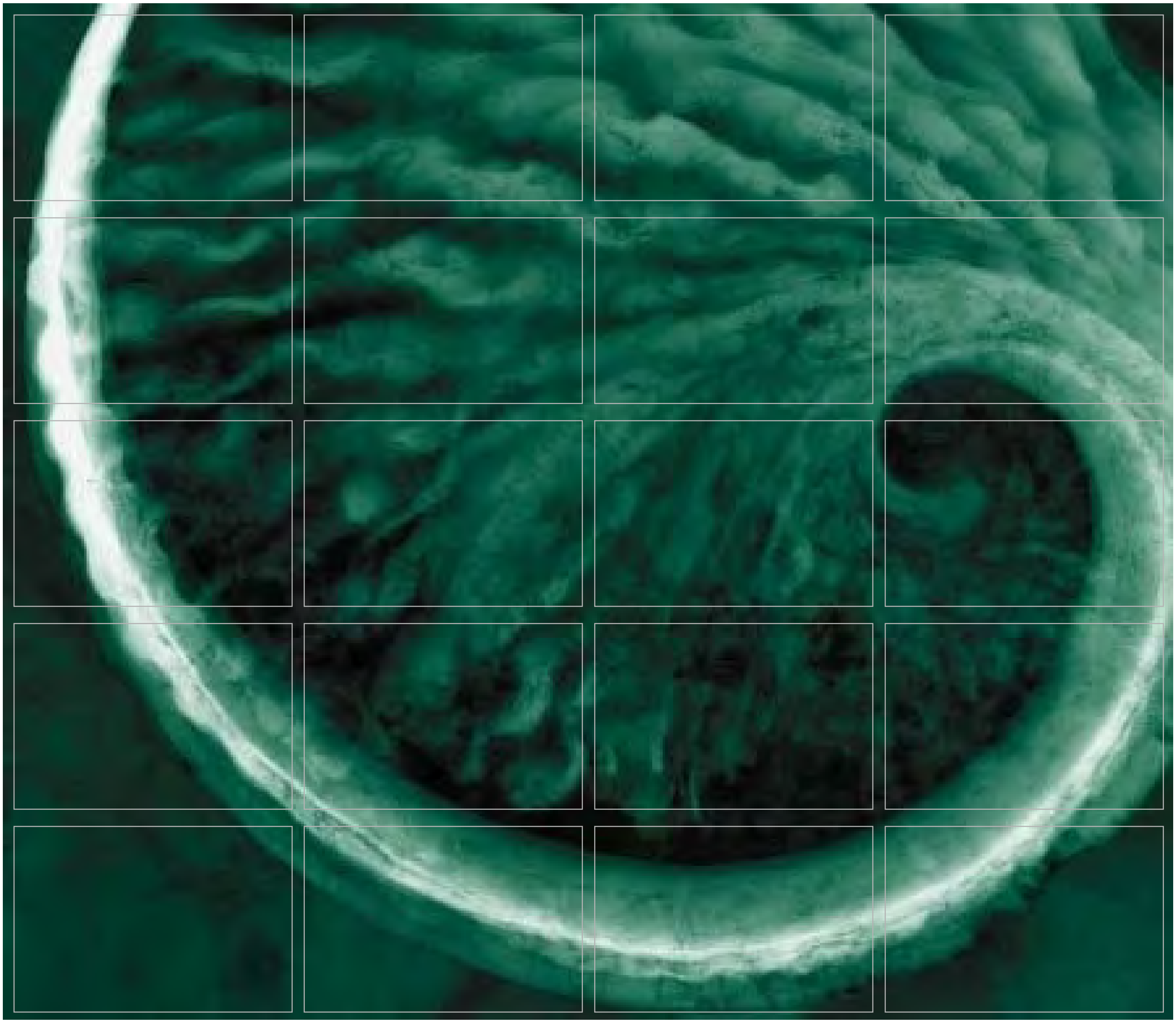


Remedial Investigation/Feasibility Study Report

BNSF Railway Black Tank Property
3202 East Wellesley Avenue
Spokane, Washington

March 2017

www.erm.com

Prepared for:
BNSF Railway Company
Husky Oil Operations Limited

The business of sustainability

ERM

BNSF Railway Company
Husky Oil Operations Limited

Remedial Investigation/ Feasibility Study Report

BNSF Railway Black Tank Property
3202 East Wellesley Avenue
Spokane, Washington

March 2017

ERM Project No. 0366860

DRAFT

Mark Ransom, P.E.
Partner-in-Charge
ERM-West, Inc.

DRAFT

David Edwards
Project Manager
ERM-West, Inc.

DRAFT

Tom Briggs, P.E., LHG
RI Team Leader
Landau Associates, Inc.

DRAFT

Merv Coover, P.E.
FS Team Leader
ERM-West, Inc.

ERM-West, Inc.
1218 3rd Avenue, Suite 1412
Seattle, Washington 98101
T: 425-462-8591
F: 425-455-3573

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

°C	Degrees Celsius
°F	Degrees Fahrenheit
ACM	Asbestos-containing material
amsl	Above mean sea level
AO	Agreed Order
API	American Petroleum Institute
AST	Aboveground storage tank
ASTM	ASTM International
Blackline	Blackline Asphalt Sales, Inc.
BNSF	Burlington Northern Santa Fe
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAP	Cleanup Action Plan
CC2	Center and Corridor Core
CH_4	Methane
cm	Centimeters
cm/second	Centimeters per second
CO_2	Carbon dioxide
COC	Constituent of concern
COPC	Constituent of potential concern
cPAH	Carcinogenic polycyclic aromatic hydrocarbon
CRBG	Columbia River Basalt Group
CSCSL	Confirmed and Suspected Contaminated Sites List
CSM	Conceptual site model
CUL	Cleanup level
DCA	Disproportionate cost analysis
DO	Dissolved oxygen
Ecology	Washington State Department of Ecology
EPH	Extractable petroleum hydrocarbon
ERM	ERM-West, Inc./Environmental Resources Management
EWE	Environmental West Exploration, Inc.
feet^2/day	Feet squared per day

feet/feet	feet per feet
FS	Feasibility study
ft bgs	Feet below ground surface
g/cc	Grams per cubic centimeter
gal HC/ac-yr	Gallons of hydrocarbons per acre per year
GIS	Geographic Information System
IDW	Investigation derived waste
ISR	In-situ respiration testing
ITRC	Interstate Technology & Regulatory Council
kg/hr	Kilograms per hour
LDRM	LNAPL Distribution and Recovery Model
LI	Light Industrial
LNAPL	Light non-aqueous phase liquid
LVP	LNAPL Vertical Profile
Marathon	Marathon Oil Company
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MTCA	Model Toxics Control Act
mV	Millivolts
MW	monitoring well
NAPL	Non-aqueous phase liquid
ND	Non-detect
NSC	North Spokane Corridor
NSZD	Natural source zone depletion
O_2	Oxygen
PAH	Polycyclic aromatic hydrocarbon
PAS	Performance Abatement Services, Inc.
PCB	Polychlorinated biphenyl
PID	photoionization detector
PLP	Potentially liable person
ppm	Parts per million
PTS	PTS Laboratories, Inc.
PVC	Polyvinyl chloride
QAPP	Quality Assurance Project Plan

RCW	Revised Code of Washington
RI	Remedial investigation
RTF	Restoration timeframe
SAP	Sampling and Analysis Plan
SEE	Steam enhanced LNAPL extraction
SemMaterials	SemMaterials L.P.
SIM	Selected ion monitoring
Site	BNSF Railway Black Tank Site
STAR	Self-sustaining Treatment for Active Remediation
SVE	Soil vapor extraction
SVOC	Semi-volatile organic compound
SVRP	Spokane Valley Rathdrum Prairie
SWAP	Source Water Assessment Program
TEE	Terrestrial Ecological Evaluation
TEQ	Toxic Equivalency Quotient
TPH	Total petroleum hydrocarbon
TPH-D	Total petroleum hydrocarbons-diesel-range
TPH-D/HO	Total petroleum hydrocarbons-combined diesel and heavy oil-range
TPH-G	Total petroleum hydrocarbons-gasoline-range
TPH-HO	Total petroleum hydrocarbons-heavy oil-range
µg/L	Micrograms per liter
µS/cm	Microsiemens per centimeter
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
VPH	Volatile petroleum hydrocarbon
WAC	Washington Administrative Code
WSDFW	Washington State Department of Fish and Wildlife
WSDOH	Washington State Department of Health
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

The Remedial Investigation/Feasibility Study (RI/FS) Report presented herein for the Burlington Northern Santa Fe Railway (BNSF) Black Tank Property (the "Site") was prepared in accordance with Agreed Order No. 9188 between BNSF, Marathon Oil Company, and the Washington State Department of Ecology (Ecology). Marathon Oil Company's obligations for this project were performed by Husky Oil Operations Limited. The RI/FS was performed in compliance with the Model Toxics Control Act (MTCA), Chapter 173-340 Washington Administrative Code, the Agreed Order, and the Final RI/FS Project Plan, which was approved by Ecology on 28 February 2013.

Site History and Background

The Site, which is approximately 18.2 acres in size, is generally located at 3202 East Wellesley Avenue in Spokane, Washington (Figure ES-1). The Site encompasses several parcels owned by BNSF and one parcel owned by the State of Washington, via the Washington State Department of Transportation. The Site and surrounding properties are currently zoned Light Industrial and Center and Corridor Core. The Site is largely inactive, vacant, and unpaved. The majority of structures associated with previous operations have been removed. The primary land use at the Site is industrial (e.g., active main BNSF rail line and access roads). Future land use is expected to be the highway and rail line infrastructure proposed as part of the Washington State Department of Transportation's North Spokane Corridor (NSC) project.

Historical Site operations included railroad transport, three locomotive fueling and maintenance systems (i.e., the Black Tank system, the Red Tank system, and the Chemical Solution Pipeline), and an asphalt storage and transfer system (i.e., the Liquid Asphalt Pipeline). These systems are illustrated on Figure ES-1. The Black Tank system, which consisted of a large aboveground storage tank (AST), a smaller AST, a pump house, a large concrete sump, piping, and unloading stanchions, was used to store and transfer Bunker C (No. 6 fuel) oil for locomotive fuel from approximately 1928 to 1955. A Chemical Solution Pipeline and an elevated steam pipeline operated concurrent with the Black Tank system. The purpose of the Chemical Solution Pipeline is uncertain, but the steam was used to heat heavy oil. From 1955 to the mid- to late-1980s, the Black Tank was used by BNSF's tenants to store asphalt and other petroleum-based mixtures that were transferred to the adjacent SemMaterials L.P. facility via the Liquid Asphalt Pipeline. By 2006, BNSF had decommissioned and demolished much of the aboveground structures and removed approximately 10,270 tons of petroleum-impacted soil from the area beneath and in the immediate vicinity of the former Black Tank. The Red Tank system, which included a large AST, two pump houses, smaller diesel and oil tanks, piping, and fuel dispensers, was used to store and transfer diesel for locomotive fuel from approximately 1955 to the mid- to late-1980s.

Physical Setting, Geology, and Hydrogeology

The Site is situated at an elevation of approximately 2,035 feet above mean sea level (amsl). The Site is relatively flat with a few piles of soil and debris up to 5 feet high and low areas up to 10 feet deep along the rail lines and at the former Black Tank excavation. Storm water generally stays within the Site boundaries and either infiltrates through the highly permeable soil or evaporates. The nearest surface water is the Spokane River approximately 1.5 miles south of the Site. The Little Spokane River is located approximately 6 miles north-northwest of the Site.

Pleistocene glaciofluvial flood deposits, consisting of interbedded sand and gravel deposits, are the primary geological unit beneath the Site and in the Hillyard Trough area. The sand and gravel deposits are generally gray to brown, poorly sorted, and contain more gravel at shallow depths. Discontinuous lenses of silt and silty sand are scattered throughout the sand and gravel deposits, and a mostly laterally continuous layer of the silt and silty sand facies occurs near the groundwater table at depths of 156 to 180 feet below ground surface (ft bgs) (see Figure ES-2).

The uppermost groundwater beneath the Site and throughout the Hillyard Trough area is the Spokane Valley Rathdrum Prairie (SVRP) aquifer. The SVRP aquifer is a sole-source drinking water aquifer, supplying more than 500,000 residents in the region. The top of the aquifer was encountered at depths ranging from approximately 158 to 179 ft bgs (1,861 to 1,868 feet amsl) and groundwater levels have fluctuated 4 to 7 feet annually (Figure ES-2). Groundwater flows to the north-northwest with a horizontal hydraulic gradient of approximately 0.0013 to 0.0014 feet per feet. Beneath the Site, the aquifer is generally unconfined (Figure ES-2). The groundwater flow velocities in the SVRP aquifer are generally very high (i.e., in excess of 60 feet per day in some areas). However, hydraulic conductivity testing of samples of the silt and silty sand facies layer at the top of the aquifer beneath the Site performed during the RI field investigation indicates much lower groundwater velocities in that portion of the aquifer.

Seven active downgradient public drinking water systems have been identified within 6 miles of the Site. Six of these systems have groundwater supply wells located between 2 and 6 miles of the Site, and one system (City of Spokane) includes two wells located between 0.8 and 1.8 miles of the Site in a cross-gradient or upgradient direction. No water wells were identified within 0.5 miles of the Site at the time of the review.

Summary of Remedial Investigation Findings

The RI dataset yielded sufficient information to identify chemicals of concern that exceed preliminary cleanup levels (CULs). The chemicals of concern and preliminary CULs identified for surface soil (≤15 ft bgs), subsurface soil (>15 ft bgs), and groundwater at the Site are summarized in Table ES-1. Consistent with Ecology's 2016 Guidance for Remediation of Petroleum Contaminated Sites, surface soils are defined as soils from ground surface to 15 ft bgs (i.e., ≤15 ft bgs).

Preliminary CULs developed for the Site are based on protection of: (1) direct contact with soils by current and future on-Site workers and the general public, and (2) direct contact and ingestion of groundwater by future on-Site and off-Site groundwater users. Although the Site is currently used for industrial purposes, its zoning allows for non-industrial uses. Therefore, MTCA Method A CULs for unrestricted land use are selected for surface (≤15 ft bgs) soils at the Site, Site-specific MTCA Method B CULs for protection of groundwater were calculated for subsurface (>15 ft bgs) soils using the MTCA models, and MTCA Method A CULs are selected for groundwater at the Site. These preliminary CULs are the most stringent state standards and would be protective if the Site were ever developed for residential use.

Soil and groundwater sampling performed at the Site identified areas of petroleum contamination exceeding the preliminary CULs in: (1) surface soil, (2) intermediate soil, (3) light non-aqueous phase liquid (LNAPL) and smear zone soil, and (4) groundwater. Analytical testing shows the petroleum contamination is a mix of Bunker C, asphaltic oils, and diesel (i.e., heavy oil- and diesel-range hydrocarbons) that is weathered and viscous (i.e., it has a consistency similar to honey). The areas of petroleum contamination are illustrated on Figure ES-3 and described below.

Site data show that petroleum product releases in the vicinity of the Black Tank, Red Tank dispensers, and Liquid Asphalt Pipeline were generally limited to surface soils and did not migrate to groundwater, whereas petroleum product releases in the vicinity of the Black Tank Sump and the Blank Tank and Chemical Solution Pipelines and Dispensers migrated in narrow vertical columns from the surface soil to the groundwater table at approximately 175 ft bgs.

There are five localized areas of surface soil (≤15 ft bgs) that exhibit petroleum hydrocarbon concentrations exceeding the preliminary CULs (see SSA-1 through SSA-5 on Figure ES-3). The impacted soil extends from ground surface to approximately 5 ft bgs in SSA-3 and SSA-5, and from ground surface to approximately 15 ft bgs in SSA-1, SSA-2, and SSA-4. The total volume of impacted surface soil is approximately 6,400 cubic yards.

