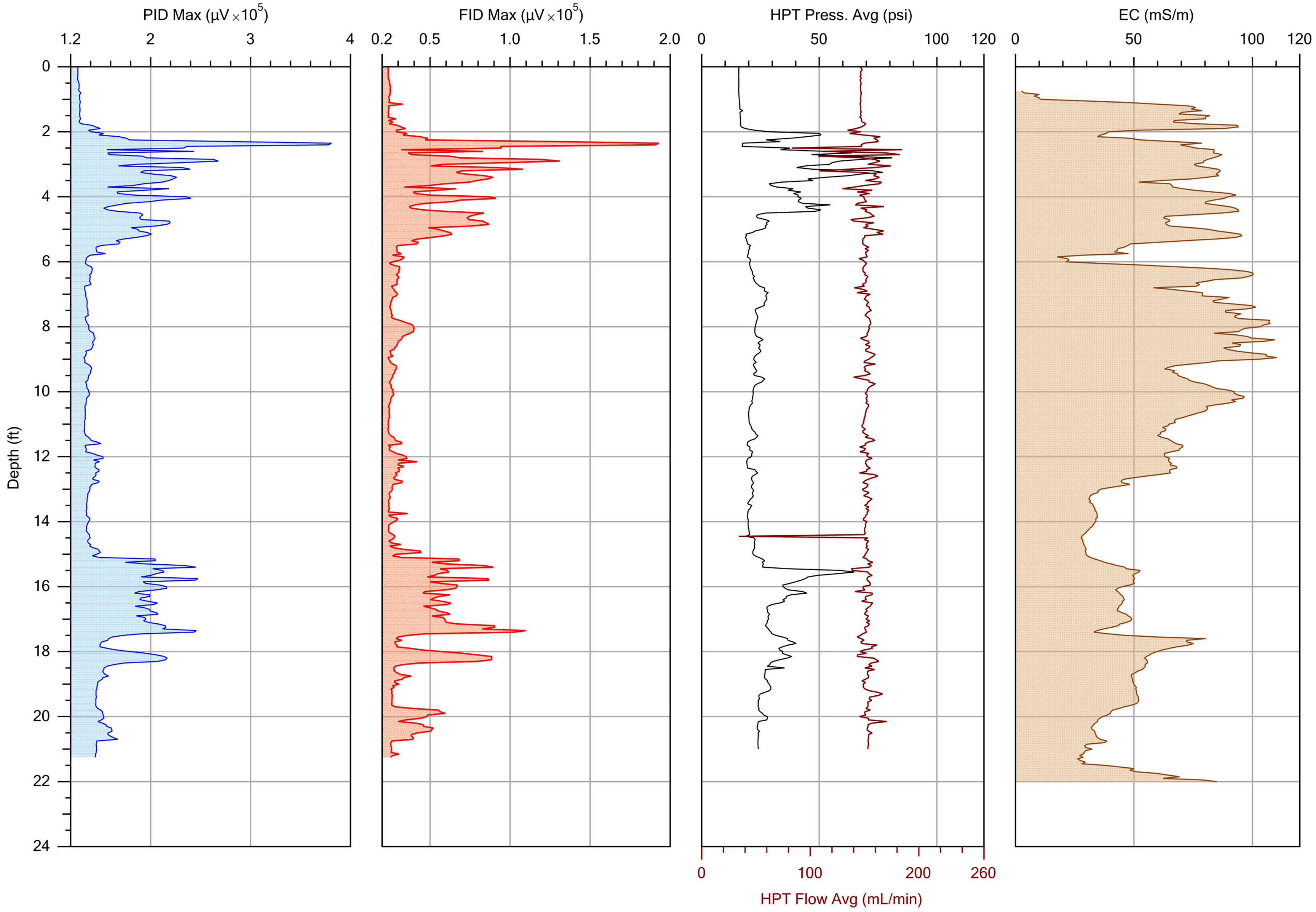

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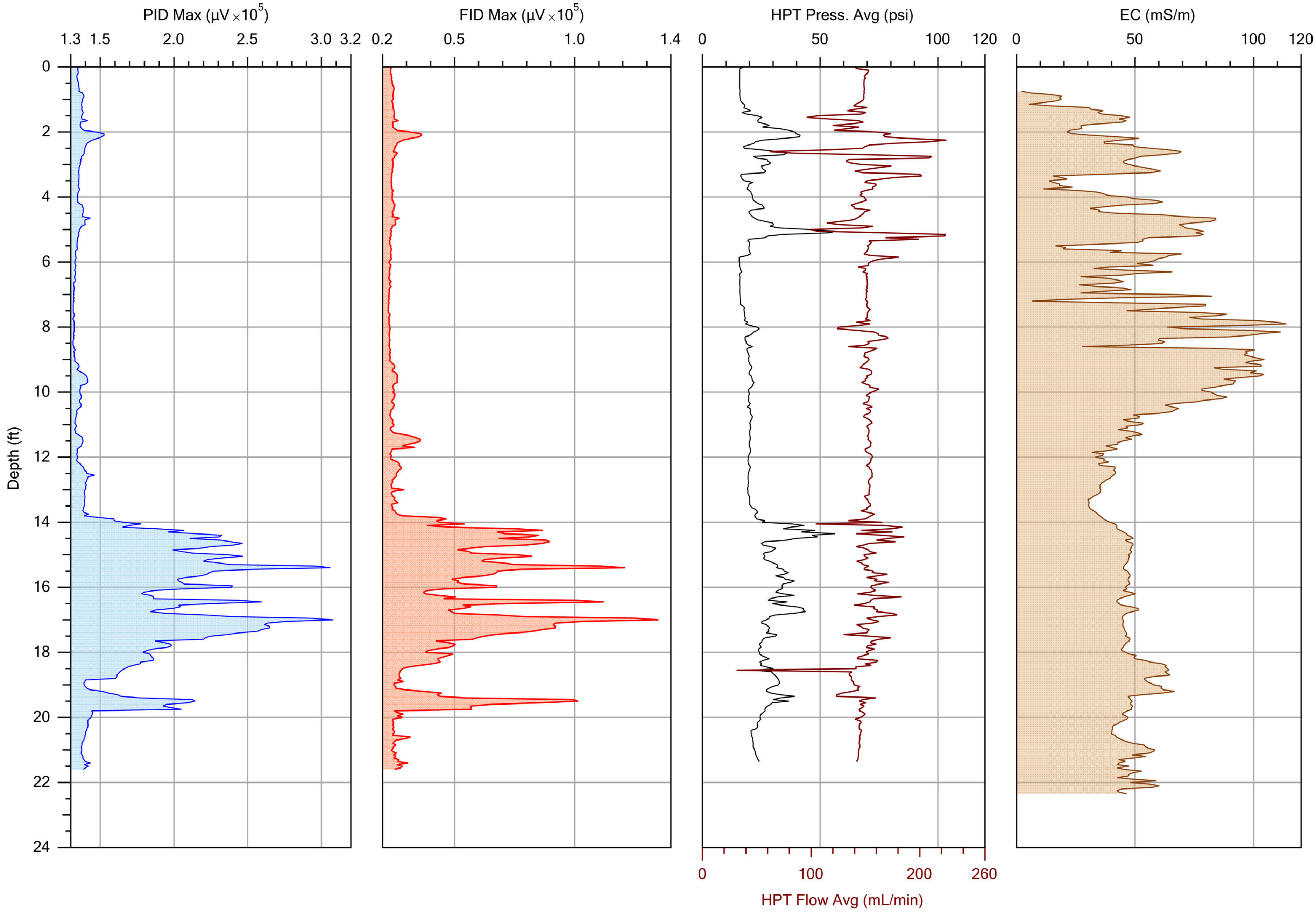
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA



COLUMBIA TECHNOLOGIES

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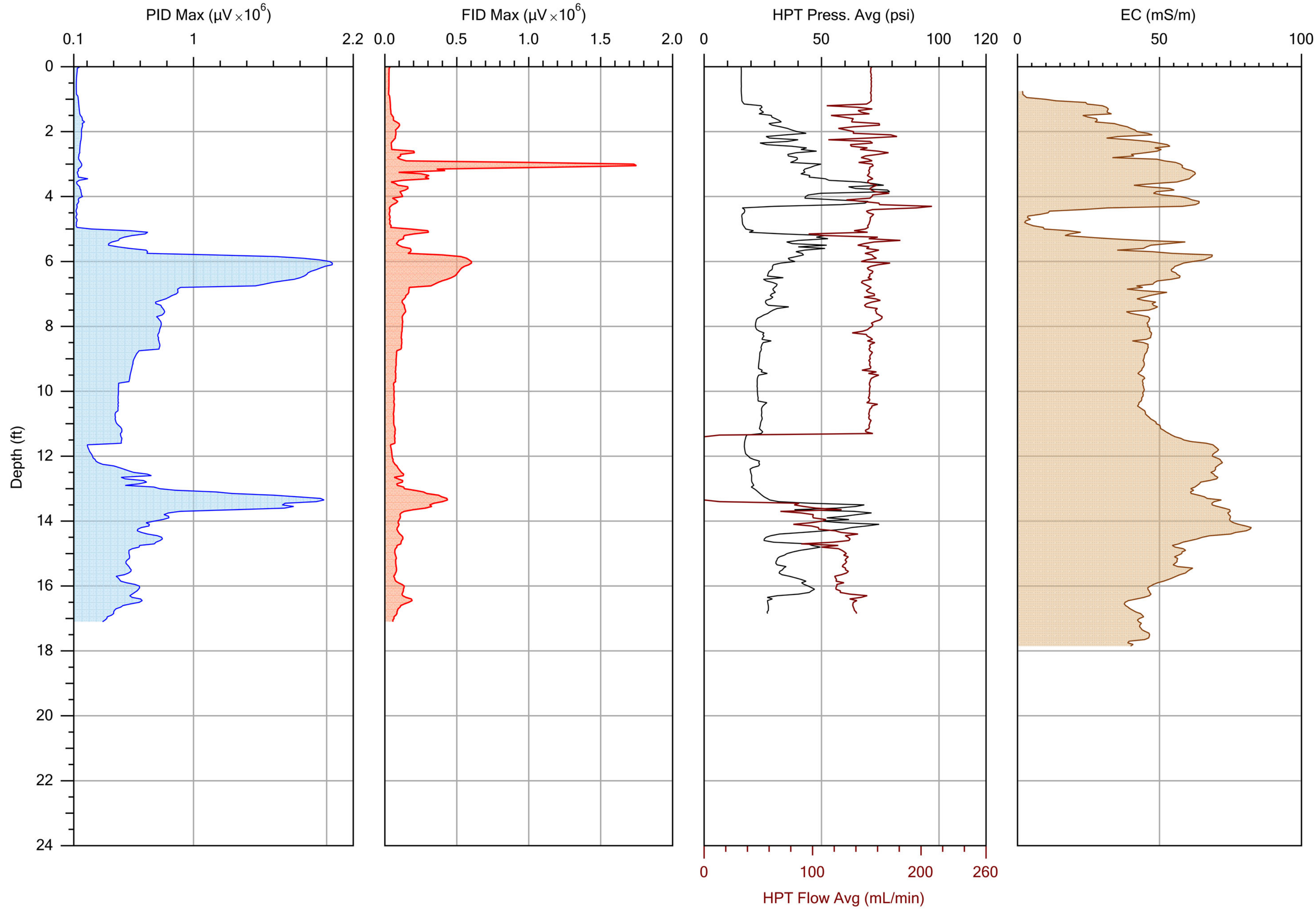

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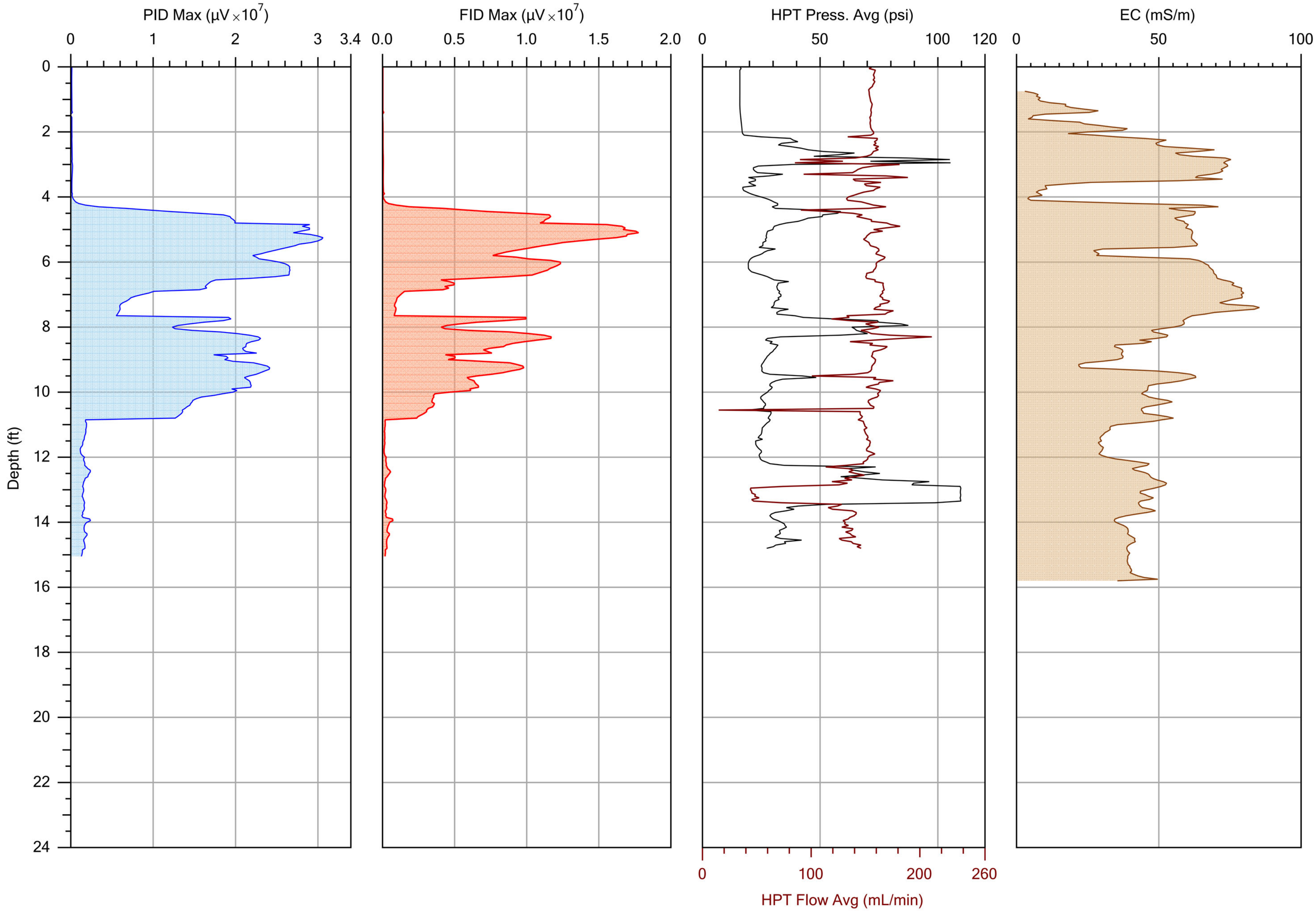

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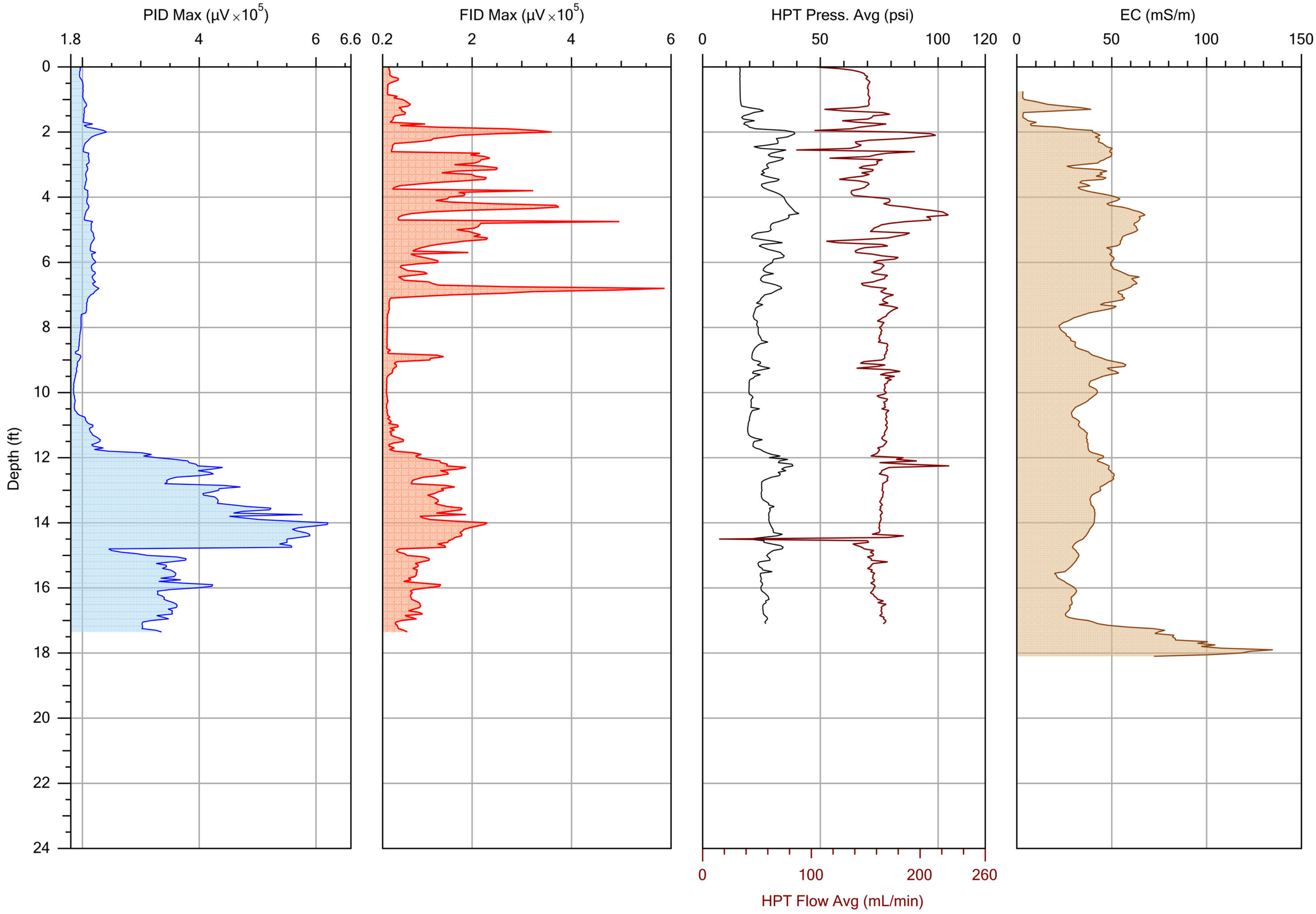

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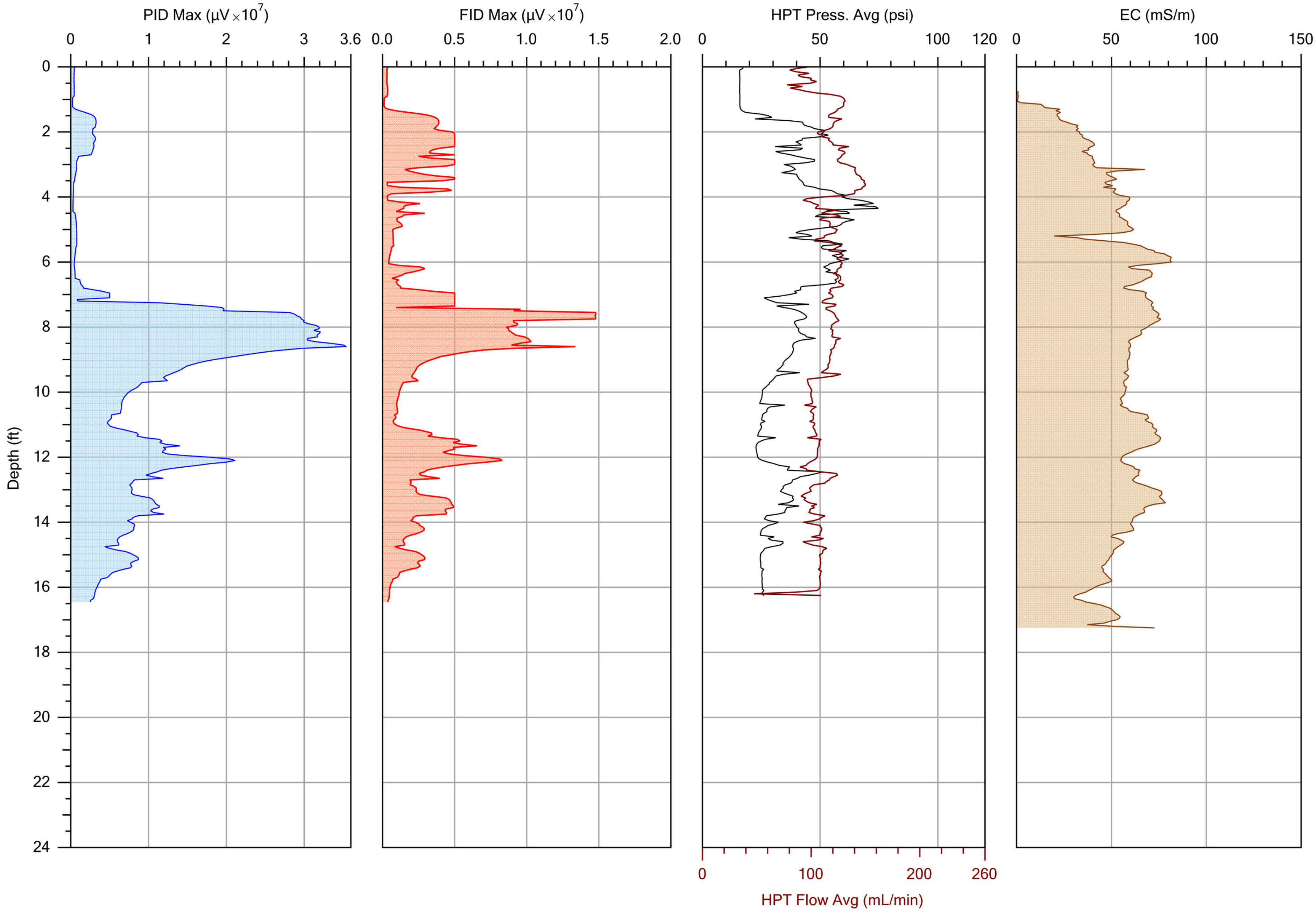
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA

APPENDIX E – Data Logs for Membrane Interface Probe/EC with Hydraulic Profile Tool (MiHpt) - Collective Scale



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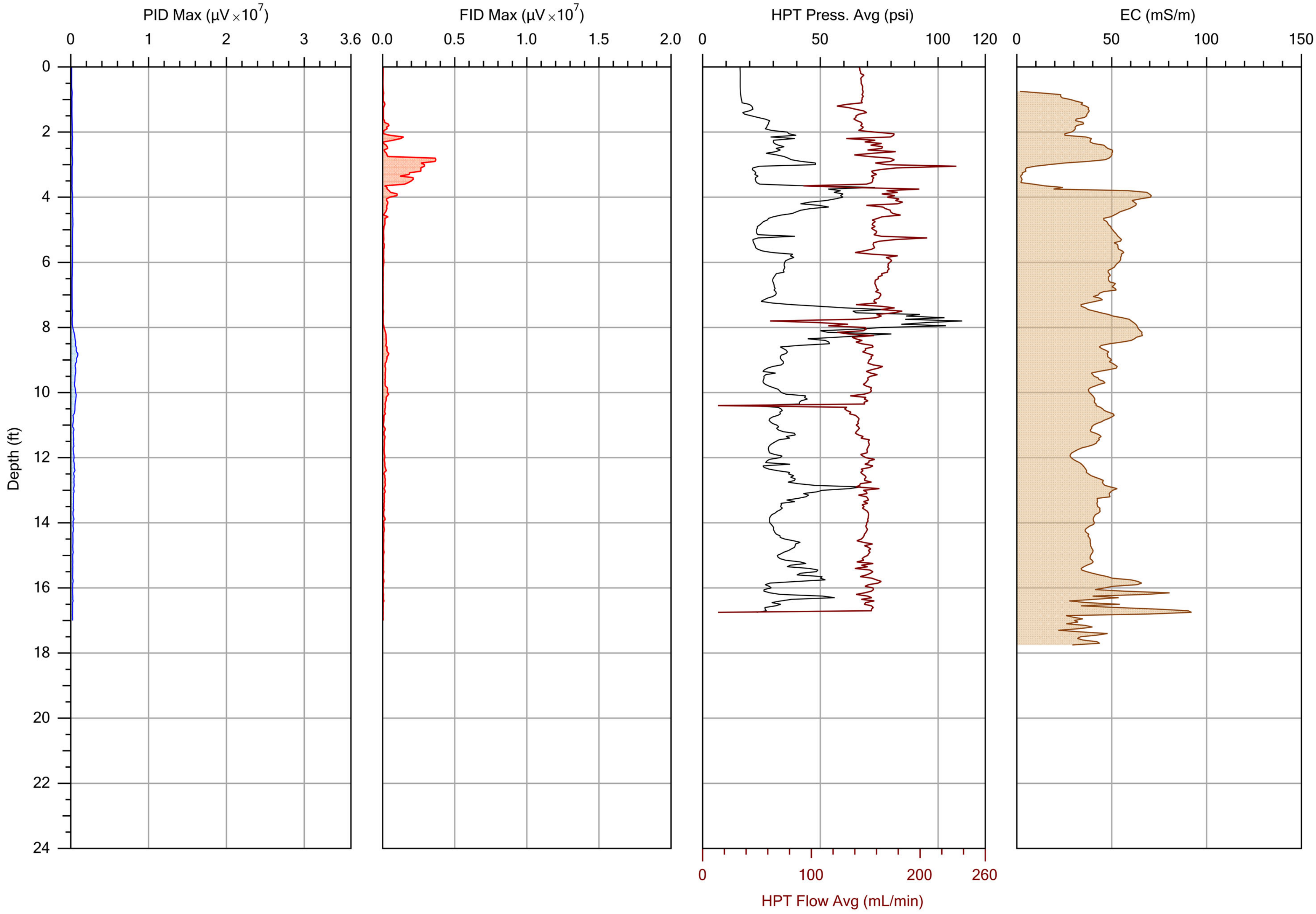

COLUMBIA
TECHNOLOGIES

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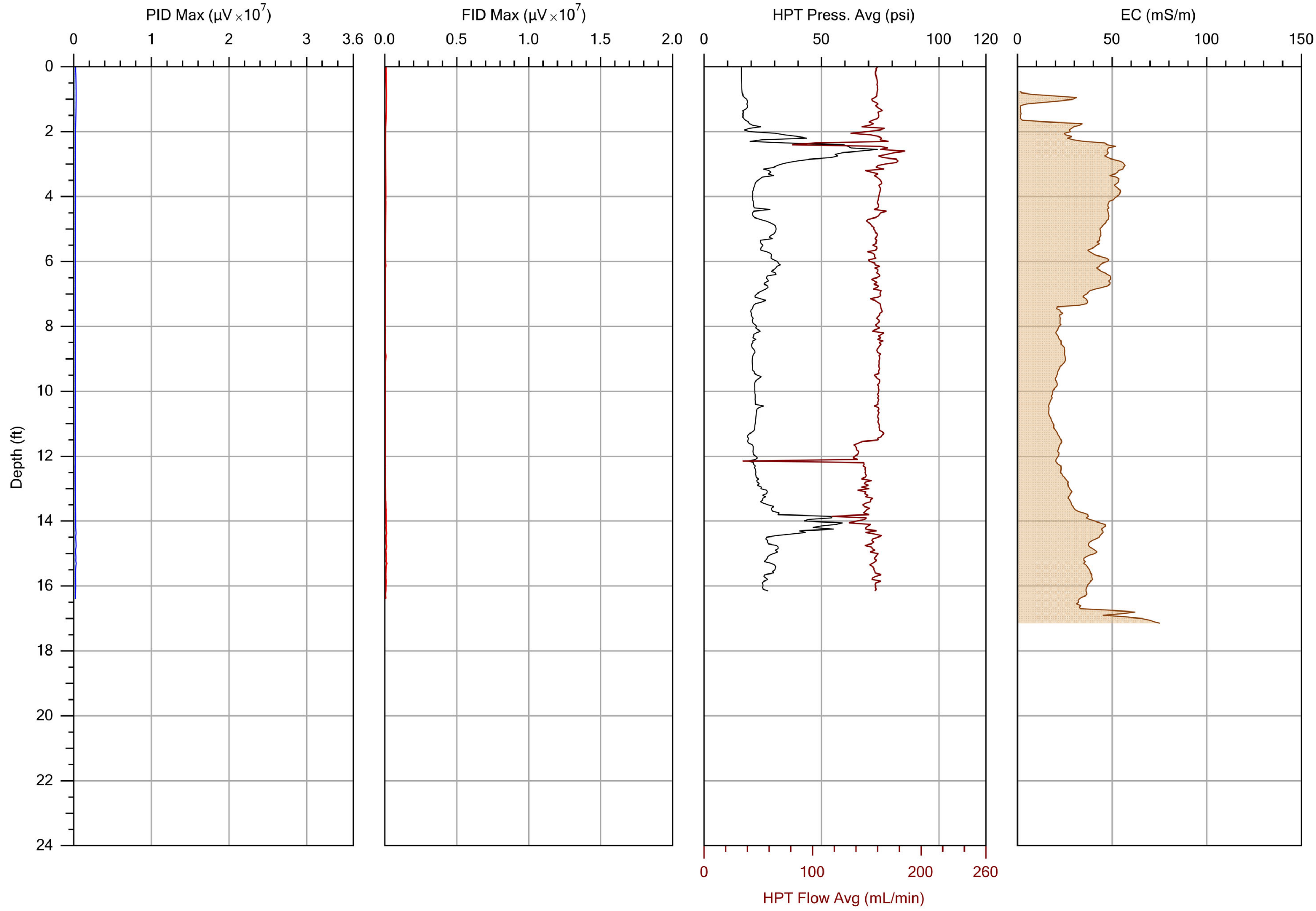

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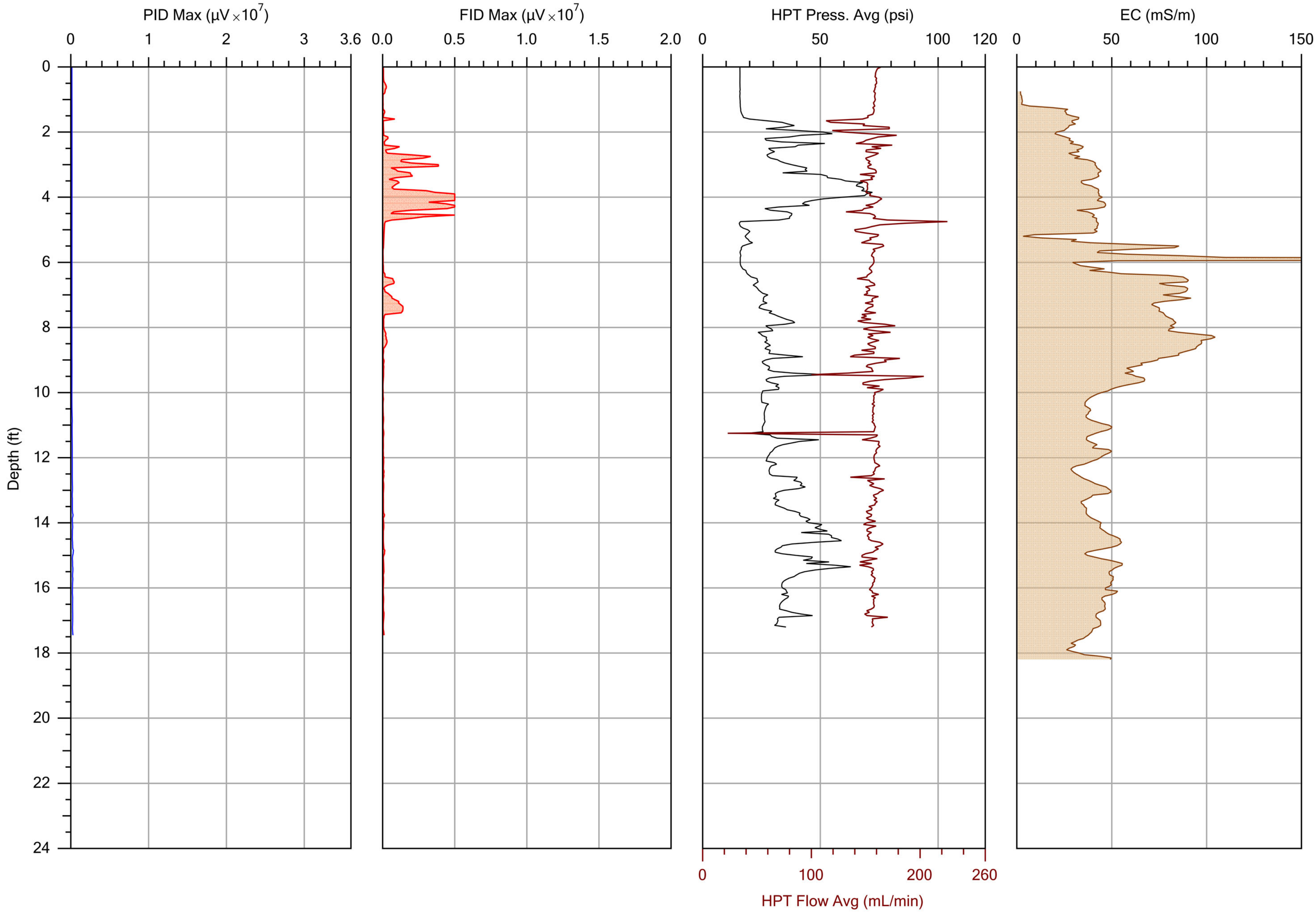

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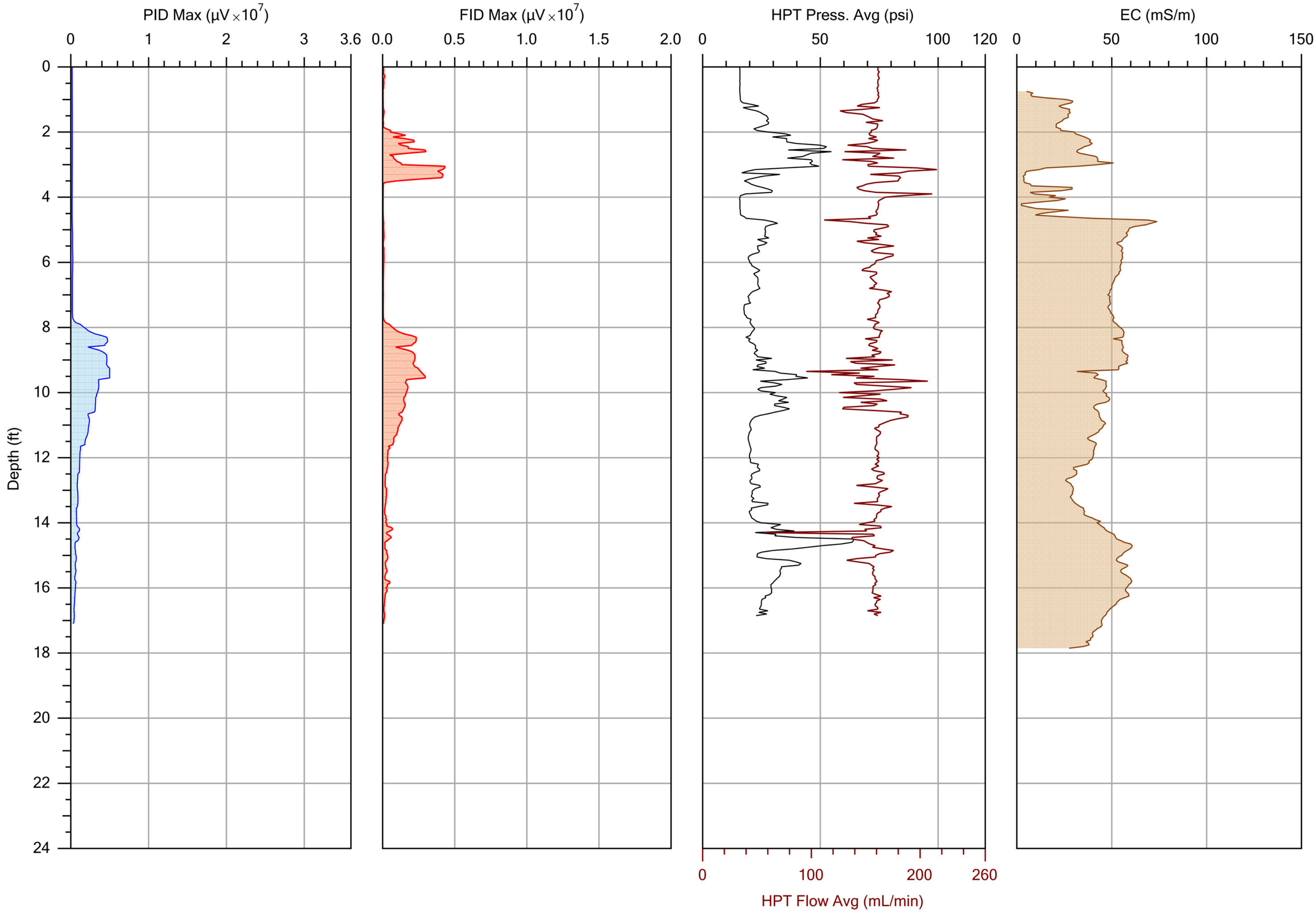

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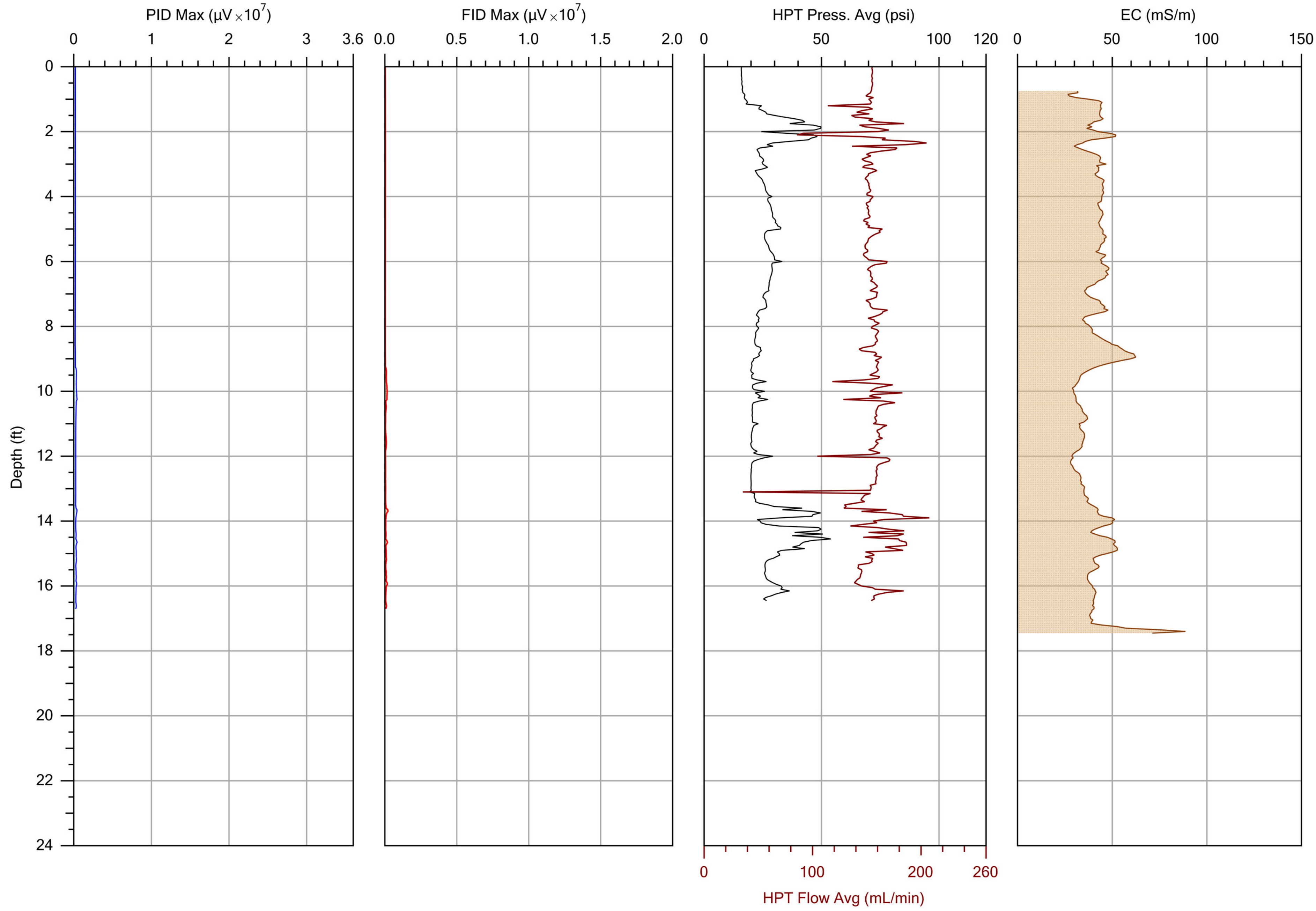
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA



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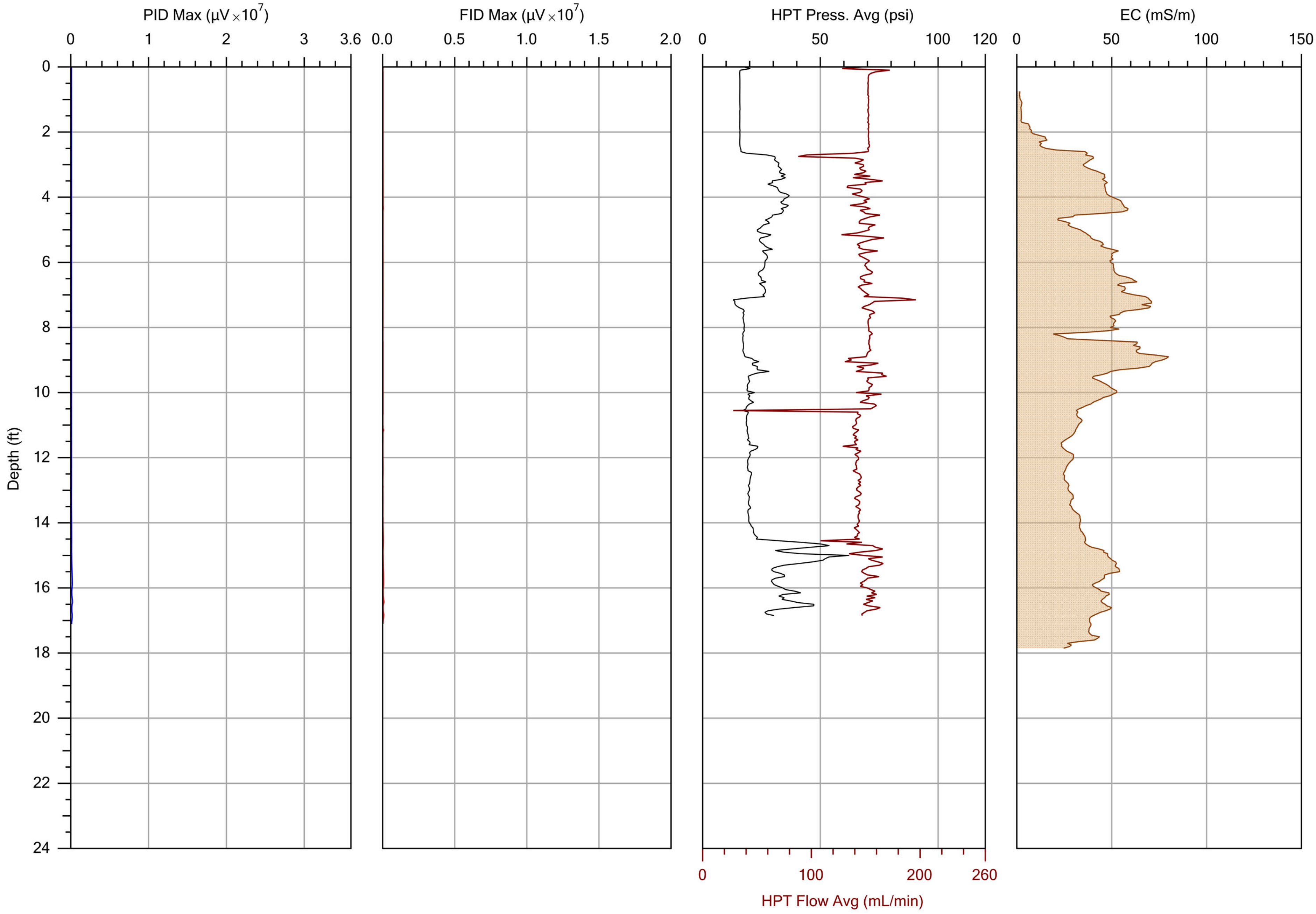

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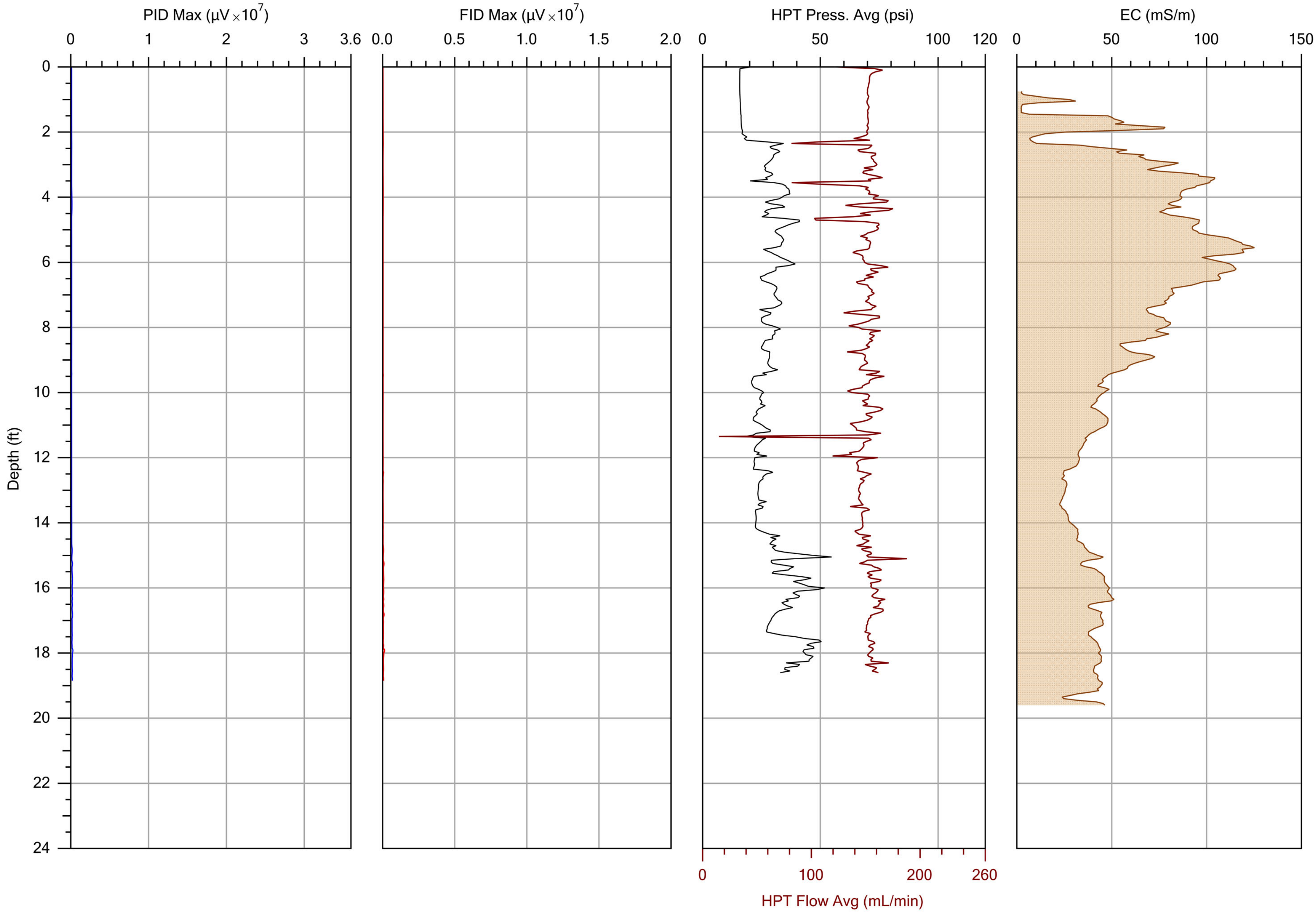

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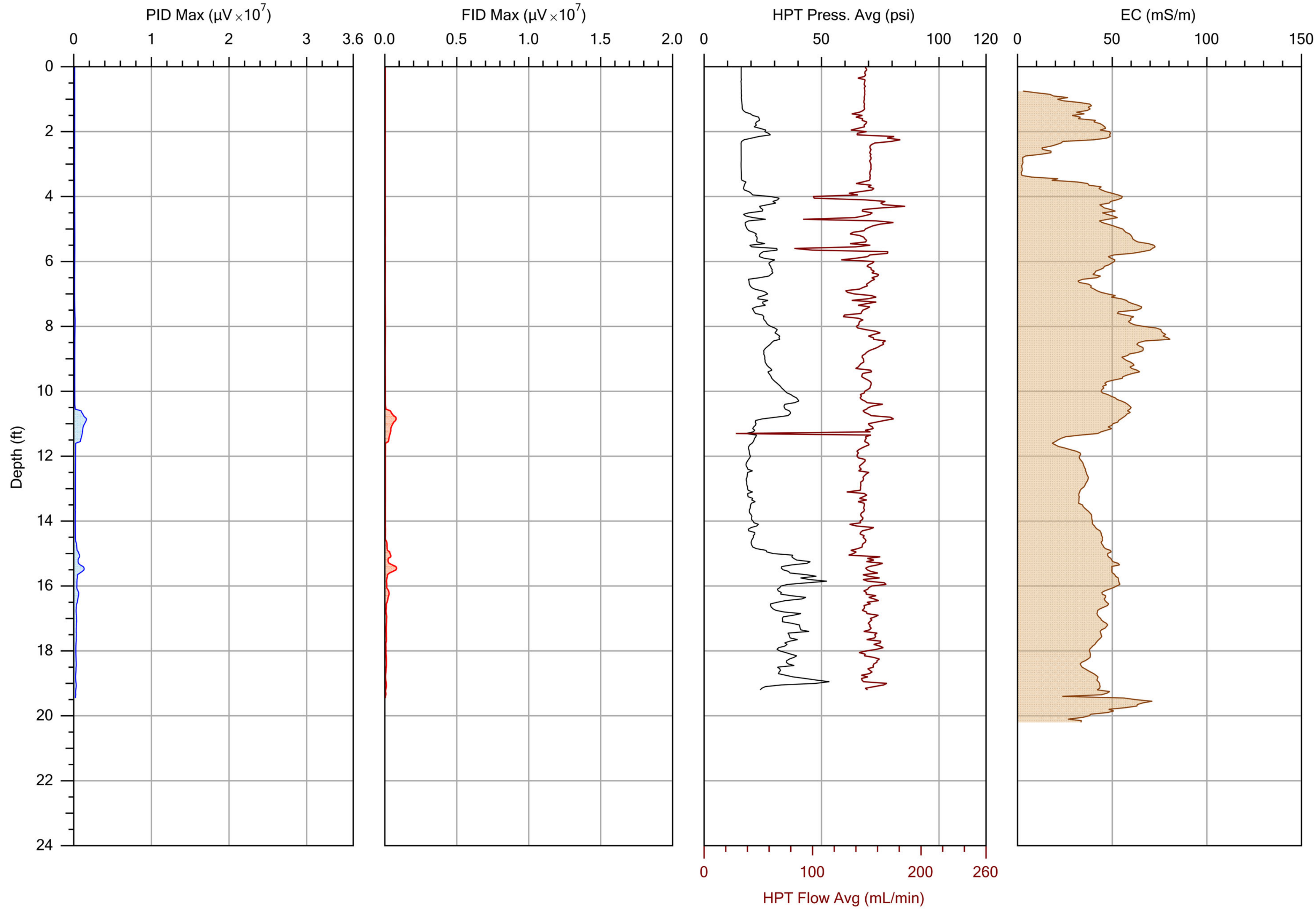
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA



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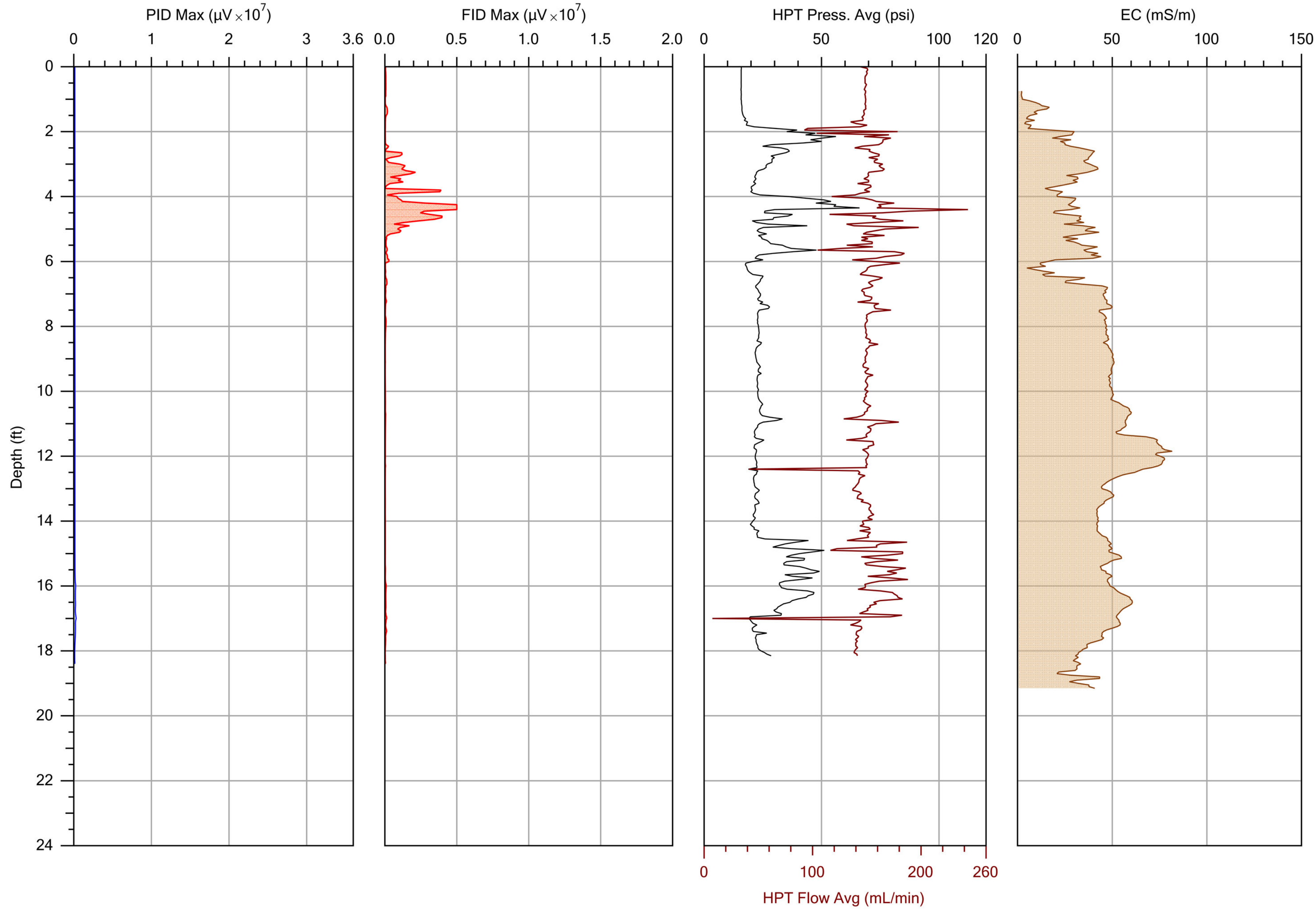

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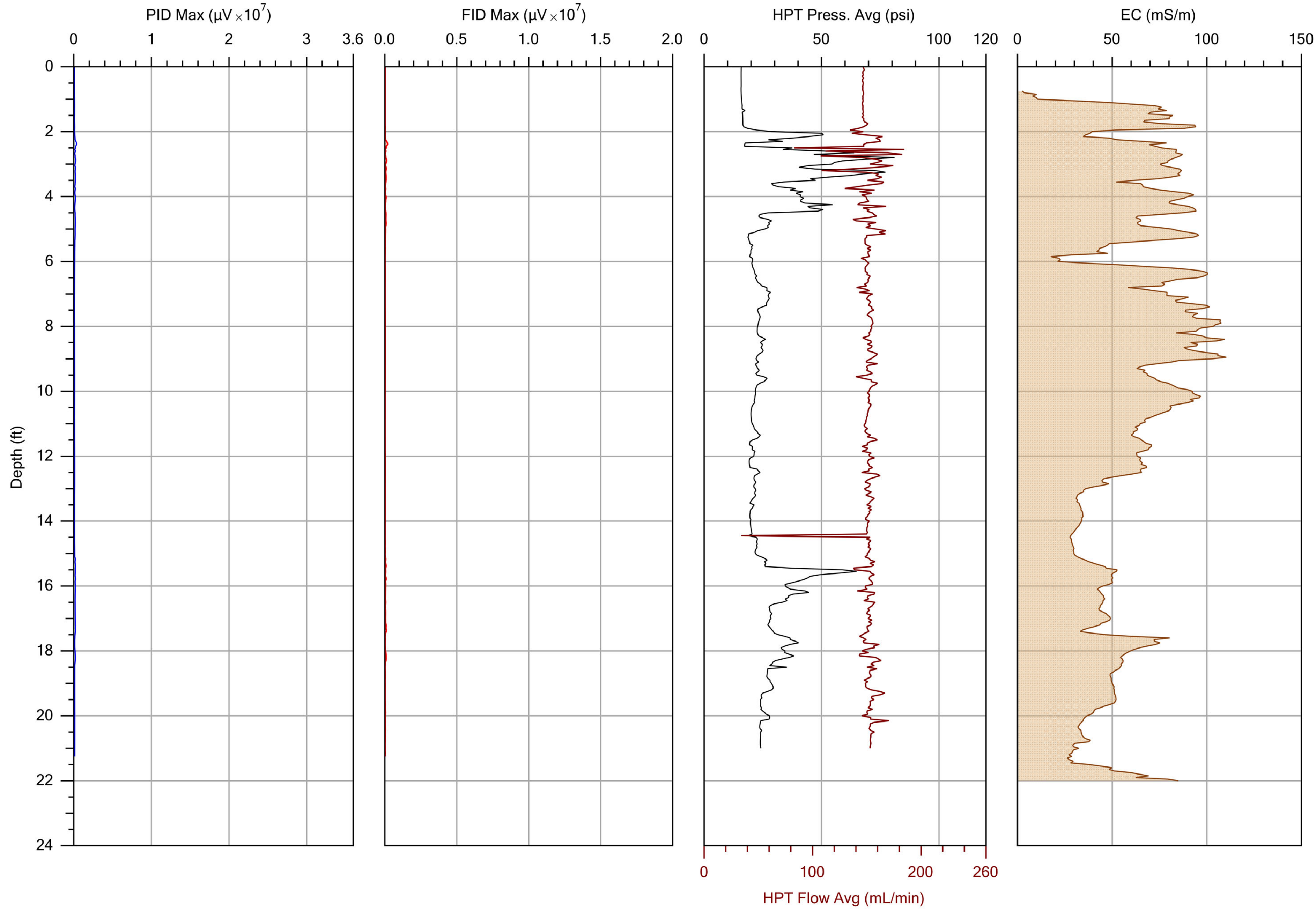

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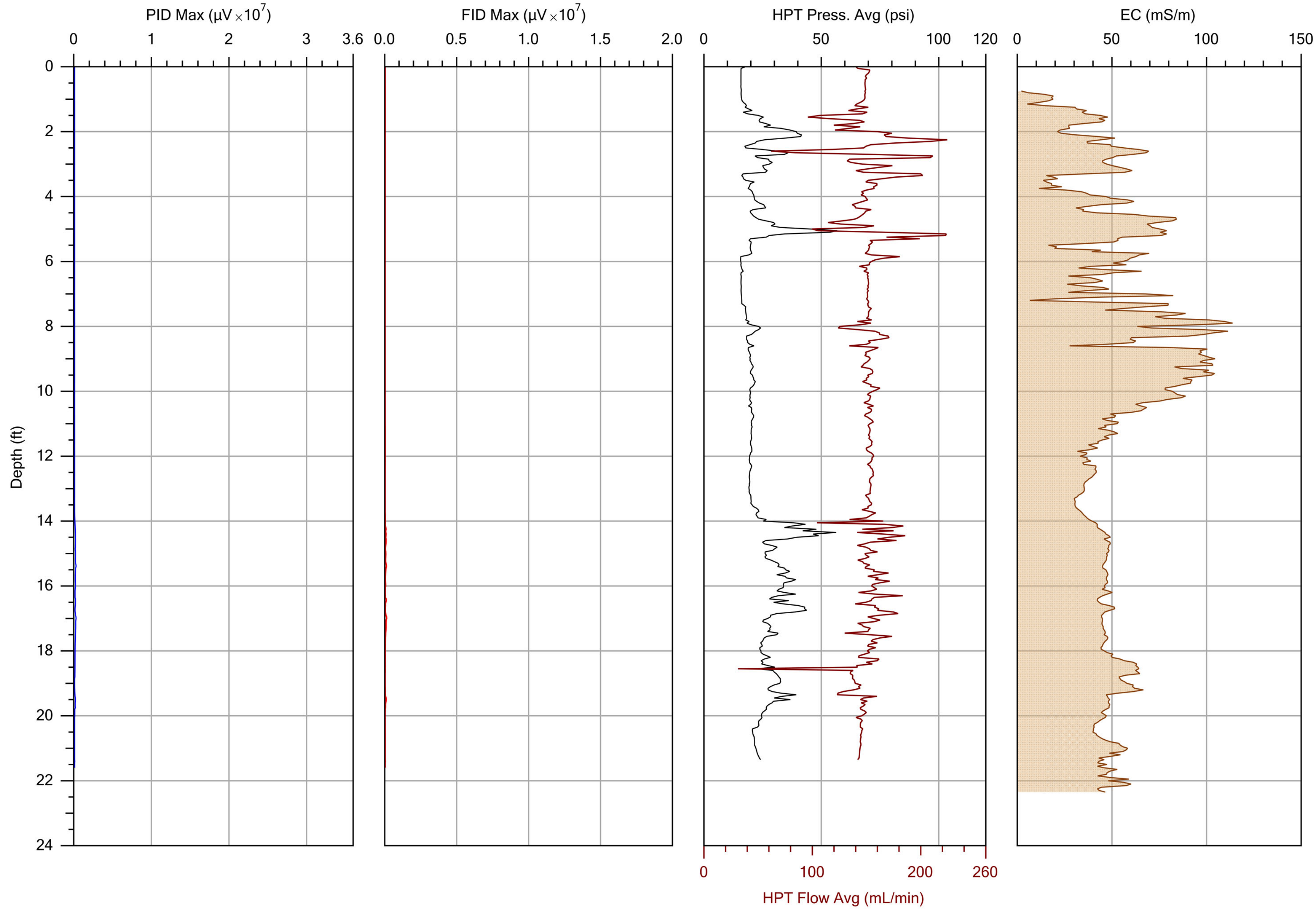
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA



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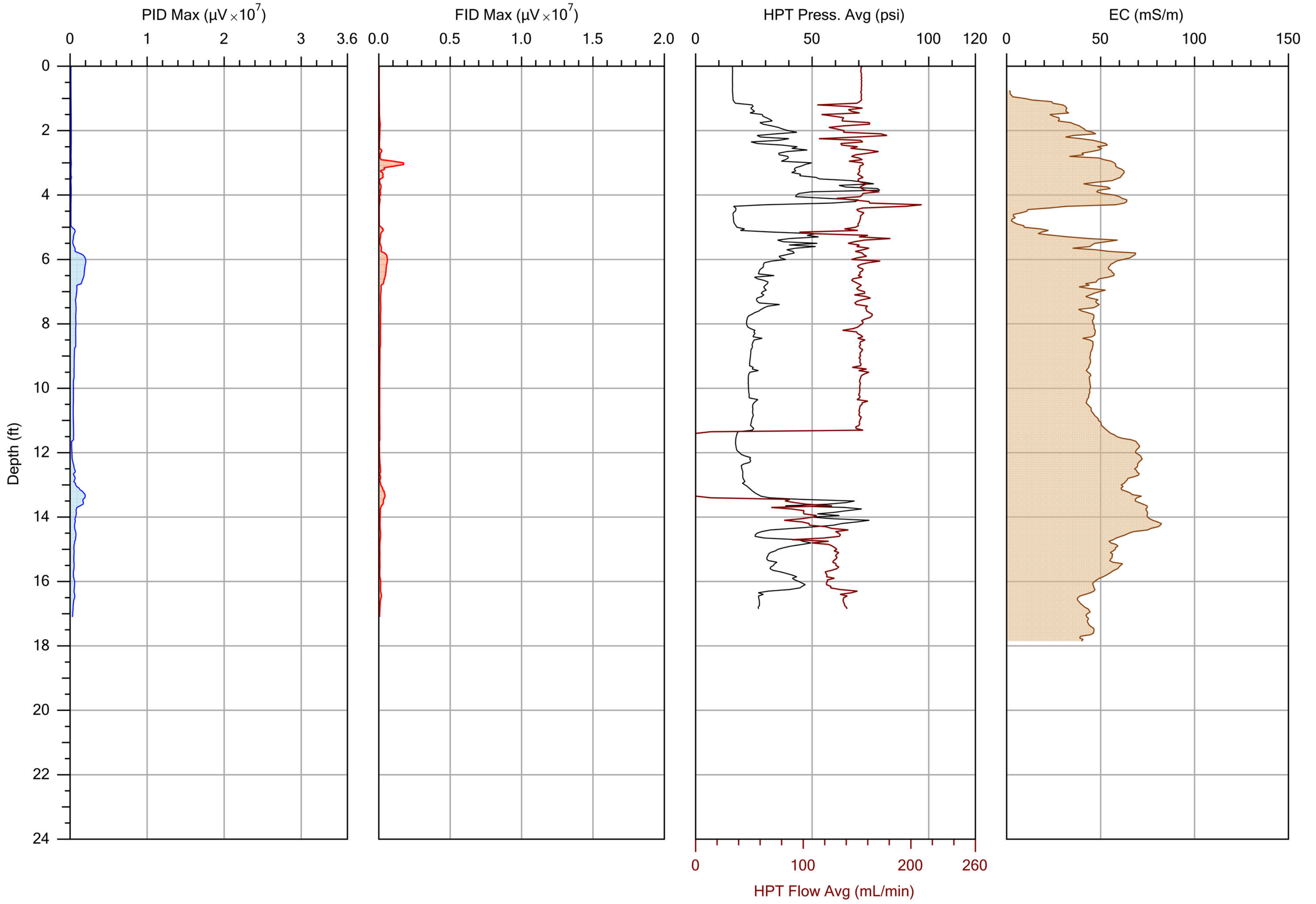
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA



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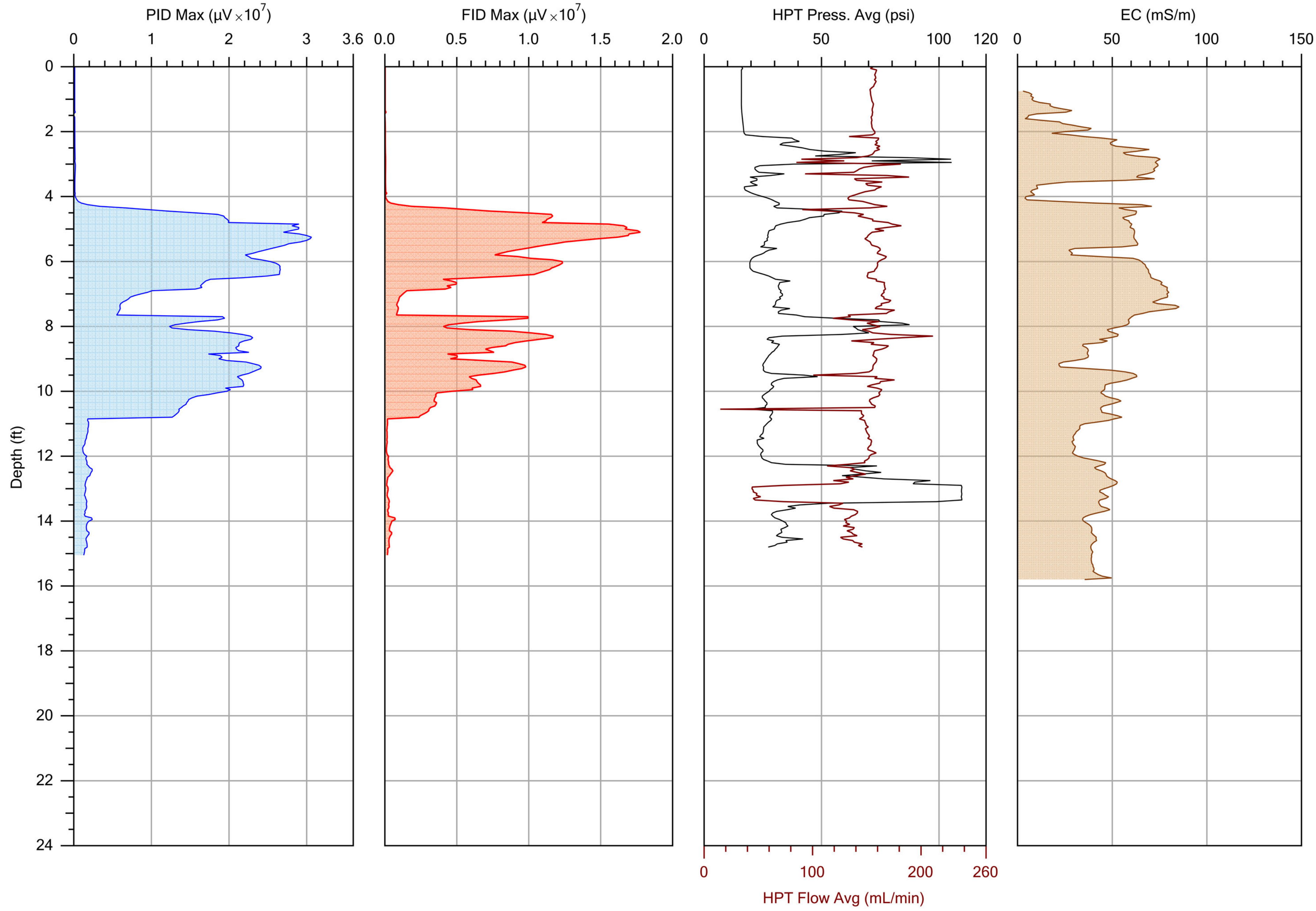