There is one localized area of intermediate soil (i.e., 15 to 156 ft bgs) that exhibits petroleum hydrocarbon concentrations exceeding the preliminary CULs (see intermediate soil area on Figure ES-3). The area is approximately 9,150 square feet in size and encompasses the former Black Tank Sump, the Black Tank and Chemical Solution Pipelines, and the area immediately north of the former Black Tank (Figure ES-3). Although petroleum hydrocarbons are present in the intermediate soil area from ground surface to the smear zone, only two intervals (one at 66 to 67 ft bgs and the other at 116 to 117 ft bgs) exhibited petroleum hydrocarbon concentrations exceeding the preliminary CUL (Figure ES-2).

Petroleum products that have a lower density than water (i.e., gasoline, diesel, Bunker C oil) are referred to as LNAPL. In its 2009 guidance documents, the Interstate Technology & Regulatory Council (ITRC) LNAPL Team developed the following classifications for LNAPL in subsurface soils: migrating, mobile, and residual. Some of the LNAPL released at or near the surface will migrate downwards until, if sufficient product is released, it reaches the saturated zone. Migrating LNAPL will then move laterally or vertically driven by a pressure head in the LNAPL that forces it into adjacent soils resulting in plume expansion. Therefore, migrating LNAPL is observed to spread or expand laterally or vertically and result in an increased LNAPL extent, usually indicated by time-series data (ITRC 2009c). Migrating LNAPL is typically present during an active release (ITRC 2009c). LNAPL will stop migrating once the active release has stopped and the LNAPL driving pressure head has dissipated (ITRC 2009c). Mobile LNAPL is interconnected in pore spaces and has the potential to move under a hydraulic gradient, but does not have sufficient LNAPL head to migrate beyond its current footprint. Therefore, mobile LNAPL exceeds residual saturation and is identified by an accumulation of LNAPL in a monitoring well (ITRC 2009c). All migrating LNAPL is mobile LNAPL, but not all mobile LNAPL is migrating LNAPL (ITRC 2009b). Residual LNAPL occurs when the LNAPL capillary pressure is lower than the pore entry pressure, and the LNAPL is discontinuous in the soil pore spaces and immobile under the applied gradient (ITRC 2009c). Residual LNAPL is where stained soil and/or elevated contaminant concentrations indicate the presence of LNAPL in soil, but the LNAPL is not mobile (i.e., it can be identified in a soil core, but will not flow into a well).

Chemical and physical testing of the LNAPL indicates that most of the LNAPL is a relatively even mix of diesel and heavy oil (Bunker C and asphaltic oils), has a density less than but very close to that of water, and a very high viscosity (meaning that it would move thousands of times slower than water). Additionally, the low LNAPL transmissivities measured at the Site (0.0006 to 0.098 feet squared per day) and low LNAPL recovery rates obtained during LNAPL skimming field tests performed at the Site demonstrate that LNAPL migration under current conditions, if it were occurring, would be extremely slow. Collectively, these data suggest that LNAPL at the Site is predominantly residual and immobile, and that mobile LNAPL comprises a small portion of the overall LNAPL-impacted soil.

The vertical extent of mobile LNAPL (based on observations of LNAPL in groundwater monitoring wells and/or where laboratory analytical data suggest mobile LNAPL may be present) and residual LNAPL (based on the presence of stained soil and/or elevated contaminant concentrations indicative of LNAPL) is illustrated on Figure ES-2 and the lateral extent of mobile and residual LNAPL is illustrated on Figure ES-3. In plan-view (Figure ES-3), the total areal extent of LNAPL covers approximately 9.7 acres and shows that a band of residual LNAPL surrounds an approximately 6.0 acre area where both mobile and residual LNAPL are present. This feature combined with time-series data of the LNAPL footprint documents that the LNAPL footprint is receding, not expanding.

In cross-sectional view (Figure ES-2), less than 14% of the total LNAPL cross-section area includes mobile LNAPL, with more than 86% being residual LNAPL. The cross-section shows that the LNAPL is distributed:

- Vertically beneath the primary contaminant release areas in narrow columns from the ground surface down to a depth of approximately 156 ft bgs (1,883 feet amsl), and
- Horizontally in a lens-shaped zone generally centered across the groundwater table.

In this report, the horizontal lens of LNAPL is referred to as the smear zone, and it is defined by the presence of soil near the groundwater table that is stained and/or contains contaminant concentrations indicative of LNAPL. The smear zone is approximately 30 feet thick beneath the primary release areas, thinning laterally until it pinches out at the perimeter of the LNAPL footprint. As shown on Figure ES-2, the smear zone is roughly centered over the midpoint between the high and low groundwater levels measured during the RI. In the vicinity of the primary release area, the smear zone extends approximately 15 feet above and 15 feet below the midpoint between the high and low groundwater level. The thicker smear zone beneath the primary release area is the result of two release-related forces:

- The groundwater table and the silt and silty sand facies layer at the groundwater table initially hindered the downward migration of the LNAPL, causing it to mound and spread laterally.
- As the LNAPL head increased during and following the release, it depressed the groundwater table by approximately 15 feet and migrated into and through the silt and silty sand facies layer.

Away from the primary release area, the LNAPL head was less and the resulting smear zone is thinner (up to approximately 15 feet thick). In these areas, the smear zone is the result of vertical redistribution of LNAPL as a result of wicking action in the capillary fringe and seasonal changes in the groundwater table. Although groundwater levels have only varied a maximum of 7 feet during the RI, it is likely that they varied by as much as 15 feet in the 50 plus years since the LNAPL release(s) first occurred.

A thin, dissolved phase total petroleum hydrocarbons-combined diesel and heavy oil-range (TPH-D/HO) plume is situated beneath the LNAPL and appears to periodically extend downgradient of the LNAPL on a seasonal basis. Although historical groundwater data from on-Site monitoring wells have only rarely and inconsistently (five out of 139 samples) shown dissolved phase petroleum concentrations above the preliminary CULs, two of the past four groundwater monitoring events have shown TPH-D/HO concentrations (based on analyses without silica gel cleanup) exceeding the CULs in one or two downgradient monitoring wells. Petroleum metabolites generated from biodegradation of the LNAPL plume are believed to be the source of the downgradient TPH-D/HO concentrations exceeding preliminary CULs. The TPH-D/HO exceedances were observed to only occur during the summer and fall monitoring events when groundwater elevations were decreasing, suggesting a seasonal expansion and contraction of the dissolved phase TPH-D/HO plume resulting from the release of petroleum metabolites during periods of falling water table levels.

TPH-D/HO data from samples analyzed without silica gel cleanup show that the downgradient extent of the dissolved phase plume is not defined in the summer and fall, but is defined in the winter and spring. Although the data document some seasonal variation in the downgradient extent of the dissolved phase petroleum contamination, the long-term trend of low to non-detect TPH-D/HO (using silica gel cleanup data) and other petroleum constituents in the downgradient wells suggest that downgradient groundwater conditions are generally stable and/or decreasing. It is well understood that petroleum metabolites are highly degradable and are unlikely to persist at concentrations exceeding the CULs. Further, the concentrations of TPH-D/HO detected in the groundwater are low considering there is LNAPL at the Site, which suggests that leaching of residual petroleum constituents from the LNAPL to the groundwater is limited due to: (1) the low solubility of the LNAPL constituents, (2) the low permeability of the silt and silty sand facies in which much of the LNAPL resides, and/or (3) LNAPL blocking interconnected pore space through which groundwater might otherwise leach contaminants.

In summary, the petroleum releases at the Site stopped approximately 30 years ago, when the petroleum storage and transfer operations ceased. Without a continuing source, the LNAPL driving head dissipated over time and the LNAPL ceased migrating laterally. Analytical data from laboratory soil tests indicate that LNAPL is predominantly residual LNAPL with some mobile LNAPL. Data collected from multiple rounds of monitoring and the presence of residual LNAPL surrounding the area with mobile LNAPL indicate the lateral extent of the LNAPL smear zone is receding, not expanding. Additionally, the LNAPL is undergoing natural source zone depletion (NSZD), which is the combined influences of natural processes responsible for changing the composition or "weathering" the LNAPL and reducing LNAPL mass over time. NSZD rate assessment testing conducted at the Site shows that NSZD is active in both the vadose zone and saturated zone and that the majority of NSZD is occurring through biodegradation. Based on data collected to date, 800 gallons of hydrocarbons per acre per year (gal HC/ac-yr) appears to be a reasonable average NSZD rate for the Site. Similar sites have reported NSZD rates ranging from 510 to 7,700 gal HC/ac-yr, making a rate of 800 gal HC/ac-yr reasonable and conservative.

In accordance with MTCA regulatory requirements, cleanup of Site-related contamination identified during the RI will focus on achieving MTCA CULs at standard points of compliance specified in the regulation. The preliminary CULs for the Site media are summarized in Table ES-1, and the points of compliance are as follows:

- Surface Soil – ground surface to 15 ft bgs;
- Intermediate Soil – throughout the Site;
- Mobile LNAPL – throughout the Site; and
- Groundwater – throughout the Site.

Feasibility Study (FS)

Cleanup actions were developed and evaluated for the Site in accordance with MTCA regulatory requirements. The cleanup actions consist of one or more cleanup technologies that have the potential to achieve the preliminary CULs (Table ES-1). Cleanup actions for surface soil contamination are evaluated separately from cleanup actions for deep contamination (i.e., intermediate soil, LNAPL, and groundwater).

Surface Soil Cleanup Actions

The cleanup actions evaluated for surface soil contamination at the Site (i.e., areas SSA-1 through SSA-5) are:

- Capping and institutional controls, and

- Excavation.

Both cleanup actions protect human health and the environment, comply with MTCA cleanup standards, are readily implementable, and can be undertaken in a manner that complies with applicable state and federal laws. The recommended cleanup action for surface soil is excavation and off-site disposal because it is a more permanent solution.

Excavation will ensure that potential risks to human health and the environment posed by the surface soil contamination are eliminated.

Part or all of the surface soil cleanup action could be implemented quickly as an interim action under MTCA if needed to accommodate NSC highway project scheduling.

Deep Contamination Cleanup Actions

Reducing LNAPL mass at the groundwater table using an active cleanup technology is the most challenging aspect of the overall Site cleanup. The LNAPL is deep (approximately 180 ft bgs), highly viscous, and present under conditions that preclude effective removal by pumping under ambient conditions in most areas of the Site. Recognizing that NSZD is occurring and can be taken advantage of for a portion of the LNAPL-impacted area, a remediation level was defined to divide the mobile LNAPL footprint into two parts:

- An area that can be expected to recover by NSZD alone and achieve the preliminary CULs in a reasonable restoration timeframe (RTF), and
- An area requiring active cleanup to achieve the preliminary CULs in a reasonable RTF.

Remediation levels are not the same as CULs. Remediation levels are used to determine where and when a transition can be made from one cleanup technology to another with the ultimate goal of achieving the CULs. The remediation level that delineates these two areas is one-foot of mobile LNAPL thickness (e.g., in a monitoring well). This remediation level is based on Ecology's evaluation of the RI data and NSZD rates.[i] Existing LNAPL gauging data was used to approximate the one-foot LNAPL isopleth (Figure ES-4).

---

[i] The Ecology recommendation for this remediation level was provided in comments dated 4 January 2017 to the 2016 Revised RI/FS.

The area proposed for NSZD is referred to as the Low RTF LNAPL Area (Figure ES-4). The area proposed for active remediation is divided into a Medium RTF LNAPL area and a High RTF LNAPL area (Figure ES-4). This partitioning is based on the concept that a more aggressive technology could be applied to the High RTF LNAPL area, which encompasses the primary source area at the Site, and a less aggressive technology could be applied to the Medium RTF LNAPL area where the contaminant mass is generally lower.

Cleanup actions developed and evaluated for the deep contamination (i.e., intermediate soil, LNAPL, and groundwater) consist of combinations of the technologies described below:

- NSZD – Allow natural biodegradation to reduce LNAPL mass.
- Bioventing/biosparging – Forced circulation of air into the subsurface via a network of wells screened above and below the groundwater table to encourage aerobic biodegradation.
- Steam Enhanced LNAPL Extraction (SEE) – Steam is injected into the subsurface near the groundwater table to reduce the viscosity of the LNAPL, thereby potentially increasing its recoverability. LNAPL and groundwater are pumped from a network of extraction wells and processed at the ground surface to separate water and oil.
- Smoldering Combustion – A network of electrical ignition and air injection wells are installed near the groundwater table. The ignitors initiate combustion of petroleum hydrocarbons and the injected air sustains and promotes propagation of the combustion front through the hydrocarbon smear zone.
- Manual LNAPL Removal – Manual removal (bailing) of LNAPL that accumulates in a network of wells.

The five Cleanup Actions assembled for the FS are summarized on Table ES-2. NSZD is used for either the entire Site (Cleanup Action A) or just the Low RTF LNAPL area (Cleanup Actions B through E). Bioventing/biosparging is used for the Medium RTF LNAPL area (Cleanup Actions B through D) and the High RTF LNAPL area (Cleanup Action B). Manual LNAPL removal and SEE are used for the High RTF LNAPL area (Cleanup Action C and D, respectively). Cleanup Action E utilizes smoldering combustion for both the High and Medium RTF LNAPL areas.

Cleanup Actions B through E are expected to protect human health and the environment, comply with MTCA cleanup standards and other requirements, and can be undertaken in a manner that complies with applicable state and federal laws. Cleanup Action A (NSZD) is included for informational purposes only; it does not meet the MTCA threshold requirement that prohibits reliance on natural processes alone to cleanup LNAPL sites. Cleanup Actions B through E are expected to reduce LNAPL in the intermediate soil and smear zone soil to MTCA CULs over RTFs of up to approximately 14 years. These calculations suggest that an RTF of approximately 20 years is therefore reasonable and appropriate. During that period, human health and the environment would be protected by controlling access to the Site, prohibiting development of the groundwater resource at the Site, and monitoring groundwater to ensure that the LNAPL and dissolved phase contamination remains stable or declines in response to the cleanup actions.

The cleanup action ultimately selected for deep contamination must use permanent solutions to the maximum extent practicable. Per Washington Administrative Code 173-340-360, a disproportionate cost analysis (DCA) was used to evaluate the cleanup actions relative to the requirement to use permanent solutions to the maximum extent practicable. The DCA compares the permanence of a cleanup action with costs while ensuring that cleanup actions protect human health and the environment. The scoring method adopted for the FS assumed equal weighting of all the following evaluation factors:

- Overall protectiveness,
- Permanence,
- Long-term effectiveness,
- Management of short-term risks, and
- Implementability.

In this DCA, a numeric scoring and ranking system was used. The scoring rubric attributed a value from one to 10 for each evaluation sub-factor.[ii] A value of one represents the lowest score and a value of 10 the highest. For example, there are eight sub-factors for implementability:

- Whether the cleanup action is technically possible;
- Availability of necessary off-Site facilities, services, and materials;
- Administrative and regulatory requirements;
- Scheduling, size, complexity;

[ii] Each DCA evaluation factor has several sub-factors. For brevity, the sub-factors are not provided here in the executive summary. For details on the scoring, ranking and supporting rationale, see Section 11.2.1.

- Monitoring requirements;
- Access for construction operations and monitoring;
- Integration with existing facility operations; and
- Integration with other current or potential remedial actions.

Once each evaluation factor was scored, Cleanup Actions B through E (four cleanup actions in all) were ordered based on the cumulative scores and assigned a rank from one to four; four being the highest benefit rank and one the lowest.[iii] The five evaluation factor ranks were then summed to yield a cumulative rank for each cleanup action. A cleanup action with a relatively high benefit ranking is viewed as using permanent solutions to a greater extent than a cleanup action with relatively low benefit ranking. Results of the DCA analysis are shown in Table ES-3 along with estimated costs for the cleanup actions. Figure ES-5 compares the estimated costs with the aggregate benefits represented numerically by the sum of scores for each cleanup action shown at the bottom of the Table ES-3.