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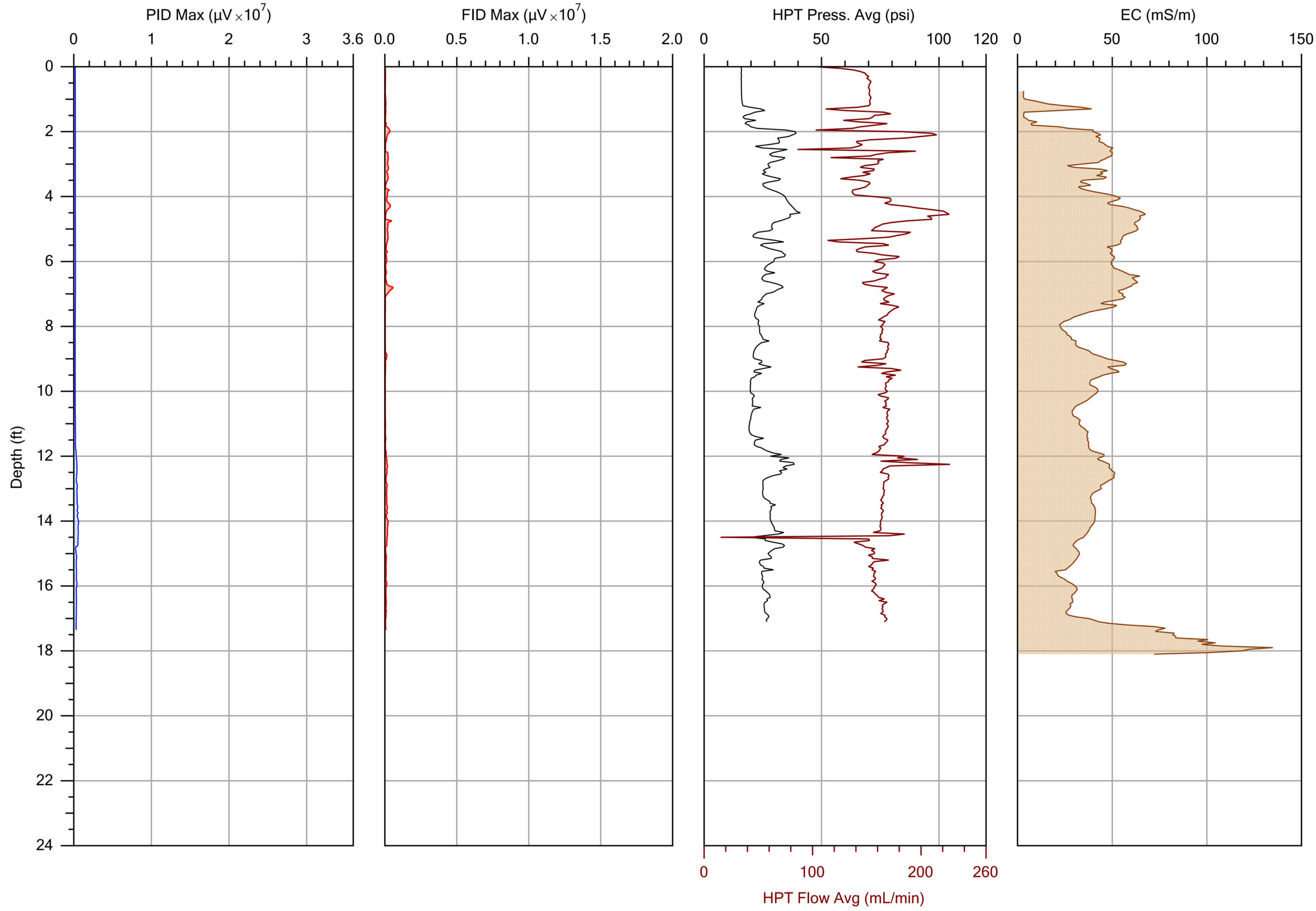

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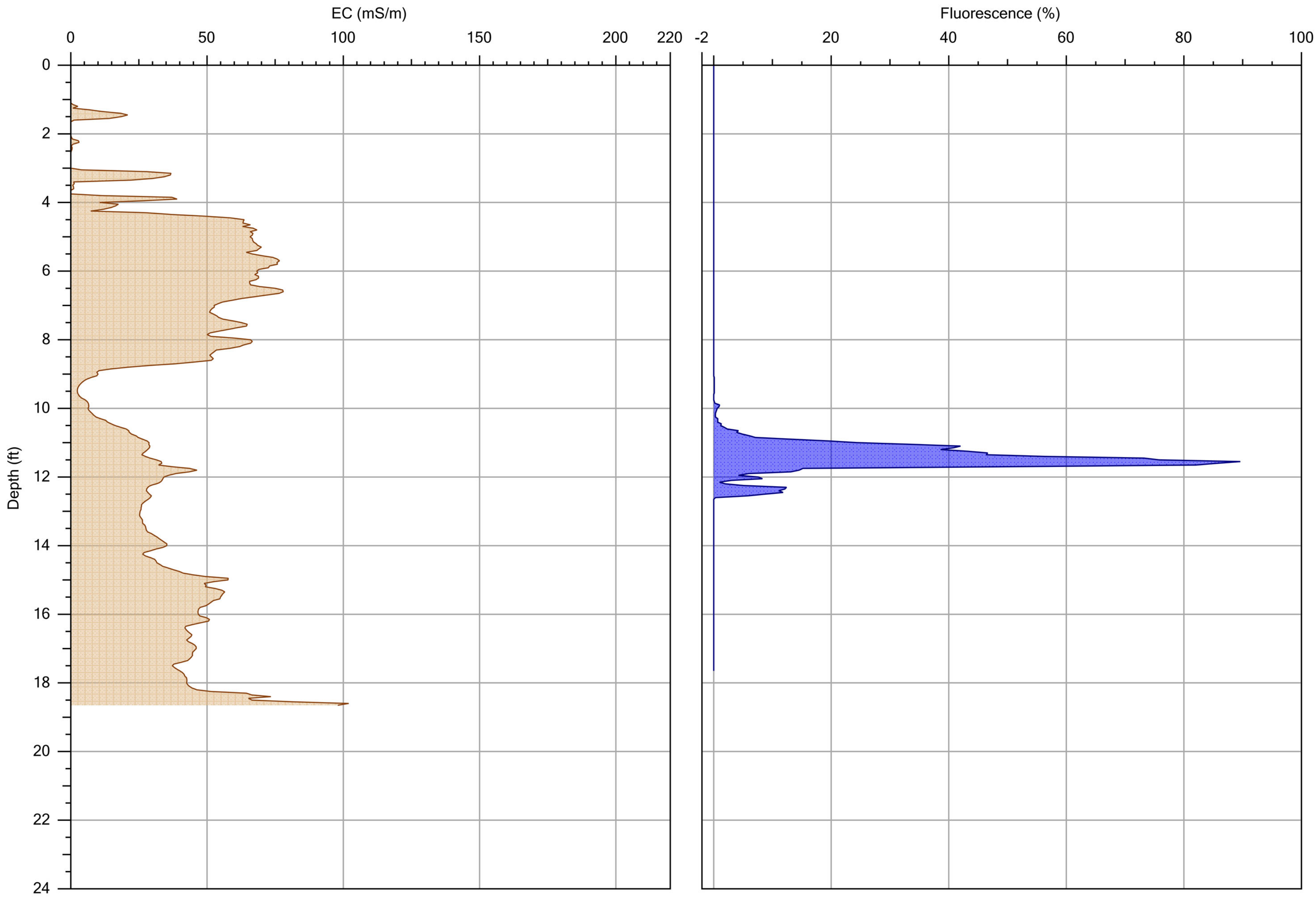
Project ID: Former Tiger Oil	Client: Maul Foster Alongi	Location: Yakima, WA

APPENDIX F – OIP® Logs



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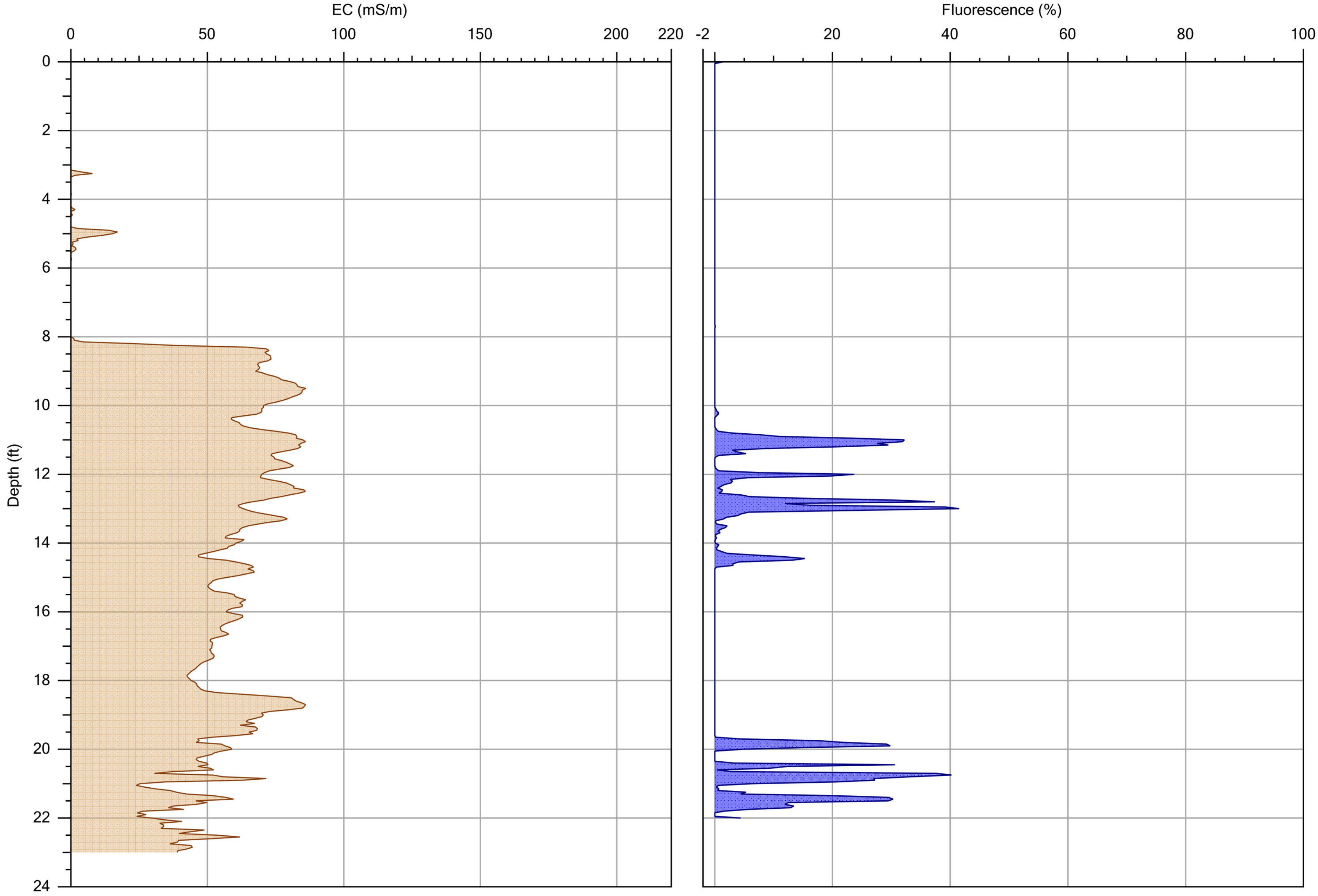

COLUMBIA TECHNOLOGIES

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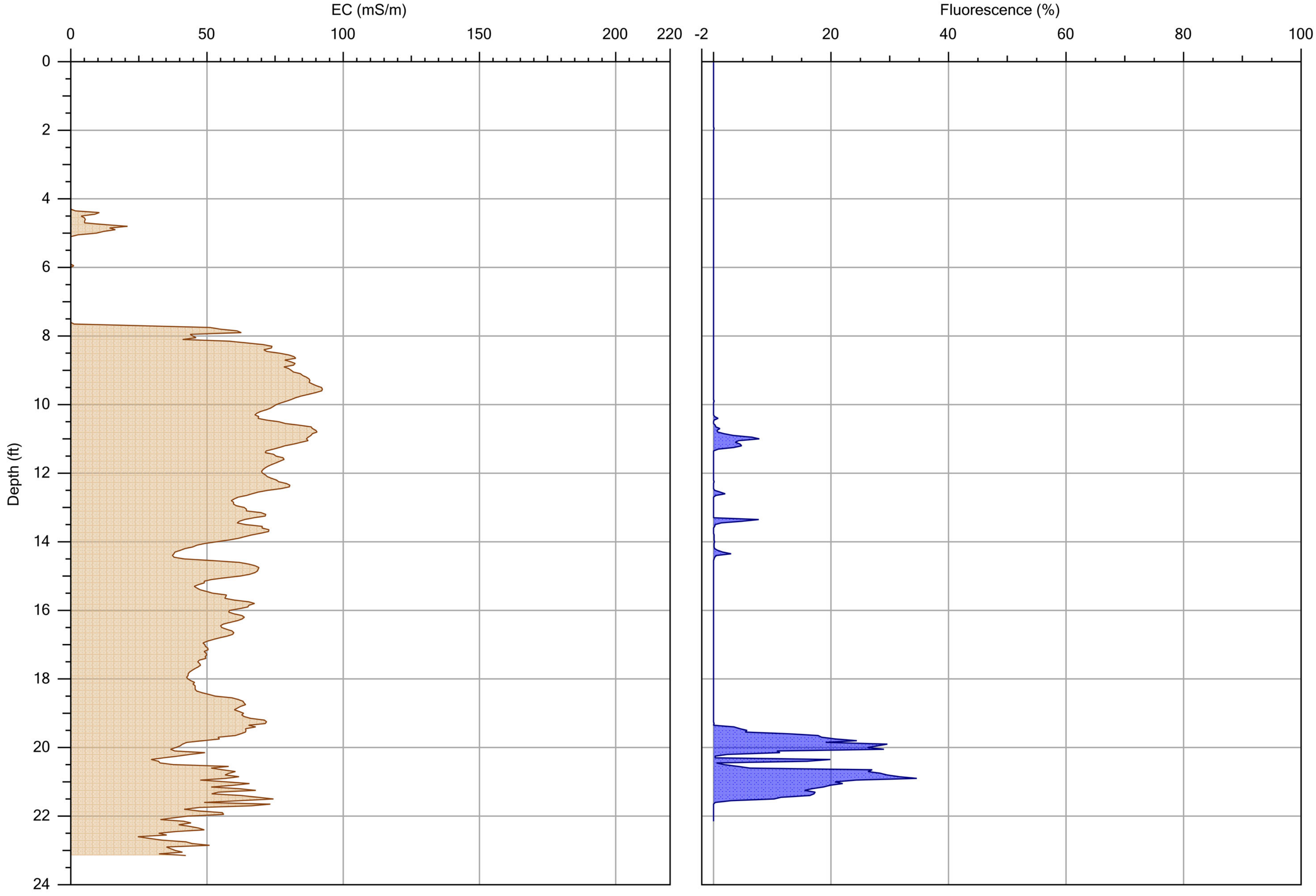

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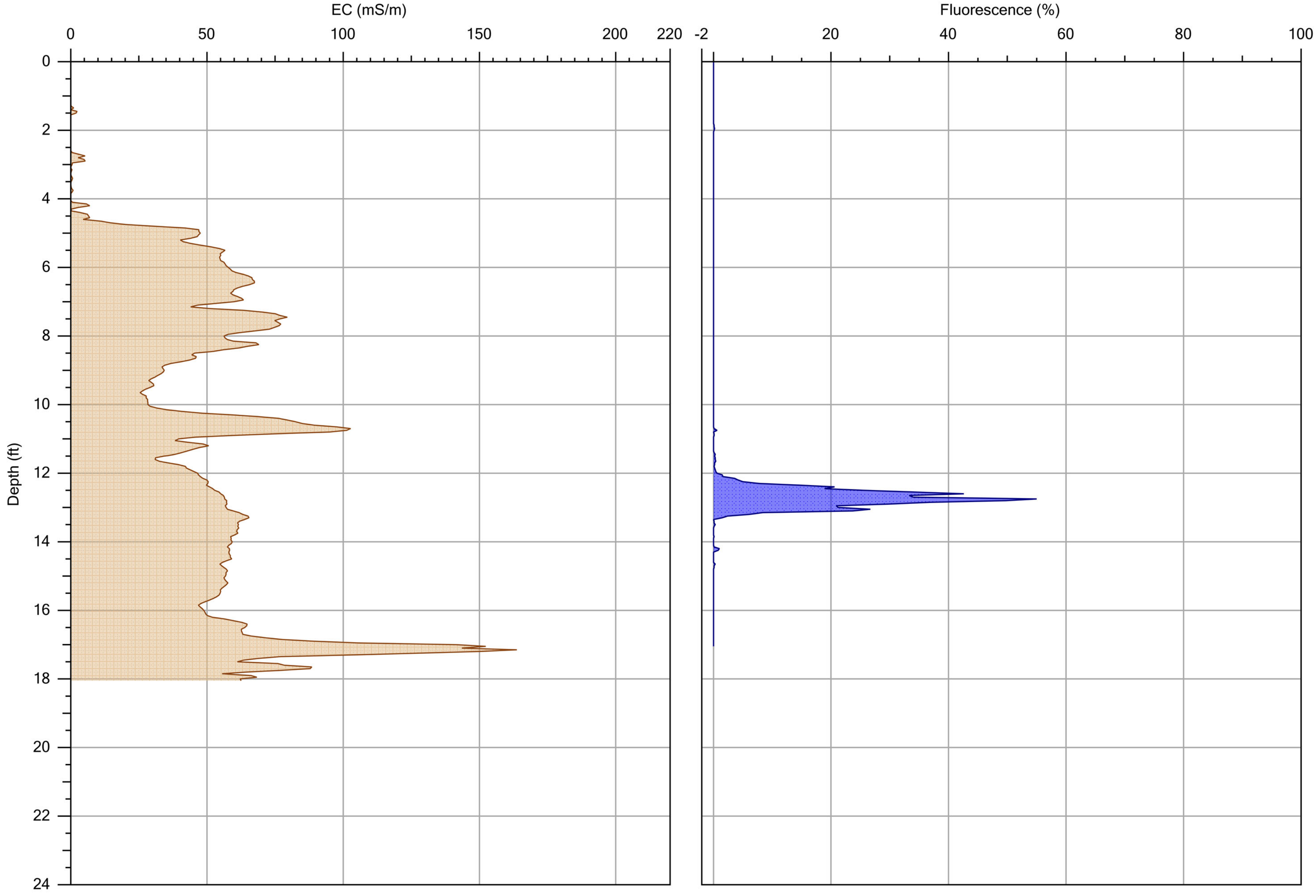

COLUMBIA TECHNOLOGIES

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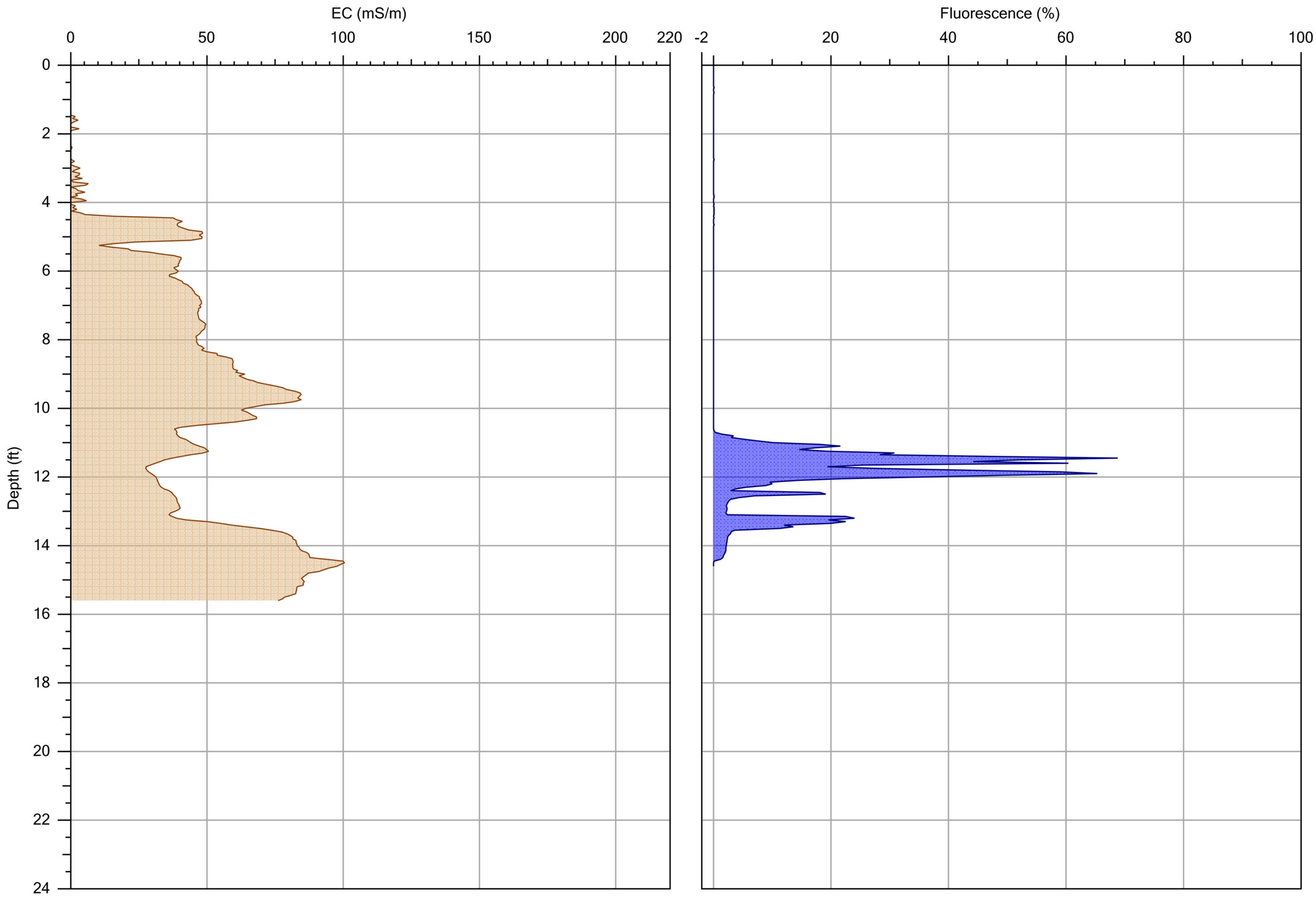
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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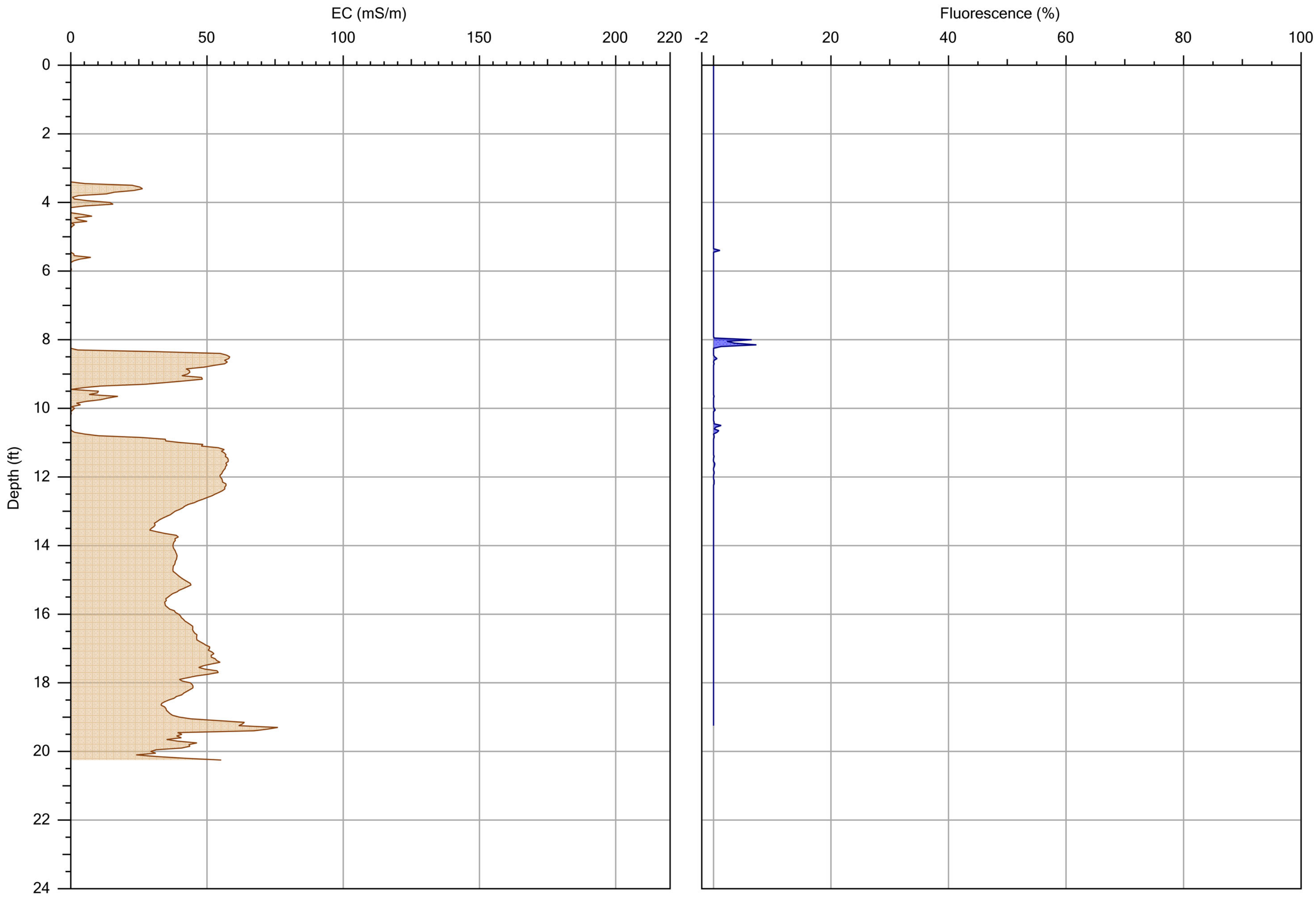

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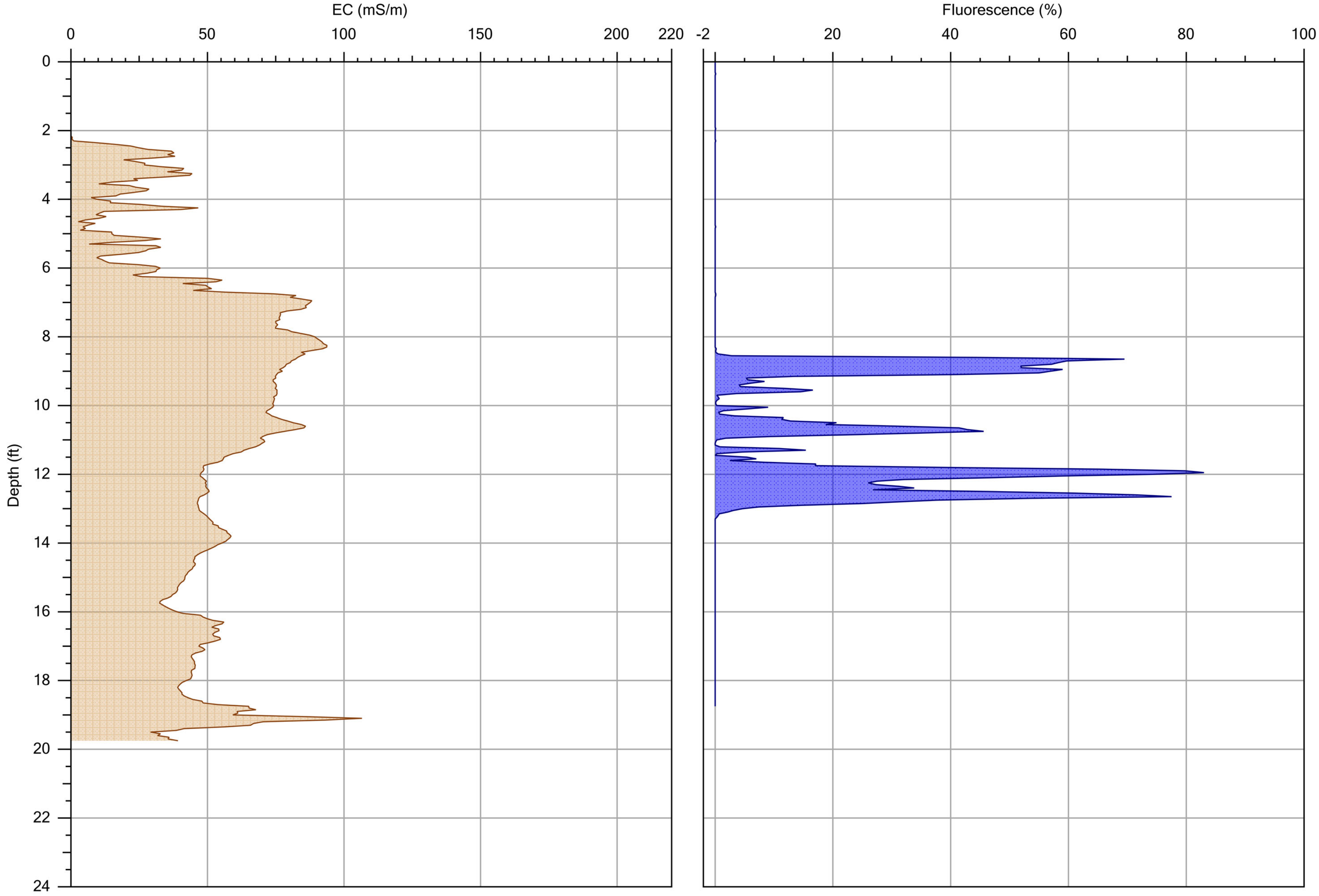
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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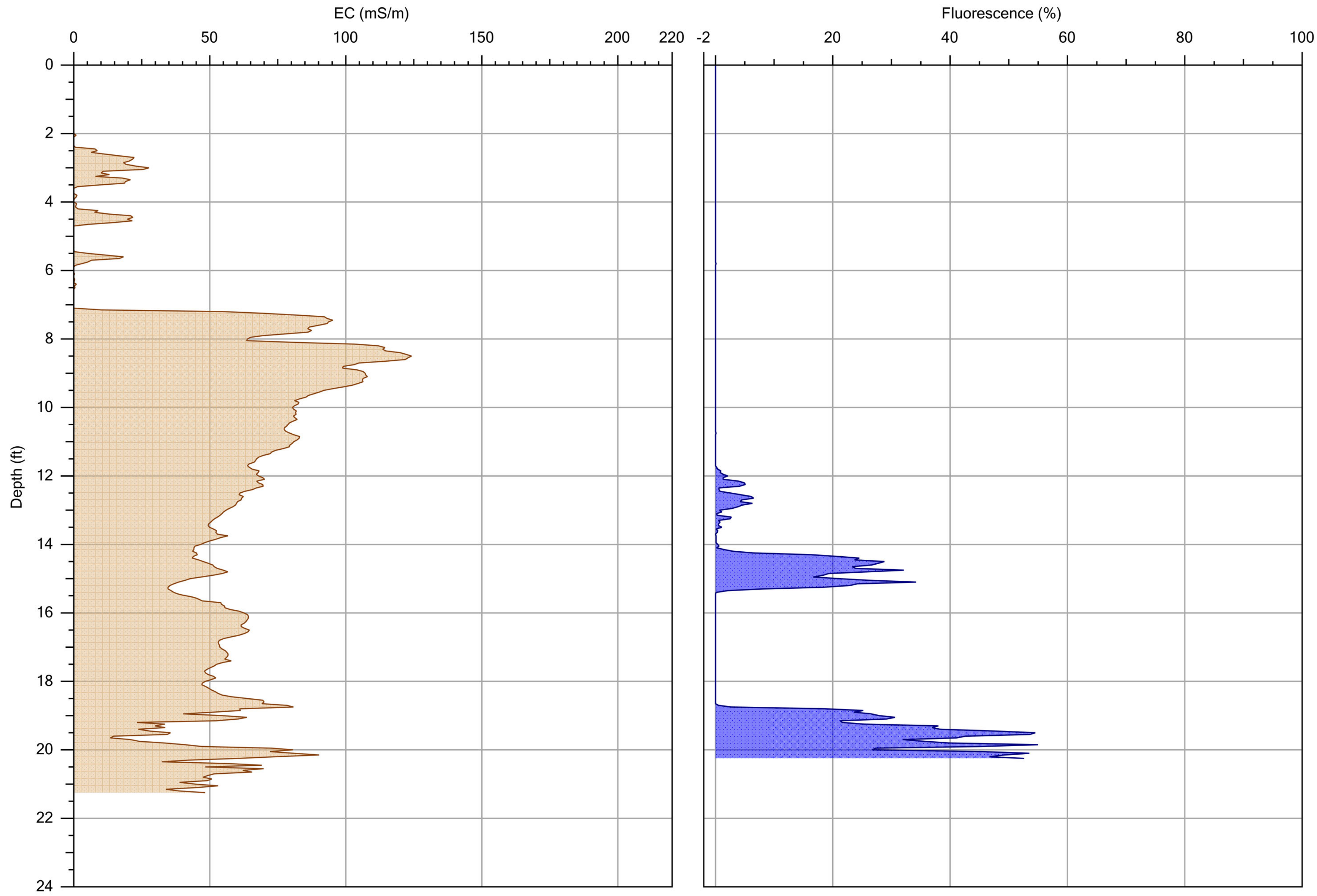
Company: Columbia Technologies	Operator: RSP	Date: 11/27/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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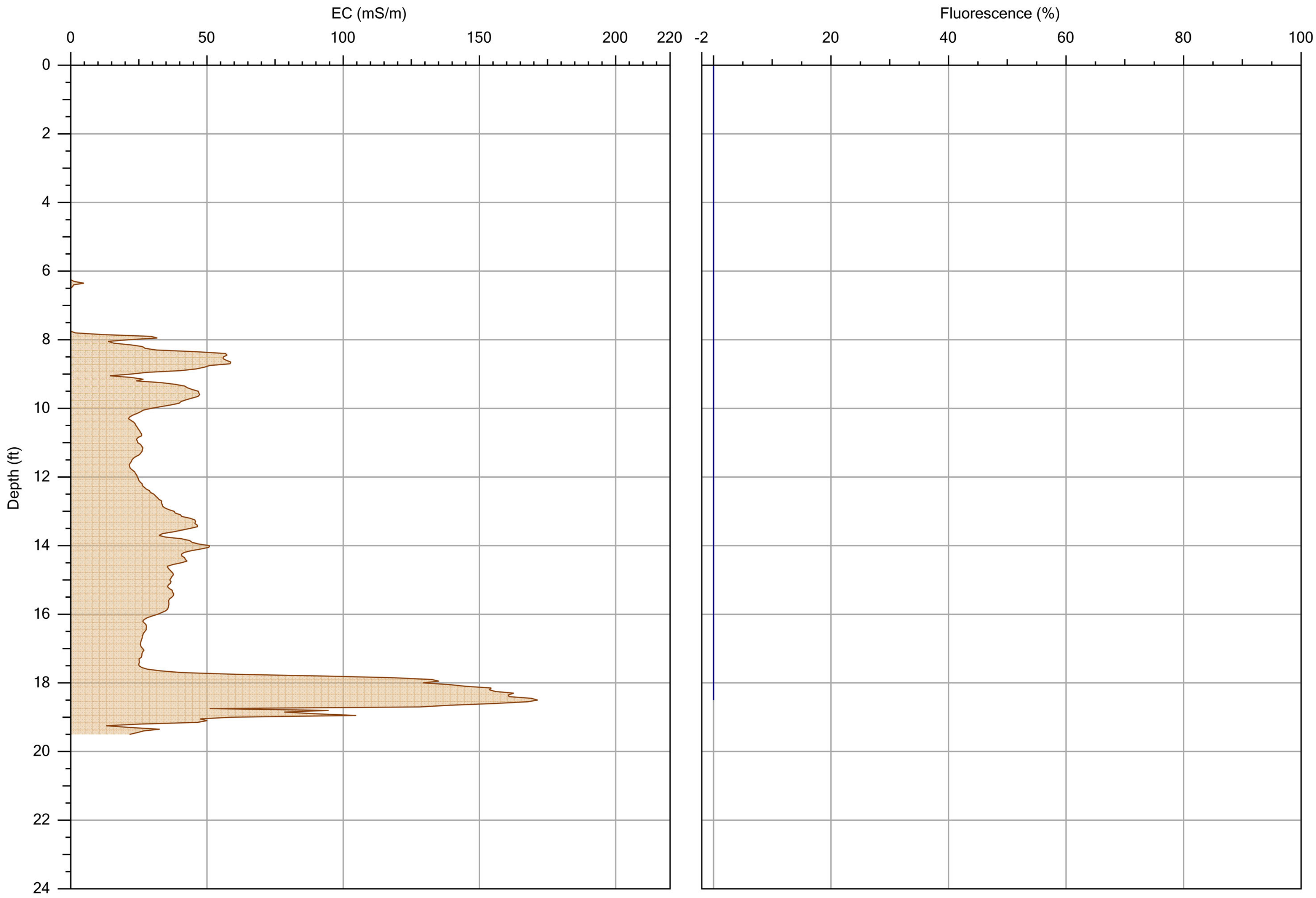
Company: Columbia Technologies	Operator: RSP	Date: 12/1/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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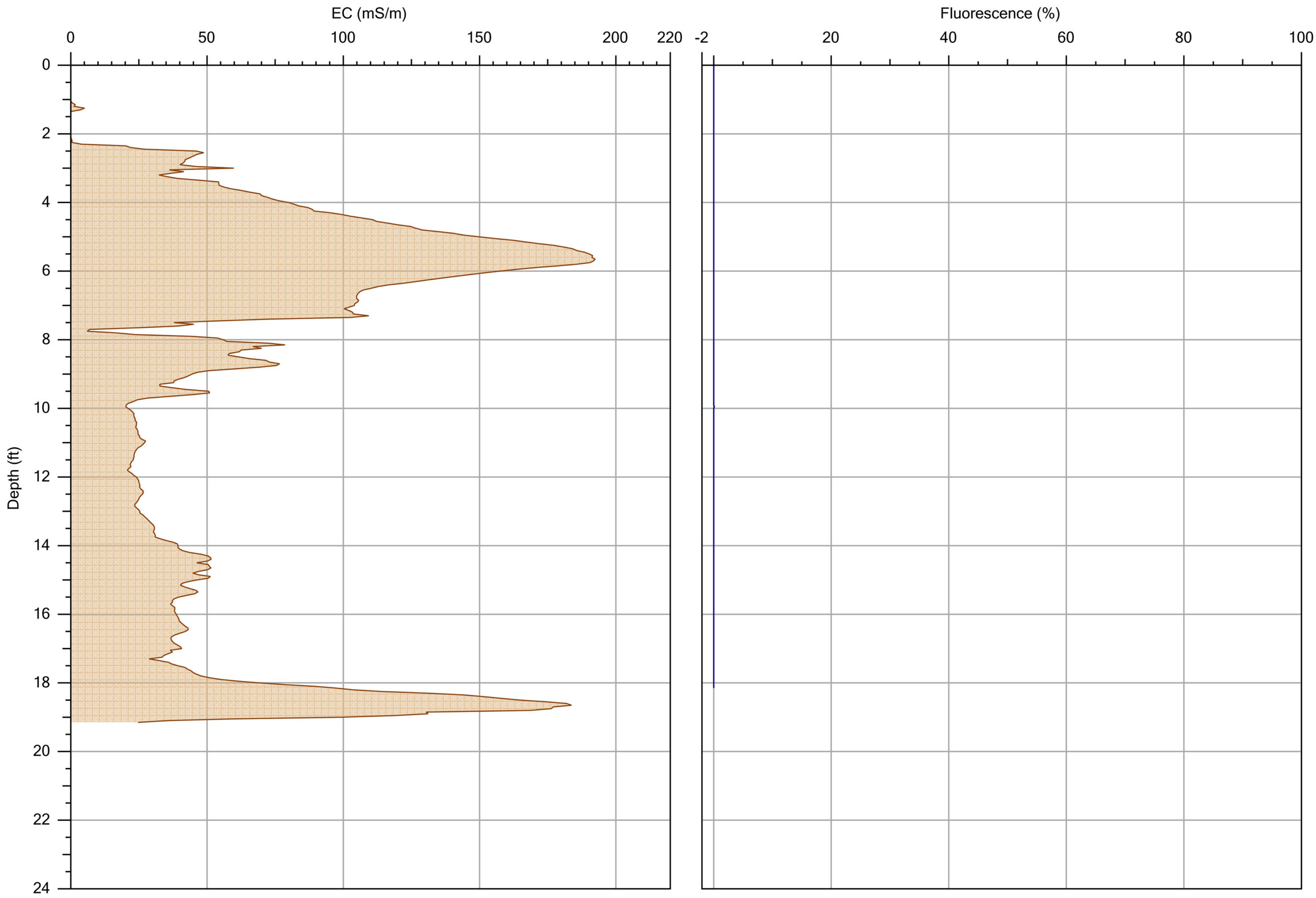
Company: Columbia Technologies	Operator: RSP	Date: 12/1/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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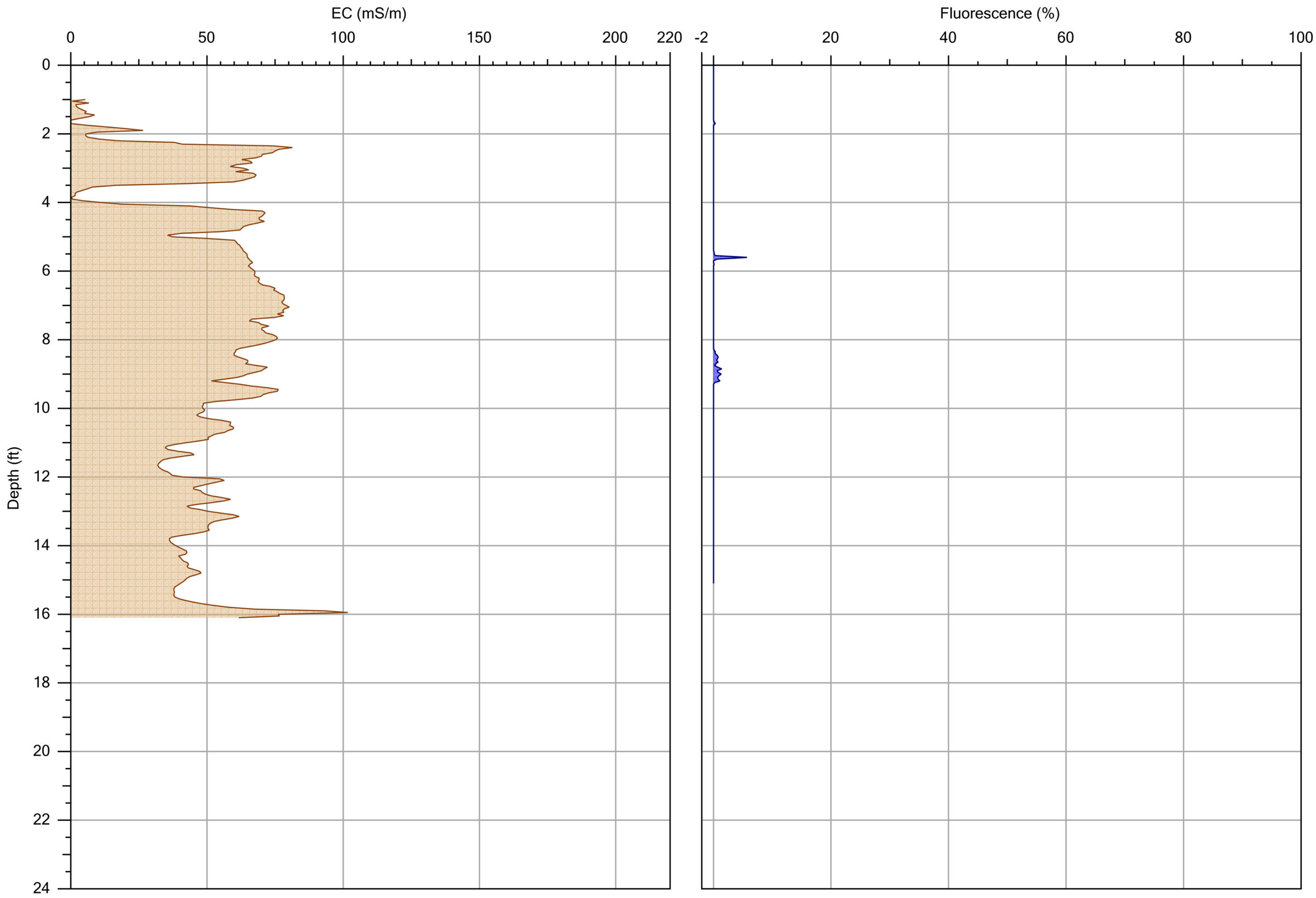
Company: Columbia Technologies	Operator: RSP	Date: 12/1/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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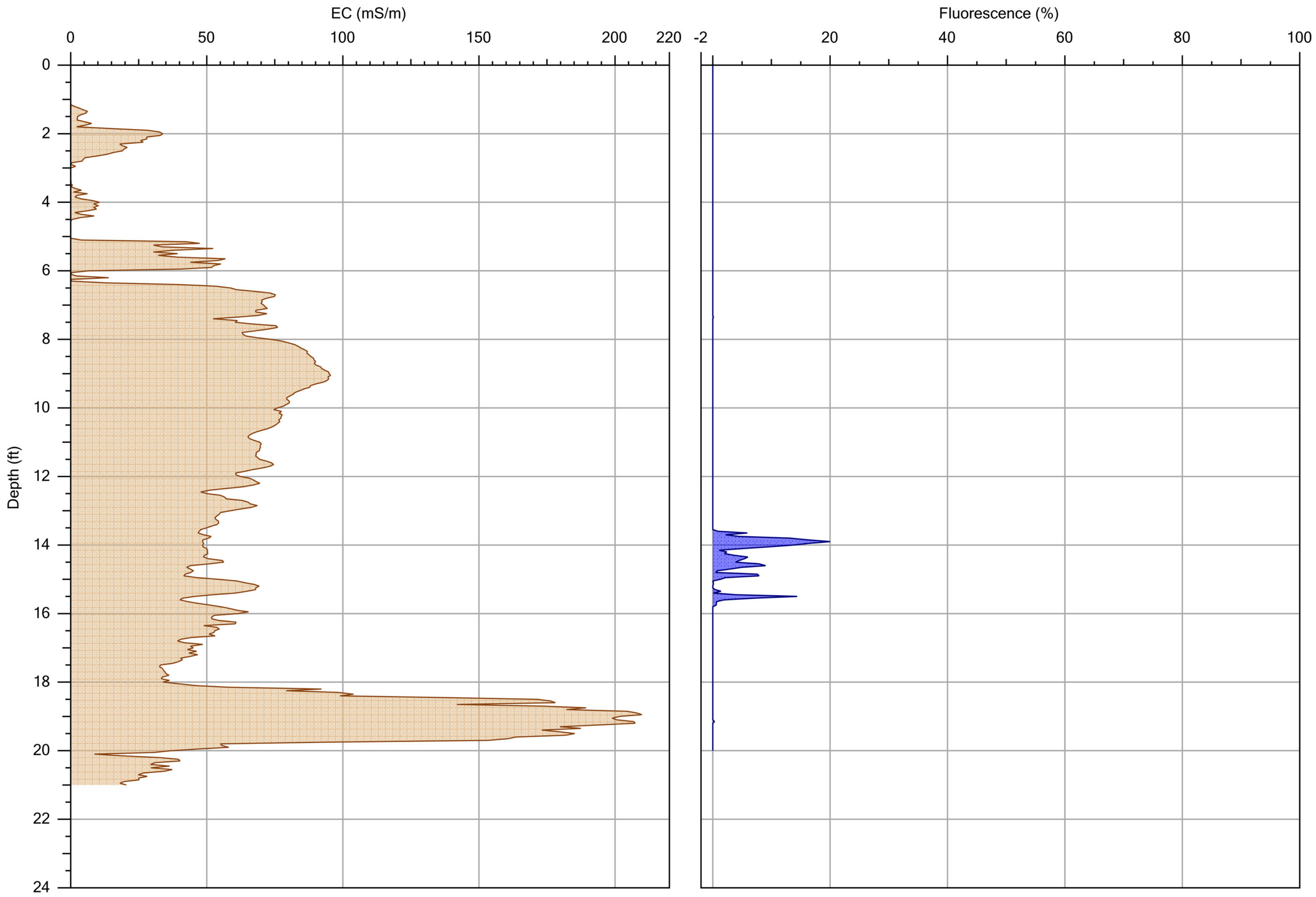
Company: Columbia Technologies	Operator: RSP	Date: 12/1/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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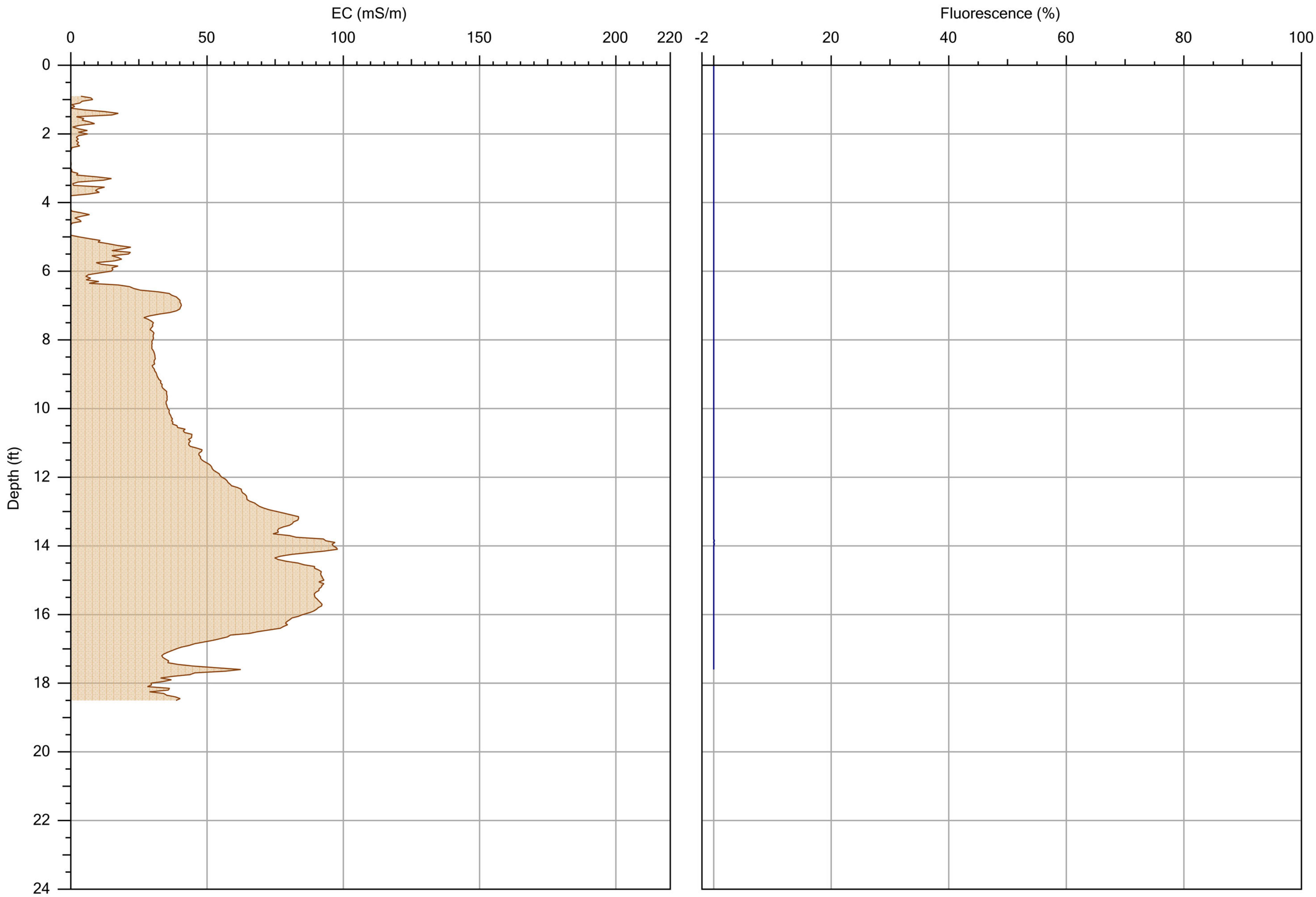
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA



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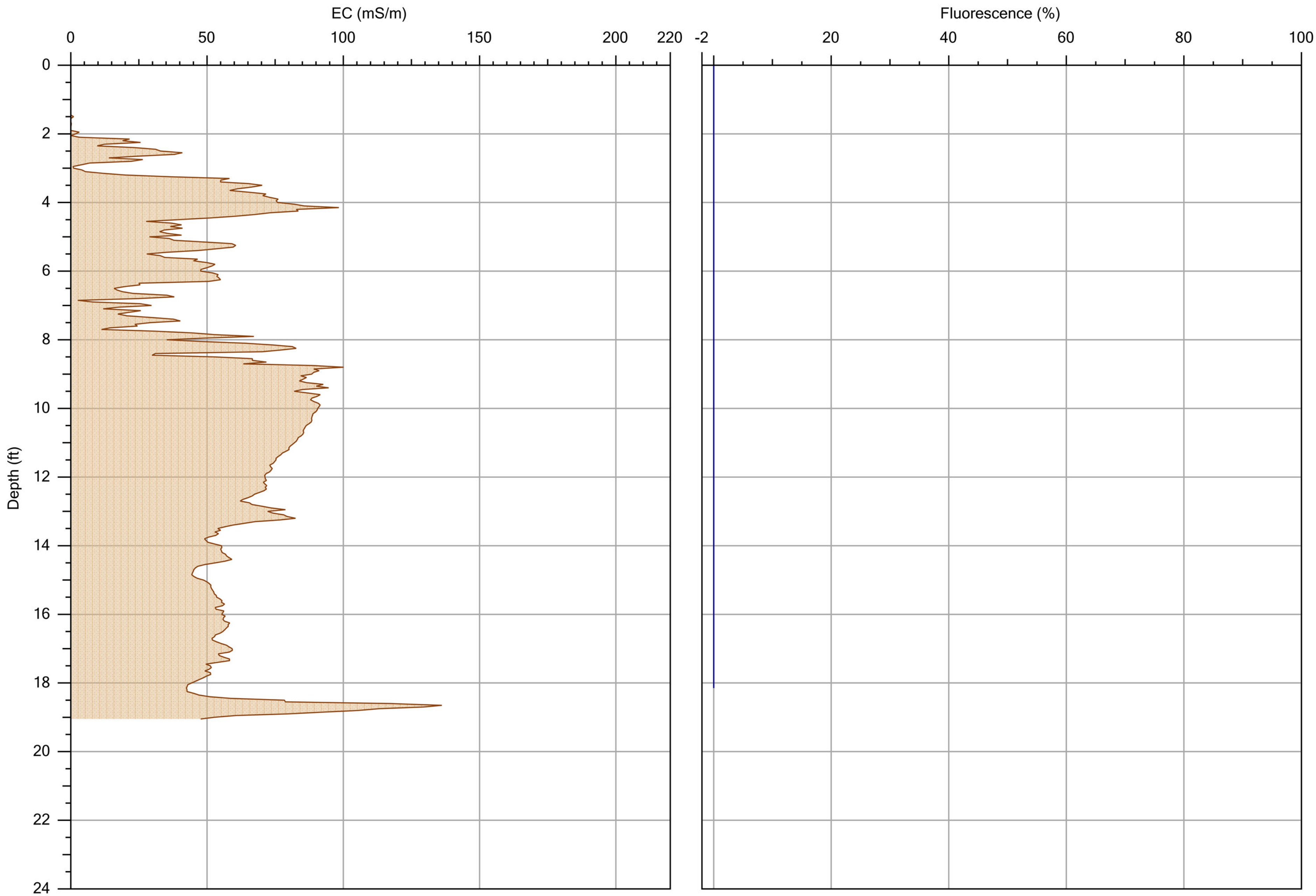
Company: Columbia Technologies	Operator: RSP	Date: 12/3/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA

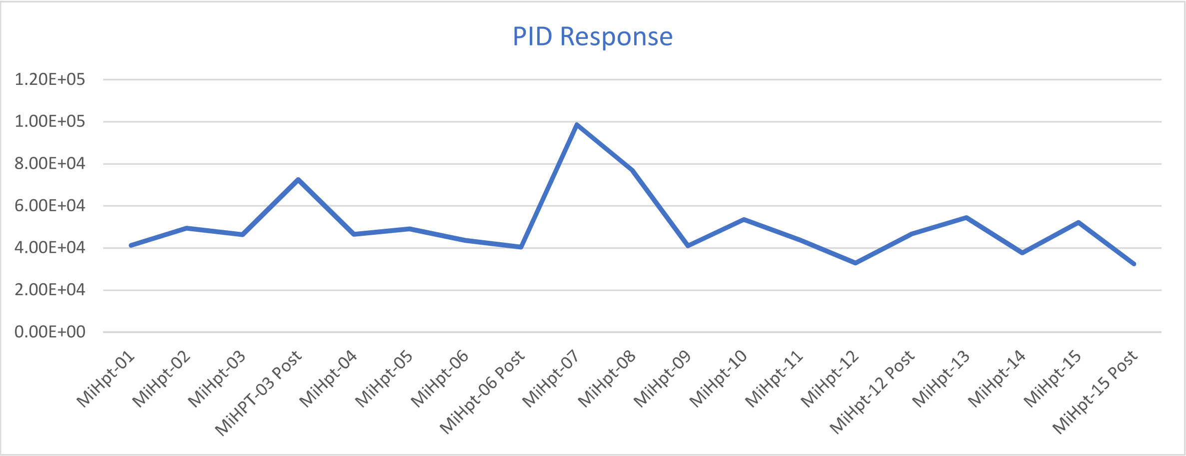


		File: OIP-13.OIP
Company: Columbia Technologies	Operator: RSP	Date: 12/3/2018
Project ID: Former Tiger Oil	Client: Maul Foster	Location: Yakima, WA

APPENDIX G - MIP Quality Control Performance Test Results

MIP Performance Test Results - Former Tiger Oil, Yakima, WA

Date	Time	File Name	MIP Response Test						PID Noise	XSD Noise	Response to Noise		Notes
			PID Max	XSD Max	PID Baseline	XSD Baseline	PID Response	XSD Response			PID	XSD	
11/27/18	1548	MiHpt-01	1.68E+05	n/a	1.26E+05	n/a	4.13E+04	n/a	300	n/a	27.5	n/a	
11/28/18	834	MiHpt-02	1.80E+05	n/a	1.31E+05	n/a	4.94E+04	n/a	200	n/a	49.4	n/a	
	1035	MiHpt-03	2.37E+05	n/a	1.90E+05	n/a	4.64E+04	n/a	1500	n/a	6.2	n/a	
	1144	MiHPT-03 Post	2.48E+05	n/a	1.76E+05	n/a	7.25E+04	n/a	2000	n/a	7.2	n/a	
	1218	MiHpt-04	2.09E+05	n/a	1.62E+05	n/a	4.64E+04	n/a	1500	n/a	6.2	n/a	
	1339	MiHpt-05	2.53E+05	n/a	2.04E+05	n/a	4.91E+04	n/a	4000	n/a	2.5	n/a	High noise following high response. This log also high.
	1522	MiHpt-06	2.54E+05	n/a	2.11E+05	n/a	4.37E+04	n/a	1500	n/a	5.8	n/a	Noise improving
	1620	MiHpt-06 Post	2.37E+05	n/a	1.97E+05	n/a	4.04E+04	n/a	1200	n/a	6.7	n/a	
11/29/18	754	MiHpt-07	1.92E+05	n/a	9.36E+04	n/a	9.86E+04	n/a	300	n/a	65.7	n/a	
	903	MiHpt-08	1.90E+05	n/a	1.13E+05	n/a	7.70E+04	n/a	400	n/a	38.5	n/a	
	1048	MiHpt-09	1.63E+05	n/a	1.22E+05	n/a	4.10E+04	n/a	500	n/a	16.4	n/a	
	1203	MiHpt-10	2.13E+05	n/a	1.59E+05	n/a	5.35E+04	n/a	1000	n/a	10.7	n/a	
	1444	MiHpt-11	1.67E+05	n/a	1.23E+05	n/a	4.37E+04	n/a	1000	n/a	8.7	n/a	
	1601	MiHpt-12	1.63E+05	n/a	1.30E+05	n/a	3.29E+04	n/a	1000	n/a	6.6	n/a	
	1710	MiHpt-12 Post	1.77E+05	n/a	1.31E+05	n/a	4.65E+04	n/a	1000	n/a	9.3	n/a	
11/30/18	755	MiHpt-13	1.63E+05	n/a	1.08E+05	n/a	5.44E+04	n/a	300	n/a	36.3	n/a	
	951	MiHpt-14	2.03E+05	n/a	1.66E+05	n/a	3.76E+04	n/a	500	n/a	15.1	n/a	
	1208	MiHpt-15	1.99E+05	n/a	1.47E+05	n/a	5.21E+04	n/a	500	n/a	20.9	n/a	
	1324	MiHpt-15 Post	2.45E+05	n/a	2.13E+05	n/a	3.24E+04	n/a	1000	n/a	6.5	n/a	



APPENDIX H - CO2 Flux and NSZD Rate Results

E•FLUX

Confidential Report
CO_2 Flux and NSZD Rate Results

SCOTT PIEPER
COLUMBIA TECHNOLOGIES
PROJECT: YAKIMA, WA
SAMPLING DATES:
12/5/2018 - 12/21/2018

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Report Date: 1/22/2019

The purpose of this document is to provide sample calculations for the reported results and to explain the method for differentiating petroleum hydrocarbon-derived CO_2 from that produced from natural soil respiration processes. The value of the ^{14}C analysis, site-specific study results and applicable notes, calculation explanations, and references are included.

The Value of the ^{14}C Analysis

How to differentiate between petroleum hydrocarbon-derived CO_2 and natural process-derived CO_2 using CO_2 flux traps:

Unimpacted soils naturally produce CO_2 fluxes due to microbial root zone activity and/or the degradation of natural organic matter (NOM). Thus, the total measured CO_2 flux at an impacted location is the sum of both natural soil respiration processes and those related to LNAPL degradation (Sihota and Mayer, 2012). The CO_2 flux caused by LNAPL degradation can be estimated by subtracting measured CO_2 fluxes at unimpacted locations from the total measured CO_2 fluxes at LNAPL impacted locations (Sihota and Mayer, 2012). This process is a spatial “background correction,” and assumes that the rates of natural soil respiration (i.e., present-day, bio-based CO_2 fluxes) are similar for both impacted and unimpacted locations. This approach is complicated to implement, given that at many industrial facilities it is difficult to find unimpacted areas, and that vegetation is different between impacted and unimpacted locations. Alternatively, carbon isotope analysis can be used as a location-specific correction for total measured carbon CO_2 fluxes, and effectively overcomes the limitations of the background correction.

Carbon Isotope Analysis Methodology:

Isotopic analysis has been previously used to differentiate between anthropogenic (due to fossil fuel burning) and natural sources of atmospheric CO, CO_2, and methane (for example, Klouda and Connolly, 1995; Levin et al., 1995; Avery et al., 2006). These findings form the basis of ASTM Method D6866-18, “Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis” (ASTM, 2018). This technique relies on the analysis of ^{14}C, an unstable carbon isotope with an absolute half-life of 5,730 years, which is generated by cosmic rays in the atmosphere. Thus, living and bio-based organic carbon is ^{14}C-rich, while fossil fuel carbon is completely ^{14}C-depleted. Furthermore, bio-based organic carbon and atmospheric samples have the same characteristic amount of ^{14}C. Despite the use of highly sensitive accelerator mass spectrometry (AMS), the short isotopic half-life of ^{14}C only allows for dating of samples younger than 60,000 years, while older samples (such as fossil fuels) contain non-detectable amounts of ^{14}C and thus cannot be dated using this method (Stuiver and Polach, 1977).

For samples that contain both contemporary and fossil fuel carbon, such as E-Flux’s fossil fuel traps, measurement of ^{14}C enables quantitation of *both* source contributions. The fossil fuel-derived fraction of the sample (ff_{sample}) and the remaining non-fossil fuel fraction ($1-ff_{sample}$) are related by the following two-component mass balance (modified from Avery, Jr. et al., 2006):

$$Fm_{sample} = (ff_{sample})(Fm_{ff}) + (1 - ff_{sample})(Fm_{atm})$$

Here, Fm_{sub} represents the fraction of modern, a measure of how close the present $^{14}C/^{12}C$ ratio of the sample is to the ratio from 1950, which is derived from a pre-industrial era standard. Fm_{sample} is the total measured fraction of modern of the sample, which takes all ^{14}C from the sample into account. Fm_{ff} is the fraction of modern of only the fossil fuel portion of the sample; this number is 0, as there is no ^{14}C in fossil fuel-derived

CO_2. Fm_{atm} is the fraction of modern of the part of the sample derived from living material and natural soil respiration processes; this value has been experimentally determined and is considered a fixed value at each point in time, and is currently equal to **1.02** (Cerling et al., 2016, Larsen et al., 2018). By convention, the results of carbon isotope analysis are reported based on a 1950 NBS oxalic acid standard, and so Fm_{sample} is reported as if the analysis was done in 1950. However, current ^{14}C atmospheric levels are now higher than in 1950 due to nuclear testing, meaning that Fm_{atm} is counter-intuitively larger than 1 (as the $^{14}C/^{12}C$ sample ratio is higher now than it would have been in 1950).

Expected Results and Recommendations:

Recent work suggests that the ^{14}C-based technique offers a built-in, location-specific correction as an alternative to a background correction, as is often done for contaminated sites. Earlier work on a limited amount of samples suggests that ^{14}C-corrected results are equivalent to background-corrected results (McCoy et al., 2015; Sihota and Mayer, 2012). However, a recent compilation of 4 sites comparing results from the background correction to the ^{14}C correction suggests that measured carbon fluxes are highly variable and can differ by up to five times among different locations within the same site (Zimbron and Kasyon, 2015). Depending on the location, the resulting difference between background-corrected and ^{14}C-corrected estimates can be up to one order of magnitude.

This suggests that the assumption implied by the background correction (that the non-fossil fuel carbon flux is constant for an entire site) might introduce large errors in the background correction of petroleum biodegradation-derived CO_2 fluxes. Contrary to the background correction, the ^{14}C correction is co-located with the measurement and thus is spatially unbiased by uncertainties related to differences with respect to the background location(s) (i.e., different vegetation and lithology, unknown impacts, different gas transport regimes, high sensitivity to soil moisture, etc.).

The fossil-fuel carbon content of unexposed CO_2 sorbent as used in the traps is non-zero (typically around 30%). This might be the result of processing of the chemical or mineral sources, or of material handling (e.g., exposure to fossil fuel fumes). Although this fossil fuel CO_2 mass is very small, its effects on the results are removed by carrying out a travel blank correction: the mass of fossil fuel CO_2 from an unexposed trap (a travel blank) is subtracted from the masses of fossil fuel CO_2 from field-deployed traps. The ^{14}C analysis is then performed on CO_2 sorbent sub-samples after homogenization of the entire bottom layer of sorbent, which follows sampling and sample analysis procedures from McCoy et al. (2015).

Study Results

The reported results below are based on proprietary technology used to measure soil gas efflux. All information contained in this report is strictly confidential to the customer. The chemical analysis is based on methods ASTM 4373-14 (Rapid Determination of Carbonate Content of Soils; ASTM, 2014) and ASTM D6866-18 (Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis; ASTM, 2018).

Easy set-up. Expert results.

Project: Yakima, WA

Customer: Columbia Technologies

Customer Contact: Scott Pieper

Report Date: 22-Jan-19

Sample ID	Deployment Dates			Raw Results (not blank-corrected)				Blank-corrected Results[a]			Blank-corrected ^{14}C Analysis Results (Fossil Fuel)[b]						
	Deployed	Retrieved	Days	Moisture content, %	Dry Sorbent Mass, g	Avg. CO_2[c], %	CV CO_2[d], %	Carbon Content[e]		CO_2 Flux, $\mu mol\ m^{-2}\ s^{-1}$	Fraction of Modern Carbon, As Reported[f]	Std. Dev., 1σ	Contemporary CO_2 Flux[g], $\mu mol\ m^{-2}\ s^{-1}$	Adjusted Fossil Fuel Carbon[h]	Grams Of Fossil Fuel CO_2, g	Fossil Fuel CO_2 Flux, $\mu mol\ m^{-2}\ s^{-1}$	Equivalent Fossil Fuel-Based NAPL Loss Rate, gal. $acre^{-1}\ yr^{-1}$
								%	g								
YKWA-R1-CO2-TB	NA	NA	0.00	18.6%	42.070	1.24%	1.24%	-	-	-	73.83%	0.28%	-	27.6%	-	-	-
YKWA-R1-CO2-01	12/5/18 15:53	12/21/18 13:07	15.88	21.4%	42.580	4.41%	0.72%	3.16%	1.35	2.75	89.83%	0.32%	2.59	11.9%	0.08	0.16	99
YKWA-R1-CO2-02	12/5/18 16:04	12/21/18 13:12	15.88	20.9%	43.270	6.04%	4.45%	4.80%	2.08	4.24	86.17%	0.29%	3.72	15.5%	0.26	0.53	329
YKWA-R1-CO2-03	12/5/18 16:21	12/21/18 12:39	15.85	20.9%	48.680	23.95%	1.21%	22.71%	11.05	22.63	47.62%	0.24%	10.25	53.3%	6.05	12.38	7743
YKWA-R1-CO2-04	12/5/18 16:35	12/21/18 12:45	15.84	19.7%	42.860	3.46%	1.76%	2.21%	0.95	1.94	74.78%	0.28%	1.44	26.7%	0.25	0.51	318
YKWA-R1-CO2-05	12/5/18 16:52	12/21/18 12:51	15.83	22.6%	42.410	2.38%	2.20%	1.14%	0.48	0.99	78.62%	0.36%	0.81	22.9%	0.09	0.18	110

This report contains Confidential Information and is to be delivered only to the Customer indicated above.

The site-specific results and interpretation are as follows:

See the following page for assumptions, project-specific quality assurance/quality control information, and notes.

General notes:

- Trap cross-sectional area is **8.11×10^{-3}** m^2 (i.e., equivalent to a **4-inch** receiver pipe).
- The flux equivalence is **1** µmol m^{-2} s^{-1} equals **625.2** gallons $acre^{-1}$ yr^{-1}. This assumes a representative hydrocarbon density of **0.77** g mL^{-1} with the formula C_8H_{18}.
- Carbon analysis of each trap/sample is conducted in duplicate if the coefficient of variation (CV) of the duplicates is ≤ 5%. If CV > 5%, duplicate analyses are repeated until CV ≤ 5%.
- NA = Not Applicable
- ND = Not Detectable

Results Report Notes:

a. Results are travel blank-corrected and are not yet ^{14}C-corrected. Blank Corrected Results = Raw Results - Travel Blank

b. Results have been both travel blank- and ^{14}C-corrected.

c. "Avg. CO_2" refers to the measured (<u>not</u> blank corrected) % CO_2 of the dry sorbent mass.

d. CV is the coefficient of variation, the ratio of the standard deviation of the % CO_2 to the average % CO_2.

e. If the travel blank contains more carbon than a trap, carbon content results (expressed as CO_2, <u>not</u> pure carbon) are reported as ND.

f. "As reported" refers to the total measured fraction of modern (Fm_{sample}) as it would have been at the time when ^{14}C testing was developed (1950). This number is reported as pMC (percent of modern carbon) and is converted into *Fm* for our calculations using the relation 100.0 pMC = 1.0 *Fm* = 100% *Fm*. This value has not been corrected to account for present-day ^{14}C atmospheric levels.

g. "Contemporary" indicates a correction has been applied which accounts for the difference between 1950's and present-day ^{14}C levels (Stenström et al., 2011). This value is the portion of the total carbon flux derived from present-day (non-fossil fuel) sources.

h. "Adjusted fossil fuel carbon" refers to the percentage of carbon in a sample that is derived from fossil fuel CO_2 according to ambient levels of ^{14}C at the time of sampling. This number is adjusted to account for the increase in atmospheric ^{14}C levels since 1950.