Cleanup Action B (Bioventing/biosparging) received the highest cumulative rank (18). Cleanup Actions C, D, and E received lower cumulative ranks of 12, 11 and 9, respectively. Based on this evaluation, Cleanup Action B uses permanent solutions to a greater practicable extent than the other cleanup actions because it possesses the following attributes:

- Moderately high overall protectiveness – all of the cleanup actions provide similar protectiveness, but bioventing/biosparging has the lowest risks from implementation and a moderate active operation time.
- High permanence – utilizes technologies that are proven to destroy hazardous substances and reduce the toxicity, mobility, and volume of contamination without generating treatment residuals.
- High for implementability – utilizes simple and conventional construction and operation technologies, has moderate permitting requirements, carries considerable design flexibility and modification potential, has few constraints regardless of the highway alignment, and requires a simple pilot test.
- Good long-term effectiveness – proven technology for petroleum at similar sites, modification and enhancement potential is high, and few uncertainties other than operational duration.

[iii] Cleanup Action A is scored for comparative purposes, but not ranked because it does not meet all MTCA threshold requirements.

- High for management of short-term risks – few construction and operation risks because of the simple and conventional technologies utilized and relatively low manpower requirements.

The other three cleanup actions have considerably lower cumulative ranks than bioventing/biosparging.

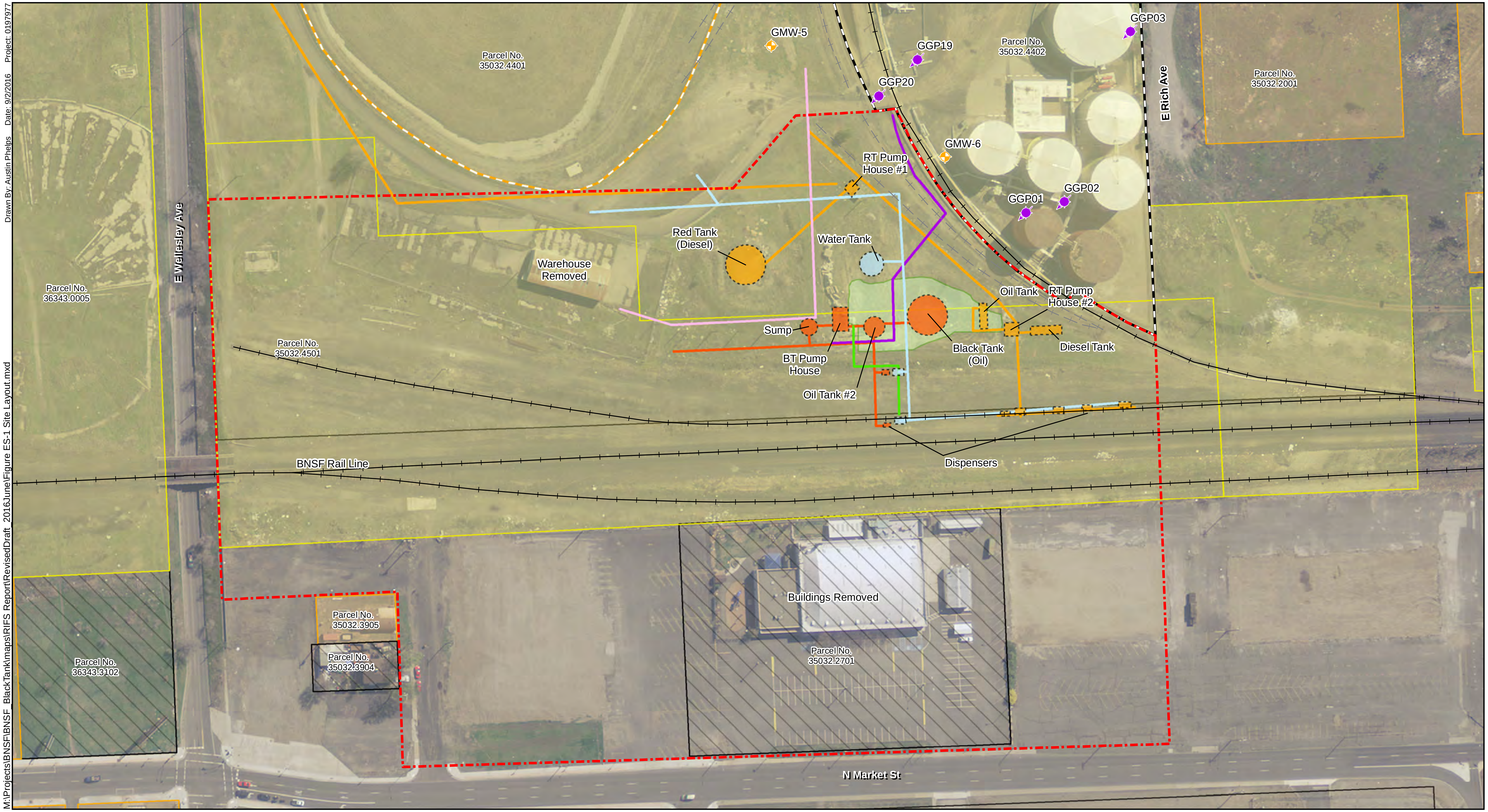
- Cleanup Action C (bioventing/biosparging and manual LNAPL removal) ranked lower primarily because it has lower-management of short-term risk and implementation scores. Manual LNAPL recovery has a high manpower requirement to install and service wells, which increases the potential for injury and exposure to LNAPL and results in a low management of short-term risk score. The implementation score for this cleanup action is also lower because an NSC highway alignment that crosses all or part of the High RTF LNAPL area would conflict with the existence and servicing of LNAPL removal wells.
- Cleanup Action D (bioventing/biosparging and SEE) ranked lower because of its complexity, utilization of technologies that carry higher risks to public health (e.g., potential to cause dissolved phase contaminant migration into the aquifer), higher risks to worker health and safety, uncertainty of success given its unproven track-record for similar sites, the impracticability of servicing critical infrastructure (i.e., wells) if the NSC highway alignment crosses all or part of the High RTF LNAPL area, and the high carbon footprint resulting from the need to generate large amounts of heat. Additionally, SEE scores relatively low on permanence because it generates considerable hazardous residuals rather than destroying the hazardous substances in situ and will not achieve MTCA required CULs without combining it with a follow-up technology. Total fluids extraction is necessary to remove the mobilized LNAPL and to control for concentration increases in groundwater during steam heating.
- Cleanup Action E (Smoldering combustion) ranked low for many of the same reasons cited above for SEE. In particular, smoldering combustion ranked low on long-term effectiveness and implementability because it is a new technology that is unproven at sites with similar conditions. Smoldering combustion has only been implemented full-scale on one site. Also, the technology possesses considerable uncertainty as to whether the distribution of LNAPL in the saturated zone is sufficiently continuous and concentrated to reliably promote advancement of the combustion front to all areas requiring cleanup. Smoldering combustion does have the theoretical potential of destroying the most petroleum mass of all the alternatives, but is not well suited to this Site for the above reasons.

Cleanup Action B, which relies on bioventing and biosparging for active remediation of the High and Medium RTF LNAPL area and NSZD for the Low RTF LNAPL area is recommended for implementation at the Site based on its highest overall DCA score (Table ES-3). The final alignment of the NSC highway would not substantively impact implementation of the recommended cleanup action. A variety of contingency actions described in the FS (e.g., increased air flow through existing wells, combining air injection with air extraction, greater density of wells) can be readily implemented to enhance the performance of Cleanup Action B and shorten the RTF of the remediation, if needed.

Executive Summary Figures

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure ES-1 Site Layout.mxd Drawn By: Austin Phelps Date: 9/2/2016 Project: 0197977

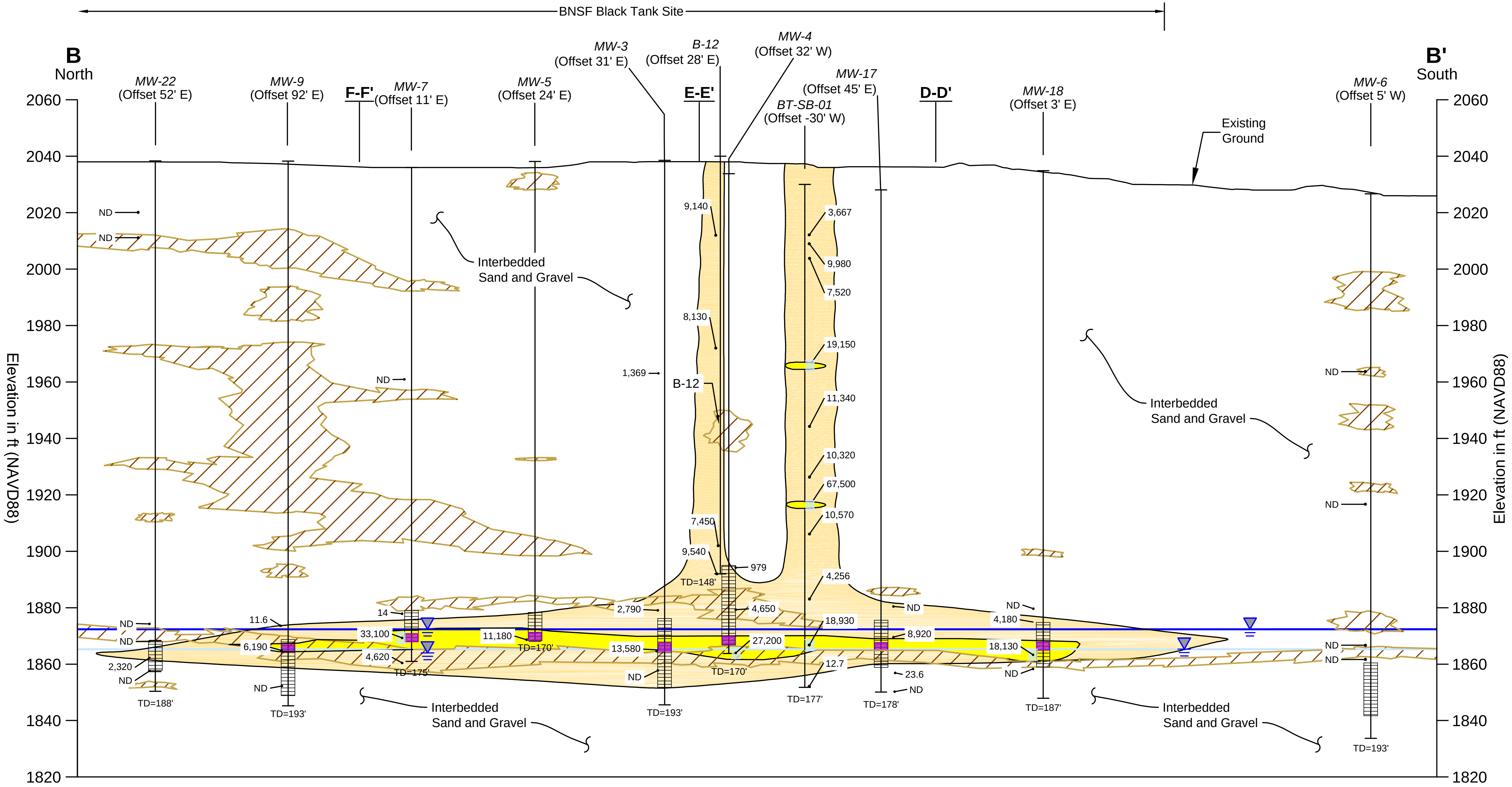


Notes:
Aerial Photo: USGS, April 2012.

Figure ES-1
Site Layout and Tax Parcels
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT



Legend

MW-6	Exploration Designation
(Offset 22' W)	Offset Distance in Feet and Direction
	Top of Exploration
	Silt and Silty Sand Facies
	Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level
	Approximate High Groundwater Level
	Approximate Low Groundwater Level
	Approximate Groundwater Level
397	TPH-D/HO Concentration in Soil (mg/kg)
	Well Screen Interval (If Installed)
	LNAPL Present in Well
	Bottom of Exploration
TD=193'	Total Depth of Exploration (feet BGS)

🟨	Mobile LNAPL
🟧	Residual LNAPL

mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

(Vertical Exaggeration = 2.5X)

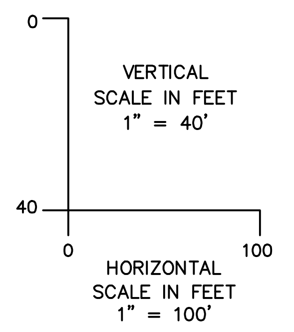


Figure ES-2

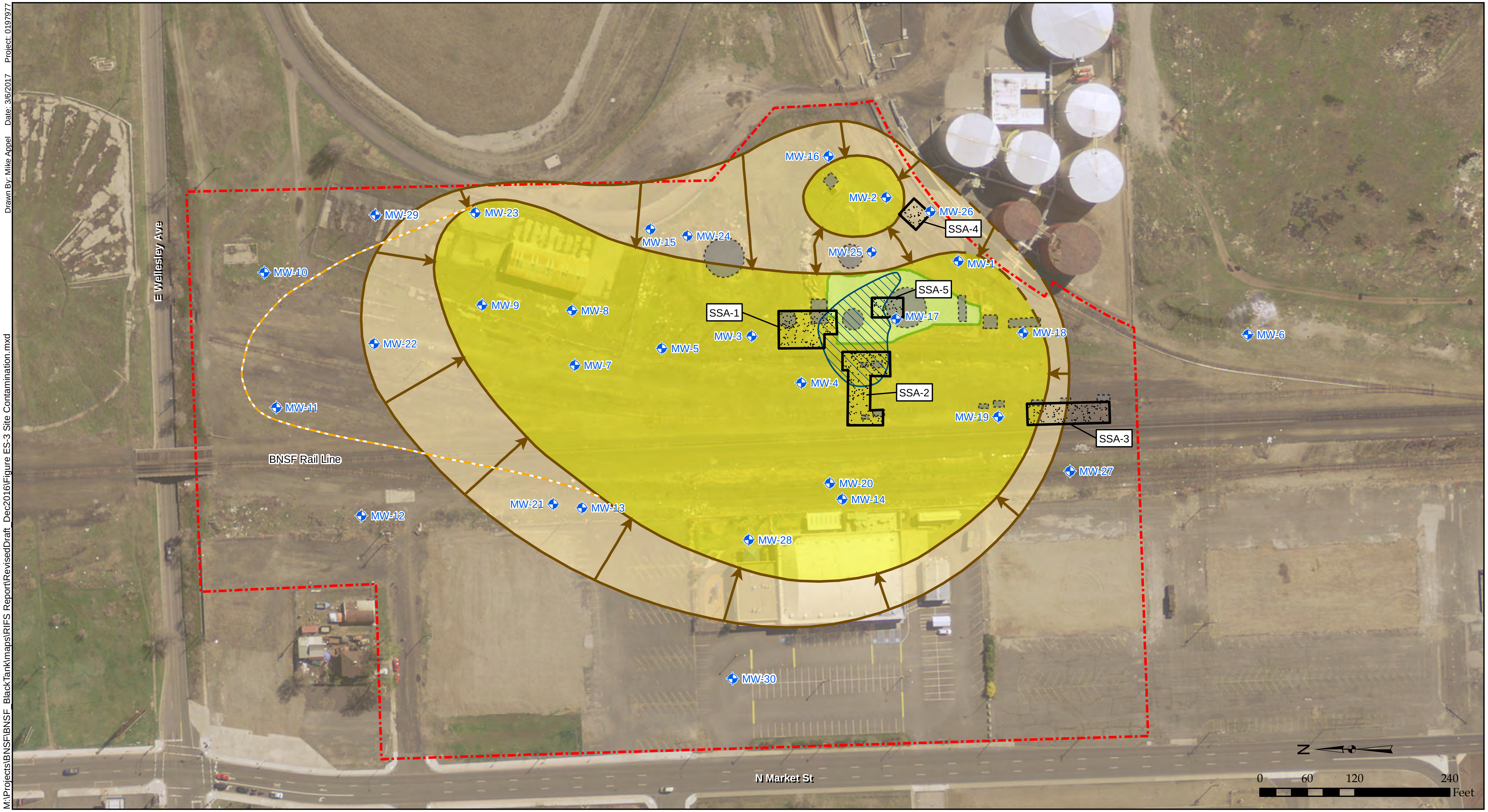
Geologic Profile B-B' with LNAPL Overlay
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