Quality Assurance / Quality Control Notes:

- The Travel Blank (TB) concentration is **1.24%**; typical TB concentration is < 2%.
- Trap tops are not saturated with CO_2 (sorbent saturation is 30%). The maximum measured (not blank-corrected) top concentration is ***5.24%*** (sample **YKWA-R1-CO2-03.1**).
- Contemporary carbon fluxes represent the CO_2 contributions from natural soil respiration processes (bio-based CO_2 production) to the total carbon flux; the ^{14}C analysis corrects for this contribution. Average contemporary CO_2 flux is **3.76** µmol m^{-2} s^{-1}, and the coefficient of variation is **101%**. The range of contemporary CO_2 fluxes is between **0.81** and **10.25** µmol m^{-2} s^{-1}. If these interferences were not removed using the results of the radiocarbon analysis, the errors in the NSZD rate estimates would be between **508** and **6407** gallons $acre^{-1}$ yr^{-1}.
- ASTM 4373-14 QA/QC criteria do not provide acceptable variability (CV) standards. Similar methods (e.g., ASTM D513-16, Total and Dissolved Carbon Dioxide in Water) allow typical errors of ≤ 20%. E-Flux practice is that a CV ≤ 5% for duplicate analyses is acceptable.

Calculation Explanations

Conversion of grams CO_2 to CO_2 Flux:

Calculating the CO_2 flux from grams of CO_2 involves the cross-sectional area of the trap (8.11×10^{-3} m^2 for a 4-inch receiver), the number of days that the trap was deployed in the field, and the molecular weight of CO_2 (44 g mol^{-1}). Grams of CO_2 is converted to CO_2 flux according to the following equation:

$$\frac{\mathrm{g\,CO_2} \cdot \frac{1\ \mathrm{mol\,CO_2}}{44\ \mathrm{g\,CO_2}} \cdot \frac{1{,}000{,}000\ \mu\mathrm{mol\,CO_2}}{\mathrm{mol\,CO_2}}}{\text{days in the field} \cdot \frac{24\ \mathrm{hr}}{\mathrm{day}} \cdot \frac{3600\ \mathrm{s}}{\mathrm{hr}} \cdot (8.11 \times 10^{-3}\ \mathrm{m^2})} = \frac{\mu\mathrm{mol\,CO_2}}{\mathrm{m^2 \cdot s}}$$

Conversion of Fraction of Modern Carbon to Fossil Fuel Carbon:

Fraction of modern (Fm_{sample}, from ^{14}C analysis) is reported by convention based on ^{14}C levels from 1950. Because of atomic testing, current environmental ^{14}C levels are approximately 5% higher than they were in 1950 (Hua et al., 2013). Thus, the equation for calculating the fraction of fossil fuel carbon (ff_{sample}) is derived from the following mass balance:

$$Fm_{sample} = (ff_{sample})(Fm_{ff}) + (1 - ff_{sample})(Fm_{atm})$$

Solving for ff_{sample} yields:

$$ff_{sample} = 1 - \frac{Fm_{sample}}{Fm_{atm}}$$

As Fm_{atm} is equal to 1.05, this equation becomes:

$$ff_{sample} = 1 - \frac{Fm_{sample}}{1.05}$$

The fraction of contemporary carbon ($cc_{sample.}$) can then be calculated using the relation:

$$cc_{sample} = 1 - ff_{sample} = 1 - \left(1 - \frac{Fm_{sample}}{1.05}\right) = \frac{Fm_{sample}}{1.05}$$

Calculating Grams of Fossil Fuel CO_2:

Grams of fossil fuel CO_2 (g $CO_{2(ff)}$) is calculated by subtracting the total fossil fuel CO_2 in the travel blank (TB) from the total fossil fuel CO_2 in the sample:

$$\mathrm{g\,CO_{2(ff)}} = \mathrm{g_{sorbent}} \cdot \left[\left((\%\,\mathrm{CO_2})_{\mathrm{sample}}(ff_{sample})\right) - \left((\%\,\mathrm{CO_2})_{\mathrm{TB}}(ff_{TB})\right)\right]$$

Here, $g_{sorbent}$ is the mass of sorbent used in the bottom layer of a trap, $(\%CO_2)_{sample}$ is the average weight percent of CO_2 in the sample, ff_{sample} is the percent of carbon in the sample derived from fossil fuels, $(\%CO_2)_{TB}$ is the average weight percent of CO_2 in the travel blank, and ff_{TB} is the percent of carbon in the travel blank derived from fossil fuels.

Converting Carbon Flux to Equivalent LNAPL Loss Rate:

The intermediate reactions for LNAPL mineralization include methanogenesis (production of methane and CO_2) and the subsequent aerobic oxidation of methane (into CO_2):

$$C_8H_{18} + 3.5\ H_2O\ \rightarrow 6.25\ CH_4 + 1.75\ CO_2 \text{ (methanogenesis)}$$

$$6.25\ CH_4 +\ 12.5\ O_2\ \rightarrow 6.25\ CO_2 + 12.5\ H_2O \text{ (methane oxidation)}$$

$$C_8H_{18} + 12.5\ O_2 \rightarrow\ 9H_2O + 8\ CO_2 \text{ (overall) reaction)}$$

Assuming a conservative LNAPL density of 0.77 g/mL (upper range of gasoline) and using the molecular weight of C_8H_{18} (octane, 114.23 g/mole), μmol m^{-2} s^{-1} of CO_2 can then be converted into gal. acre^{-1} yr^{-1}:

$$1\ \frac{\mu\text{mol CO}_2}{\text{m}^2\ \text{s}} \cdot \left(\frac{1\ \mu\text{mol C}_8\text{H}_{18}}{8\ \mu\text{mol CO}_2}\right)\left(\frac{\text{mol}}{1\times 10^6\ \mu\text{mol}}\right)\left(\frac{4{,}046\ \text{m}^2}{1\ \text{acre}}\right)\left(\frac{3600\ \text{s}}{1\ \text{h}}\right)\left(\frac{24\ \text{h}}{1\ \text{d}}\right)\left(\frac{365\ \text{d}}{1\ \text{yr}}\right)\cdot$$

$$\left(\frac{114\ \text{g C}_8\text{H}_{18}}{1\ \text{Mole C}_8\text{H}_{18}}\right)\left(\frac{1\ \text{mL C}_8\text{H}_{18}}{0.77\ \text{g C}_8\text{H}_{18}}\right)\left(\frac{1\ \text{L}}{1000\text{mL}}\right)\left(\frac{1\ \text{gal.}}{3.785\ \text{L}}\right) = 625\,\frac{\text{gal. C}_8\text{H}_{18}}{\text{acre} - \text{yr}}$$

Note that both the LNAPL formula and its density are assumed, and thus this conversion is subject to uncertainty; however, site-specific data can be used if available. Using alternative representative hydrocarbon formulas and densities generally results in conversion factors that are within 10-15% of 625.2 gal. acre^{-1} yr^{-1-}. Therefore, the uncertainty associated with these values does not preclude an acceptable estimate.

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List of Symbols, Abbreviations, and Acronyms

Symbol or Abbreviation	**Definition**
CSM	**Conceptual Site Model.** A **CSM** is a method to describe what is known or can be inferred about a site for the purpose of making a decision. A CSM generally will address physical, chemical and biological systems; contaminant release and transport; societal issues; policy, land use, and exposures.
CVOC	**Chlorinated Volatile Organic Contaminant.** A **VOC** containing chlorine atoms; typically, a cleaning solvent.
DPT	**Direct-Push Technology** (DPT) refers to a group of techniques used for subsurface investigation by driving, pushing and/or vibrating small-diameter rods into the ground.
DNAPL	**Dense Non-Aqueous Phase Liquid.** A **DNAPL** is a denser-than-water NAPL, i.e. a liquid that is both denser than water and is immiscible in or does not dissolve in water.
HPT	**Hydraulic Profiling Tool**. The **HPT** is a logging **tool** that measures the pressure required to inject a flow of water into the soil as the probe is advanced into the subsurface. In addition to measurement of injection pressure, the HPT can also be used to measure hydrostatic pressure under the zero flow condition.
LCSM	**LNAPL Conceptual Site Model.** A **LCSM** is a conceptual site model focused on the release and transport of LNAPL contaminants.
LIF	**Laser-induced fluorescence** is a spectroscopic method in which an atom or molecule is excited to a higher energy level by the absorption of laser light followed by spontaneous emission of light.
LNAPL	**Light Non-Aqueous Phase Liquids** are groundwater contaminants that are not soluble in water and have lower density than water, in contrast to a **DNAPL** which has higher density than water.
PHC	**Petroleum Hydrocarbons.** The presence of petroleum hydrocarbon fuels in any phase. **(PHC).**
PID	**Photo Ionization Detector.** In a **PID** high-energy photons to break molecules into positively charged ions. The **PID** will only respond to components that have ionization energies at or below the energy of the photons produced by the **PID** lamp.
SPOC	**Shock Protected Optical Cavity**. The **SPOC** is the component of the LIF system that contains the mirror and sapphire window for proper

	alignment of the laser beam.
TCE	**Trichloroethylene.** The chemical compound **TCE** is a halocarbon commonly used as an industrial solvent. It is a clear non-flammable liquid with a sweet smell.
UST	**Underground Storage Tank.** Under Federal law **UST** means any one or combination of tanks including connected underground pipes that is used to contain regulated substances, and the volume of which including the volume of underground pipes is 10 percent or more beneath the surface of the ground. This does not include, among other things, any farm or residential tank of 1,100 gallons or less capacity used for storing motor fuel for noncommercial purposes, tanks for storing heating oil for consumption on the premises, or septic tanks.
UVOST®	**Ultraviolet Optical Scanning Tool®.** A **LIF** is a tool that uses laser light in the ultraviolet spectrum to excite fluorescent molecules that exist in the vast majority of hazardous non-aqueous phase liquids (NAPLs) such as petroleum fuels/oils, coal tars, and creosotes.
VOC	**Volatile organic compounds** (**VOCs**) are organic chemicals that have a high vapor pressure at ordinary room temperature. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air, a trait known as volatility.
XSD	**Halogen Specific Detector.** The **XSD** was developed for the selective detection of halogen-containing compounds.

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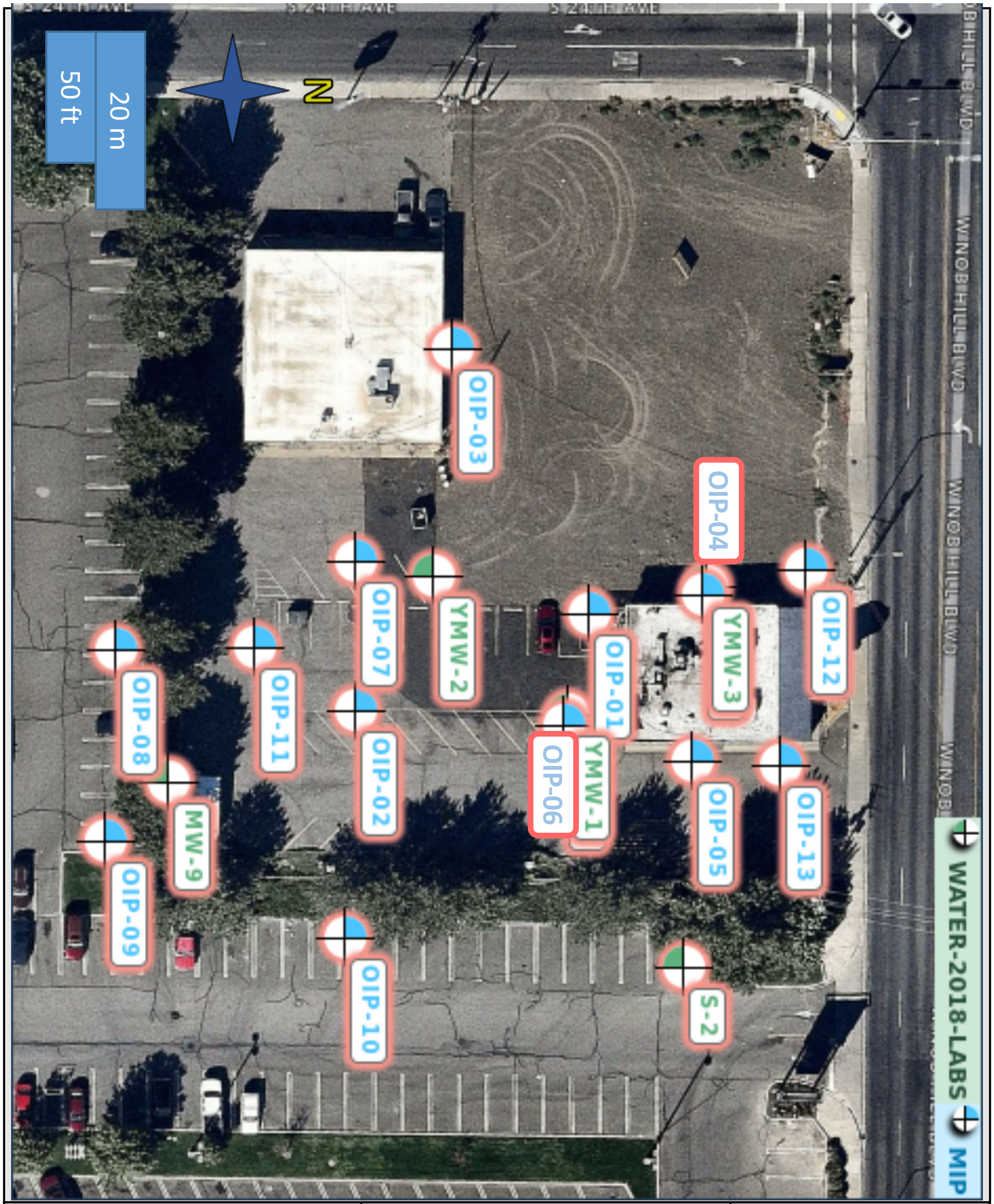
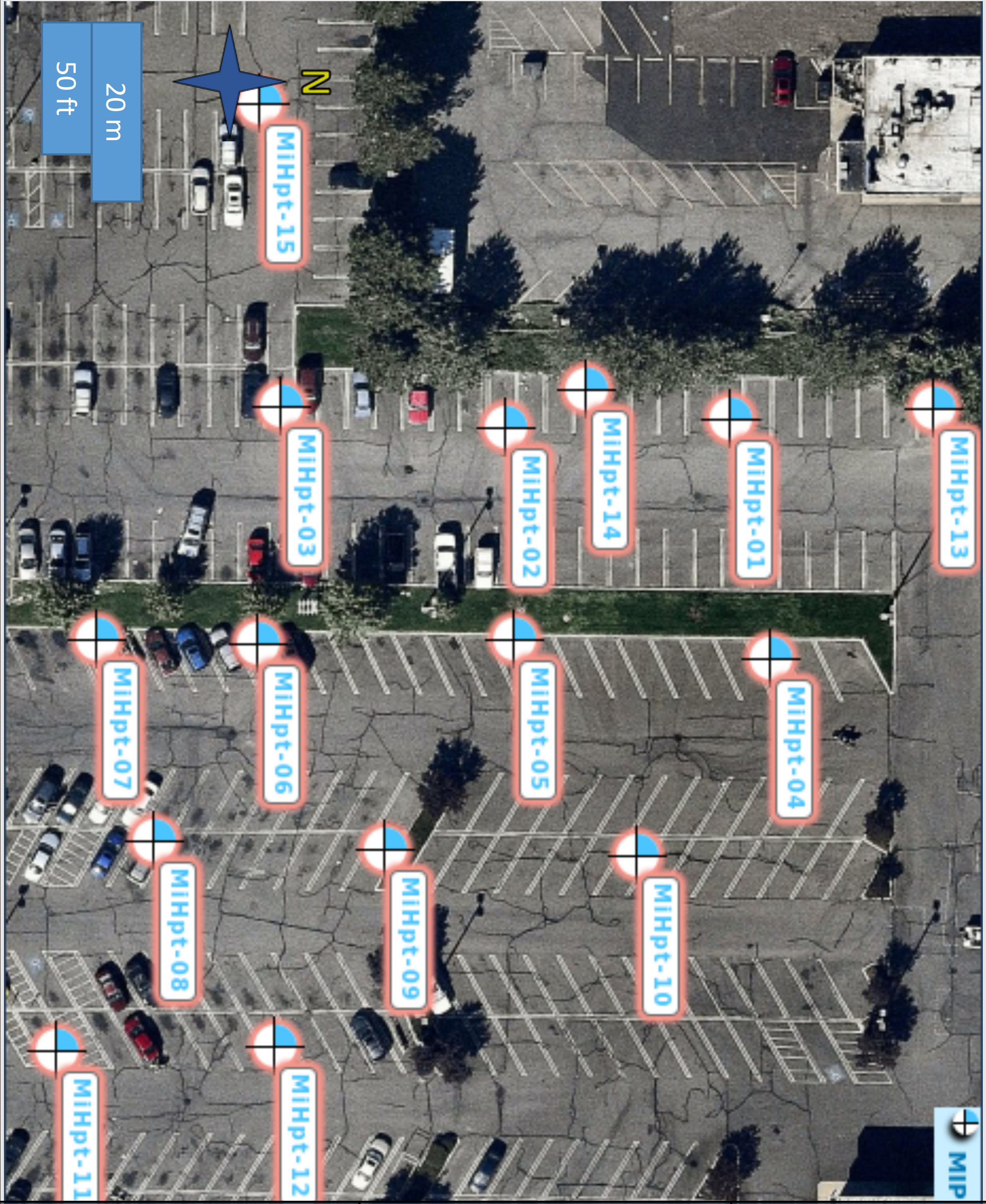
COLUMBIA TECHNOLOGIES	**Former Tiger Oil** Yakima, WA	**Site Overview**
	High-Resolution Site Characterization / December 2018	**Figure 5**



COLUMBIA TECHNOLOGIES	**Former Tiger Oil** Yakima, WA		**OIP Locations**
	High-Resolution Site Characterization	December 2018	**Figure 6**



COLUMBIA TECHNOLOGIES

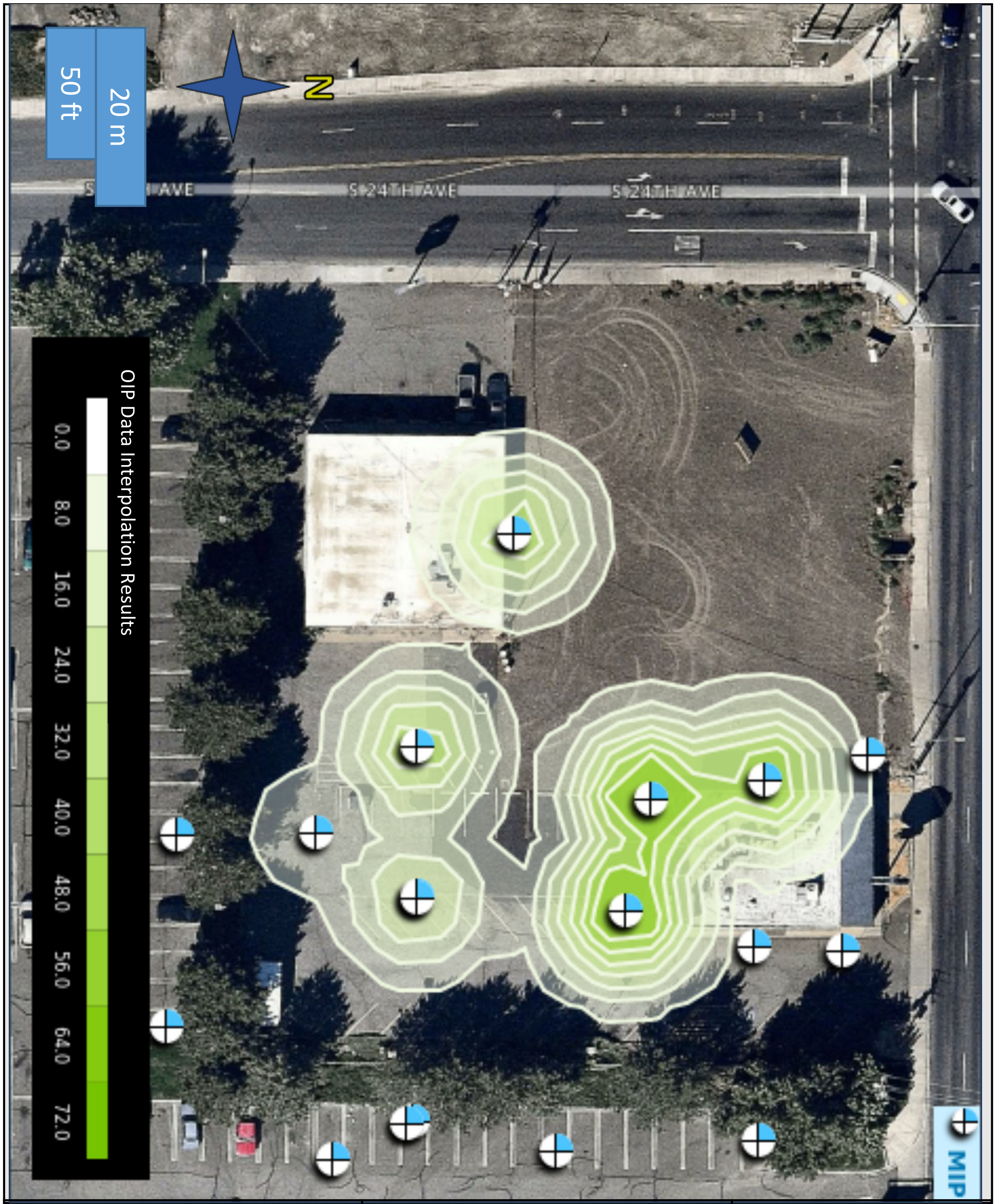
Former Tiger Oil
Yakima, WA

MiHpt Locations

High-Resolution Site Characterization

December 2018

Figure 7



COLUMBIA TECHNOLOGIES

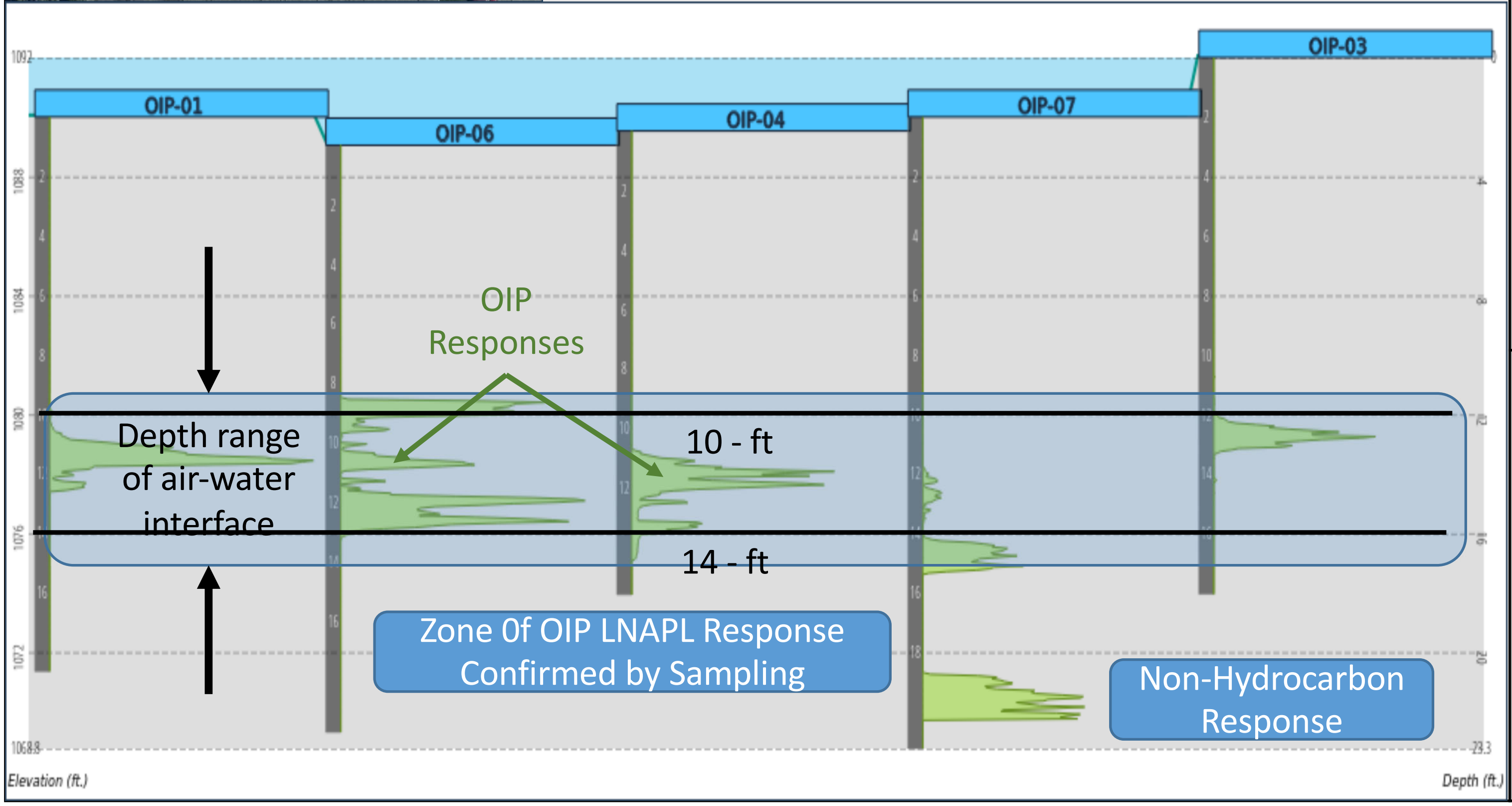
Former Tiger Oil
Yakima, WA

LNAPL Aerial Distribution from OIP

High-Resolution Site Characterization

December 2018

Figure 8



OIP Responses

Depth range of air-water interface

10 - ft

14 - ft

Zone Of OIP LNAPL Response Confirmed by Sampling

Non-Hydrocarbon Response

COLUMBIA TECHNOLOGIES

Former Tiger Oil
Yakima, WA

High-Resolution Site Characterization

December 2018

LNAPL Vertical Distribution on OIP

Figure 9

Residual Saturation Screening Values (API Bulletin No. 9, 2000)				
LNAPL	Soil	C_{Sat}	C_{Res}	S_r
Type	Type	mg/kg	mg/kg	cm^3/cm^3
Gasoline	M-C Sand	143	3,387	0.02
Gasoline	M-F Sand	215	5,833	0.03
Gasoline	Silt – F Sand	387	10,000	0.05
Middle Distillates	M-C Sand	5	7,742	0.04
Middle Distillates	M-F Sand	9	13,333	0.06
Middle Distillates	Silt – F Sand	18	22,857	0.1

COLUMBIA TECHNOLOGIES

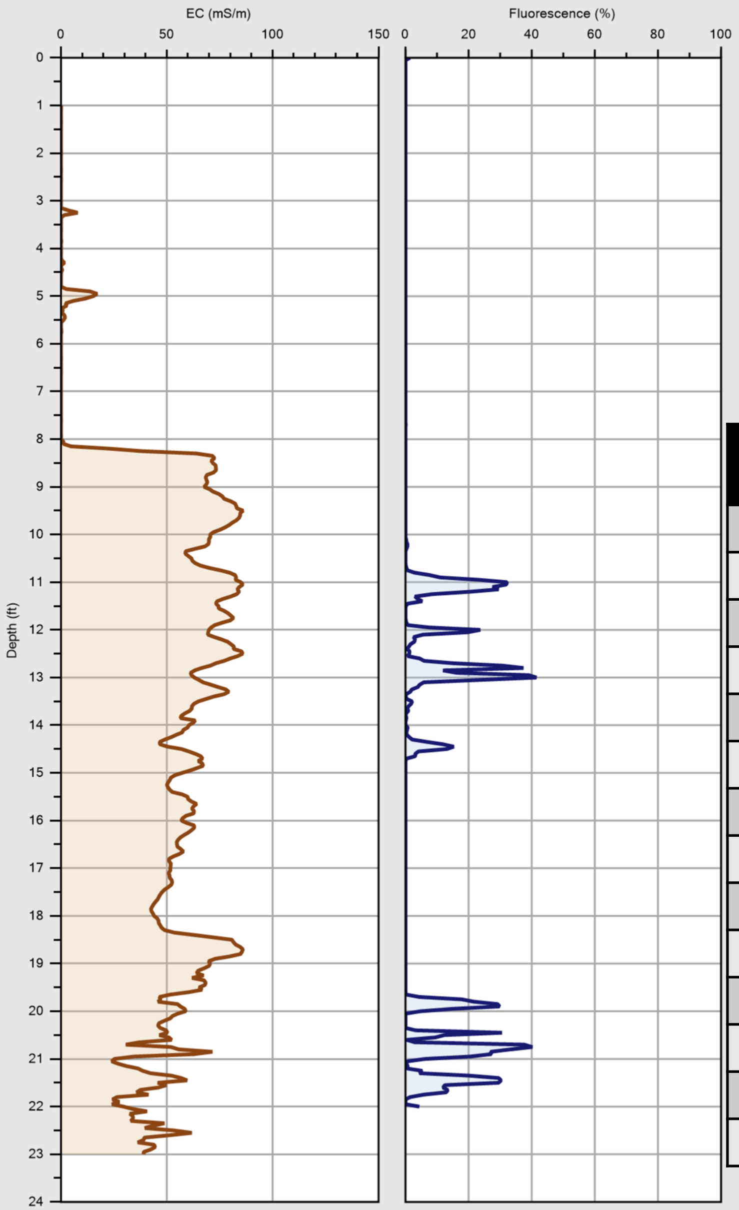
High-Resolution Site Characterization

Former Tiger Oil
Yakima, WA

December 2018

LNAPL Footprint on OIP and MIP

Figure 10



Depth	TPH mg/kg
10	530
11	240
12	2100
13	No sample
14	1300
15	960
16	Not sampled
17	Not sampled
18	Not sampled
19	ND
20	ND
21	ND
22	ND
23	ND

COLUMBIA TECHNOLOGIES

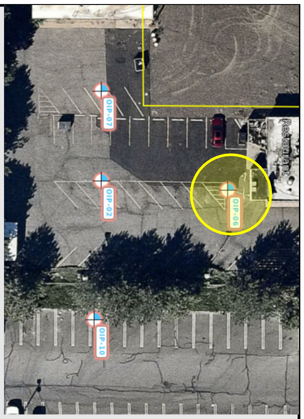
Former Tiger Oil
Yakima, WA

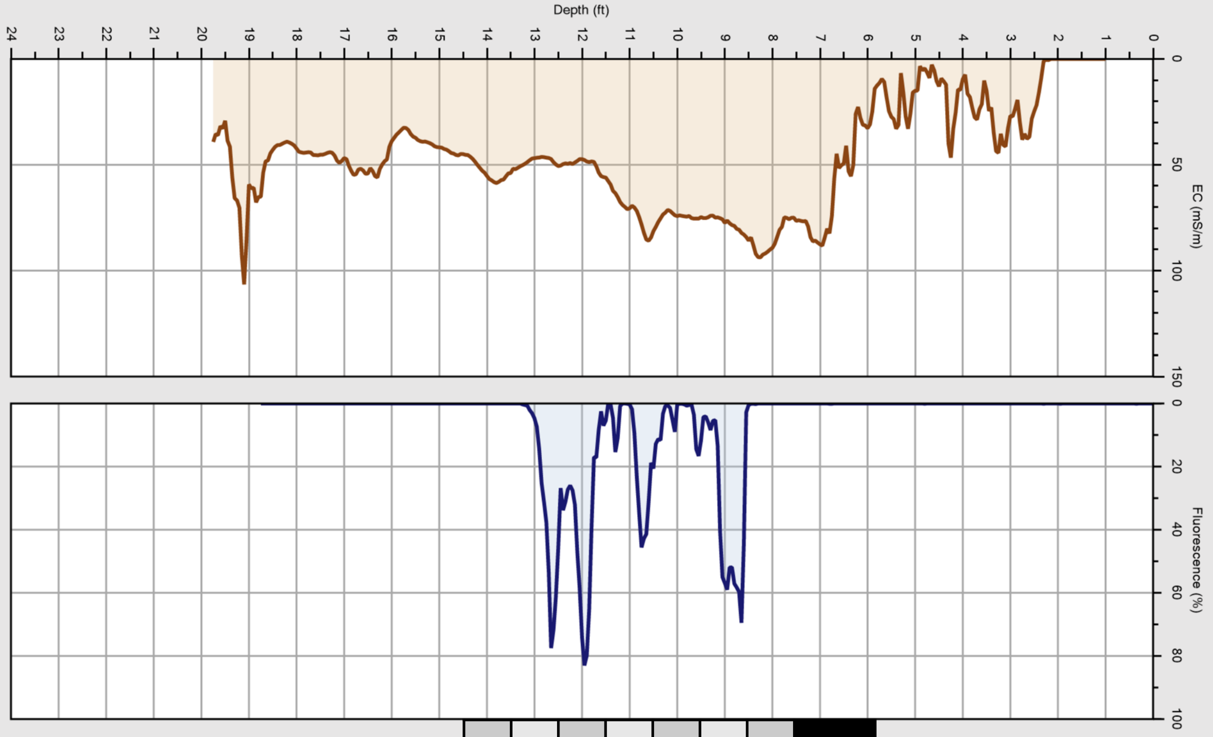
High-Resolution Site Characterization

December 2018

DSS-OIP-02
Lab Results

Figure 11





Depth	TPH mg/kg
8.5	11
9	9.8
10	69
11	No Recovery
12	Collected Core
13	1700
14	29

COLUMBIA TECHNOLOGIES

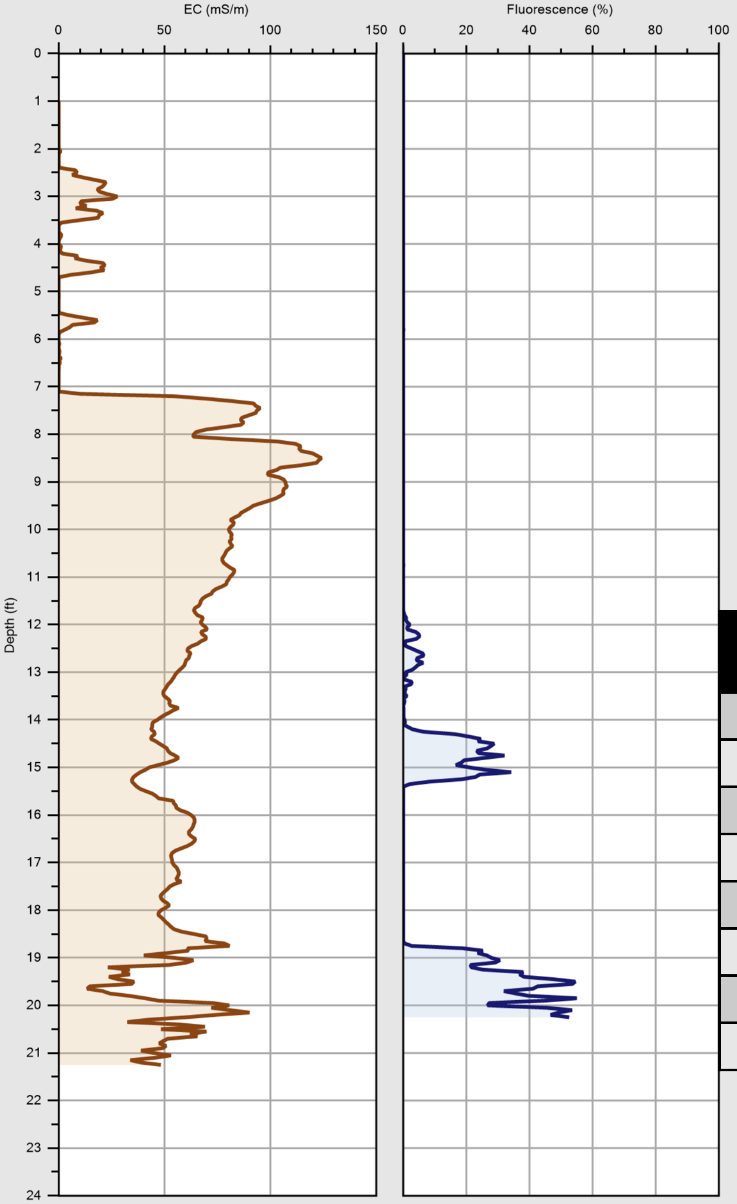
Former Tiger Oil
Yakima, WA

DSS-OIP-06
Lab Results

High-Resolution Site Characterization

December 2018

Figure 12



Depth	TPH mg/kg
14	1100
15	90
16	ND
17	Not sampled
18	Not sampled
19	6.5
20	23
21	6.0

COLUMBIA TECHNOLOGIES

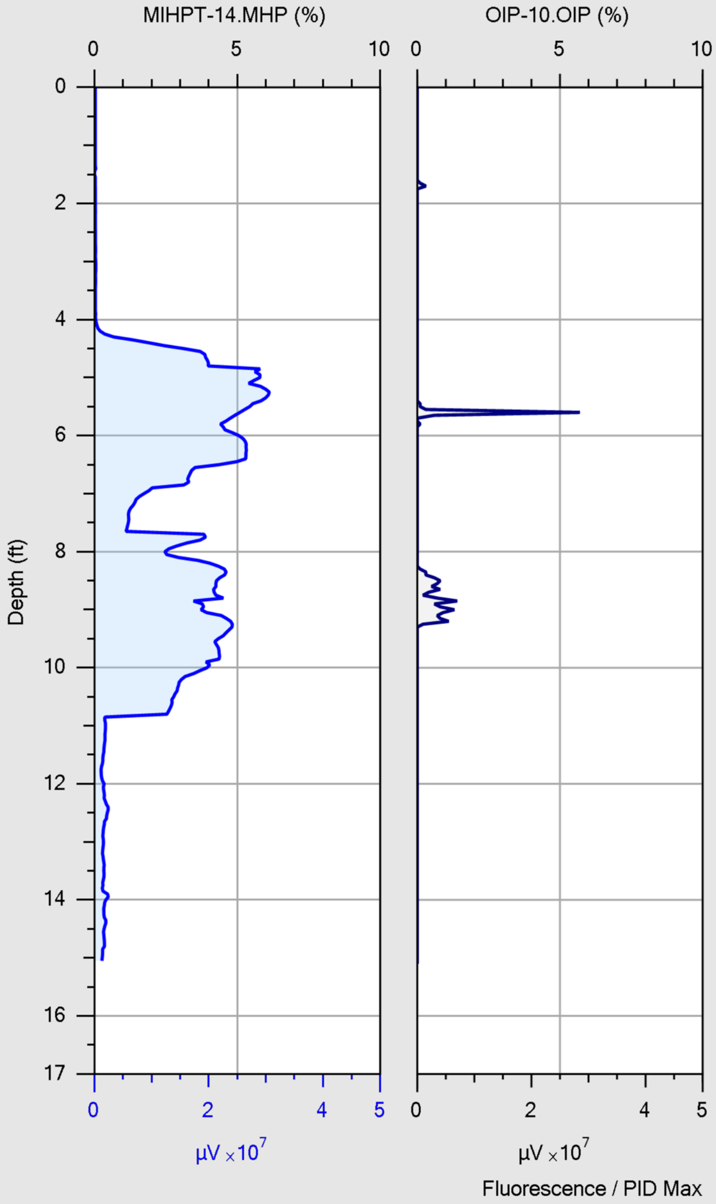
Former Tiger Oil
Yakima, WA

High-Resolution Site Characterization

December 2018

DSS-OIP-07
Lab Results

Figure 13



Depth	TPH mg/kg
4	140
5	2900
6	670
7	930
8	930
9	2600
10	8.6
11	830
12	9.5

COLUMBIA TECHNOLOGIES

Former Tiger Oil
Yakima, WA

High-Resolution Site Characterization

December 2018

DSS-OIP-10
Lab Results

Figure 14

COLUMBIA TECHNOLOGIES

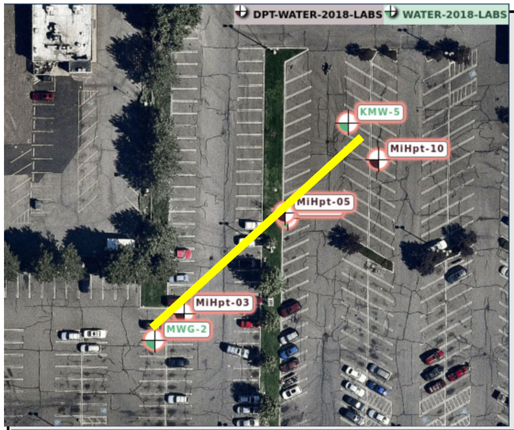
Former Tiger Oil
Yakima, WA

High-Resolution Site Characterization

December 2018

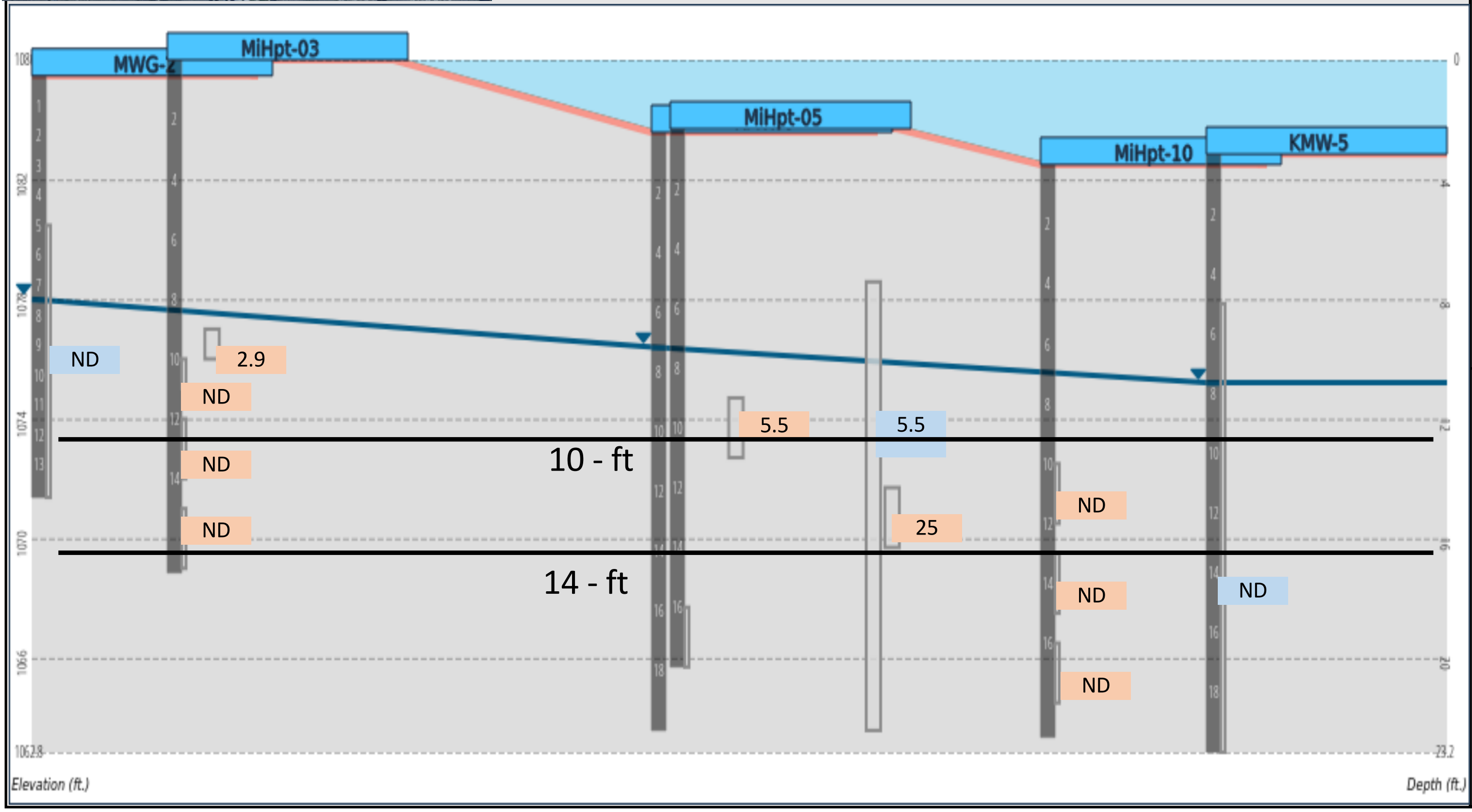
Benzene in Groundwater Nov 2018

Figure 15



MW Benzene (µg/L) Nov 2018

DPT Benzene (µg/L) Dec 2018



Former Tiger Oil
Yakima, WA

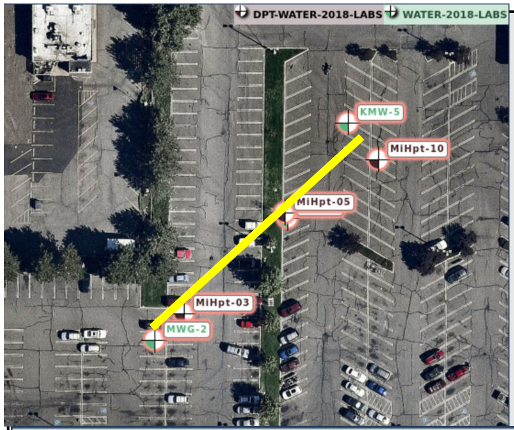
MW vs Discrete Sample Results

High-Resolution Site Characterization

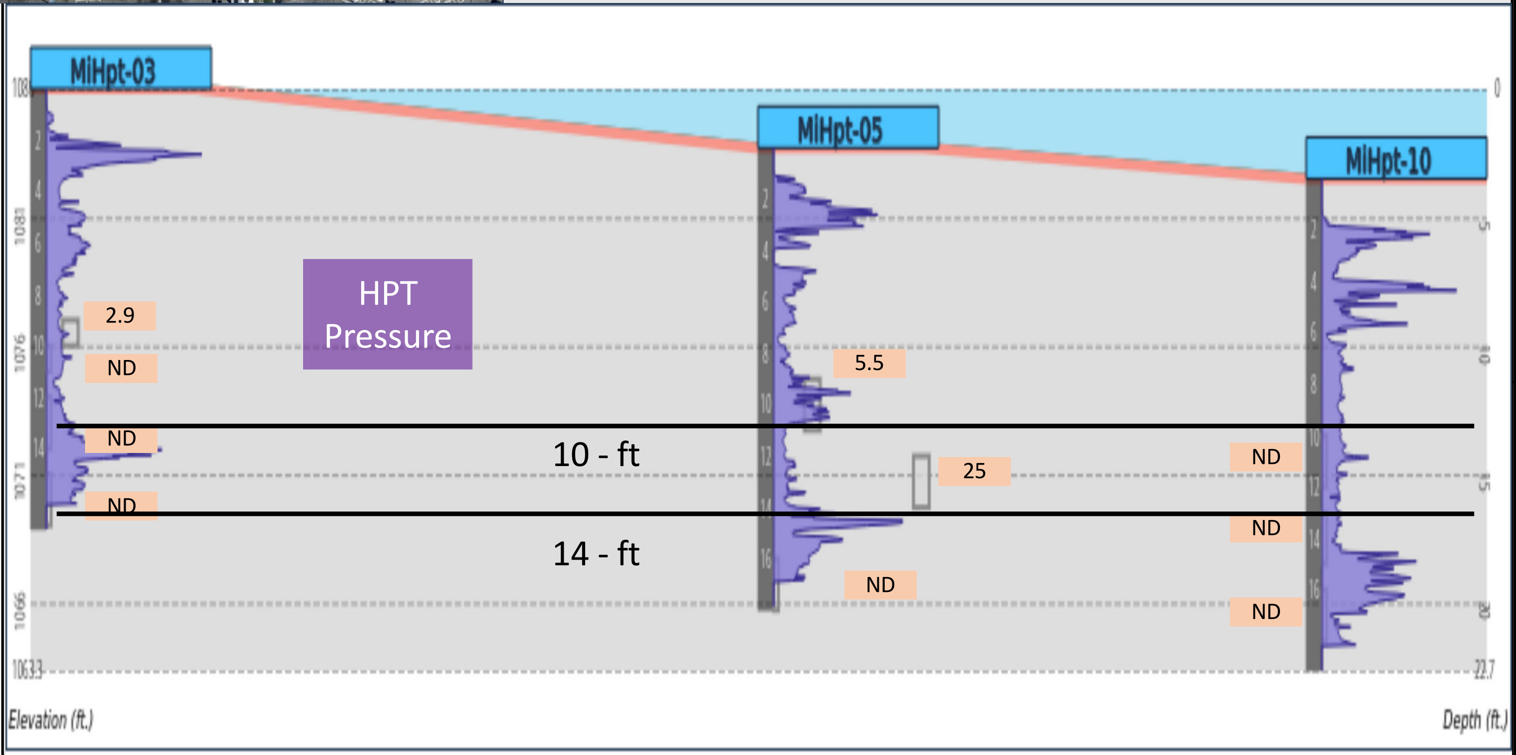
December 2018

Figure 16

COLUMBIA TECHNOLOGIES



Discrete Sampling Results
Benzene (µg/L) Dec 2018



HPT vs Discrete Sample Results

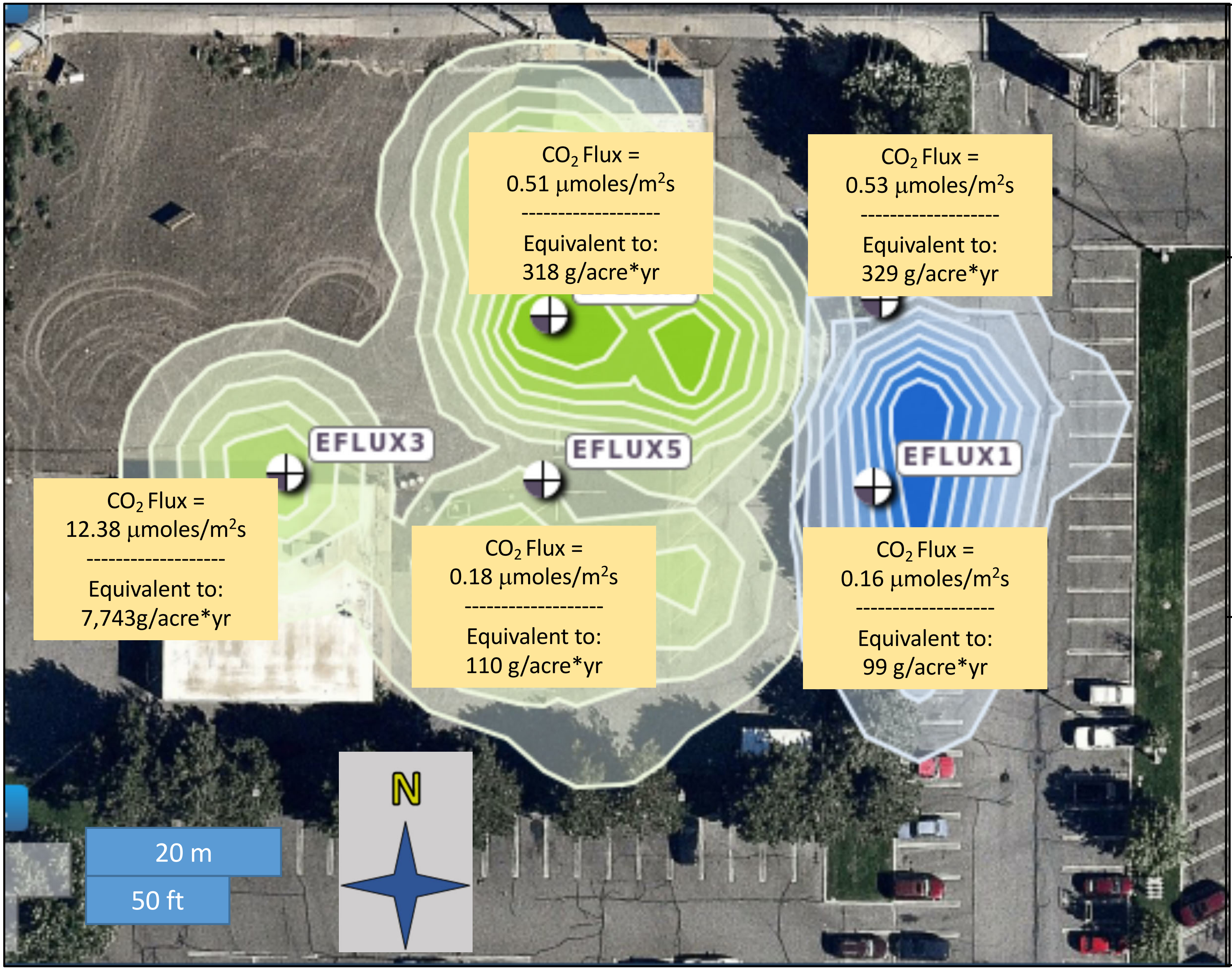
Figure 17

Former Tiger Oil
Yakima, WA

December 2018

High-Resolution Site Characterization

COLUMBIA TECHNOLOGIES



COLUMBIA TECHNOLOGIES

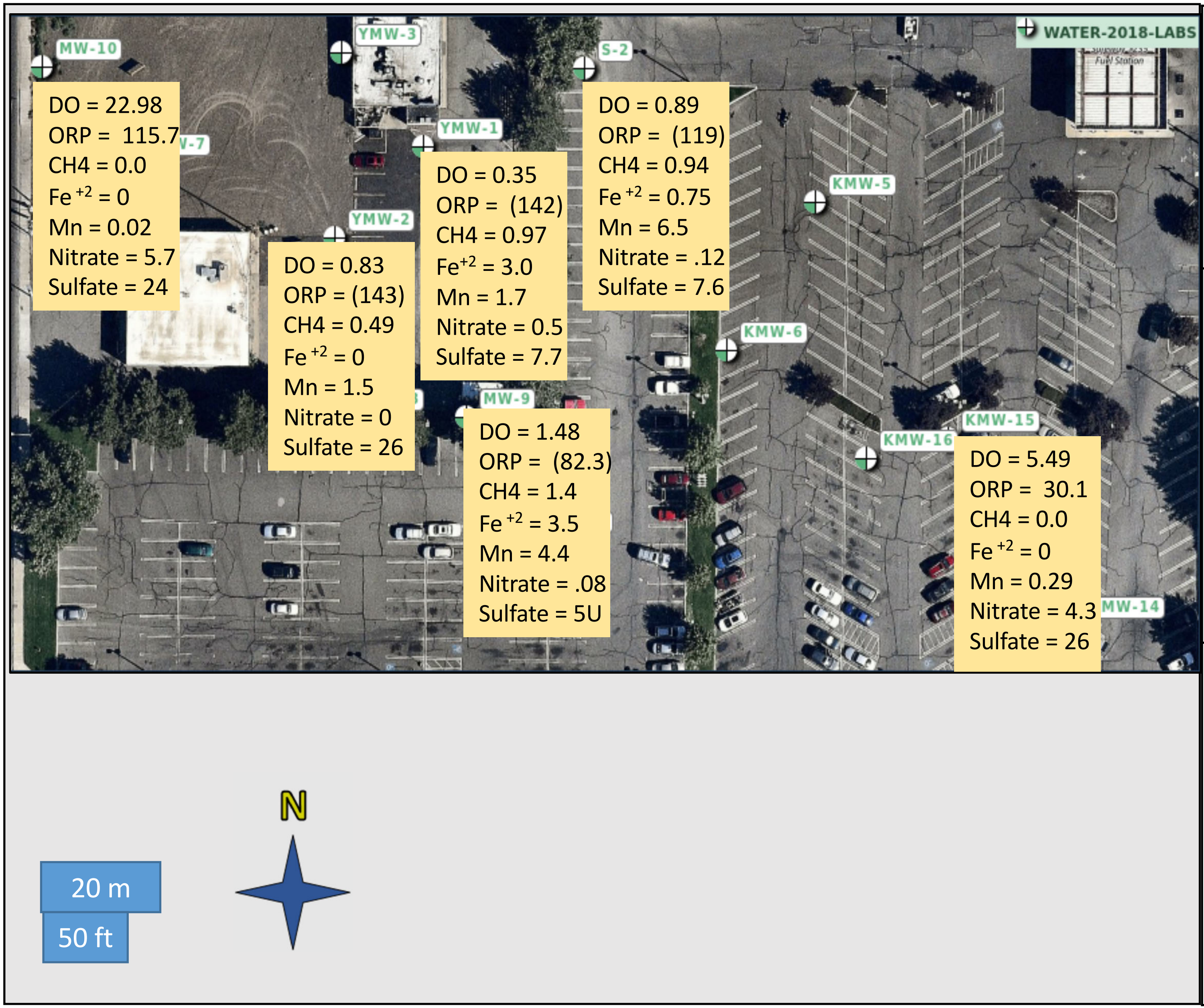
Former Tiger Oil
Yakima, WA

High-Resolution Site Characterization

December 2018

CO2 Flux results

Figure 18



Dissolved Phase Degradation Parameters

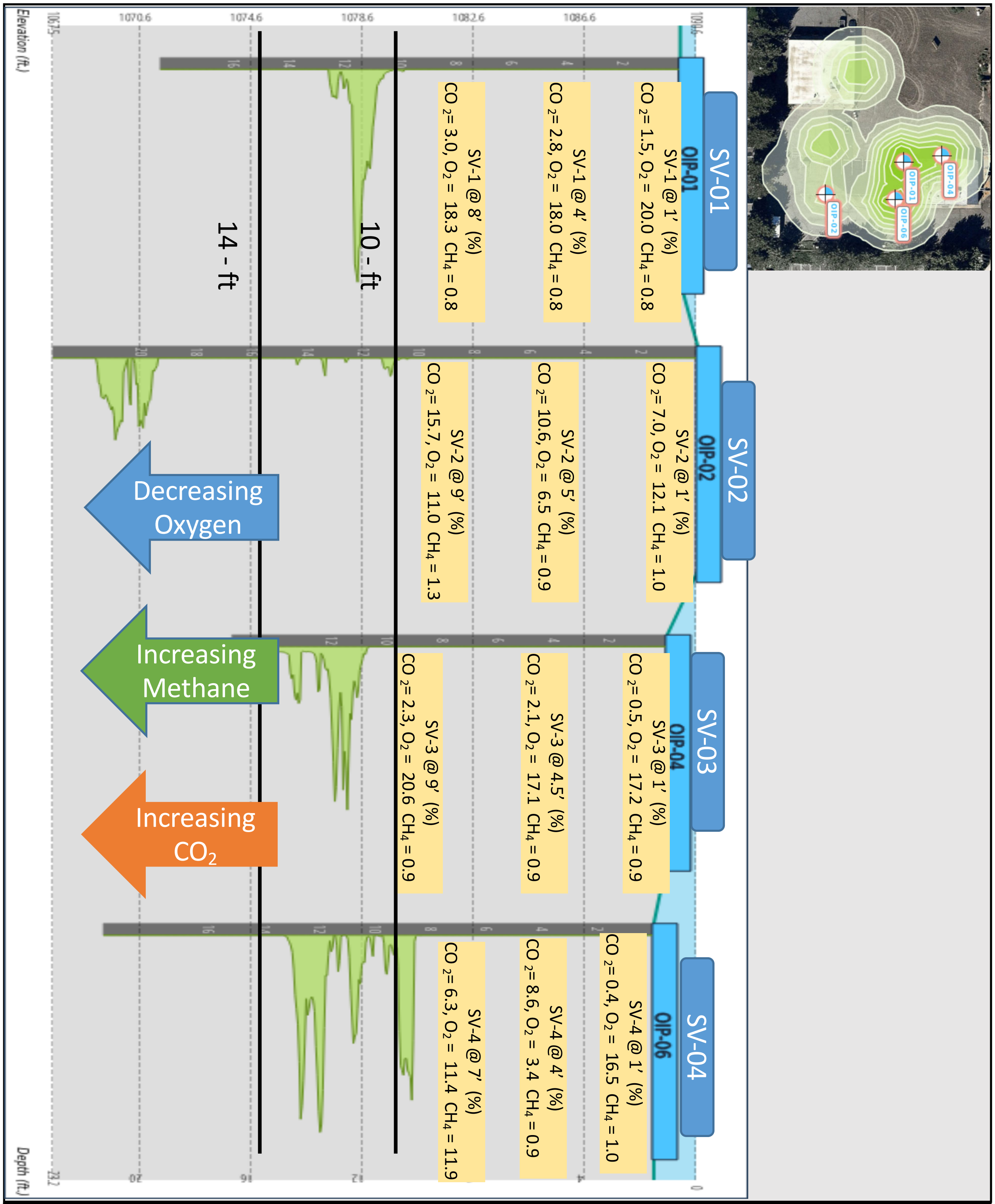
Figure 19

Former Tiger Oil
Yakima, WA

December 2018

High-Resolution Site Characterization

COLUMBIA TECHNOLOGIES



COLUMBIA TECHNOLOGIES

Former Tiger Oil
Yakima, WA

Soil Vapor Gradients

High-Resolution Site Characterization

December 2018

Figure 20

APPENDIX B

HRSC WATER FIELD SAMPLING DATA SHEETS

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSW-MiHpt03
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/4/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSW-MiHpt03-10.0
Sub Area		**Sample Depth**	10
FSDS QA:	CRW 12/13/2018		

Easting ______ **Northing** ______ **TOC** ______

Hydrology/Level Measurements

Date	Time	DT-Bottom	DT-Product	DT-Water	(Product Thickness) DTP-DTW	(Water Column) DTB-DTW	(Gallons/ft x Water Column) Pore Volume

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	3:38:00 PM	1	0.1		12	741.2	3.58	160	
	3:40:00 PM	1.2	0.1	7.29	12.1	741.2	4.59	119.8	
	3:42:00 PM	1.4	0.1	7.31	12.1	741.3	9.46	106.3	
Final Field Parameters	3:44:00 PM	1.6	0.1	7.3	12.4	741.3	9.29	100.2	

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations: Clear. No sheen. NO3 recorded during purging: 0.34, 0.26, 0.23, 0.22.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	3:10:00 PM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSW-MiHpt03
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/4/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSW-MiHpt03-11.0
Sub Area		**Sample Depth**	11
FSDS QA:	CRW 12/13/2018	**Easting**	
		Northing	
		TOC	

Hydrology/Level Measurements

Date	Time	DT-Bottom	DT-Product	DT-Water	(Product Thickness) DTP-DTW	(Water Column) DTB-DTW	(Gallons/ft x Water Column) Pore Volume

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	4:28:00 PM	0.5	0.1		13	740	7.96	137	
	4:30:00 PM	0.7	0.1	7.82	13.1	796	8.37	131.3	
Final Field Parameters	4:36:00 PM	0.9	0.1	7.83	14.4	802	6.03	122.1	

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations:

Clear. NO3 recorded during purging: 1.16, 1.14, 1.02. Atmospheric pressure recorded during purging: 741, 740.9, 740.9 mmHg. Ferrous iron = 0.5 mg/L

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	4:38:00 PM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSS-MiHpt03
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSS-MiHpt03-12-14
Sub Area		**Sample Depth**	13
FSDS QA:	CRW 12/13/2018	**Easting**	
		Northing	
		TOC	

Hydrology/Level Measurements

Date	Time	DT-Bottom	DT-Product	DT-Water	DTP-DTW (Product Thickness)	DTB-DTW (Water Column)	Pore Volume (Gallons/ft x Water Column)

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	8:31:00 AM	0.5	0.1		12.9	776	5.17	174.1	
	8:33:00 AM	0.7	0.1	7.79	12.7	740.5	5.26	160.3	
Final Field Parameters	8:35:00 AM	0.9	0.1	7.78	12.4	740.5	5.19	154.6	6.8

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations: Clear. NO3 recorded during purging: 1.91, 1.84, 1.82. Ferrous iron = 0.5 mg/L.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	8:40:00 AM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSS-MiHpt05
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSS-MiHpt05-9-11
Sub Area		**Sample Depth**	10
FSDS QA:	CRW 12/13/2018		

Easting		**Northing**		**TOC**	

Hydrology/Level Measurements

					(Product Thickness)	(Water Column)	(Gallons/ft x Water Column)
Date	**Time**	**DT-Bottom**	**DT-Product**	**DT-Water**	**DTP-DTW**	**DTB-DTW**	**Pore Volume**
12/5/2018				8.5			

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	10:27:00 AM	1	0.1	7.55	13.8	928	3.13	110.3	
	10:29:00 AM	1.2	0.1		13.2	923	2.88	104.4	
	10:33:00 AM	1.5	0.1		13.4	924	3.37	84.7	
Final Field Parameters	10:36:00 AM	1.7	0.1	7.55	13	908	3.56	73.4	8.6

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations:

Clear. NO3 recorded during purging: 0.13, 0.13, 0.13, 0.14. Ferrous iron = 0.25 mg/L.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	10:40:00 AM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSS-MiHpt05
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSS-MiHpt05-12-14
Sub Area		**Sample Depth**	13
FSDS QA:	CRW 12/13/2018		

Easting		**Northing**		**TOC**	

Hydrology/Level Measurements

Date	Time	DT-Bottom	DT-Product	DT-Water	DTP-DTW (Product Thickness)	DTB-DTW (Water Column)	Pore Volume (Gallons/ft x Water Column)
12/5/2018				8.5			

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	11:10:00 AM	1	0.1		13.7	917.2	1.75	121.6	
	11:14:00 AM	1.2	0.1		13.7	940.8	1.67	111.3	
Final Field Parameters	11:17:00 AM	1.4	0.1	7.55	13.8	941	2.6	96.4	12.4

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations: NO3 recorded during purging: 0.78, 0.40, 0.22. Ferrous iron = 0.4 mg/L.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	11:25:00 AM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSS-MiHpt05
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSS-MiHpt05-16-18
Sub Area		**Sample Depth**	17
FSDS QA:	CRW 12/13/2018		

Easting		**Northing**		**TOC**	

Hydrology/Level Measurements

Date	Time	DT-Bottom	DT-Product	DT-Water	(Product Thickness) DTP-DTW	(Water Column) DTB-DTW	(Gallons/ft x Water Column) Pore Volume
12/5/2018				8.5			

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	11:44:00 AM	0.5	0.1		12.6	978	3.3	124.6	
	11:47:00 AM	0.7	0.1		12.5	992	3.36	118.7	
Final Field Parameters	11:50:00 AM	1	0.1	7.55	12.5	986	3.18	116.1	10.3

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations: Clear. NO3 recorded during purging:2.61, 2.16, 1.95. Ferrous iron = 0.25 mg/L.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	12:00:00 PM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSW-MiHpt10
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSW-MiHpt10-10-12
Sub Area		**Sample Depth**	11
FSDS QA:	CRW 12/13/2018		

Easting		**Northing**		**TOC**	

Hydrology/Level Measurements

					(Product Thickness)	(Water Column)	(Gallons/ft x Water Column)
Date	**Time**	**DT-Bottom**	**DT-Product**	**DT-Water**	**DTP-DTW**	**DTB-DTW**	**Pore Volume**
12/5/2018				9.5			

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	1:34:00 PM	1.5	0.1		17.5	1240	1.4	126.2	
	1:35:00 PM	1.7	0.1		17.5	1219	1.25	120.1	
Final Field Parameters	1:37:00 PM	1.9	0.1	7.35	17.6	1222	1.21	114.5	58

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations:

Slightly turbid groundwater after 30 minutes of purging, parameters stabilized for sample collection. NO3 recorded during purging: 1.24, 1.22, 1.21.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	1:55:00 PM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ________________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSW-MiHpt10
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSW-MiHpt10-13-15
Sub Area		**Sample Depth**	14
FSDS QA:	CRW 12/13/2018		

Easting		**Northing**		**TOC**	

Hydrology/Level Measurements

					(Product Thickness)	(Water Column)	(Gallons/ft x Water Column)
Date	**Time**	**DT-Bottom**	**DT-Product**	**DT-Water**	**DTP-DTW**	**DTB-DTW**	**Pore Volume**
12/5/2018				9.5			

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	2:04:00 PM	1	0.1		14.8	976	0.83	117.8	
	2:14:00 PM	1.2	0.1	7.59	14.9	977	0.69	114.8	
Final Field Parameters	2:17:00 PM	1.4	0.1	7.59	15	977	0.53	111.9	3.15

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations: NO3 recorded during purging: 0.83, 0.69, 0.53.

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	2:25:00 PM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ______________________________

Maul Foster & Alongi, Inc.

400 E. Mill Plain Blvd, Suite 400, Vancouver, WA 98660 (360) 694-2691 Fax. (360) 906-1958

Water Field Sampling Data Sheet

Client Name	City of Yakima	**Sample Location**	DSW-MiHpt10
Project #	0818.02.01	**Sampler**	Y. Van
Project Name	Tiger Oil - W. Nob Hill Blvd.	**Sampling Date**	12/5/2018
Sampling Event	December 2018 - HRSC	**Sample Name**	DSW-MiHpt10-16-18
Sub Area		**Sample Depth**	17
FSDS QA:	CRW 12/13/2018		

Easting		**Northing**		**TOC**	

Hydrology/Level Measurements

					(Product Thickness)	(Water Column)	(Gallons/ft x Water Column)
Date	**Time**	**DT-Bottom**	**DT-Product**	**DT-Water**	**DTP-DTW**	**DTB-DTW**	**Pore Volume**
12/5/2018				9.5			

(0.75" = 0.023 gal/ft) (1" = 0.041 gal/ft) (1.5" = 0.092 gal/ft) (2" = 0.163 gal/ft) (3" = 0.367 gal/ft) (4" = 0.653 gal/ft) (6" = 1.469 gal/ft) (8" = 2.611 gal/ft)

Water Quality Data

Purge Method	Time	Purge Vol (gal)	Flowrate l/min	pH	Temp (C)	E Cond (uS/cm)	DO (mg/L)	ORP	Turbidity
(2) Peristaltic Pump	2:41:00 PM	0.5	0.1		15.9	872	4.89	128.8	
	2:54:00 PM	1	0.1		15.8	872	2.82	121.1	
	2:56:00 PM	1.2	0.1		16	870	2.6	117.5	
Final Field Parameters	3:28:00 PM	2	0.1	7.62	15.9	872	2.57	113.8	101

Methods: (1) Submersible Pump (2) Peristaltic Pump (3) Disposable Bailer (4) Vacuum Pump (5) Dedicated Bailer (6) Inertia Pump (7) Other (specify)

Water Quality Observations: Slightly to moderately turbid after 60 minutes of purging. NO3 recorded during purging: 2.09, 2.26, 2.50, 2.76. Ferrous iron = 0.25 mg/L

Sample Information

Sampling Method	Sample Type	Sampling Time	Container Code/Preservative	#	Filtered
(2) Peristaltic Pump	Groundwater	3:15:00 PM	VOA-Glass	6	No
			Amber Glass		
			White Poly	1	Yes
			Yellow Poly	1	No
			Green Poly		
			Red Total Poly		
			Red Dissolved Poly		
			Total Bottles	8	

General Sampling Comments

Signature ____________________________________

APPENDIX C

LABORATORY REPORT

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

James E. Bruya, Ph.D.
Yelena Aravkina, M.S.
Michael Erdahl, B.S.
Arina Podnozova, B.S.
Eric Young, B.S.