\\wdwalfs01\CAD\DWGS\0366860 Black Tank\21\036686021.01.dwg
0366860.21
3/06/2017
J.Rahmani

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure ES-3 Site Contamination.mxd Drawn By: Mike Appel Date: 3/6/2017 Project: 0197977



Legend

- ⯐ Monitoring Well
- → Receding Mobile LNAPL Due to Natural Source Zone Depletion
- ― Most Recent Approximate Extent of LNAPL, June 2016
- – – Most Recent Inferred Extent of LNAPL, June 2016
- - - Approximate Seasonal Maximum Extent of Dissolved Phase TPH-D/HO Plume
- ⬚ Proposed BNSF Black Tank Site Boundary
- ▨ Intermediate Soil Exceeding the Preliminary CUL
- ☐ Surface Soil Exceeding Preliminary CULs
- 🟩 Former Black Tank Excavation
- ▩ Historical Aboveground Storage Tank
- 🟨 Mobile and Residual LNAPL
- ▢ Residual LNAPL

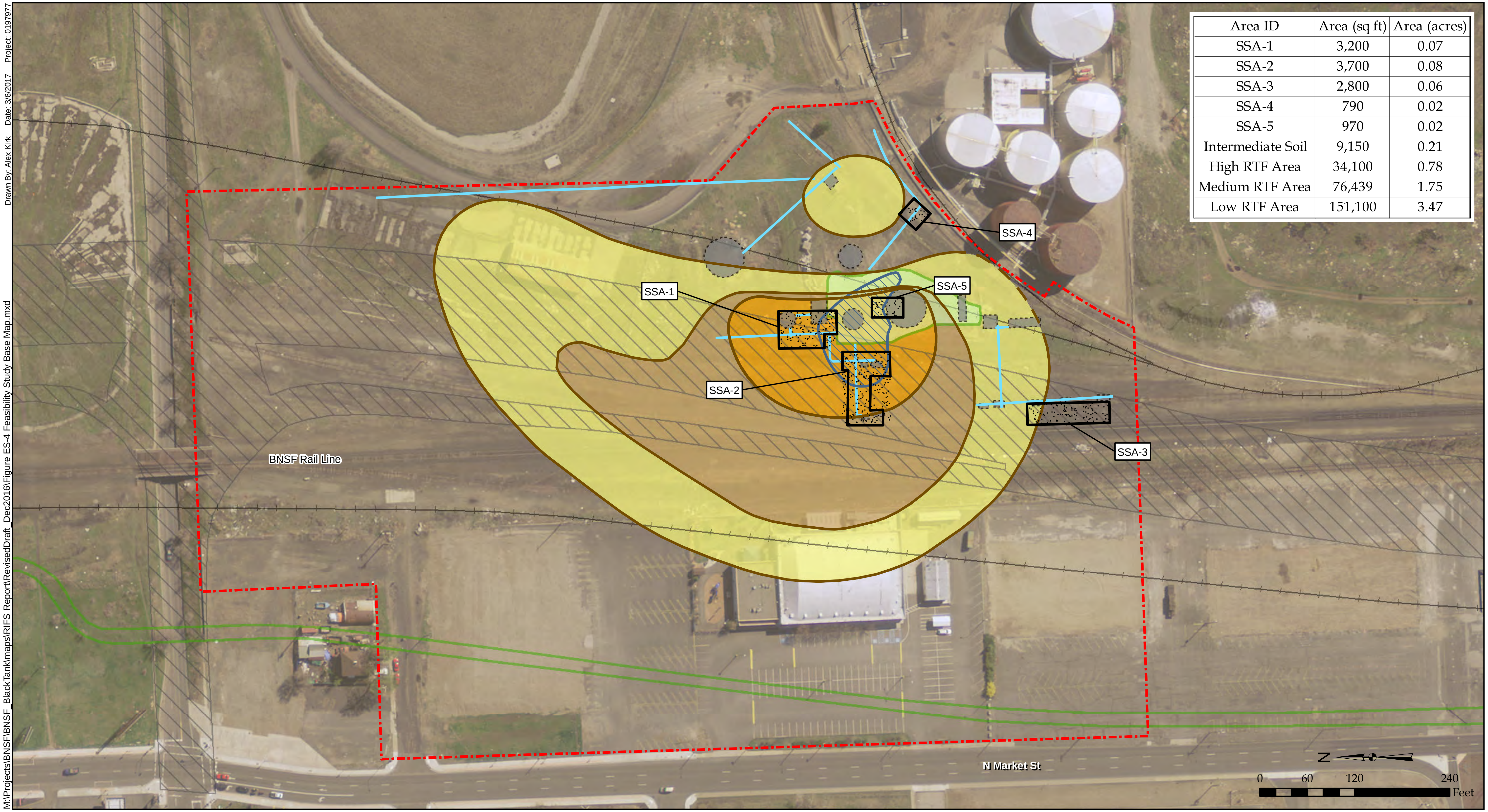
Notes:
CUL = Cleanup Level
LNAPL = Light Non-Aqueous Phase Liquid
Mobile LNAPL = LNAPL that is interconnected in pore space and has the potential to move under a hydraulic gradient.
Residual LNAPL = The portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients. Residual LNAPL is present throughout the mobile and residual LNAPL areas shown.
Aerial Photo: USGS, April 2012.

Figure ES-3
Site Contamination
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure ES-4 Feasibility Study Base Map.mxd Drawn By: Alex Kirk Date: 3/6/2017 Project: 0197977



Area ID	Area (sq ft)	Area (acres)
SSA-1	3,200	0.07
SSA-2	3,700	0.08
SSA-3	2,800	0.06
SSA-4	790	0.02
SSA-5	970	0.02
Intermediate Soil	9,150	0.21
High RTF Area	34,100	0.78
Medium RTF Area	76,439	1.75
Low RTF Area	151,100	3.47

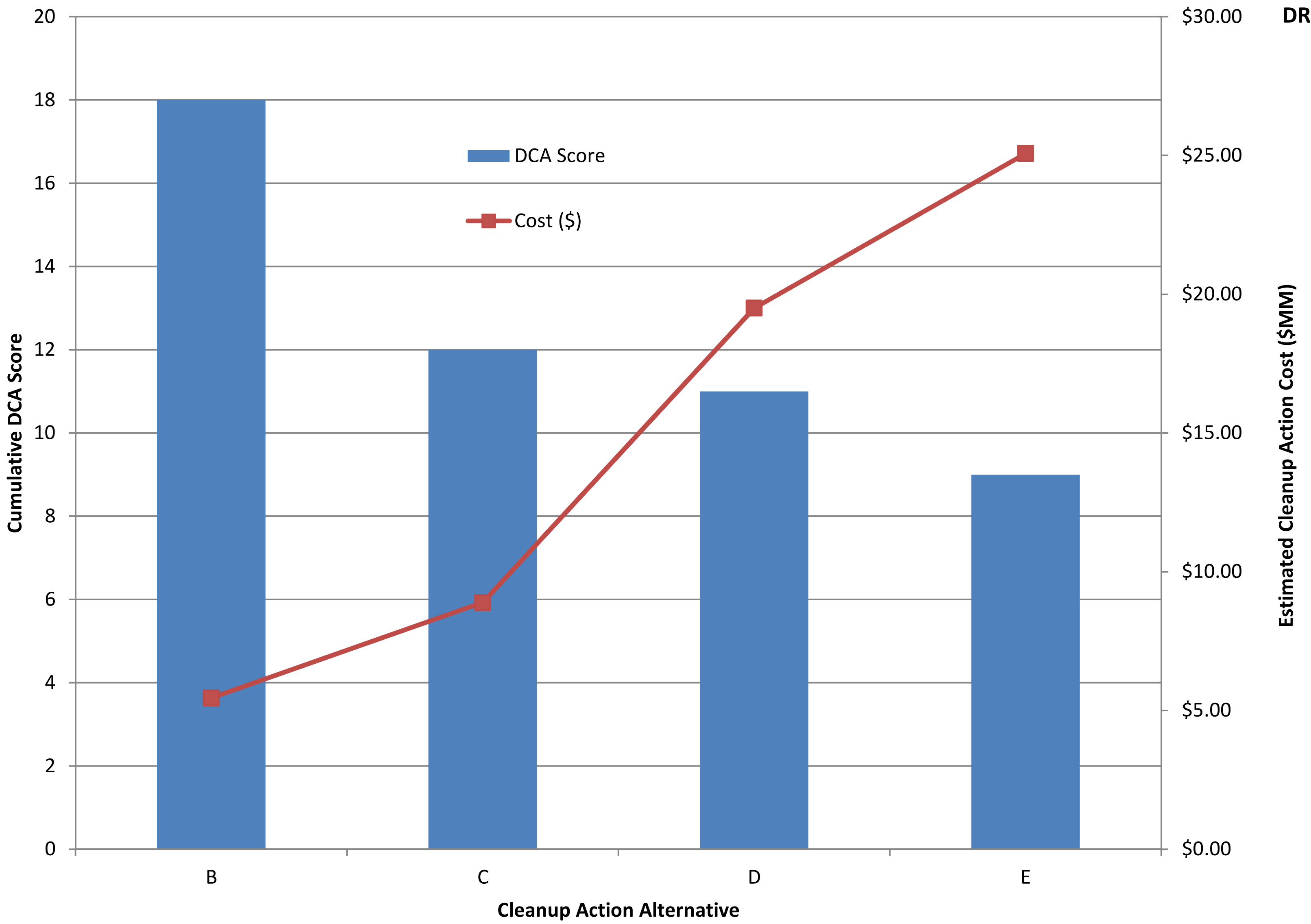
Legend

- Existing Piping (Petroleum and Chemical Solution)
- DOT Proposed Railroad Realignment Option - 2014
- Proposed BNSF Black Tank Site Boundary
- ▨ TPH-D/HO in Intermediate Soil Exceeding the Preliminary CUL
- Approximate Lateral Limits of Surface Soil Cleanup Areas
- ▨ DOT Proposed Highway Alignment Option - 2014
- 🟩 DOT Proposed Pedestrian Pathway - 2014
- 🟩 Former Black Tank Excavation
- Historical Aboveground Storage Tank, Sump or Pump House
- 🟧 High RTF Area
- 🟫 Medium RTF Area
- 🟨 Low RTF Area

Notes:
CUL = Cleanup Level
LNAPL = Light Non-Aqueous Phase Liquid
RTF: Restoration Timeframe
TPH-D/HO = Combined Diesel and Heavy Oil-Range Petroleum Hydrocarbons
Preliminary CUL = 13,600 milligrams per kilogram
Aerial Photo: USGS, April 2012.

Figure ES-4
Cleanup Action Areas
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM



Environmental Resources Management
www.erm.com

Notes:
DCA = Disproportionate Cost Analysis
$MM = Million Dollars

Figure ES-5
Results of the DCA for Deep Contamination
BNSF Black Tank
Spokane, Washington

Executive Summary Tables

Table ES-1

Preliminary Cleanup Levels
BNSF Black Tank Site
Spokane, Washington

Contaminant of Concern	**Surface Soil (< 15 feet bgs)** (mg/kg)	**Subsurface Soil (> 15 feet bgs)** (mg/kg)	**Groundwater** (µg/L)
TPH-D/HO	2,000	13,600	500
Benzo(a)Pyrene	0.1	n/a	0.1
Benzo(a)Pyrene TEQ	0.1	n/a	0.1
Naphthalene	5	n/a	n/a
Total Naphthalenes	5	n/a	n/a
LNAPL (Mobile)	Removal using normally accepted engineering practices.		

Abbreviations:

bgs = below ground surface
LNAPL = light non-aqueous phase liquid
mg/kg = milligrams per kilogram
n/a = not applicable
TEQ = Toxic Equivalency Quotient
TPH-D/HO = Total Petroleum Hydrocarbons as Diesel/Heavy Oil per method NWTPH-Dx
µg/L = micrograms per liter

Table ES-2

Cleanup Actions for Deep Contamination
(LNAPL, Intermediate Soil, Groundwater)
BNSF Black Tank Site
Spokane, Washington

Cleanup Action	Low RTF LNAPL Area[1]	Medium RTF LNAPL Area[1]	High RTF LNAPL Area[1] and Intermediate Soil[2]	Groundwater
A[3]	NSZD	NSZD	NSZD	Monitoring and Institutional Controls
B		Bioventing/Biosparging	Bioventing/Biosparging	
C		Bioventing/Biosparging	Bioventing/Biosparging and Manual LNAPL Removal	
D		Bioventing/Biosparging	Bioventing/Biosparging and Steam Enhanced Extraction	
E		Smoldering Combustion	Smoldering Combustion	

Notes:

Groundwater monitoring and institutional controls will apply to all cleanup actions.

[1] The LNAPL area is divided into low, medium, and high RTF areas based on the remediation level analysis (see Section 8.5).

[2] Intermediate Soil refers to soil that exceeds cleanup levels between the LNAPL smear zone at the water table and the standard point of compliance for surface soils (15 feet bgs). The footprint of the Intermediate Soil generally coincides with the High RTF LNAPL area.

[3] Cleanup Action A is included for informational purposes only; it does not meet the MTCA threshold requirement that prohibits reliance on natural processes alone to cleanup LNAPL sites (see Section 8.1.2.4).

Abbreviations:

ft bgs = feet below ground surface
LNAPL = Light non-aqueous phase liquid
NSZD = Natural Source Zone Depletion
RTF = Restoration timeframe

DRAFT

Table ES-3

Cleanup Action Ranking Summary for Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

MTCA Requirements and Evaluation Factors		A: NSZD	B: Bioventing/ Biosparging	C: Bioventing/ Biosparging and Manual LNAPL Recovery	D: Bioventing/ Biosparging and Steam Enhanced Extraction	E: Smoldering Combustion
Threshold Requirements	Protect human health and the environment	Protective	Protective	Protective	Protective	Protective
	Comply with cleanup standards	Complies	Complies	Complies	Complies	Complies
	Comply with applicable state and federal laws	Does not Comply	Complies	Complies	Complies	Complies
	Provide for compliance monitoring	Complies	Complies	Complies	Complies	Complies
Use Permanent Solution to the Maximum Extent Practicable	Overall protectiveness	NA	3 ◕	1 ◔	4 ●	2 ◑
	Permanence	NA	3 ◕	2 ◑	1 ◔	4 ●
	Long-term effectiveness	NA	4 ●	3 ◕	2 ◑	1 ◔
	Management of short-term risks	NA	4 ●	3 ◕	2 ◑	1 ◔
	Implementability	NA	4 ●	3 ◕	2 ◑	1 ◔
	Consideration of public concerns	NA	0	0	0	0
	Cumulative Rank	NA	18 ●	12 ◕	11 ◑	9 ◔
Costs	**Deep Contamination Cleanup Costs**	NA	$3,996,000	$7,433,000	$18,045,000	$23,618,000
	Total Estimated Cleanup Costs[1]	NA	$5,451,000	$8,888,000	$19,500,000	$25,073,000

Notes:

[1] Total estimated cleanup costs include cost of surface soil cleanup (estimated at $1,455,000).

Abbreviations:

LNAPL = Light non-aqueous phase liquid
MTCA = Model Toxics Control Act
NA = Not applicable
NSZD = Natural Source Zone Depletion

Rank:

1 ◔ = Low
2 ◑ = Medium
3 ◕ = Medium-High
4 ● = High

1.0 INTRODUCTION

On behalf of Husky Oil Operations Limited and Burlington Northern Santa Fe Railway Company (BNSF), a team of technical professionals led by ERM-West, Inc. (ERM) and its sub-consultant Landau Associates, Inc. prepared this Remedial Investigation/Feasibility Study (RI/FS) Report to address petroleum hydrocarbon contamination associated with the BNSF Black Tank Property, generally located at 3202 East Wellesley Avenue in Spokane, Washington (the "Site"). The Site is a former locomotive fueling and petroleum storage facility that previously included two large aboveground storage tanks (ASTs) referred to as the Black Tank and Red Tank. Releases of Site-related contaminants (petroleum hydrocarbons) from historic operations at the Site are the focus of the RI/FS. BNSF and Marathon Oil Company (Marathon) have been identified as potentially liable persons (PLPs) for remedial actions related to historical releases at the Site. Marathon's obligations for this project are being performed by Husky Oil Operations Limited.

Technical specialists were added to the technical team during the preparation of Revisions 1 and 2 of the RI/FS. The technical specialists provided expertise needed to assess key site data and evaluate cleanup action alternatives. The PLP's responses to Ecology's 4 January 2017 comments on the September 2016 RI/FS report can be found in Appendix 1 and are hereby incorporated into this document by reference and to avoid redundancy to extent practicable. The technical specialists who assisted with the RI/FS and responses include:

- Bernard Kueper, Ph.D., P.E., Queen's University – a research professor and recognized expert on the subsurface behavior and cleanup of non-aqueous phase liquids (NAPLs).

- Rob Hinchee, Ph.D., P.E., Integrated Science & Technology, Inc. – a consulting engineer and recognized expert in bioremediation technologies, including bioventing and biosparging.

- John Wilson, Ph.D., Scissortail Environmental Solutions, LLC – a consulting scientist and the United States Environmental Protection Agency's (USEPA's) former technical expert in biotransformation processes of organic compounds in groundwater and the subsurface environment.

- Helen Dawson, Ph.D., Geosyntec Consultants – a consulting engineer, former USEPA regulator, and recognized expert in regulatory analysis and evaluation of complex environmental systems.

- Mike Kavanaugh, Ph.D., P.E., BCEE, Geosyntec Consultants – a consulting engineer and recognized expert in environmental engineering and hydrogeologic issues related to hazardous waste sites.

1.1 *REGULATORY FRAMEWORK/AGREED ORDER*

The PLPs and the Washington State Department of Ecology (Ecology) entered into Agreed Order (AO) No. 9188 on 6 August 2012 to conduct a RI/FS for contamination related to historical activities at the Site (Ecology 2012). The RI/FS was performed in compliance with the Model Toxics Control Act (MTCA), Chapter 173-340 Washington Administrative Code (WAC), the AO, and the Final RI/FS Project Plan, approved by Ecology on 28 February 2013. The Final RI/FS Project Plan included a Work Plan (ERM 2013a), Sampling and Analysis Plan ([SAP]; ERM [Environmental Resources Management] 2013b), Quality Assurance Project Plan ([QAPP]; ERM 2013c), Health and Safety Plan (ERM 2013d), and Project Plan addenda dated 15 September 2014 (ERM 2014) and 3 March 2016 (ERM 2016). Preparation of this RI/FS Report is a required element of the AO.

1.2 *PURPOSE AND OBJECTIVES*

The purpose of the RI is to characterize the nature and extent of Site-related contaminants (petroleum hydrocarbons) originating from the Black Tank and other petroleum storage tanks and associated piping, and assess the risk to human health and the environment in order to select an appropriate cleanup action for the Site in accordance with the MTCA regulations. The purpose of the FS is to evaluate applicable cleanup actions in accordance with the MTCA regulations. Based on the results of the RI/FS, Ecology will select the cleanup action for the Site.

Specific objectives for the RI were documented in the RI/FS Work Plan and include:

- Identifying any additional contaminant sources;
- Assessing Site hydrogeology, contaminant characteristics, and contaminant fate and transport;
- Assessing the extent and mobility of the light non-aqueous phase liquid (LNAPL); and
- Evaluating the overall risk to human health and the environment.

The RI establishes the nature and extent of the Site-related contaminants, the physical characteristics of the Site, and the fate and transport of the Site-related contaminants. This information is used to develop a conceptual site model (CSM) that identifies contamination sources, contaminant fate and transport mechanisms, potential human and ecological receptors, and exposure pathways at the Site. The CSM is used to evaluate potential human health and ecological risks associated with exposure to Site contaminants and to support the development of appropriate cleanup actions.

The RI is intended to provide the necessary data to support the FS evaluation of applicable cleanup actions for the Site. The primary objectives of the FS include:

- Identifying the basis for the cleanup action, including an analysis of cleanup standards, points of compliance, and applicable or relevant and appropriate requirements;
- Identifying, evaluating, and screening remedial technologies that may be applicable to the Site;
- Developing and evaluating a range of cleanup actions against the MTCA criteria; and
- Recommending a cleanup action for the Site.

1.3 TERMINOLOGY

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

- Cleanup Action. Any remedial action, except interim actions, taken at a site to eliminate, render less toxic, stabilize, contain, immobilize, isolate, treat, destroy, or remove a hazardous substance that complies with WAC 173-340-350 through WAC 173-340-390.
- Cleanup Action Alternative. One or more treatment technology, containment action, removal action, engineering control, institutional control, or other type of remedial action that, individually or, in combination, achieves a cleanup action at a site.
- Cleanup Level (CUL). The concentration of a hazardous substance in soil, water, air, or sediment that is determined to be protective of human health and the environment under specific exposure conditions.
- Cleanup Standards. Specification of: (1) CULs; (2) points of compliance; and (3) additional regulatory requirements that apply to a cleanup action because of the type of action and/or the location of the site.
- Conceptual Site Model (CSM). An interpretation or working description of a site that identifies potential or suspected sources of hazardous substances,

types, and concentrations of hazardous substances, potentially contaminated media, and actual and potential exposure pathways and receptors.

- Formation. The subsurface soil or rock in which LNAPL, water, and air may exist. In this report, this term is used in regional geology and hydrogeology discussions and not site-specific discussions.
- Light Non-aqueous Phase Liquid (LNAPL). LNAPL (e.g., petroleum products) of varying compositions, characteristics, ages, and origins having a specific gravity less than 1 and composed of one or more organic compounds that are immiscible or sparingly soluble in water. The term encompasses all potential states of LNAPL (e.g., free-phase, residual, mobile, migrating, entrapped, etc.).
- LNAPL Saturation. The percentage of the soil pore space that is filled with LNAPL. The LNAPL saturation depends on the geology, LNAPL fluid properties, and release dynamics.
- LNAPL Distribution. The presence of LNAPL in the subsurface (laterally and vertically), and includes migrating, mobile, and residual (i.e., immobile) LNAPL.
- Residual LNAPL. The portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients. Residual LNAPL possesses a LNAPL transmissivity of zero.
- Mobile LNAPL. LNAPL that is interconnected in pore space and has the potential to move under a hydraulic gradient. Mobile LNAPL possesses an LNAPL transmissivity of greater than zero.
- Migrating LNAPL. LNAPL that is both mobile LNAPL and is subjected to a driving LNAPL pressure head that forces the mobile LNAPL into adjacent soils and results in expansion of the LNAPL footprint. LNAPL present in this condition is typically present during an active release and will stop once the active release is stopped and the LNAPL driving pressure head has dispersed.
- LNAPL Residual Saturation. The saturation of LNAPL in the pore space below which LNAPL will be residual LNAPL and above which LNAPL will be mobile LNAPL. The LNAPL residual saturation depends on grain size and other soil properties, which typically vary across a site, and the water saturation state of the native soils (i.e., saturated versus unsaturated).
- Interval of Mobile LNAPL. The vertical or horizontal length of aquifer where mobile LNAPL exists at a given location. The interval of mobile LNAPL represents the interval over which the LNAPL transmissivity is greater than zero.
- LNAPL Transmissivity. The unit volume of LNAPL that will flow parallel to a pressure gradient, across a unit width of the porous media in a given time

period for a unit gradient. In general, higher LNAPL transmissivity equates to higher LNAPL recoverability.

- LNAPL Recoverability. The portion of LNAPL at a location (e.g., well) that is practicably recoverable using hydraulic remediation technologies such as skimming and pumping.
- LNAPL Recovery Rate. The rate of LNAPL recovery for a given remedial technology, typically measured in volume per unit time.
- Natural Source Zone Depletion (NSZD). A combination of processes that reduce the mass of LNAPL in the subsurface. These processes include dissolution into groundwater and volatilization into the vadose zone, followed by biodegradation via microbial and/or enzymatic activity.
- Non-aqueous Phase Liquid (NAPL). A hazardous substance that is present in the soil, bedrock, groundwater, or surface water as a liquid not dissolved in water.
- Point of Compliance. Point or points where CULs established in accordance with WAC 173-340-720 through WAC 173-340-760 shall be attained.
- Practicable. Capable of being designed, constructed, and implemented in a reliable and effective manner, including consideration of cost. When considering cost under this analysis, a cleanup action shall not be considered practicable if the incremental costs of the action are disproportionate to the incremental degree of benefits provided by the action over other lower cost cleanup actions.
- Smear Zone. The vertical and horizontal interval over which LNAPL (as defined by stained soil and/or contaminant concentrations indicative of LNAPL) exists in the vicinity of the groundwater table. The LNAPL is vertically distributed "smeared" in this interval as a result of the LNAPL release (LNAPL head) and a fluctuating groundwater table.
- Vadose Zone. The unsaturated zone between the land surface and the water table. It includes the capillary fringe and may also include localized perched groundwater.
- Water Table. The top of an unconfined aquifer where water pressure is equal to atmospheric pressure; in other words, the surface between the zone of saturation and the zone of aeration. In unconfined aquifers, the water table is equal to the corrected groundwater interface.

2.0 SITE DESCRIPTION AND BACKGROUND

The following sections describe the Site, including its location, current usage and appearance, historical ownership and operations, current land use and zoning, pre-RI investigations and cleanup actions, and future land use. Neighboring properties are also described.

2.1 SITE DESCRIPTION

2.1.1 Site Location

The Site, referred to in the AO as the BNSF Railway Black Tank Property, is generally located at 3202 East Wellesley Avenue in Spokane, Washington (Figure 1). It is situated in an industrial and transportation corridor in the Hillyard neighborhood of northeast Spokane. As shown on Figure 1, the Site is located in the northwest quarter of Section 3, Township 25 North, Range 43 East, of the Willamette Meridian, along a main north-south trending BNSF railway line.

2.1.2 Site Description

According to the AO, the "Site is defined by the extent of contamination caused by the release of hazardous substances at the Site." Using data from the RI and pre-RI investigations, ERM identified the extent of contamination caused by the release of Site-related contaminants (e.g., petroleum hydrocarbons) and defined the Site boundary as illustrated on Figure 2. Recent Site data document the seasonal presence of dissolved phase Site-related contaminants in one of the two northern-most monitoring wells location on the Site. However, the northern Site boundary remains as shown on Figure 2 because the Site-related contaminant detected in the well is a highly degradable petroleum metabolite, the monitoring well is located approximately 100 feet south of the northern Site boundary, and there are no data documenting the presence of Site-related contaminants beyond the northern Site boundary. The Site includes approximately 18.2 acres and encompasses portions of Spokane County Tax Parcel Numbers 35032.4501, 35032.4401, and 35032.2701 as well as a portion of the right-of-way for the BNSF rail line. As illustrated on Figure 2, BNSF owns Tax Parcel Numbers 35032.4501 and 35032.4401 and the BNSF railway right-of-way. The Washington State Department of Transportation (WSDOT) owns Tax Parcel Number 35032.2701 and manages the right-of-way areas outside the BNSF railway right-of-way (Figure 2).

The Site previously contained a 50-foot-diameter AST referred to as the Black Tank, a smaller AST, a pump house, a large-diameter concrete sump, and piping associated with the Black Tank. The Black Tank reportedly contained Bunker C (Fuel Oil No. 6) oil, asphaltic petroleum hydrocarbons, and other petroleum-based mixtures. BNSF decommissioned and removed the Black Tank in 2006. In addition to the Black Tank, historical facilities on the Site included a large AST containing diesel fuel referred to as the Red Tank, two pump houses, smaller diesel and oil tanks, fuel dispensers, an elevated water tank and dispensers, a Chemical Solution Pipeline, and an elevated steam pipeline. The locations of these historic features are shown on Figure 2, and additional information about the historic features is provided in Section 2.2.2.2.

With the exception of the active BNSF rail lines, the Site is currently inactive, vacant, and mostly unpaved. All of the structures associated with previous operations have been removed, except the steel super-structure and concrete slab-on-grade foundation of a large warehouse building, the former Black Tank system sump, the Black Tank Pump House foundation, the Red Tank pump houses, some of the underground piping, some fencing, utility poles, and piles of concrete rubble (Figure 2). A partially filled excavation, approximately 200 feet long x 80 feet wide x 7 feet deep, is present where contaminated soil was removed from beneath the former Black Tank (Figure 2). An active BNSF rail line and a series of rail spurs extend from the southern to northern Site boundary, along the western third of the Site. A rail spur that serves Western States Asphalt, located on the SemMaterials L.P. (SemMaterials) Spokane site, extends from the main rail line and along approximately 130 feet of the boundary between the Site and the Western States Asphalt facility. The recently demolished former Hillyard Center Institution for Extended Learning building and the associated parking lot are situated on the western portion of the Site (Figure 2). Vehicular access to the Site is via North Ferrall Street, which is a gravel road that extends from East Wellesley Avenue along the Aluminum Recycling Corporation BNSF Dross Cap site (Dross Cap site) to the SemMaterials facility. The Site is partially fenced.

2.1.3 *Neighboring Properties*

The properties neighboring the Site, including their tax parcels numbers, are illustrated on Figure 2. The Site is bordered on the north by East Wellesley Avenue followed by BNSF-owned Tax Parcel Number 36343.0005. To the east, the Site encompasses a part of and is bordered by BNSF-owned Tax Parcel Number 35032.4401. To the southeast, the Site is bordered by BNSF-owned Tax Parcel Number 35032.4402, the location of the SemMaterials facility. BNSF-owned Tax Parcel Number 35032.4501 and WSDOT-managed right-of-way continue to the southwest, beyond the Site boundary. The Site is bordered to the west by Market Street and then commercial and residential properties. A private commercial property (Tax Parcel Number 35032.3905) followed by a WSDOT-owned parcel (Tax Parcel Number 35032.3904) are to the northwest of the Site.

Information regarding neighboring properties that are on Ecology's Confirmed and Suspected Contaminated Sites List (CSCSL) is presented in Section 2.3.

2.1.4 Land Use and Zoning

The current land use of the Site (Figure 2) is industrial. It includes a transportation corridor having an active main BNSF rail line and an active truck route to the neighboring SemMaterials facility. Other areas of the Site are inactive and most of the historic facilities have been removed (Figure 2).

The anticipated future land use of the Site remains as a transportation corridor. WSDOT's North Spokane Corridor (NSC) project, which is a 10.5 mile limited access freeway linking I-90 to US 2 and US 395, will pass through or will be adjacent to the Site, although the final alignment has not been determined as of the authoring of this report (WSDOT 2016). Groundbreaking for the project began in 2001, and approximately half of the project has been completed. Funding for the remainder of the NSC project was approved in June 2015. Construction of the highway is planned for completion by 2029. Construction of two mainline NSC bridges north of the Site and city street improvement and utility relocating projects along the alignment extending from the Spokane River north of the Site will begin in Spring 2017. Figure 3 shows the original proposed alignment for the transportation corridor presented by WSDOT in 2014. The 2014 option encompasses nearly the entire Site; however, other alignments currently under consideration place the highway further to the west and away from the main area of Site contamination. The limited-access freeway will pass over East Wellesley and the preliminary design indicates that fill will be placed over the northern portion of the Site to elevate the freeway to the necessary grade. A mixed use recreational trail is part of the NSC project near the Site, but its location has not yet been determined.

The Site and surrounding properties are located within areas zoned for Light Industrial (LI) and Center and Corridor Core (CC2) use by the City of Spokane. The BNSF-owned portion of the Site is zoned LI, and the WSDOT-owned portion of the Site is zoned CC2. Permitted uses for LI-zoned properties include transportation and light-industrial, commercial, schools, parks, and high-density residential. Permitted uses in CC2-zoned areas include commercial, office, and residential uses as well as parks and open spaces.

Although the Site does not qualify as "industrial" per WAC 173-340-200 because of its zoning, the current and planned future use of the Site is a transportation corridor. Therefore, access to the Site by the general public will be limited and controlled by the presence of the following manmade structures: active rail lines, a limited access freeway and off-ramp(s), East Wellesley (an arterial street in an underpass on the north side of the Site), the Dross Cap site (a secured landfill) immediately east of the Site, and SemMaterials (a secured industrial facility) on the south side of the Site.