3012 16th Avenue West
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December 27, 2018

Yen-Vy Van, Project Manager
Maul Foster Alongi
2815 2nd Ave, Suite 540
Seattle, WA 98121

Dear Ms Van:

Included are the results from the testing of material submitted on December 7, 2018 from the Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105 project. There are 37 pages included in this report. Any samples that may remain are currently scheduled for disposal in 30 days. If you would like us to return your samples or arrange for long term storage at our offices, please contact us as soon as possible.

We appreciate this opportunity to be of service to you and hope you will call if you should have any questions.

Sincerely,

FRIEDMAN & BRUYA, INC.

Michael Erdahl
Project Manager

Enclosures
MFA1227R.DOC

CASE NARRATIVE

This case narrative encompasses samples received on December 7, 2018 by Friedman & Bruya, Inc. from the Maul Foster Alongi Former Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105 project. Samples were logged in under the laboratory ID's listed below.

Laboratory ID	Maul Foster Alongi
812105 -01	DSS-OIP2-10.0
812105 -02	DSS-OIP2-11.0
812105 -03	DSS-OIP2-12.0
812105 -04	DSS-OIP2-14.0
812105 -05	DSS-OIP2-15.0
812105 -06	DSS-OIP2-19.0
812105 -07	DSS-OIP2-20.0
812105 -08	DSS-OIP2-21.0
812105 -09	DSS-OIP2-22.0
812105 -10	DSS-OIP2-23.0
812105 -11	DSS-OIP7-14.0
812105 -12	DSS-OIP7-15.0
812105 -13	DSS-OIP7-16.0
812105 -14	DSS-OIP7-19.0
812105 -15	DSS-OIP7-20.0
812105 -16	DSS-OIP7-21.0
812105 -17	DSS-OIP6-8.5
812105 -18	DSS-OIP6-9.0
812105 -19	DSS-OIP6-10.0
812105 -20	DSS-OIP6-13.0
812105 -21	DSS-OIP6-14.0
812105 -22	DSS-OIP10-4.0
812105 -23	DSS-OIP10-5.0
812105 -24	DSS-OIP10-6.0
812105 -25	DSS-OIP10-7.0
812105 -26	DSS-OIP10-8.0
812105 -27	DSS-OIP10-9.0
812105 -28	DSS-OIP10-10.0
812105 -29	DSS-OIP10-11.0
812105 -30	DSS-OIP10-12.0
812105 -31	DSW-Miltpt03-10.0
812105 -32	DSW-Miltpt03-11.0
812105 -33	DSW-Miltpt03-12-14
812105 -34	DSW-Miltpt03-15-17
812105 -35	DSW-Miltpt05-9-11
812105 -36	DSW-Miltpt05-12-14

CASE NARRATIVE (continued)

Laboratory ID	Maul Foster Alongi
812105 -37	DSW-Miltpt05-16-18
812105 -38	DSW-Miltpt10-10-12
812105 -39	DSW-Miltpt10-13-15
812105 -40	DSW-Miltpt10-16-18
812105 -41	Trip Blank
812105 -42	KMW10-LNAPL

The water samples were sent to Fremont Analytical for dissolved carbon dioxide and sulfate analyses. In addition, sample KMW10-LNAPL was sent to Fremont for EPH and VPH analyses. The report is enclosed.

All quality control requirements were acceptable.

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: NA
Date Analyzed: 12/10/18

RESULTS FROM THE ANALYSIS OF THE SOIL SAMPLES FOR PERCENT MOISTURE USING ASTM D2216-98

Sample ID Laboratory ID	% Moisture
DSS-OIP2-10.0 812105-01	7
DSS-OIP2-11.0 812105-02	23
DSS-OIP2-12.0 812105-03	19
DSS-OIP2-14.0 812105-04	23
DSS-OIP2-15.0 812105-05	18
DSS-OIP2-19.0 812105-06	24
DSS-OIP2-20.0 812105-07	26
DSS-OIP2-21.0 812105-08	33
DSS-OIP2-22.0 812105-09	28
DSS-OIP2-23.0 812105-10	28
DSS-OIP7-14.0 812105-11	19
DSS-OIP7-15.0 812105-12	20

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: NA
Date Analyzed: 12/10/18

RESULTS FROM THE ANALYSIS OF THE SOIL SAMPLES FOR PERCENT MOISTURE USING ASTM D2216-98

Sample ID Laboratory ID	% Moisture
DSS-OIP7-16.0 812105-13	21
DSS-OIP7-19.0 812105-14	16
DSS-OIP7-20.0 812105-15	25
DSS-OIP7-21.0 812105-16	7
DSS-OIP6-8.5 812105-17	16
DSS-OIP6-9.0 812105-18	18
DSS-OIP6-10.0 812105-19	19
DSS-OIP6-13.0 812105-20	26
DSS-OIP6-14.0 812105-21	17
DSS-OIP10-4.0 812105-22	17
DSS-OIP10-5.0 812105-23	16
DSS-OIP10-6.0 812105-24	19

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: NA
Date Analyzed: 12/10/18

RESULTS FROM THE ANALYSIS OF THE SOIL SAMPLES FOR PERCENT MOISTURE USING ASTM D2216-98

Sample ID Laboratory ID	% Moisture
DSS-OIP10-7.0 812105-25	20
DSS-OIP10-8.0 812105-26	17
DSS-OIP10-9.0 812105-27	24
DSS-OIP10-10.0 812105-28	26
DSS-OIP10-11.0 812105-29	22
DSS-OIP10-12.0 812105-30	27

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: 12/10/18 and 12/12/18
Date Analyzed: 12/10/18, 12/11/18, and 12/12/18

RESULTS FROM THE ANALYSIS OF SOIL SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES AND TPH AS GASOLINE USING METHODS 8021B AND NWTPH-Gx

Results Reported on a Dry Weight Basis
Results Reported as mg/kg (ppm)

Sample ID Laboratory ID	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Gasoline Range	Surrogate (% Recovery) (Limit 50-132)
DSS-OIP2-10.0 812105-01	<0.02	0.032	2.3	4.1	530	96
DSS-OIP2-11.0 812105-02	0.086	0.14	1.7	6.8	240	91
DSS-OIP2-12.0 812105-03 1/20	1.2	3.5	33	170	2,100	118
DSS-OIP2-14.0 812105-04 1/10	1.8	4.0	20	100	1,300	119
DSS-OIP2-15.0 812105-05 1/10	0.78	2.0	17	40	960	89
DSS-OIP2-19.0 812105-06	<0.02	0.028	<0.02	<0.06	<5	90
DSS-OIP2-20.0 812105-07	<0.02	<0.02	<0.02	<0.06	<5	80
DSS-OIP2-21.0 812105-08	<0.02	<0.02	<0.02	0.14	<5	82
DSS-OIP2-22.0 812105-09	<0.02	<0.02	<0.02	<0.06	<5	81
DSS-OIP2-23.0 812105-10	<0.02	<0.02	<0.02	<0.06	<5	82
DSS-OIP7-14.0 812105-11 1/10	0.75	8.3	17	92	1,100	115

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: 12/10/18 and 12/12/18
Date Analyzed: 12/10/18, 12/11/18, and 12/12/18

RESULTS FROM THE ANALYSIS OF SOIL SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES AND TPH AS GASOLINE USING METHODS 8021B AND NWTPH-Gx

Results Reported on a Dry Weight Basis
Results Reported as mg/kg (ppm)

Sample ID Laboratory ID	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Gasoline Range	Surrogate (% Recovery) (Limit 50-132)
DSS-OIP7-15.0 812105-12	0.11	1.5	1.3	7.3	90	111
DSS-OIP7-16.0 812105-13	<0.02	0.042	0.18	1.0	<5	81
DSS-OIP7-19.0 812105-14	<0.02	0.044	0.43	0.64	6.5	84
DSS-OIP7-20.0 812105-15	0.080	0.071	1.3	2.1	23	83
DSS-OIP7-21.0 812105-16	<0.02	0.032	0.073	0.31	6.0	82
DSS-OIP6-8.5 812105-17	<0.02	<0.02	0.12	0.25	11	81
DSS-OIP6-9.0 812105-18	<0.02	<0.02	0.12	0.18	9.8	83
DSS-OIP6-10.0 812105-19	0.073	0.14	0.45	1.4	69	87
DSS-OIP6-13.0 812105-20 1/20	7.7	52	31	170	1,700	110
DSS-OIP6-14.0 812105-21	0.37	1.1	0.37	2.3	29	83
DSS-OIP10-4.0 812105-22	0.33	0.31	2.8	14	140	116

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: 12/10/18 and 12/12/18
Date Analyzed: 12/10/18, 12/11/18, and 12/12/18

RESULTS FROM THE ANALYSIS OF SOIL SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES AND TPH AS GASOLINE USING METHODS 8021B AND NWTPH-Gx

Results Reported on a Dry Weight Basis
Results Reported as mg/kg (ppm)

Sample ID Laboratory ID	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Gasoline Range	Surrogate (% Recovery) (Limit 50-132)
DSS-OIP10-5.0 812105-23 1/50	8.2	11	53	220	2,900	86
DSS-OIP10-6.0 812105-24 1/5	1.4	2.8	8.9	32	670	118
DSS-OIP10-7.0 812105-25 1/10	4.3	8.1	15	74	930	111
DSS-OIP10-8.0 812105-26 1/10	2.4	5.3	14	57	930	113
DSS-OIP10-9.0 812105-27 1/50	6.5	18	46	250	2,600	104
DSS-OIP10-10.0 812105-28	0.14	<0.02	0.16	0.19	8.6	102
DSS-OIP10-11.0 812105-29 1/10	2.0	4.0	13	66	830	111
DSS-OIP10-12.0 812105-30	<0.02	0.041	0.090	0.51	9.5	100
Method Blank 08-2554 MB	<0.02	<0.02	<0.02	<0.06	<5	84
Method Blank 08-2553 MB	<0.02	<0.02	<0.02	<0.06	<5	82

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105
Date Extracted: 12/10/18
Date Analyzed: 12/10/18

RESULTS FROM THE ANALYSIS OF WATER SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES AND TPH AS GASOLINE USING METHODS 8021B AND NWTPH-Gx

Results Reported as ug/L (ppb)

Sample ID Laboratory ID	Benzene	Toluene	Ethyl Benzene	Total Xylenes	Gasoline Range	Surrogate (% Recovery) (Limit 52-124)
DSW-Miltpt03-10.0 812105-31	2.9	2.6	10	3.8	360	102
DSW-Miltpt03-11.0 812105-32	<1	<1	<1	<3	<100	94
DSW-Miltpt03-12-14 812105-33	<1	<1	<1	5.8	<100	92
DSW-Miltpt03-15-17 812105-34	<1	<1	<1	<3	<100	91
DSW-Miltpt05-9-11 812105-35	5.5	4.5	89	34	1,800	114
DSW-Miltpt05-12-14 812105-36	25	1.6	29	<3	760	105
DSW-Miltpt05-16-18 812105-37	<1	<1	<1	<3	<100	92
DSW-Miltpt10-10-12 812105-38	<1	<1	<1	<3	<100	93
DSW-Miltpt10-13-15 812105-39	<1	<1	<1	<3	<100	92
DSW-Miltpt10-16-18 812105-40	<1	<1	<1	<3	<100	90
Method Blank 08-2552 MB	<1	<1	<1	<3	<100	86

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt03-10.0	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-31 x10
Date Analyzed:	12/11/18	Data File:	812105-31 x10.148
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	2,910

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt03-11.0	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-32
Date Analyzed:	12/11/18	Data File:	812105-32.149
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	834

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt03-12-14	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-33
Date Analyzed:	12/11/18	Data File:	812105-33.150
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	278

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt03-15-17	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-34
Date Analyzed:	12/11/18	Data File:	812105-34.151
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	220

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt05-9-11	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-35 x10
Date Analyzed:	12/11/18	Data File:	812105-35 x10.160
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	1,210

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt05-12-14	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-36 x10
Date Analyzed:	12/11/18	Data File:	812105-36 x10.161
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	2,310

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt05-16-18	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-37
Date Analyzed:	12/11/18	Data File:	812105-37.162
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	349

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt10-10-12	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-38 x10
Date Analyzed:	12/11/18	Data File:	812105-38 x10.163
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	1,640

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt10-13-15	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-39
Date Analyzed:	12/11/18	Data File:	812105-39.167
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	65.1

Analysis For Total Metals By EPA Method 6020B

Client ID:	DSW-Miltpt10-16-18	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	812105-40
Date Analyzed:	12/11/18	Data File:	812105-40.168
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	23.0

Analysis For Total Metals By EPA Method 6020B

Client ID:	Method Blank	Client:	Maul Foster Alongi
Date Received:	NA	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/10/18	Lab ID:	I8-846 mb
Date Analyzed:	12/12/18	Data File:	I8-846 mb.051
Matrix:	Water	Instrument:	ICPMS2
Units:	ug/L (ppb)	Operator:	SP

Analyte:	Concentration ug/L (ppb)
Manganese	<1

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt03-10.0	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-31
Date Analyzed:	12/13/18	Data File:	007F0701.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	31

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt03-11.0	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-32
Date Analyzed:	12/13/18	Data File:	008F0801.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	<5

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt03-12-14	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-33
Date Analyzed:	12/13/18	Data File:	009F0901.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	<5

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt03-15-17	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-34
Date Analyzed:	12/13/18	Data File:	010F1001.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	<5

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt05-9-11	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-35
Date Analyzed:	12/13/18	Data File:	011F1101.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	140

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt05-12-14	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-36
Date Analyzed:	12/13/18	Data File:	012F1201.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	240

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt05-16-18	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-37
Date Analyzed:	12/13/18	Data File:	013F1301.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	<5

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt10-10-12	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-38
Date Analyzed:	12/13/18	Data File:	014F1401.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	20

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt10-13-15	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-39
Date Analyzed:	12/13/18	Data File:	015F1501.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	8.1

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	DSW-Miltpt10-16-18	Client:	Maul Foster Alongi
Date Received:	12/07/18	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	812105-40
Date Analyzed:	12/13/18	Data File:	016F1601.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	<5

Analysis For Dissolved Gasses By RSK 175

Client Sample ID:	Method Blank	Client:	Maul Foster Alongi
Date Received:	NA	Project:	Former Tiger Oil 0818.02.01 Task 17
Date Extracted:	12/13/18	Lab ID:	08-2760 mb
Date Analyzed:	12/13/18	Data File:	005F0501.D
Matrix:	Water	Instrument:	GC8
Units:	ug/L (ppb)	Operator:	JS

Compounds:	Concentration ug/L (ppb)
Methane	<5

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF SOIL SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES, AND TPH AS GASOLINE USING METHOD 8021B AND NWTPH-Gx

Laboratory Code: 811475-43 (Duplicate)

Analyte	Reporting Units	Sample Result (Wet Wt)	Duplicate Result (Wet Wt)	RPD (Limit 20)
Benzene	mg/kg (ppm)	<0.02	<0.02	nm
Toluene	mg/kg (ppm)	<0.02	<0.02	nm
Ethylbenzene	mg/kg (ppm)	<0.02	<0.02	nm
Xylenes	mg/kg (ppm)	<0.06	<0.06	nm
Gasoline	mg/kg (ppm)	<5	<5	nm

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Acceptance Criteria
Benzene	mg/kg (ppm)	0.5	97	69-120
Toluene	mg/kg (ppm)	0.5	101	70-117
Ethylbenzene	mg/kg (ppm)	0.5	104	65-123
Xylenes	mg/kg (ppm)	1.5	102	66-120
Gasoline	mg/kg (ppm)	20	80	71-131

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF SOIL SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES, AND TPH AS GASOLINE USING EPA METHOD 8021B AND NWTPH-Gx

Laboratory Code: 812105-19 (Duplicate)

Analyte	Reporting Units	Sample Result (Wet Wt)	Duplicate Result (Wet Wt)	RPD (Limit 20)
Benzene	mg/kg (ppm)	0.05	0.05	0
Toluene	mg/kg (ppm)	0.09	0.08	12
Ethylbenzene	mg/kg (ppm)	0.29	0.27	7
Xylenes	mg/kg (ppm)	0.93	0.86	8
Gasoline	mg/kg (ppm)	45	42	7

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Acceptance Criteria
Benzene	mg/kg (ppm)	0.5	97	69-120
Toluene	mg/kg (ppm)	0.5	101	70-117
Ethylbenzene	mg/kg (ppm)	0.5	104	65-123
Xylenes	mg/kg (ppm)	1.5	102	66-120
Gasoline	mg/kg (ppm)	20	80	71-131

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF WATER SAMPLES FOR BENZENE, TOLUENE, ETHYLBENZENE, XYLENES, AND TPH AS GASOLINE USING EPA METHOD 8021B AND NWTPH-Gx

Laboratory Code: 812105-31 (Duplicate)

Analyte	Reporting Units	Sample Result	Duplicate Result	RPD (Limit 20)
Benzene	ug/L (ppb)	2.9	2.7	5
Toluene	ug/L (ppb)	2.6	2.8	5
Ethylbenzene	ug/L (ppb)	10	12	11
Xylenes	ug/L (ppb)	3.8	4.7	21 a
Gasoline	ug/L (ppb)	360	430	18

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Acceptance Criteria
Benzene	ug/L (ppb)	50	106	65-118
Toluene	ug/L (ppb)	50	103	72-122
Ethylbenzene	ug/L (ppb)	50	100	73-126
Xylenes	ug/L (ppb)	150	96	74-118
Gasoline	ug/L (ppb)	1,000	97	69-134

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF WATER SAMPLES FOR TOTAL METALS USING EPA METHOD 6020B

Laboratory Code: 812106-02 x100 (Matrix Spike)

Analyte	Reporting Units	Spike Level	Sample Result	Percent Recovery MS	Percent Recovery MSD	Acceptance Criteria	RPD (Limit 20)
Manganese	ug/L (ppb)	20	<100	82	86	75-125	5

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Acceptance Criteria
Manganese	ug/L (ppb)	20	99	80-120

Date of Report: 12/27/18
Date Received: 12/07/18
Project: Former Tiger Oil HRSC 0818.02.01 Task 17, F&BI 812105

QUALITY ASSURANCE RESULTS FOR THE ANALYSIS OF WATER SAMPLES FOR DISSOLVED GASSES USING METHOD RSK 175

Laboratory Code: 812105-40 (Matrix Spike)

Analyte	Reporting Units	Spike Level	Sample Result	Percent Recovery MS	Acceptance Criteria
Methane	ug/L (ppb)	59	<5	82	50-150

Laboratory Code: Laboratory Control Sample

Analyte	Reporting Units	Spike Level	Percent Recovery LCS	Percent Recovery LCSD	Acceptance Criteria	RPD (Limit 20)
Methane	ug/L (ppb)	59	77	76	50-150	1

Data Qualifiers & Definitions

a - The analyte was detected at a level less than five times the reporting limit. The RPD results may not provide reliable information on the variability of the analysis.

b - The analyte was spiked at a level that was less than five times that present in the sample. Matrix spike recoveries may not be meaningful.

ca - The calibration results for the analyte were outside of acceptance criteria. The value reported is an estimate.

c - The presence of the analyte may be due to carryover from previous sample injections.

cf - The sample was centrifuged prior to analysis.

d - The sample was diluted. Detection limits were raised and surrogate recoveries may not be meaningful.

dv - Insufficient sample volume was available to achieve normal reporting limits.

f - The sample was laboratory filtered prior to analysis.

fb - The analyte was detected in the method blank.

fc - The compound is a common laboratory and field contaminant.

hr - The sample and duplicate were reextracted and reanalyzed. RPD results were still outside of control limits. Variability is attributed to sample inhomogeneity.

hs - Headspace was present in the container used for analysis.

ht – The analysis was performed outside the method or client-specified holding time requirement.

ip - Recovery fell outside of control limits. Compounds in the sample matrix interfered with the quantitation of the analyte.

j - The analyte concentration is reported below the lowest calibration standard. The value reported is an estimate.

J - The internal standard associated with the analyte is out of control limits. The reported concentration is an estimate.

jl - The laboratory control sample(s) percent recovery and/or RPD were out of control limits. The reported concentration should be considered an estimate.

js - The surrogate associated with the analyte is out of control limits. The reported concentration should be considered an estimate.

lc - The presence of the analyte is likely due to laboratory contamination.

L - The reported concentration was generated from a library search.

nm - The analyte was not detected in one or more of the duplicate analyses. Therefore, calculation of the RPD is not applicable.

pc - The sample was received with incorrect preservation or in a container not approved by the method. The value reported should be considered an estimate.

ve - The analyte response exceeded the valid instrument calibration range. The value reported is an estimate.

vo - The value reported fell outside the control limits established for this analyte.

x - The sample chromatographic pattern does not resemble the fuel standard used for quantitation.

Fremont Analytical
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Friedman & Bruya
Michael Erdahl
3012 16th Ave. W.
Seattle, WA 98119

RE: 812105
Work Order Number: 1812108

December 24, 2018

Attention Michael Erdahl:

Fremont Analytical, Inc. received 11 sample(s) on 12/10/2018 for the analyses presented in the following report.

Extractable Petroleum Hydrocarbons by NWEPH
Ion Chromatography by EPA Method 300.0
Total Alkalinity by SM 2320B
Volatile Petroleum Hydrocarbons by NWVPH

This report consists of the following:

- Case Narrative
- Analytical Results
- Applicable Quality Control Summary Reports
- Chain of Custody

All analyses were performed consistent with the Quality Assurance program of Fremont Analytical, Inc. Please contact the laboratory if you should have any questions about the results.

Thank you for using Fremont Analytical.

Sincerely,

Mike Ridgeway
Laboratory Director

DoD/ELAP Certification #L17-135, ISO/IEC 17025:2005
ORELAP Certification: WA 100009-007 (NELAP Recognized)

Date: *12/24/2018*

CLIENT:	Friedman & Bruya
Project:	812105
Work Order:	1812108

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Date/Time Collected	Date/Time Received
1812108-001	DSW-Miltpt03-10.0	12/04/2018 3:21 PM	12/10/2018 11:57 AM
1812108-002	DSW-Miltpt03-11.0	12/04/2018 4:38 PM	12/10/2018 11:57 AM
1812108-003	DSW-Miltpt03-12-14	12/05/2018 8:40 AM	12/10/2018 11:57 AM
1812108-004	DSW-Miltpt03-15-17	12/05/2018 9:15 AM	12/10/2018 11:57 AM
1812108-005	DSW-Miltpt05-9-11	12/05/2018 10:40 AM	12/10/2018 11:57 AM
1812108-006	DSW-Miltpt05-12-14	12/05/2018 11:25 AM	12/10/2018 11:57 AM
1812108-007	DSW-Miltpt05-16-18	12/05/2018 12:00 PM	12/10/2018 11:57 AM
1812108-008	DSW-Miltpt10-10-12	12/05/2018 1:55 PM	12/10/2018 11:57 AM
1812108-009	DSW-Miltpt10-13-15	12/05/2018 2:25 PM	12/10/2018 11:57 AM
1812108-010	DSW-Miltpt10-16-18	12/05/2018 3:15 PM	12/10/2018 11:57 AM
1812108-011	KMW10-LNAPL	12/04/2018 12:15 PM	12/10/2018 11:57 AM

Note: If no "Time Collected" is supplied, a default of 12:00AM is assigned

Case Narrative

WO#: **1812108**
Date: **12/24/2018**

CLIENT: Friedman & Bruya
Project: 812105

I. SAMPLE RECEIPT:
Samples receipt information is recorded on the attached Sample Receipt Checklist.

II. GENERAL REPORTING COMMENTS:
Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report ("mg/kg-dry" or "ug/kg-dry").

Matrix Spike (MS) and MS Duplicate (MSD) samples are tested from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. The sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The LCS and the MB are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

III. ANALYSES AND EXCEPTIONS:
Exceptions associated with this report will be footnoted in the analytical results page(s) or the quality control summary page(s) and/or noted below.

Qualifiers:

* - Flagged value is not within established control limits
B - Analyte detected in the associated Method Blank
D - Dilution was required
E - Value above quantitation range
H - Holding times for preparation or analysis exceeded
I - Analyte with an internal standard that does not meet established acceptance criteria
J - Analyte detected below Reporting Limit
N - Tentatively Identified Compound (TIC)
Q - Analyte with an initial or continuing calibration that does not meet established acceptance criteria (<20%RSD, <20% Drift or minimum RRF)
S - Spike recovery outside accepted recovery limits
ND - Not detected at the Reporting Limit
R - High relative percent difference observed

Acronyms:

%Rec - Percent Recovery
CCB - Continued Calibration Blank
CCV - Continued Calibration Verification
DF - Dilution Factor
HEM - Hexane Extractable Material
ICV - Initial Calibration Verification
LCS/LCSD - Laboratory Control Sample / Laboratory Control Sample Duplicate
MB or MBLANK - Method Blank
MDL - Method Detection Limit
MS/MSD - Matrix Spike / Matrix Spike Duplicate
PDS - Post Digestion Spike
Ref Val - Reference Value
RL - Reporting Limit
RPD - Relative Percent Difference
SD - Serial Dilution
SGT - Silica Gel Treatment
SPK - Spike
Surr - Surrogate

Analytical Report

Work Order: **1812108**
Date Reported: **12/24/2018**

CLIENT: Friedman & Bruya
Project: 812105

Lab ID: 1812108-001 **Collection Date:** 12/4/2018 3:21:00 PM
Client Sample ID: **DSW-Miltpt03-10.0** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	14.9	1.50	D	mg/L	5	12/17/2018 10:31:00 PM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	549	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-002 **Collection Date:** 12/4/2018 4:38:00 PM
Client Sample ID: **DSW-Miltpt03-11.0** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	28.4	1.50	D	mg/L	5	12/18/2018 12:03:00 AM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	384	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-003 **Collection Date:** 12/5/2018 8:40:00 AM
Client Sample ID: **DSW-Miltpt03-12-14** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	32.6	1.50	D	mg/L	5	12/18/2018 12:26:00 AM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	374	2.50		mg/L	1	12/13/2018 10:10:00 AM

Analytical Report

CLIENT: Friedman & Bruya
Project: 812105

Lab ID: 1812108-004 **Collection Date:** 12/5/2018 9:15:00 AM
Client Sample ID: **DSW-Miltpt03-15-17** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	31.9	1.50	D	mg/L	5	12/18/2018 12:49:00 AM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	365	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-005 **Collection Date:** 12/5/2018 10:40:00 AM
Client Sample ID: **DSW-Miltpt05-9-11** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	16.7	1.50	D	mg/L	5	12/18/2018 1:13:00 AM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	500	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-006 **Collection Date:** 12/5/2018 11:25:00 AM
Client Sample ID: **DSW-Miltpt05-12-14** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	15.6	1.50	D	mg/L	5	12/18/2018 2:35:00 PM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	446	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-007 **Collection Date:** 12/5/2018 12:00:00 PM
Client Sample ID: **DSW-Miltpt05-16-18** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	25.7	3.00	D	mg/L	10	12/18/2018 2:58:00 PM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	506	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-008 **Collection Date:** 12/5/2018 1:55:00 PM
Client Sample ID: **DSW-Miltpt10-10-12** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	36.4	3.00	D	mg/L	10	12/18/2018 3:21:00 PM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	601	2.50		mg/L	1	12/13/2018 10:10:00 AM

Analytical Report

Work Order: **1812108**
Date Reported: **12/24/2018**

CLIENT: Friedman & Bruya
Project: 812105

Lab ID: 1812108-009 **Collection Date:** 12/5/2018 2:25:00 PM
Client Sample ID: **DSW-Miltpt10-13-15** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	30.4	3.00	D	mg/L	10	12/18/2018 3:44:00 PM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	458	2.50		mg/L	1	12/13/2018 10:10:00 AM

Lab ID: 1812108-010 **Collection Date:** 12/5/2018 3:15:00 PM
Client Sample ID: **DSW-Miltpt10-16-18** **Matrix:** Groundwater

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Ion Chromatography by EPA Method 300.0				Batch ID: 22956		Analyst: TN
Sulfate	31.0	1.50	D	mg/L	5	12/18/2018 4:07:00 PM
Total Alkalinity by SM 2320B				Batch ID: R48346		Analyst: ME
Carbon dioxide	425	2.50		mg/L	1	12/13/2018 10:10:00 AM

Analytical Report

Work Order: **1812108**
Date Reported: **12/24/2018**

CLIENT: Friedman & Bruya
Project: 812105

Lab ID: 1812108-011 **Collection Date:** 12/4/2018 12:15:00 PM
Client Sample ID: **KMW10-LNAPL** **Matrix:** Product

Extractable Petroleum Hydrocarbons by NWEPH

Batch ID: 22931 Analyst: SB

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Aliphatic Hydrocarbon (C8-C10)	229,000	20,000	D*	mg/Kg	50	12/21/2018 12:31:00 PM
Aliphatic Hydrocarbon (C10-C12)	171,000	10,000	D	mg/Kg	50	12/21/2018 12:31:00 PM
Aliphatic Hydrocarbon (C12-C16)	87,000	10,000	D	mg/Kg	50	12/21/2018 12:31:00 PM
Aliphatic Hydrocarbon (C16-C21)	684	200		mg/Kg	1	12/20/2018 6:25:00 PM
Aliphatic Hydrocarbon (C21-C34)	ND	200		mg/Kg	1	12/20/2018 6:25:00 PM
Aromatic Hydrocarbon (C8-C10)	21,900	2,000	D*	mg/Kg	10	12/21/2018 10:19:00 AM
Aromatic Hydrocarbon (C10-C12)	36,600	2,000	D*	mg/Kg	10	12/21/2018 10:19:00 AM
Aromatic Hydrocarbon (C12-C16)	45,500	2,000	D	mg/Kg	10	12/21/2018 10:19:00 AM
Aromatic Hydrocarbon (C16-C21)	1,440	200		mg/Kg	1	12/21/2018 3:48:00 AM
Aromatic Hydrocarbon (C21-C34)	ND	200		mg/Kg	1	12/21/2018 3:48:00 AM
Surr: 1-Chlorooctadecane	77.5	60 - 140		%Rec	1	12/20/2018 6:25:00 PM
Surr: o-Terphenyl	82.7	60 - 140		%Rec	1	12/21/2018 3:48:00 AM

NOTES:
* - Flagged value is not within established control limits.

Volatile Petroleum Hydrocarbons by NWVPH

Batch ID: 22936 Analyst: CR

Analyses	Result	RL	Qual	Units	DF	Date Analyzed
Aliphatic Hydrocarbon (C5-C6)	1,320	151	D	mg/Kg	10	12/14/2018 2:20:42 AM
Aliphatic Hydrocarbon (C6-C8)	19,400	2,160	D	mg/Kg	100	12/14/2018 12:59:12 AM
Aliphatic Hydrocarbon (C8-C10)	104,000	6,030	D	mg/Kg	500	12/18/2018 12:24:46 PM
Aliphatic Hydrocarbon (C10-C12)	96,200	6,470	D	mg/Kg	500	12/18/2018 12:24:46 PM
Aromatic Hydrocarbon (C8-C10)	344,000	12,900	D	mg/Kg	500	12/18/2018 12:24:46 PM
Aromatic Hydrocarbon (C10-C12)	202,000	2,590	D	mg/Kg	500	12/18/2018 12:24:46 PM
Aromatic Hydrocarbon (C12-C13)	83,200	30,200	D	mg/Kg	500	12/18/2018 12:24:46 PM
Benzene	68.5	51.7	D	mg/Kg	10	12/14/2018 2:20:42 AM
Toluene	3,360	60.3	D	mg/Kg	10	12/14/2018 2:20:42 AM
Ethylbenzene	8,670	603	D	mg/Kg	100	12/14/2018 12:59:12 AM
m,p-Xylene	75,800	1,120	D	mg/Kg	100	12/14/2018 12:59:12 AM
o-Xylene	30,500	517	D	mg/Kg	100	12/14/2018 12:59:12 AM
Naphthalene	12,900	431	DQ	mg/Kg	100	12/14/2018 12:59:12 AM
Methyl tert-butyl ether (MTBE)	ND	43.1	D	mg/Kg	10	12/14/2018 2:20:42 AM
Surr: 1,4-Difluorobenzene	120	65 - 140	D	%Rec	10	12/14/2018 2:20:42 AM
Surr: Bromofluorobenzene	114	65 - 140	D	%Rec	10	12/14/2018 2:20:42 AM

NOTES:
Q - Indicates an analyte with a continuing calibration that does not meet established acceptance criteria
E - Estimated value. The amount exceeds the linear working range of the instrument.

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Total Alkalinity by SM 2320B

Sample ID **MB-R48346** SampType: **MBLK** Units: **mg/L** Prep Date: **12/13/2018** RunNo: **48346**
Client ID: **MBLKW** Batch ID: **R48346** Analysis Date: **12/13/2018** SeqNo: **946069**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Alkalinity, Total (As CaCO3)	ND	2.50									

Sample ID **LCS-R48346** SampType: **LCS** Units: **mg/L** Prep Date: **12/13/2018** RunNo: **48346**
Client ID: **LCSW** Batch ID: **R48346** Analysis Date: **12/13/2018** SeqNo: **946070**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Alkalinity, Total (As CaCO3)	100	2.50	100.0	0	100	80	120				

Sample ID **1812108-001ADUP** SampType: **DUP** Units: **mg/L** Prep Date: **12/13/2018** RunNo: **48346**
Client ID: **DSW-Miltpt03-10.0** Batch ID: **R48346** Analysis Date: **12/13/2018** SeqNo: **946072**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Carbon dioxide	547	2.50						548.8	0.343	20	

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Ion Chromatography by EPA Method 300.0

Sample ID **LCS-22956A** SampType: **LCS** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **LCSW** Batch ID: **22956** Analysis Date: **12/17/2018** SeqNo: **947533**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	91.2	3.00	98.60	0	92.5	90	110				D

Sample ID **MB-22956** SampType: **MBLK** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **MBLKW** Batch ID: **22956** Analysis Date: **12/17/2018** SeqNo: **947534**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	ND	0.300									

Sample ID **1812108-001ADUP** SampType: **DUP** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **DSW-Miltpt03-10.0** Batch ID: **22956** Analysis Date: **12/17/2018** SeqNo: **947536**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	16.8	1.50						14.88	11.9	20	D

Sample ID **1812108-001AMS** SampType: **MS** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **DSW-Miltpt03-10.0** Batch ID: **22956** Analysis Date: **12/17/2018** SeqNo: **947537**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	34.2	1.50	18.75	14.88	103	80	120				D

Sample ID **1812108-001AMSD** SampType: **MSD** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **DSW-Miltpt03-10.0** Batch ID: **22956** Analysis Date: **12/17/2018** SeqNo: **947538**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	34.6	1.50	18.75	14.88	105	80	120	34.17	1.12	20	D

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Ion Chromatography by EPA Method 300.0

Sample ID **1812114-002CDUP** SampType: **DUP** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **BATCH** Batch ID: **22956** Analysis Date: **12/18/2018** SeqNo: **947561**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	6.82	0.300						6.715	1.55	20	

Sample ID **1812114-002CMS** SampType: **MS** Units: **mg/L** Prep Date: **12/17/2018** RunNo: **48386**
Client ID: **BATCH** Batch ID: **22956** Analysis Date: **12/18/2018** SeqNo: **947562**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Sulfate	10.7	0.300	3.750	6.715	106	80	120				

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Extractable Petroleum Hydrocarbons by NWEPH

Sample ID **MB-22931** SampType: **MBLK** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **MBLKS** Batch ID: **22931** Analysis Date: **12/20/2018** SeqNo: **950787**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C8-C10)	ND	20.0									*
Aliphatic Hydrocarbon (C10-C12)	ND	10.0									
Aliphatic Hydrocarbon (C12-C16)	ND	10.0									
Aliphatic Hydrocarbon (C16-C21)	ND	10.0									
Aliphatic Hydrocarbon (C21-C34)	ND	10.0									
Surr: 1-Chlorooctadecane	77.9		100.0		77.9	60	140				

NOTES:
* - Flagged value is not within established control limits.