2.2 SITE HISTORY

The following sections describe the ownership and operational history of the Site and associated features.

2.2.1 *Site Ownership*

BNSF and its predecessors (i.e., Great Northern Railroad and Burlington Northern Railroad) reportedly have owned the majority of the Site property since at least 1910. The State of Washington, via WSDOT, acquired the portion of the Site west of the BNSF railway right-of-way through right-of-way acquisitions for the NSC project in 2014. BNSF and its predecessors leased portions of the Site property and associated tankage to other operators. According to historical documents provided by the PLPs, lessees of the Black Tank and associated facilities included Blackline Asphalt Sales (1955 record), Husky Oil Company (1974 and 1977 records), Intermountain Asphalt Company (1982 record), and Koch Materials (1983 record).

2.2.2 *Site Operations and Features*

To evaluate the historical operations and features of the Site, ERM obtained and reviewed historical documents provided by the PLPs and Ecology (Table 1) as well as historical aerial photographs covering the period from the 1920s through 2012 (Table 2). Key historical documents are included as Appendix A and representative aerial photographs are included as Appendix B. Descriptions of the historic operations and infrastructure systems at the Site are presented below.

2.2.2.1 *Historic Operations*

Based on historical documents and photographs, the Site was developed as early as 1913. By 1928, the Black Tank, Oil Tank #2 (elevated), the Black Tank Pump House, the sump, and sewer pipelines had been constructed on the Site (Figure 2). The purpose and usage of the Black Tank system prior to 1956 is not documented; however, it appears to have been used to store Bunker C oil. By 1955, Site infrastructure had been expanded to include the following additional structures: the Red Tank, the Red Tank pump houses #1 and #2, diesel tank, oil tank, oil spur, additional dispensers, an elevated water tank, water dispensers, solution pipeline, and an elevated steam pipeline (Figure 2). During its operation as a fueling facility, the only known materials stored and used at the facility included diesel and Bunker C fuels, lubricants, and water. No water additives or other chemicals are known to have been stored and/or used on the Site during that period of operation.

According to a 1974 lease assignment/transfer document between Blackline Asphalt Sales, Inc. (Blackline) and Husky Oil Company, Blackline had the following lease agreements with Burlington Northern Inc. covering property at Spokane (Hillyard), Washington:

- Agreement No. 57744, dated 16 April 1954, for roadway and two private road crossings over rail spur track.
- Agreement No. 59066, dated 10 March 1955, for two storage tanks, sump and pump house and connection to Lessor's steam line.
- Agreement No. 61702, dated 20 December 1956, for a 4-inch liquid asphalt pipeline.
- Agreement No. 64376, dated 21 November 1958 for warehouse and tank.
- Agreement No. 206296, dated 1 August 1971, for asphalt and fuel oil storage tanks and mixing plant.

Only lease agreement No. 61702 was available for review by ERM, and it indicates that Blackline constructed and operated a 4-inch Liquid Asphalt Pipeline between the Black Tank Pump House and the neighboring SemMaterials facility (Figure 2). The alignment of the Liquid Asphalt Pipeline is shown on a drawing attached to the lease agreement. Based on these documents, it appears that Blackline leased the Black Tank, Oil Tank #2, Black Tank Pump House, the sump, and sewer pipelines on the Site beginning in 1955. Then in 1956, they obtained rights to construct and operate a Liquid Asphalt Pipeline that extended from the leased Black Tank system to a series of ASTs on their facility at the present location of SemMaterials. A 1969 drawing shows the alignment for an elevated steam line for the Blackline operation. The records show no indication of additional infrastructure being constructed at the Site during the period that it was leased to other operators. The 1974 lease assignment/transfer document between Blackline and Husky Oil Company transfers the five lease agreements indicated above from Blackline to Husky Oil Company.

A 5 May 1988 Chemical Processors Interdepartmental Communication summarizes information provided by former employees regarding historical operations of the Black Tank. The former employees report that during the 1970s, the Black Tank was primarily used to store MC250 and No. 6 fuel oil, both common asphaltic oils. They also report that there were several incidents of overfilling, broken or frozen heating coils, or valves accidently left open, resulting in spills of oil to the ground surface around the tank and that the material hardened into tar. Tarry material was reported left in place because it formed an impermeable barrier to downward migration. A containment structure was built around it in approximately 1973 to address spill prevention, control, and countermeasure requirements. The historical aerial photographs corroborate these descriptions.

In the 1980s, the Black Tank was reportedly used to store dust oil (a rolling mill oil from Kaiser's Trentwood Plant) and clarified dust oil (a viscous greenish product having a high sulfur content) from Husky Oil Company. Chemical analysis of these product residues was conducted in 1988 and showed the bottom sludge was mostly asphaltic oil (MC250 and No. 6 fuel oil), the next layer was a yellow-colored dust oil, and the top layer was the greenish clarified dust oil. Laboratory testing from the residual product indicated that the asphaltic oil contained 5 parts per million (ppm) polychlorinated biphenyls (PCBs) and that it was not analyzed for other constituents. The dust oil contained less than 2 ppm PCBs, 142 ppm chlorinated solvents, 8.9 ppm chromium, 79 ppm copper, 6.9 ppm nickel, 1,900 ppm lead, 2.0 ppm cadmium, and 720 ppm zinc. These chemical analyses were not performed using laboratory methods that meet current standards; therefore, the results from these analyses are considered suspect. In particular, the analytical report indicates that the chlorinated solvent analysis was "by Dohrmann" and the "Initial high chloride reading by Dohrmann before toluene wash indicates possible sea water (inorg CL source) contamination." Dohrmann is the brand name of the laboratory instrument used for the analysis and the comment indicates that reported chlorinated solvent concentration is suspect because of potential inorganic chloride interference.

Based on the historic documents and aerial photographs, it appears that BNSF ceased operations other than rail transport at the Site in the mid- to late-1980s and that lessee operation of the Black Tank system and the Liquid Asphalt Pipeline ceased around 2005.

2.2.2.2 *Historic Facilities*

The Black Tank was a 50-feet-diameter, 10,000 barrel (or 420,000 gallons) AST. It was reportedly constructed of riveted steel and was equipped with a heating coil. Based on documentation, historical maps, and images of the Site, the Black Tank was constructed as early as 1913 and was removed in 2006. Review of historical aerial photographs indicates that a containment wall was constructed on the west side and a containment berm was constructed on the north, east, and south sides of the Black Tank between 1974 and 1976. A 1937 base map (with later additions) of Site features (Figure 2) indicates that the Black Tank was plumbed to, or associated with, a distribution system consisting of the following:

- A smaller oil tank (approximately 25-feet diameter), labeled "#2" (referred to herein as "Oil Tank #2"), which appears in historical photographs to have been elevated on legs. Oil Tank #2 was plumbed to, and located approximately 30 feet north of, the Black Tank.

- A pump house (referred to herein as "Black Tank Pump House") was plumbed to Oil Tank #2 and located approximately 70 feet north of the Black Tank. Distribution pipelines were also plumbed from Oil Tank #2 to two to four unloading stanchions and/or dispensers located approximately 40 feet and 100 feet west of Oil Tank #2, between sets of railroad tracks. It is unclear whether the distribution pipelines from Oil Tank #2 were also connected to the other two unloading stanchions and/or dispensers located in the area or whether those units were connected to the solution and/or water lines described below. The Liquid Asphalt Pipeline appears to have been plumbed from the Black Tank Pump House to the SemMaterials facility located to the southeast of the facility.
- A 20-foot-diameter sump (referred to herein as the "Sump") was plumbed to the Black Tank Pump House and was located approximately 110 feet north of the Black Tank. A distribution pipeline was plumbed from the Sump approximately 10 feet to the west, where it splits into an approximately 160-feet-long, north-south pipeline equipped with five loading/unloading racks located along a railroad spur identified as the "Oil Spur."

Approximately 180 feet to the north-northeast of the Black Tank was a 10,000-barrel diesel tank known as the "Red Tank." The 1937 map of Site features (Figure 2) indicates that the Red Tank was plumbed to, or associated with, a fueling system consisting of the following features:

- A pump house (referred to herein as "Red Tank Pump House #1," located approximately 150 feet northeast of the Black Tank) was plumbed to, via two 4-inch pipelines, and located approximately 120 feet southeast of the Red Tank.
- An oil pipeline labeled on the 1937 map as "Oil Pipes on Conc. Blks." ran approximately 80 feet northeast of Red Tank Pump House #1 to an unidentified terminus and approximately 260 feet southwest to another pump house (referred to herein as "Red Tank Pump House #2," located approximately 80 feet south of the Black Tank). The portion of the pipeline on "Conc. Blks" was above ground, whereas the rest of the pipeline was buried.
- Red Tank Pump House #2 was plumbed to a rectangular diesel tank located approximately 15 feet to the south and a rectangular oil tank located approximately 25 feet to the north of the pump house.
- An oil pipeline also extended from Red Tank Pump House #2 approximately 90 feet west to an approximately 160-feet-long, north-south diesel oil pipeline, labeled as "Service Manifolds," equipped with what appears to be five or six fuel dispensers.

Other pipelines and features indicated on the 1937 map (Figure 2) as being in the immediate vicinity of the Site include:

- A north-south oriented 4-inch oil pipeline that extended from at or near the Red Tank Pump House #1 northward an undetermined distance beyond the Site (i.e., the terminus is not shown on the 1937 map).
- An overhead steam pipeline that extended from a steam building located approximately 800 feet north of the Black Tank to the vicinity of the Sump then eastward beyond the eastern boundary of the Site.

A pipeline labeled as 1-inch "Solution Pipe" or "Chem Pipes" ran from the Black Tank Pump House west, then south, parallel and west of the Oil Spur, then west to the dispensers between the tracks. Based on the 1937 map, the solution pipe may be connected to the two dispensers along the Service Manifold; however, one or more of the dispensers may have been connected to the water line (see below) or a distribution line from Oil Tank #2 (see above). A water tank (approximately 25-feet diameter) that appears in historical photographs to have been elevated (i.e., a water tower) was located approximately 50 feet northeast of the Black Tank. Pipelines extended from the water tank to the west to dispensers adjacent to the dispensers fed by Oil Tank #2 and potentially to the dispensers along the Service Manifold fed by the Red Tank. The water pipeline also extends to the east then north an undetermined distance beyond the Site (i.e., the terminus is not shown on the 1937 map).

The Liquid Asphalt Pipeline runs between the Black Tank Pump House and the SemMaterials facility (formerly Blackline) and apparently transported petroleum (i.e., asphaltic oil, fuel oils, dust oil, and clarified dust oil) stored in the Black Tank to the SemMaterials facility (Figure 2).

Structures at the Site began to be removed or demolished as early as 1955 and nearly all of the structures had been removed by 2006. Based on a review of the historical aerial photographs, Oil Tank #2 (elevated) was removed between 1955 and 1957, the elevated water tank was removed between 1968 and 1972, the Black Tank Pump House was removed between 1974 and 1976, and the Red Tank and Red Tank Pump House #2 were removed between 1990 and 1997. The Black Tank and associated containment wall and berm were removed in 2006. A rail spur that extended along the southern boundary of the Site was removed between 2000 and 2012.

Historical documents and aerial photographs document releases or potential releases in the area of the Red Tank, the Black Tank, and the refueling manifold on the rail main line to the southwest of the Black Tank. Aerial photographs from 1967 through 1991 show a dark crescent-shaped area within the containment area of the Red Tank (Appendix B). The Red Tank and the associated dark crescent-shaped area are not obvious on the 1997 and more recent aerial photographs. Similarly, an irregular area of dark material is present in the immediate area of the Black Tank on aerial photographs from 1967 through 2000. A containment structure was constructed around the Black Tank and the adjacent dark-colored soil between 1974 and 1976. On the 1976 aerial photograph, approximately 80% of the containment area around the Black Tank contains dark-colored soil.

The 1955 aerial photograph (Appendix B) shows areas of dark soil at the location of each fuel dispenser and along the refueling manifold situated to the southwest of the Black Tank. The dark soil is not obvious in subsequent aerial photographs; however, the resolution and quality of the 1957, 1962, and 1963 aerial photographs are not conducive to identification of these relatively small areas of dark staining.

The 5 May 1988 Chemical Processors Interdepartmental Communication and the 12 October 1988 Burlington Environmental Inc., letter to Koch Asphalt (Appendix A), refer to the presence of asphaltic material within the Black Tank containment area and provide the results of laboratory analyses of samples of the tar-like material, soil, and surface water collected from the Black Tank containment area. The tar-like material contained 31 to 62 ppm PCBs, the soil contained 14 to 72 ppm PCBs, and the surface water contained less than 2 ppm PCBs. The information presented in these documents suggests that the dark staining observed around the Black Tank in the aerial photographs from 1967 through 2000 likely was asphaltic material and/or oily sludge released from the Black Tank or associated structures.

2.2.3 *Pre-RI Investigations and Cleanup Actions*

2.2.3.1 *Previous Investigations*

Between 2006 and 2012, GeoEngineers conducted a series of investigation activities on behalf of BNSF to characterize Site conditions and the nature and extent of contaminant impact. The results of these investigations are summarized in the following reports:

- *Black Tank Removal, Remedial Excavation, and Supplemental Assessment Report* (GeoEngineers 2008);
- *Black Tank Supplemental Well Installation and Groundwater Monitoring Report* (GeoEngineers 2010);
- *Supplemental Assessment Report* (GeoEngineers 2011a);
- *Groundwater Monitoring Report, Third and Fourth Quarters 2010* (GeoEngineers 2011b);

- *Groundwater Monitoring Report, First Quarter 2011* (GeoEngineers 2011c); and
- *Groundwater Monitoring Report, 2011 Annual Report* (GeoEngineers 2012).

During the course of these investigation activities, GeoEngineers drilled and sampled 26 soil borings (B-1 through B-26) ranging in depth from 2 to 206 feet, constructed 15 monitoring wells (MW-1 through MW-15), and periodically monitored groundwater in the monitoring wells. The locations of the borings and monitoring wells installed by GeoEngineers are shown on Figure 4. Well construction information, groundwater elevation measurements, groundwater quality measurements, and analytical data from the pre-RI investigations are combined with the RI data and included in the data tables presented in this report.

Soil Conditions. The pre-RI investigations showed that the primary contaminants of concern in soil at the Site are total petroleum hydrocarbons-diesel range (TPH-D) and total petroleum hydrocarbons-heavy oil range (TPH-HO). Sampling and analysis for carcinogenic polycyclic aromatic hydrocarbons (cPAHs); lead; benzene, toluene, ethylbenzene, xylenes (BTEX); and PCBs in soil were conducted, and with one exception, the results show that these constituents were either not present, or present only at concentrations well below their respective MTCA Method A soil CULs for unrestricted land use. One soil sample from the soil boring for MW-3, which is situated near the Sump, contained BTEX compounds at concentrations exceeding their respective MTCA Method A soil CULs for unrestricted land use.

Total petroleum hydrocarbons-combined diesel and heavy oil-range (TPH-D/HO)-impacted soil was identified in the vicinity of the Black Tank and the Sump. Nearly all of the shallow soil within the containment area around the Black Tank contained elevated concentrations of TPH-D/HO and the impacted soil extended to a depth of approximately 20 feet below ground surface (ft bgs). The impacted soil extended north of the Black Tank to the vicinity of the Sump. Based on soil screening and sampling data from soil borings B-12 through B-16 and B-26, the TPH-D/HO contamination in the vicinity of the Sump extends down to the groundwater table (approximately 170 ft bgs), forming a steep cone having a maximum diameter of approximately 60 feet.

These pre-RI investigations also identified a significant zone of TPH-D/HO-impacted soil at the groundwater table. The zone of impacted soil was typically associated with wells that contained LNAPL. Based on pre-RI investigation data, the "smear" zone was estimated to be up to 15 feet thick and approximately 1,000 feet long (north-south direction) and 600 feet wide (east-west direction). Intermediate zones of impacted soil having no apparent connection with the shallow impacted soil above or below the smear zone were also identified. These intermediate zones of impacted soil are likely the result of petroleum that spread laterally along discontinuous silt layers.