Sample ID **LCS-22931** SampType: **LCS** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **LCSS** Batch ID: **22931** Analysis Date: **12/20/2018** SeqNo: **950785**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C8-C10)	271	20.0	500.0	0	54.2	70	130				S
Aliphatic Hydrocarbon (C10-C12)	252	10.0	250.0	0	101	70	130				
Aliphatic Hydrocarbon (C12-C16)	219	10.0	250.0	0	87.7	70	130				
Aliphatic Hydrocarbon (C16-C21)	186	10.0	250.0	0	74.2	70	130				
Aliphatic Hydrocarbon (C21-C34)	242	10.0	250.0	0	96.9	70	130				
Surr: 1-Chlorooctadecane	75.1		100.0		75.1	60	140				

NOTES:
S - Outlying spike recovery observed (low bias). Samples will be qualified with a *.

Sample ID **LCSD-22931** SampType: **LCSD** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **LCSS02** Batch ID: **22931** Analysis Date: **12/20/2018** SeqNo: **950786**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C8-C10)	274	20.0	500.0	0	54.9	70	130	271.2	1.15	20	S
Aliphatic Hydrocarbon (C10-C12)	221	10.0	250.0	0	88.5	70	130	252.2	13.0	20	
Aliphatic Hydrocarbon (C12-C16)	195	10.0	250.0	0	77.9	70	130	219.1	11.8	20	
Aliphatic Hydrocarbon (C16-C21)	177	10.0	250.0	0	70.8	70	130	185.5	4.72	20	
Aliphatic Hydrocarbon (C21-C34)	230	10.0	250.0	0	92.1	70	130	242.2	5.06	20	
Surr: 1-Chlorooctadecane	72.4		100.0		72.4	60	140		0		

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Extractable Petroleum Hydrocarbons by NWEPH

Sample ID **LCSD-22931** SampType: **LCSD** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **LCSS02** Batch ID: **22931** Analysis Date: **12/20/2018** SeqNo: **950786**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

NOTES:
S - Outlying spike recovery observed (low bias). Samples will be qualified with a *.

Sample ID **MB-22931** SampType: **MBLK** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **MBLKS** Batch ID: **22931** Analysis Date: **12/21/2018** SeqNo: **950795**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aromatic Hydrocarbon (C8-C10)	ND	10.0									*
Aromatic Hydrocarbon (C10-C12)	ND	10.0									*
Aromatic Hydrocarbon (C12-C16)	ND	10.0									
Aromatic Hydrocarbon (C16-C21)	ND	10.0									
Aromatic Hydrocarbon (C21-C34)	ND	10.0									
Surr: o-Terphenyl	87.1		100.0		87.1	60	140				

NOTES:
* - Flagged value is not within established control limits.

Sample ID **LCS-22931** SampType: **LCS** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **LCSS** Batch ID: **22931** Analysis Date: **12/21/2018** SeqNo: **950793**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aromatic Hydrocarbon (C8-C10)	111	10.0	250.0	0	44.3	70	130				S
Aromatic Hydrocarbon (C10-C12)	151	10.0	250.0	0	60.6	70	130				S
Aromatic Hydrocarbon (C12-C16)	196	10.0	250.0	0	78.4	70	130				
Aromatic Hydrocarbon (C16-C21)	188	10.0	250.0	0	75.1	70	130				
Aromatic Hydrocarbon (C21-C34)	191	10.0	250.0	0	76.2	70	130				
Surr: o-Terphenyl	79.3		100.0		79.3	60	140				

NOTES:
S - Outlying spike recovery observed (low bias). Samples will be qualified with a *.

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Extractable Petroleum Hydrocarbons by NWEPH

Sample ID **LCSD-22931** SampType: **LCSD** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48528**
Client ID: **LCSS02** Batch ID: **22931** Analysis Date: **12/21/2018** SeqNo: **950794**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aromatic Hydrocarbon (C8-C10)	150	10.0	250.0	0	60.2	70	130	110.7	30.4	20	RS
Aromatic Hydrocarbon (C10-C12)	177	10.0	250.0	0	70.9	70	130	151.5	15.6	20	
Aromatic Hydrocarbon (C12-C16)	192	10.0	250.0	0	76.6	70	130	196.0	2.32	20	
Aromatic Hydrocarbon (C16-C21)	190	10.0	250.0	0	75.8	70	130	187.7	0.977	20	
Aromatic Hydrocarbon (C21-C34)	188	10.0	250.0	0	75.0	70	130	190.5	1.53	20	
Surr: o-Terphenyl	79.8		100.0		79.8	60	140		0		

NOTES:

S - Outlying spike recovery observed (low bias). Samples will be qualified with a *.

R - High RPD observed.

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Volatile Petroleum Hydrocarbons by NWVPH

Sample ID **LCS-22936** SampType: **LCS** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48371**
Client ID: **LCSS** Batch ID: **22936** Analysis Date: **12/13/2018** SeqNo: **946756**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C5-C6)	30.1	1.75	30.00	0	100	70	130				
Aliphatic Hydrocarbon (C6-C8)	10.9	2.50	10.00	0	109	70	130				
Aliphatic Hydrocarbon (C8-C10)	7.64	1.40	10.00	0	76.4	70	130				
Aliphatic Hydrocarbon (C10-C12)	8.57	1.50	10.00	0	85.7	70	130				
Aromatic Hydrocarbon (C8-C10)	43.8	3.00	40.00	0	109	70	130				
Aromatic Hydrocarbon (C10-C12)	10.5	0.600	10.00	0	105	70	130				
Aromatic Hydrocarbon (C12-C13)	9.35	7.00	10.00	0	93.5	70	130				
Benzene	10.5	0.600	10.00	0	105	70	130				
Toluene	10.8	0.700	10.00	0	108	70	130				
Ethylbenzene	11.0	0.700	10.00	0	110	70	130				
m,p-Xylene	22.3	1.30	20.00	0	112	70	130				
o-Xylene	11.1	0.600	10.00	0	111	70	130				
Naphthalene	9.36	0.500	10.00	0	93.6	70	130				
Methyl tert-butyl ether (MTBE)	10.1	0.500	10.00	0	101	70	130				
Surr: 1,4-Difluorobenzene	2.79		2.500		112	65	140				
Surr: Bromofluorobenzene	2.73		2.500		109	65	140				

Sample ID **LCSD-22936** SampType: **LCSD** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48371**
Client ID: **LCSS02** Batch ID: **22936** Analysis Date: **12/13/2018** SeqNo: **946757**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C5-C6)	30.1	1.75	30.00	0	100	70	130	30.08	0.0643	20	
Aliphatic Hydrocarbon (C6-C8)	7.97	2.50	10.00	0	79.7	70	130	10.92	31.3	20	R
Aliphatic Hydrocarbon (C8-C10)	7.00	1.40	10.00	0	70.0	70	130	7.639	8.76	20	S
Aliphatic Hydrocarbon (C10-C12)	9.97	1.50	10.00	0	99.7	70	130	8.572	15.1	20	
Aromatic Hydrocarbon (C8-C10)	44.3	3.00	40.00	0	111	70	130	43.77	1.16	20	
Aromatic Hydrocarbon (C10-C12)	9.75	0.600	10.00	0	97.5	70	130	10.47	7.09	20	
Aromatic Hydrocarbon (C12-C13)	11.2	7.00	10.00	0	112	70	130	9.346	17.9	20	
Benzene	10.8	0.600	10.00	0	108	70	130	10.46	3.23	20	
Toluene	11.1	0.700	10.00	0	111	70	130	10.83	2.48	20	

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Volatile Petroleum Hydrocarbons by NWVPH

Sample ID **LCSD-22936** SampType: **LCSD** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48371**
Client ID: **LCSS02** Batch ID: **22936** Analysis Date: **12/13/2018** SeqNo: **946757**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Ethylbenzene	11.3	0.700	10.00	0	113	70	130	11.04	2.08	20	
m,p-Xylene	22.7	1.30	20.00	0	114	70	130	22.31	1.93	20	
o-Xylene	11.2	0.600	10.00	0	112	70	130	11.06	1.54	20	
Naphthalene	8.67	0.500	10.00	0	86.7	70	130	9.362	7.67	20	
Methyl tert-butyl ether (MTBE)	10.8	0.500	10.00	0	108	70	130	10.11	6.16	20	
Surr: 1,4-Difluorobenzene	2.75		2.500		110	65	140		0		
Surr: Bromofluorobenzene	2.69		2.500		108	65	140		0		

NOTES:

S - Outlying spike recovery(ies) observed. A duplicate analysis was performed and recovered within range.

R - High RPD observed, spike recoveries are within range.

Sample ID **MB-22936** SampType: **MBLK** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48371**
Client ID: **MBLKS** Batch ID: **22936** Analysis Date: **12/14/2018** SeqNo: **946758**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C5-C6)	ND	1.75		0	0						
Aliphatic Hydrocarbon (C6-C8)	ND	2.50		0	0						
Aliphatic Hydrocarbon (C8-C10)	ND	1.40		0	0						
Aliphatic Hydrocarbon (C10-C12)	ND	1.50		0	0						
Aromatic Hydrocarbon (C8-C10)	ND	3.00		0	0						
Aromatic Hydrocarbon (C10-C12)	ND	0.600		0	0						
Aromatic Hydrocarbon (C12-C13)	ND	7.00		0	0						
Benzene	ND	0.600		0	0						
Toluene	ND	0.700		0	0						
Ethylbenzene	ND	0.700		0	0						
m,p-Xylene	ND	1.30		0	0						
o-Xylene	ND	0.600		0	0						
Naphthalene	ND	0.500		0	0						Q
Methyl tert-butyl ether (MTBE)	ND	0.500		0	0						
Surr: 1,4-Difluorobenzene	2.79		2.500		112	65	140				
Surr: Bromofluorobenzene	2.58		2.500		103	65	140				

Work Order: 1812108
CLIENT: Friedman & Bruya
Project: 812105

QC SUMMARY REPORT

Volatile Petroleum Hydrocarbons by NWVPH

Sample ID **MB-22936** SampType: **MBLK** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48371**
Client ID: **MBLKS** Batch ID: **22936** Analysis Date: **12/14/2018** SeqNo: **946758**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

NOTES:
Q - Indicates an analyte with a continuing calibration that does not meet established acceptance criteria

Sample ID **1812108-011BDUP** SampType: **DUP** Units: **mg/Kg** Prep Date: **12/13/2018** RunNo: **48371**
Client ID: **KMW10-LNAPL** Batch ID: **22936** Analysis Date: **12/14/2018** SeqNo: **946752**

Analyte	Result	RL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aliphatic Hydrocarbon (C5-C6)	1,290	151		0	0			1,316	2.12	25	D
Aliphatic Hydrocarbon (C6-C8)	17,200	216		0	0			17,450	1.68	25	DE
Aliphatic Hydrocarbon (C8-C10)	55,400	121		0	0			54,710	1.18	25	DE
Aliphatic Hydrocarbon (C10-C12)	31,600	129		0	0			36,050	13.1	25	DE
Aromatic Hydrocarbon (C8-C10)	128,000	259		0	0			127,600	0.649	25	DE
Aromatic Hydrocarbon (C10-C12)	65,500	51.7		0	0			71,620	8.91	25	DEQ
Aromatic Hydrocarbon (C12-C13)	24,100	603		0	0			27,640	13.6	25	DEQ
Benzene	71.4	51.7		0	0			68.48	4.14	25	D
Toluene	3,480	60.3		0	0			3,357	3.52	25	D
Ethylbenzene	7,200	60.3		0	0			7,023	2.51	25	DE
m,p-Xylene	49,300	112		0	0			47,780	3.15	25	DE
o-Xylene	22,700	51.7		0	0			21,870	3.62	25	DE
Naphthalene	8,860	43.1		0	0			8,621	2.74	25	DEQ
Methyl tert-butyl ether (MTBE)	ND	43.1		0	0			0		25	D
Surr: 1,4-Difluorobenzene	270		215.5		125	65	140		0		D
Surr: Bromofluorobenzene	289		215.5		134	65	140		0		D

NOTES:
Q - Indicates an analyte with a continuing calibration that does not meet established acceptance criteria
E - Estimated value. The amount exceeds the linear working range of the instrument.

Fremont *Analytical*

Sample Log-In Check List

Client Name: **FB** Work Order Number: **1812108**

Logged by: **Brianna Barnes** Date Received: **12/10/2018 11:57:00 AM**

Chain of Custody

1. Is Chain of Custody complete? Yes ☑ No ☐ Not Present ☐
2. How was the sample delivered? Client

Log In

3. Coolers are present? Yes ☐ No ☑ NA ☐

Samples received at appropriate temperature.

4. Shipping container/cooler in good condition? Yes ☑ No ☐
5. Custody Seals present on shipping container/cooler? Yes ☐ No ☐ Not Required ☑
(Refer to comments for Custody Seals not intact)
6. Was an attempt made to cool the samples? Yes ☑ No ☐ NA ☐
7. Were all items received at a temperature of >0°C to 10.0°C * Yes ☑ No ☐ NA ☐
8. Sample(s) in proper container(s)? Yes ☑ No ☐
9. Sufficient sample volume for indicated test(s)? Yes ☑ No ☐
10. Are samples properly preserved? Yes ☑ No ☐
11. Was preservative added to bottles? Yes ☑ No ☐ NA ☐
MeOH VOA extracted for 011B.
12. Is there headspace in the VOA vials? Yes ☐ No ☐ NA ☑
13. Did all samples containers arrive in good condition(unbroken)? Yes ☑ No ☐
14. Does paperwork match bottle labels? Yes ☑ No ☐
15. Are matrices correctly identified on Chain of Custody? Yes ☑ No ☐
16. Is it clear what analyses were requested? Yes ☑ No ☐
17. Were all holding times able to be met? Yes ☑ No ☐

Special Handling (if applicable)

18. Was client notified of all discrepancies with this order? Yes ☐ No ☐ NA ☑

Person Notified: Date

By Whom: Via: ☐ eMail ☐ Phone ☐ Fax ☐ In Person

Regarding:

Client Instructions:

19. Additional remarks:

Item Information

Item #	Temp °C
Sample	1.7

* Note: DoD/ELAP and TNI require items to be received at 4°C +/- 2°C

SUBCONTRACT SAMPLE CHAIN OF CUSTODY

1012108

Page # 1 of 2

Send Report To Michael Erdahl
Company F&Binc
Address 3012 16th Ave W
City, State, ZIP Seattle, WA 98119
Phone # Fax #

SUBCONTRACTOR Fremont

PROJECT NAME/NO.	PO #
812105	A-651

REMARKS
EQUIS EDD

TURNAROUND TIME
☒ Standard ~~(2 Weeks)~~ 1 week
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☐ Dispose after 30 days
☐ Return samples
☐ Will call with instructions

						ANALYSES REQUESTED										
Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Containers	CO2	Sulfate									Notes
DSW-Miltpt03-10.0		12/4/2018	1521	GW	1	X	X									
DSW-Miltpt03-11.0		12/4/2018	1638	GW	1	X	X									
DSW-Miltpt03-12-14		12/5/2018	840	GW	1	X	X									
DSW-Miltpt03-15-17		12/5/2018	915	GW	1	X	X									
DSW-Miltpt05-9-11		12/5/2018	1040	GW	1	X	X									
DSW-Miltpt05-12-14		12/5/2018	1125	GW	1	X	X									
DSW-Miltpt05-16-18		12/5/2018	1200	GW	1	X	X									
DSW-Miltpt10-10-12		12/5/2018	1355	GW	1	X	X									
DSW-Miltpt10-13-15		12/5/2018	1425	GW	1	X	X									
DSW-Miltpt10-16-18		12/5/2018	1515	GW	1	X	X									

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282
Fax (206) 283-5044

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Michael Erdahl	F&Binc	12/10/18	0920
Received by:	Carter Johnson	FAI	12/10/18	1157
Relinquished by:				
Received by:				

FORMS\COC\COC.DOC

SAMPLE CHAIN OF CUSTODY

Report To Michael Erdahl

Company

Address

City, State, ZIP

Phone Email

SAMPLERS (*signature*) Fremont	
PROJECT NAME 812105	PO # A-651
REMARKS	INVOICE TO

Page # 2 of 2

TURNAROUND TIME
☒ Standard Turnaround
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☐ Dispose after 30 days
☐ Archive Samples
☐ Other

						ANALYSES REQUESTED											
Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Jars	TPH-HCID	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260C	SVOCs by 8270D	PAHs 8270D SIM	EPH	VPH			Notes
KMW10-L NAPL		12/4/16	12:15	product	3								X	X			

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Michael Erdahl	F& Bru	12/10/18	0920
Received by:	Carter Johnson	FAI	12/10/18	1157
Relinquished by:				
Received by:				

812105

(SOIL)

SAMPLE CHAIN OF CUSTODY

ME 12-07-18 VNS BI4 / VS3 / D02

Page # 1 of 4

Report To Yen-Vy Van

Company MFA

Address 2815 2nd St #540

City, State, ZIP Seattle, WA 98121

Phone 253-320-5378 Email yvan@maulfoster.com

SAMPLERS (*signature*)	
PROJECT NAME Former Tiger Oil HRSC	PO # 0818.02.01 Task 17
REMARKS	INVOICE TO MFA

TURNAROUND TIME
☒ Standard Turnaround
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☒ Dispose after 30 days
☐ Archive Samples
☐ Other

Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Jars	TPH-HCID	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260C	SVOCs by 8270D	PAHs 8270D SIM					Notes
DSS-OIP2-10.0	01 A-E	12/3/18	1611	Soil	5			X	X								
DSS-OIP2-11.0	02		1629					X	X								
DSS-OIP2-12.0	03		1636					X	X								
DSS-OIP2-14.0	04		1642					X	X								
DSS-OIP2-15.0	05		1648					X	X								
DSS-OIP2-19.0	06		1656					X	X								
DSS-OIP2-20.0	07		1659					X	X								
DSS-OIP2-21.0	08		1707					X	X								
DSS-OIP2-22.0	09		1712					X	X								Samples received at 3 °C
DSS-OIP2-23.0	10		1719					X	X								

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Yen-Vy Van	MFA	12/5/18	1745
Received by:	Don	FBI	12-7-18	14.45
Relinquished by:				
Received by:				

812105

Soil

SAMPLE CHAIN OF CUSTODY

ME 12-07-18 vw /BI4 /VS3

DO

Page # 2 of 4

Report To Yen-Vy Van
Company MFA
Address 2815 2nd St #540
City, State, ZIP Seattle, WA 98121
Phone 253-320-5378 Email yvan@maulfoster.com

SAMPLERS (signature)	
PROJECT NAME Former Tiger Oil HRSC	PO # 0818.02.01 Task 17
REMARKS	INVOICE TO MFA

TURNAROUND TIME
☒ Standard Turnaround
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☒ Dispose after 30 days
☐ Archive Samples
☐ Other

						ANALYSES REQUESTED											
Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Jars	TPH-HCID	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260C	SVOCs by 8270D	PAHs 8270D SIM					Notes
DSS-OIP7-14.0	11 A-E	12/4/18	0916	Soil	5			X	X								
DSS-OIP7-15.0	12		0919					X	X								
DSS-OIP7-16.0	13		0926					X	X								
DSS-OIP7-19.0	14		0940					X	X								
DSS-OIP7-20.0	15		0945					X	X								
DSS-OIP7-21.0	16		0950					X	X								
DSS-OIP6-8.5	17		1120					X	X								
DSS-OIP6-9.0	18		1125					X	X								
DSS-OIP6-10.0	19		1127					X	X								Samples received at 3 °C
DSS-OIP6-13.0	20		1135					X	X								

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Yen-Vy Van	MFA	12/5/18	1745
Received by:	Dd Vo	F&BI	12-7-18	14.45
Relinquished by:				
Received by:				

812105

SAMPLE CHAIN OF CUSTODY

ME 12-07-18 VW5/ BI4 /VS3 D02

Page # 3 of 4

Report To Yen-Vy Van
Company MFA
Address 2815 2nd St #540
City, State, ZIP Seattle, WA 98121
Phone 253-320-5378 Email yvan@maulfoster.com

SAMPLERS (signature)

PROJECT NAME	PO #
Yen-Vy Van	0818.02.01 Task 17
REMARKS Former Tiger Oil HRSC	INVOICE TO

TURNAROUND TIME
☒ Standard Turnaround
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☒ Dispose after 30 days
☐ Archive Samples
☐ Other

						ANALYSES REQUESTED											
Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Jars	TPH-HCID	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260C	SVOCs by 8270D	PAHs 8270D SIM					Notes
DSS-OIP6-14.0	21 A-E	12/4/18	1140	soil	5			X	X								
DSS-OIP10-4.0	22		1345					X	X								
DSS-OIP10-5.0	23		1548 1347	NP				X	X								
DSS-OIP10-6.0	24		1352					X	X								
DSS-OIP10-7.0	25		1355					X	X								
DSS-OIP10-8.0	26		1402					X	X								
DSS-OIP10-9.0	27		1406					X	X								
DSS-OIP10-10.0	28		1410					X	X								Samples received at 3 °C
DSS-OIP10-11.0	29		1418					X	X								
DSS-OIP10-12.0	30		1423					X	X								

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Yen-Vy Van	MFA	12/5/18	1745
Received by:	D of IO	F&BI	12-7-18	14:45
Relinquished by:				
Received by:				

812105 GW

SAMPLE CHAIN OF CUSTODY

ME 12-07-18 VW5/ BI4 /VS3 D02

Page # 4 of 4

Report To Yen-Vy Van

Company MFA

Address 2815 2nd St #540

City, State, ZIP Seattle, WA 98121

Phone 253-320-5378 Email yvan@maulfoster.com

SAMPLERS (signature)

PROJECT NAME Former Tiger Oil HRSC

PO # 0818.02.01 Task 17

REMARKS

INVOICE TO

TURNAROUND TIME
☑ Standard Turnaround
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☑ Dispose after 30 days
☐ Archive Samples
☐ Other

						ANALYSES REQUESTED											
Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Jars NP	TPH-HCID	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260C	SVOCs by 8270D	PAHs 8270D SIM	Is	SO4	CH4	CO2	Notes
DSW-MiHpt03-10.0	31 A-H	12/4/18	1521	GW	8			X	X				X	X	X	X	
DSW-MiHpt03-11.0	32	12/4/18	1638					X	X				X	X	X	X	
DSW-MiHpt03-12-14	33	12/5/18	0840					X	X				X	X	X	X	
DSW-MiHpt03-15-17	34	12/5/18	0915					X	X				X	X	X	X	
DSW-MiHpt05-9-11	35	12/5/18	1040					X	X				X	X	X	X	
DSW-MiHpt05-12-14	36	12/5/18	1125					X	X				X	X	X	X	
DSW-MiHpt05-16-18	37	12/5/18	1200					X	X				X	X	X	X	
DSW-MILTPT10 (NP) -10-12	38	12/5/18	1355					X	X				X	X	X	X	
DSW-MILTPT10 (NP) -13-15	39	12/5/18	1425					X	X				X	X	X	X	
DSW-MILTPT10 (NP) -16-18	40	12/5/18	1515		6			X	X				X	X	X	X	
TripBlank	41 A-F			water													

Samples received at 3 °C

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Yen-Vy Van	MFA	12/5/18	1745
Received by:	DD	F&BI	12-7-18	14:45
Relinquished by:				
Received by:				

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282

812105

SAMPLE CHAIN OF CUSTODY

ME 12/07/18 VW5/ BD4/ VS3

D02

Report To Yen-Vy Van
Company MFA
Address
City, State, ZIP
Phone Email

SAMPLERS (*signature*)

PROJECT NAME Former Tiger Oil HRSC	PO # 0818.02.01 TASK 17
REMARKS + COC generated at lab Nej 12/7	INVOICE TO

Page # 5 of

TURNAROUND TIME
☐ Standard Turnaround
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☐ Dispose after 30 days
☐ Archive Samples
☐ Other

						ANALYSES REQUESTED											
Sample ID	Lab ID	Date Sampled	Time Sampled	Sample Type	# of Jars	TPH-HCID	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260C	SVOCs by 8270D	PAHs 8270D SIM	EPH/VPH				Notes
KMW10 - LNAPL	42-A-F	12/4/18	12:15	Prod.	6								⊗				⊗ - per YW
																	12/10/16 ME

Samples received at 3 °C

Friedman & Bruya, Inc.
3012 16th Avenue West
Seattle, WA 98119-2029
Ph. (206) 285-8282

	SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:					
Received by:		Nhan Phan	F&BT	12/7/18	1445
Relinquished by:					
Received by:					

APPENDIX D

DATA VALIDATION MEMORANDUM

DATA QUALITY ASSURANCE/QUALITY CONTROL REVIEW

PROJECT NO. 0818.02.01 | APRIL 26, 2019| CITY OF YAKIMA

Maul Foster & Alongi, Inc. (MFA) conducted an independent review of the quality of analytical results for soil, groundwater, and product samples collected at the former Tiger Oil site located in Yakima, Washington. The samples were collected on December 4 and 5, 2018.

Friedman & Bruya, Inc. (FBI) and Fremont Analytical (FA) performed the analyses. FBI report number 812105 and FA report 1812108 were reviewed. Samples were subcontracted by FBI to FA for some analysis and subcontracted report 1812108 is appended to 812105. The analyses performed and samples analyzed are listed below.

Analysis	Reference
Anions	USEPA 300.0
BTEX	USEPA 8021B
Total Alkalinity (Carbon Dioxide)	SM 2320B
Extractable- and Volatile-Petroleum Hydrocarbons	NWTPH-EPH/NWTPH-VPH
Gasoline-Range Hydrocarbons	NWTPH-Gx
Dissolved Gases	RSK-175
Percent Moisture	ASTM D2216-98
Total Metals	USEPA 6020B

ASTM = American Society for Testing and Materials.
BTEX = Benzene, toluene, ethylbenzene, and total xylenes.
NWTPH = Northwest Total Petroleum Hydrocarbons.
RSK = USEPA National Risk Management Research Laboratory.
SM = Standard Methods for the Examination of Water and Wastewater.
USEPA = U.S. Environmental Protection Agency.

Samples Analyzed			
Report 812105/1812108			
DSS-OIP2-10.0	DSS-OIP7-15.0	DSS-OIP10-5.0	DSW-Miltpt03-15-17
DSS-OIP2-11.0	DSS-OIP7-16.0	DSS-OIP10-6.0	DSW-Miltpt05-9-11
DSS-OIP2-12.0	DSS-OIP7-19.0	DSS-OIP10-7.0	DSW-Miltpt05-12-14
DSS-OIP2-14.0	DSS-OIP7-20.0	DSS-OIP10-8.0	DSW-Miltpt05-16-18
DSS-OIP2-15.0	DSS-OIP7-21.0	DSS-OIP10-9.0	DSW-Miltpt10-10-12
DSS-OIP2-19.0	DSS-OIP6-8.5	DSS-OIP10-10.0	DSW-Miltpt10-13-15
DSS-OIP2-20.0	DSS-OIP6-9.0	DSS-OIP10-11.0	DSW-Miltpt10-16-18
DSS-OIP2-21.0	DSS-OIP6-10.0	DSS-OIP10-12.0	Trip Blank
DSS-OIP2-22.0	DSS-OIP6-13.0	DSW-Miltpt03-10.0	KMW10-LNAPL
DSS-OIP2-23.0	DSS-OIP6-14.0	DSW-Miltpt03-11.0	-
DSS-OIP7-14.0	DSS-OIP10-4.0	DSW-Miltpt03-12-14	-

DATA QUALIFICATIONS

Analytical results were evaluated according to applicable sections of USEPA procedures (USEPA, 2017a,b) and appropriate laboratory and method-specific guidelines (FA, 2017; FBI, 2015); USEPA, 1986).

Data validation procedures were modified, as appropriate, to accommodate quality-control requirements for methods not specifically addressed by the USEPA procedures (e.g., NWTPH-Gx).

The data are considered acceptable for their intended use, with the appropriate data qualifiers assigned.

HOLDING TIMES, PRESERVATION, AND SAMPLE STORAGE

Holding Times

Extractions and analyses were performed within the recommended holding time criteria.

Preservation and Sample Storage

The samples were preserved and stored appropriately.

BLANKS

Method Blanks

Laboratory method blank analyses were performed at the required frequencies. For purposes of data qualification, the method blanks were associated with all samples prepared in the analytical batch.

In FA report 1812108, SM 2320B batch quality control results were reported with a total alkalinity method blank instead of a carbon dioxide method blank. The reviewer confirmed that the carbon dioxide sample results reported by SM 2320B are calculated (as specified in SM 4500-CO2-D) based on alkalinity, and that when total alkalinity is non-detect, the concentration of carbon dioxide cannot be calculated. The reviewer confirmed that a non-detect carbon dioxide method blank may be inferred from a non-detect total alkalinity method blank, as carbon dioxide concentration is dependent on the total carbonate concentration used to derive alkalinity. No additional action was required.

All remaining laboratory method blanks were non-detect to laboratory reporting limits.

Trip Blanks

Trip blanks were not required for this sampling event.

Equipment Rinsate Blanks

Equipment rinsate blanks were not required for this sampling event, as all samples were collected using dedicated, single-use equipment.

SURROGATE RECOVERY RESULTS

The samples were spiked with surrogate compounds to evaluate laboratory performance on individual samples. The laboratory appropriately documented and qualified surrogate outliers. All surrogate recoveries were within acceptance limits.

MATRIX SPIKE/MATRIX SPIKE DUPLICATE RESULTS

Matrix spike/matrix spike duplicate (MS/MSD) results are used to evaluate laboratory precision and accuracy All MS/MSD samples were extracted and analyzed at the required frequency. All MS/MSD results were within acceptance limits for percent recovery and relative percent difference (RPD).

LABORATORY DUPLICATE RESULTS

Duplicate results are used to evaluate laboratory precision. All duplicate samples were extracted and analyzed at the required frequency. Laboratory duplicate results within five times the MRL were not evaluated for precision.

In FBI report 812105, the USEPA Method 8021B water matrix laboratory duplicate (812105-31 [Duplicate]) exceeded the RPD control limit of 20% for total xylenes, at 21%. The reviewer confirmed that the laboratory duplicate and associated sample result were less than five times the MRL. Qualification was not required.

In FA report 1812108, the NWTPH-VPH laboratory duplicate exceeded several upper instrument calibration range limits. The reviewer confirmed that while the sample was reported with results from multiple dilutions, the laboratory duplicate was reported from a single, 1:10 diluted result. All RPDs were within control limits; thus, no associated sample results were qualified.

All remaining laboratory duplicate RPDs were within acceptance limits.

LABORATORY CONTROL SAMPLE/LABORATORY CONTROL SAMPLE DUPLICATE RESULTS

An LCS/LCSD is spiked with target analytes to provide information on laboratory precision and accuracy. The LCS/LCSD samples were extracted and analyzed at the required frequency.

In FA report 1812108, the NWTPH-EPH LCS and LCSD results for aliphatic hydrocarbon carbon (C)8-C10 were below the lower percent recovery acceptance limit of 70%, at 54.2% and 54.9%, respectively. The LCS and LCSD results for aromatic hydrocarbon C8-C10 were also below the lower percent recovery acceptance limit of 70%, at 44.3% and 60.2%, respectively, and the aromatic C8-C10 RPD control limit of 20% was exceeded, at 30.4%. The reviewer confirmed that FA did not attempt a reanalysis, as EPH extraction routinely returns low C8-C10 aliphatic and aromatic LCS/LCSD percent recoveries. The associated sample results have been qualified by the reviewer with "J-," as estimated with a low bias, in the following table.

In FA report 1812108, the NWTPH-EPH LCS and LCSD results for aromatic hydrocarbon C8-C10 were below the lower percent recovery acceptance limit of 70%, at 44.3% and 60.2%, respectively, and the LCS/LCSD control limit for aromatic C8-C10 of 20% was exceeded, at 30.4%. The associated sample results have been qualified by the reviewer with "J," as estimated, in the following table.

Report	Sample	Component	Original Result (mg/kg)	Qualified Result (mg/kg)
1812108	KMW10-LNAPL	Aliphatic Hydrocarbon C8-C10	229000	229000 J-
		Aromatic Hydrocarbon C8-C10	21900	21900 J-

NOTES:
J- = The result is estimated with a low bias.
mg/kg = milligrams per kilograms.

In FA report 1812108, the NWTPH-EPH LCS also had aromatic hydrocarbon C10-C12 results below the lower percent recovery acceptance limit of 70%, at 60.6%. The associated LCSD percent recovery and LCS/LCSD RPD control limit met acceptance criteria; thus, no results were qualified.

In FA report 1812108, the NWTPH-VPH LCSD result for aliphatic hydrocarbon C8-C10 was flagged by FA due to percent recovery acceptance limit exceedance. The percent recovery was at the lower percent recovery acceptance limit of 70.0%; thus, no results were qualified. The NWTPH-VPH LCS/LCSD for aliphatic hydrocarbon C6-C8 exceeded the RPD control limit of 20%, at 31.3%. The associated sample result has been qualified by the reviewer with "J," as estimated, in the following table.

Report	Sample	Component	Original Result (mg/kg)	Qualified Result (mg/kg)
1812108	KMW10-LNAPL	Aliphatic Hydrocarbon C6-C8	19400	19400 J

NOTES:
J = The result is estimated.
mg/kg = milligrams per kilograms.

All remaining LCS/LCSD results were within acceptance limits for percent recovery and RPD.

FIELD DUPLICATE RESULTS

Field duplicate samples measure both field and laboratory precision. Field duplicate samples were not submitted for analysis.

CONTINUING CALIBRATION VERIFICATION RESULTS

Continuing calibration verification (CCV) results are used to demonstrate instrument precision and accuracy through the end of the sample batch. CCV results were not reported. If quality control results met acceptance criteria, flags of quality control analytical results for CCV exceedances required no action from the reviewer.

In FA report 1812108, the NWTPH-VPH naphthalene result was flagged by FA due to a continuing calibration verification result that did not meet acceptance criteria. The result has been qualified by the reviewer with "J" as estimated.

Report	Sample	Component	Original Result (mg/kg)	Qualified Result (mg/kg)
1812108	KMW10-LNAPL	Naphthalene	12900	12900 J

NOTES:
J = The result is estimated.
mg/kg = milligrams kilograms.

In FA report 1812108, the NWTPH-VPH laboratory duplicate aromatic hydrocarbon C10-C12, C12-C13, and naphthalene results were flagged by FA due to a continuing calibration verification result that did not meet acceptance criteria. The laboratory duplicate results were also flagged due to exceedance of the upper instrument calibration range. The laboratory duplicate results met RPD control limits; thus, no associated sample results were qualified.

REPORTING LIMITS

FBI and FA used laboratory reporting limits for non-detect results, except for samples requiring dilutions because of high analyte concentrations and/or matrix interferences.

DATA PACKAGE

The data packages were reviewed for transcription errors, omissions, and anomalies.

In report 812105, product sample KMW10-LNAPL was submitted to FBI but was not recorded on the chain of custody (COC). FBI generated a separate COC with the sample and laboratory receipt information and indicated that NWTPH-EPH and NWTPH-VPH analysis was confirmed with the MFA project manager. The date of the confirmed analysis was recorded incorrectly as 12/10/2016 instead of 12/10/2018. The laboratory-generated COC was appended to the report. No action was required by the reviewer.

No additional issues were found.

REFERENCES

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