Groundwater Conditions. Pre-RI investigations showed that the primary contaminants of concern in groundwater are TPH-D and TPH-HO. Sampling and analysis for BTEX and cPAHs in groundwater were conducted, and the results show that these constituents were either not present, or present only at concentrations well below their respective MTCA Method A groundwater CULs.

Petroleum LNAPL was identified in five monitoring wells situated adjacent to or downgradient of the Black Tank (MW-3 through -5, MW-7 and MW-9) and in two monitoring wells located upgradient of the Black Tank (MW-1 and MW-2). The LNAPL thickness was not determined; however, laboratory testing of the physical and chemical properties of the LNAPL recovered from monitoring wells showed that it is comprised of diesel and/or heavy oil (e.g., Bunker C fuel, asphaltic oil).

Some pre-RI groundwater sampling results have shown TPH-D and TPH-HO concentrations exceeding the MTCA Method A CULs. The dissolved phase plume generally corresponded with or extended slightly beyond the area of LNAPL. Groundwater samples from downgradient monitoring wells, and soil and groundwater samples from intervals below the smear zone contained no or very low detections of TPH-D and TPH-HO.

2.2.3.2 Cleanup Actions

After BNSF decommissioned and removed the Black Tank in 2006, a total of 10,270 tons of petroleum-impacted soil was excavated from the area around and beneath the former Black Tank. The excavation extended from approximately 8 to 20 ft bgs, and the TPH-D/HO concentrations at the final limits of the excavation were less than 4,500 milligrams per kilogram (mg/kg), except at the northern end of the excavation, where the former oil pump house is located. The approximate extent of the Black Tank excavation is shown on Figure 2. The sidewall and floor samples from the north end of the excavation contained TPH-D/HO concentrations up to 7,240 mg/kg. Portions of the former underground Liquid Asphalt Pipeline, Black Tank pipeline, Red Tank pipeline, and a water pipeline were encountered and removed from within the excavation limits during the Black Tank excavation work. The cut ends of the pipelines were not capped and small amounts of tarry free product were observed to have oozed from the cut end of either the Black Tank or Liquid Asphalt Pipeline at the north end of the excavation. No other cleanup actions have occurred at the Site.

2.3 NEARBY CONTAMINATED SITES

Sites on Ecology's CSCSL are situated immediately to the north, east, and south of the Site. These sites include:

- BNSF Hillyard Lead site (Ecology Cleanup Site ID No. 1371),
- Aluminum Recycling Company/BNSF Dross Cap site (Ecology Cleanup Site ID No. 3243), and
- SemMaterials Spokane site (Ecology Cleanup Site ID No. 3229).

The locations of the BNSF Dross Cap site and the SemMaterials Spokane CSCSL sites are illustrated on Figures 2 and 3. The Hillyard Lead site is located north of East Wellesley Avenue, to the north of the area captured on Figures 2 and 3. The SemMaterials site is situated immediately upgradient of the Black Tank Site and is a potential source of Black Tank Site contamination. The Aluminum Recycling Company/BNSF Dross Cap site and the BNSF Hillyard Lead site are situated side-gradient and downgradient of the Black Tank Site and are not likely sources of Black Tank Site contamination.

2.3.1 BNSF Hillyard Lead Site

BNSF acquired the former Hillyard railyard in the 1970s and demolished the facilities in the 1980s (WDOH 2005). The property has remained vacant since that time (WDOH 2005).

In 2001 and 2002, soil from the Hillyard railyard property was screened and excavated for use as final cover on the Aluminum Recycling Company/BNSF Dross Cap site landfill cap. However, analytical results showed that part of the excavated soil contained elevated lead concentrations (WDOH 2005). Surface soil and test pit sampling was conducted to determine the source of the lead-contaminated soil. The sampling identified approximately 20,000 cubic yards of soil containing lead concentrations up to 35,400 mg/kg. Arsenic and cadmium were also detected in some samples at concentrations exceeding MTCA CULs. According to Ecology (2014b), total petroleum hydrocarbon (TPH) and PCBs were also confirmed present in the site soil and polycyclic aromatic hydrocarbons (PAHs) are suspected. The site is enrolled in Ecology's Voluntary Cleanup Program, a cleanup action plan (CAP) has been developed and reviewed by Ecology, and Ecology lists the status of the cleanup as "cleanup started" (Ecology 2014b).

2.3.2 *Aluminum Recycling Company/BNSF Dross Cap Site*

The Aluminum Recycling Company/BNSF Dross Cap site is an 8-acre property located side-gradient to the Black Tank Site. It was initially operated as a gravel pit and then from 1954 to 1987 as a reprocessing facility for aluminum and aluminum dross (Ecology 2014a). Aluminum dross is known to contain elevated concentrations of metals, chloride, fluoride, ammonia, and nitrates.

Ecology conducted a preliminary assessment of the property in 1985, and then a preliminary assessment/site investigation in 1987 and concluded that the property was potentially contaminated with hazardous substances. BNSF, the property owner, performed a site characterization study in 1988. In 1991, using the results of the BNSF study, Ecology ranked the site using the Washington Ranking Method as a 2 on a scale of 1 to 5, with 1 representing the greatest risk. In 1998, BNSF and Ecology signed an AO to complete a RI/FS for the site, and the results of the RI/FS showed that groundwater at the site was impacted by chloride, fluoride, nitrate, and nitrite, and soil was impacted with lead where it was mixed with dross. A CAP was prepared in 2000, and the remedy, implemented in 2001, consisted of consolidating approximately 65,000 cubic yards of dross and soil mixed with dross into an on-site pit, capping the consolidation area with a low permeability multimedia cover system, and routing storm water to an on-site lined evaporation pond. Four monitoring wells were sampled on a quarterly basis for chloride, fluoride, nitrate, and nitrite. The remedy was completed in 2003 and 5-year periodic reviews have been performed by Ecology in 2008 and 2013. The latest periodic review shows that the cleanup actions are effective, contaminant concentrations are generally low and showing improvements. However, the chloride, nitrate, and nitrite are not yet meeting the CULs and remediation at the site is not complete (Ecology 2014a).

2.3.3 *SemMaterials L.P. Spokane Site*

The SemMaterials Spokane site is a 10-acre property, the western portion of which is located directly upgradient of the Black Tank Site. It has been used for asphalt- and petroleum-related storage and distribution activities since 1955 and is currently operated by Western States Asphalt (Ecology 2013). Previous operators of the SemMaterials facility leased the Black Tank system and piped petroleum (i.e., asphaltic oils, fuel oil, dust oil, and clarified dust oil) stored in the Black Tank system to the SemMaterials facility via the Liquid Asphalt Pipeline. The property is mostly unpaved and occupied by ASTs of varying capacities. The quantity and capacity of ASTs on the property have varied with time; the total AST capacity for the property has been as high as 12.5 million gallons.

Contaminated soil was identified beneath the northeast tank farm at the SemMaterials site in 1992 during replacement of several ASTs (Aspect 2013).

Ecology conducted an initial investigation in 1993 and the property was added to Ecology's Hazardous Sites List in 1995. An asphalt cap and a bioventing system were constructed in the area of the soil contamination. The bioventing system operated from 1996 to 2004 as an active system, but was subsequently switched to a passive mode and continues to operate in that mode (Aspect 2013).

Ecology identified BNSF, Koch Materials, LLC, Marathon, and SemMaterials as PLPs for the SemMaterials site. The PLPs and Ecology signed AO No. 5589 in 2008 requiring the performance of a RI/FS in accordance with MTCA. The RI field activities were conducted between 2008 and 2011 and included shallow and deep soil investigations, installation of monitoring wells, and performance of seven rounds of groundwater monitoring (Aspect 2013).

The results of the RI/FS are presented in a draft RI/FS Report, dated 31 January 2013 (Aspect 2013). The identified constituents of concern (COCs) include TPH-D, TPH-HO, and cPAHs. Draft MTCA CULs were proposed for soil and groundwater based on protection of potable groundwater and industrial workers. The proposed groundwater CULs are MTCA Method A, and the proposed soil CULs are MTCA Method C for direct contact at an industrial site and MTCA Method B for protection of groundwater. Ecology is still in the process of preparing a draft CAP for the SemMaterials site.

Soils in the northeast tank farm area showed exceedances of the draft CULs to depths of 20 ft bgs and some limited exceedances to a depth of 125 feet (Aspect 2013). Shallow soil contamination was also identified along the northern perimeter and in the central portion of the SemMaterials site. Contamination concentrations decreased with depth and deep migration to the water table was not documented in either area (Aspect 2013).

Groundwater at the SemMaterials site has shown no exceedances of the MTCA Method A groundwater cleanup standards (Aspect 2013), and LNAPL has not been identified in any of the on-site monitoring wells.

It should be noted that the RI primarily focused on the central and eastern portion of the property. Only five direct-push soil borings (GGP01B, GGP02, GGP03, GGP19, and GGP20) and two monitoring wells (GMW-05 and GMW-06) were advanced and sampled on the western portion of the property, which is immediately upgradient of the Black Tank Site (Figure 2). The western portion of the property is unpaved and includes seven of the largest ASTs on the property (Figure 2). Seven soil samples were collected from the borings, three from GGP03, and one from each of the other borings, at depths ranging from 2.5 to 15 ft bgs. Low levels of TPH-D and TPH-HO were detected in the three samples from GGP03 as well as the samples from GGP02 and GGP20. The detected concentrations are below the draft MTCA CULs; however, the source and extent of the contamination on the western portion of the property was not investigated.

Because of its location upgradient of the Site and the materials handled at the facility, SemMaterials is a potential source of the petroleum contamination observed in the upgradient portion of the Site; however, the environmental investigations conducted to date show no confirmed contaminant impact from SemMaterials to the Site. Similar hazardous substances were used at both sites, and their operations were connected for a number of years.

3.0 ENVIRONMENTAL SETTING

The following describes the physical setting of the Site, including the topography, climate, hydrology, vegetation, wildlife, geology, and hydrogeology.

3.1 PHYSICAL SETTING

3.1.1 Topography

The Site is situated at an elevation of approximately 2,035 feet above mean sea level (amsl) based on the North American Vertical Datum of 1988 (NAVD88). The Site is relatively flat, having about 11 feet total relief. The main areas of relief include the Black Tank excavation, the main rail line corridor, and the former rail spur between the Site and SemMaterials (Figure 2). The former Black Tank excavation was partially backfilled, but a depression approximately 10 feet deep remains (Figure 2). The main rail line corridor and the rail spur between the Site and SemMaterials are approximately 9 feet lower than the adjacent lands. A few piles of soil and pieces of concrete debris up to 5 feet high are scattered across the Site.

The topography in the Site vicinity slopes downward very gradually to the west. The topography is relatively flat to the east for approximately 1 mile and then abruptly rises approximately 500 feet in elevation at Beacon Hill. North of the Site, the topography slopes downward at 2% to 5% to the Little Spokane River, approximately 6 miles north of the Site. South of the Site, the topography slopes downward approximately 1% to 2% to the Spokane River valley, where a steep bluff drops approximately 30 feet to the river. In general, the Site area topography ranges from elevations of 1,870 feet at the Spokane River, approximately 1.5 miles south of the Site, to 5,889 feet at the summit of Mt. Spokane, approximately 12 miles northeast of the Site.

3.1.2 Climate

Spokane has a high desert climate. It receives an average of 16.5 inches of precipitation per year (at the airport), including an average snowfall of 49 inches per year. The precipitation in the Site area is typically 18 or 19 inches per year. The number of days with any measurable precipitation is approximately 113. On average, there are 171 sunny days per year in Spokane. The monthly average maximum temperature is 83 degrees, which occurs in July and the monthly average minimum temperature is 21 degrees, which occurs in January.

Evapotranspiration in the Site area is reasonably high, resulting in a recharge rate of approximately 8.6 inches per year (Hsieh, et al. 2007).

3.1.3 *Surface Water Hydrology*

The Site is located within the Spokane River watershed, which includes the Little Spokane River. The nearest surface water is the Spokane River located approximately 1.5 miles south of the Site. The Little Spokane River, which is located approximately 6 miles north-northwest of the Site discharges to the Spokane River below Nine Mile Dam approximately 10 miles northwest of the Site. The Spokane River discharges to the Columbia River approximately 48 miles west of the Site. A discussion of the interactions between groundwater and surface water is included in Section 3.3.1.

Surface water runoff at the Site generally stays within the Site boundaries and rapidly infiltrates the highly permeable surface soils or evaporates. There are no perennial surface water features on the Site. The manmade storm water collection basin on the adjacent Dross Cap site reportedly contains water year-round.

3.1.4 *Vegetation*

A formal vegetation survey was not conducted for this project. The Site is located within an urban industrial area where native vegetation has been significantly altered and consists of highly disturbed, arid- to semi-arid conditions, with areas that are more densely vegetated and others with very sparse cover. The vegetation is primarily composed of the herbaceous layer, containing a mixture of native and invasive grasses and forbs, with a small percent coverage consisting of deciduous shrub layer, and some sparse coniferous trees.

3.1.5 *Wildlife*

The Site and surrounding parcels consist of industrial properties that have been significantly altered. It is unlikely that the Site and surrounding properties provide habitat for species other than transient wildlife. However, there are Washington State Department of Fish and Wildlife (WSDFW) priority habitats located within 2 miles of the Site and a number of Endangered, Threatened, Sensitive, and other Priority Species located within Spokane County that are discussed in the following sections.

3.1.5.1 *Habitat*

The WSDFW Priority Habitats and Species web-tool map indicates two priority habitats (the Beacon Hill Biodiversity Region and the Spokane River) within a 2-

mile radius of the Site. The Beacon Hill Biodiversity Region is located about 1.5 miles east of the Site and includes habitat for white-tailed deer, moose, elk, red-tailed hawk, Cooper's hawk, great horned owl, saw-whet owl, and pygmy owls (J&S 2007). The Spokane River corridor, located about 1.5 miles south of the Site, provides riparian habitat for winter waterfowl, nesting red-tailed hawk, and some occurrences of nesting osprey and wintering bald eagles.

3.1.5.2 Endangered, Threatened, Sensitive, and other Priority Species

The 2013 WSDFW Priority Habitats and Species Statewide List and Distribution by County spreadsheet was used to determine the endangered and threatened species and species of concern that inhabit Spokane County. A review of this list showed the following species:

- Federal Threatened Species: Bull Trout, Chinook Salmon, Chum Salmon, Steelhead
- Federal Species of Concern: Pacific Lamprey, River Lamprey, Sagebrush Lizard, Bald Eagle, Ferruginous Hawk, Peregrine Falcon, Burrowing Owl, Loggerhead Shrike, Preble's Shrew, Townsend's Big-eared Bat, Townsend's Ground Squirrel, California Floater, and Columbia Clubtail
- Federal Candidate Species: Yellow-billed Cuckoo
- State Endangered Species: American White Pelican
- State Threatened Species: Ferruginous Hawk, Greater Sage-grouse
- State Candidate Species:
    - Fish: River Lamprey, Leopard Dace, Umatilla Dace, Mountain Sucker, Bull Trout, Chinook Salmon, Chum Salmon, Steelhead, and Sockeye Salmon
    - Reptiles: Striped Whipsnake and Sagebrush Lizard
    - Birds: Western grebe, Golden Eagle, Yellow-billed Cuckoo, Burrowing Owl, Vaux's Swift, Lewis' Woodpecker, Loggerhead Shrike, Sage Sparrow, and Sage Thrasher
    - Mammals: Merriam's Shrew, Preble's Shrew, Townsend's Big-eared Bat, Black-tailed Jackrabbit, White-tailed Jackrabbit, and Townsend's Ground Squirrel
    - Invertebrates: California Floater and Columbia Clubtail
- State Sensitive Species: Peregrine Falcon

3.2 GEOLOGICAL SETTING

3.2.1 Regional Geology

The regional stratigraphy in the Site area includes, from oldest to youngest: Precambrian metamorphic basement rock, Cretaceous to Eocene igneous intrusive rocks, Miocene lake deposits and flood basalts, and Pleistocene glaciofluvial flood deposits. The basement rock is very old, high-grade metamorphic rock that includes the Hauser Lake gneiss and Priest River metamorphic core complex. Cretaceous to Eocene age quartz monzonite to granite plutons intruded the basement rock and can be seen throughout the Mead area (Boleneus and Derkey 1996). The Miocene Latah Formation, a poorly indurated unit of sedimentary rock, sits unconformably on the basement and intrusive rock. The Latah Formation consists of interbedded siltstone, claystone, sandstone, and minor conglomerate with scattered beds of volcanic ash. Based on the nature of the deposits and the fossils found within them, the Latah Formation is thought to have been deposited in a shallow lake-type environment.

Miocene Columbia River Basalt Group (CRBG) basalt flows are interbedded with and overlie the Latah Formation. The basalt flows generally occupy the lower valleys and foothills and abut the higher mountains in the Site area. Two formations of the CRBG, the Wanapum Basalt (Priest Rapid Member) and the Grande Ronde Basalt, have been mapped in the Site area (Derkey 1997; Derkey, et al. 1998) as having a thickness of 50 feet to 150 feet (Griggs 1973). The earlier basalt flows likely blocked stream/river drainages, forming either a series of lakes or a single large basin along the north and east rim of the basalt field. Lacustrine sediments of the Latah Formation are thus interbedded with the lower CRBG basalt flows.

Pleistocene glaciofluvial deposits overlie the Miocene CRBG and Latah Formation and cover an area of approximately 370 square miles across Idaho and Washington (Kahle and Bartolino 2007). During the climax of the glaciation, much of northern Washington and Idaho were covered by lobes of the Cordilleran ice sheet, which flowed southward out of Canada, overriding mountain ranges and filling the river valleys. The glacial ice formed dams in several of the valleys and lakes formed behind the ice dams. The largest of the lakes was Glacial Lake Missoula. The lake water periodically burst through the dams, causing widespread flood events (outburst floods) that extended across parts of Montana, Idaho, Washington, and Oregon, before reaching the Pacific Ocean (Kahle and Barolino 2007). As many as 100 outburst floods may have occurred as the glacial ice continued to flow southward and re-dam the valleys (Atwater 1986).

The outburst floods flowed along the major river courses, such as the Spokane and Little Spokane Rivers, and scoured large quantities of sediment from the valleys. One of those valleys, the Hillyard Trough, follows the ancestral course of the Spokane River and trends north-south through the Site area. As the flood waters receded, the sediment was re-deposited in the river valleys. Coarse sediments, such as boulders, cobbles, and coarse gravel, were generally deposited near the center of the valleys, whereas finer sediments, such as fine gravel, sand, and silt were deposited along the valley margins (Kahle and Bartolino 2007). In addition, glacial lakes, such as Glacial Lake Spokane and Glacial Lake Columbia, periodically formed in the valleys and deposited glaciolacustrine deposits consisting of silts, clays, and scattered dropstones from melting icebergs. Glaciofluvial deposits from outburst floods accumulated in the Spokane area to a maximum elevation of 2,700 feet and a maximum thickness on the order of 500 feet in the Little Spokane River valley (Derkey 1997). After the final outburst flood, the climate warmed, the continental ice sheets retreated northward, and the rivers resumed their flow. Because thick deposits of glaciofluvial sediments had accumulated in the Hillyard Trough area, the Spokane River was not able to resume its previous course northward through the trough and instead was redirected westward through what is now downtown Spokane before turning north to join the Little Spokane River on its path to the Columbia River.

The Pleistocene glaciofluvial flood deposits are the primary geologic units in the Hillyard Trough area. The unit consists of a poorly sorted, stratified mixture of boulders, cobbles, gravel, and sand (Joseph 1990). The percentage of boulders and cobbles in the deposit is lower in the Hillyard Trough than further south along the Spokane River valley. Intermittent layers of silt and clay are present within the outburst flood deposits and represent periods of deposition from glacial lakes. In the northern portion of the Hillyard Trough, a continuous silty clay and sand layer, up to 200 feet thick, is found at a depth of 100 to 300 ft bgs (Kahle and Bartolino 2007). This layer becomes thin and discontinuous to the south, where the Site is located.

3.2.2 *Site Geology*

Soil borings drilled at the Site for the RI and pre-RI investigations confirm the presence of the glaciofluvial flood deposits and glaciolacustrine deposits identified in the Site area. Soil boring and well construction logs from the RI and pre-RI investigations are included as Appendix A. Geologic cross-sections of the Site were prepared based on the soil boring and well construction logs. The cross-section locations are shown on Figure 4, and the cross-sections are presented on Figures 5 through 9.

The Site geology is described using fit-for-purpose facies. The primary purpose is assessing contaminant migration; therefore, two grain-size based facies are defined:

- Sand and gravel facies - coarse-grained deposits including lenses and beds of gravel, coarse-, medium- and fine sand and interbedded zones of these materials – interpreted as high-energy glaciofluvial flood deposits; and

- Silt and silty sand facies - fine-grained deposits including lenses and beds of silt, silty sand, sand with silt and interbedded zones of these materials – interpreted as low-energy glaciolacustrine and/or glacialfluvial over-bank deposits.

An evaluation of the soil boring logs (Appendix F), the soil core photographs (Appendix D) and grain size data (Table 5) illustrates the distinctive nature of these two facies. Although both facies contain some amount of fine- and/or medium-grained sand, the sand and gravel facies also contains gravel and coarse sand and generally has less than 10% silt and clay. Conversely, the silt and silty sand facies has no gravel and coarse sand and generally contains 20% to 40% silt and clay and may have as much as 85% silt and clay. The difference in percentages of coarse-grained and fine-grained components result in very different hydraulic conductivities and impacts on contaminant (i.e., LNAPL) migration. The interbedded nature and thinness of individual beds within the silt and silty sand facies make subdividing the facies into its components impractical and unnecessary. As an example, the soil boring logs and soil core photographs for MW-17, MW-20, MW-24 and MW-28 through MW30 (which is the most reproducible stratigraphic data from the Site) show interbedded silt and silty sand layers as thin as 0.3 feet (Appendices F and D). Therefore, these layers are described as a single facies because they commonly occur together, the individual beds are too thin to show as separate layers on the cross-sections, and they have a common fine-grained component that makes them distinct from the sand and gravel facies.

The sand and gravel facies deposits are generally gray to brown, poorly sorted, and contain more gravel at shallow depths. Discontinuous beds of silt and silty sand facies are present at various depths throughout the Site. As shown on the cross-sections (Figures 5 through 9), the silt and silty sand facies beds are typically thin (approximately 0.5 to 6.0 feet thick) and laterally discontinuous (less than 50 feet horizontally). A few silt and silty sand facies beds are up to 17 feet thick and one lens (near MW-9) is approximately 60 feet thick (Figure 6). Lenses and beds of the silt and silty sand facies are sparse in the upper 85 feet of the soil column, particularly in the central portion of the Site. However, their frequency increases at depths greater than 85 ft bgs, particularly at depths of 145 to 185 ft bgs, and in the north-central portion of the Site.

Most beds of the silt and silty sand facies are laterally discontinuous; however, a bed of the silt and silty sand facies is observed in most of the Site soil borings at a depth near the groundwater table (Figures 5 through 9). In the vadose zone, beds of the silt and silty sand facies generally cannot be correlated laterally beyond a single soil boring; however, in a few places they appear to be laterally continuous for up to 550 feet (Figures 6, 7, and 9). The bed of silt and silty sand facies near the groundwater table ranges in thickness from less than 1 to 20 feet, but is generally less than 6 feet thick (Table 3 and Figures 5 through 9). This bed is a key feature of the Site geology because it occurs at the same general depth interval as the groundwater table and, thus, influences contaminant migration. It was observed in all the Site borings except the borings for monitoring wells MW-10, MW-12, and MW-15, which are all situated along the northern or eastern borders of the Site. As shown on Figure 10, the elevation of the top of this silt and sandy silt facies layer varies by more than 20 feet across the Site, and as illustrated on Figures 9 and 10, a north-south trending trough with a branch that extends to the southeast occurs in the top of the bed. The two lowest areas in the trough are situated near monitoring wells MW-3/MW-4 and MW-2. High areas adjacent to the trough are situated near monitoring wells MW-14/MW-20 and MW-17/MW-25/MW-26.

3.3 HYDROGEOLOGICAL SETTING

3.3.1 Regional Hydrogeology

The Site overlies the Spokane Valley Rathdrum Prairie (SVRP) aquifer, which covers about 370 square miles and includes the Rathdrum Prairie, Idaho, and the Spokane Valley and Hillyard Trough, Washington. The aquifer extends from Lake Pend Oreille, south to Lake Coeur d'Alene, and west across the Washington-Idaho State border to near Nine Mile Falls northwest of Spokane. The SVRP aquifer is a sole-source drinking water aquifer supplying more than 500,000 residents in the region.

The SVRP aquifer consists mostly of coarse-grained sediments (sands, gravels, cobbles, and boulders) deposited during a series of outburst floods resulting from repeated collapse of the ice dam that impounded ancient Glacial Lake Missoula (Kahle and Bartolino 2007). The aquifer sediments are situated within broad river valleys cut into the underlying granite or metasedimentary bedrock formations or basalt and associated sedimentary deposits. Discontinuous fine-grained layers are found throughout the SVRP aquifer at different depths and thicknesses. In the Hillyard Trough and the Little Spokane River Arm of the aquifer, a thick, fine-grained layer separates the aquifer into upper and lower units. In the vicinity of the Site, the top of this fine-grained layer is projected to be approximately 400 ft bgs. The thickness of the aquifer in the Hillyard Trough is more than 600 feet in some places.

Recharge to the SVRP aquifer occurs mainly from losing reaches of the Spokane River as well as lakes, tributaries, and infiltration from precipitation, landscape irrigation, and septic systems (Kahle and Bartolino 2007). Permeable glaciofluvial deposits overlie the SVRP aquifer in the Hillyard Trough area and most precipitation infiltrates into the underlying aquifer with little overland flow. Most of the infiltration occurs in the winter and early spring from winter rains or snowmelt (Cline 1969). Discharge mainly occurs to gaining reaches of the Spokane River and Little Spokane River as well as groundwater extraction, subsurface discharge to Long Lake, and infiltration of groundwater into sewers.

The transmissivity of the SVRP aquifer ranges from approximately 0.13 to 11 million square feet per day (Drost and Seitz 1977). Corresponding groundwater velocities for the aquifer have been calculated in excess of 60 feet per day in some areas. In the Hillyard Trough, the average transmissivity is 3.9 million square feet per day, which translates to a horizontal hydraulic conductivity of 12,000 feet per day and velocities ranging from 41 to 47 feet per day (Drost and Seitz 1977). In comparison, a typical aquifer has a groundwater flow velocity of between 0.02 feet to a few feet per day (Golder 2008). The hydraulic gradient of the aquifer ranges from 2 feet per mile to more than 60 feet per mile. The groundwater table elevation seasonally fluctuates less than 15 feet in most areas (Drost and Seitz 1977).

Regional groundwater flow within the SVRP aquifer generally reflects the ground surface topography (Kahle, et al. 2005). In the Spokane Valley, groundwater generally flows from east to west, parallel to the Spokane River, whereas in the Hillyard Trough, groundwater flows from south to north.

As discussed in Section 3.1.3, the nearest surface water feature is the Spokane River, situated approximately 1.5 miles south of the Site (Figure 1). Based on the northward regional groundwater flow direction in the Hillyard Trough area, the Spokane River is hydraulically upgradient of the Site and thus would not be impacted by releases at the Site. The Little Spokane River is located approximately 6 miles north of the Site (Figure 1), and based on the northward regional groundwater flow direction, it is hydraulically downgradient of the Site. According to Hsieh, et al. (2007) and Kahle, et al. (2005), stream gage data collected from the Little Spokane River (United States Geological Survey Station Nos. 12431500 and 12431000) shows groundwater from the SVRP aquifer discharges to the Little Spokane River between these two stream gage locations.

3.3.2 *Site Hydrogeology*

Groundwater beneath the Site occurs at depths ranging from approximately 158 to 179 ft bgs (1,861 to 1,876 feet amsl) and flows to the north-northwest with a horizontal hydraulic gradient of approximately 0.0013 to 0.0014 feet per feet (feet/feet). Depth to groundwater measurements collected during the RI and pre-RI investigations are summarized in Table 4 and piezometric surface maps constructed for the eight most recent quarters of groundwater monitoring are included as Figures 11 through 15. Groundwater levels fluctuated on the order of 4 to 7 feet annually, with the highest groundwater levels occurring in early summer (June) and the lowest groundwater levels occurring in fall (October). These findings are consistent with those reported by Kahle and Bartolino (2007) for the Hillyard Trough portion of the SVRP aquifer. Only data from monitoring wells that are screened across the water table and do not contain LNAPL was used to construct the piezometric surface maps. The viscosity of the LNAPL is too high to allow accurate measurements of the depth to groundwater in wells containing LNAPL. The groundwater flow direction and horizontal hydraulic gradient at the Site were generally consistent throughout the RI and pre-RI investigations. However, a more prominent westerly flow component was observed in the northwest portion of the Site during the first and third quarters. The groundwater flow direction and the horizontal hydraulic gradient at the Site are generally consistent with the findings of Kahle and Bartolino (2007) for the Hillyard Trough portion of the SVRP aquifer.

Groundwater levels beneath the Site seasonally fluctuate across a mostly laterally continuous bed of the silt and silty sand facies, possibly creating localized and transitory aquifer conditions. As illustrated on the geologic cross-sections of the Site (Figures 5 through 9), a bed of the silt and silty sand facies occurs at the same depth range as the groundwater table. Where this facies is absent, unconfined conditions exist year around, but where it occurs, possible perched or semi-confined conditions have been documented. For example, vertical gradient data suggest that perched and/or semi-confined conditions may exist in the vicinity of MW-14/MW-20 and MW-13/MW-21 (Appendix C). Differences in the static water levels measured at the MW-14/MW-20 monitoring well pair show an average downward vertical hydraulic gradient of 0.11 feet/feet over the last monitoring events between 3 December 2013 and 23 June 2016; however, the vertical gradient ranged from 0.26 feet/feet downward to 0.13 feet/feet upward over that time span (Appendix C). The midpoints of the well screens for the MW-14/MW-20 monitoring well pair are separated by 32 feet, which is greater than the horizontal separation of the wells (25 feet), making this a good well pair for evaluating vertical gradient. The shallow well (MW-20) is screened in thick sections of the silt and silty sand facies, whereas the deep well is screened in the underlying sand and gravel facies (Figures 5 and 9). The variability and abnormally high values of vertical hydraulic gradients measured at this well pair suggests that the presence of the silt and silty sand facies at this location may create transitory perched and/or semi-confined conditions in this area of the Site.

Differences in the static water levels measured at the other monitoring well pair at the Site (MW-13/MW-21) show an average upward vertical hydraulic gradient of 0.05 feet/feet over the seven monitoring events between 3 December 2013 and 20 June 2016 (Appendix C). This monitoring well pair is not as reliable an indicator of vertical gradient because the midpoints of their screens are only separated by 8.2 feet, but the wells are separated horizontally by approximately 36 feet. Nonetheless, both wells are screened below the silt and silty sand facies, which has the potential to produce localized semi-confined conditions and a small upward gradient. It should be noted that the difference in static water levels in this well pair may be due to the horizontal position of the wells.

It is reasonable that the presence of a bed of the silt and silty sand facies at the groundwater table could lead to transient aquifer conditions. During periods of decreasing groundwater levels, migration of infiltrating precipitation and residual groundwater above the silt and silty sand facies may be slowed by this lower permeability unit, possibly creating temporary and localized perched conditions. During periods of rising groundwater levels, the silt and silty sand facies may slow upward flow, possibly producing temporary and localized semi-confined conditions. Possible perched and/or semi-confined conditions are likely transient and would dissipate as groundwater levels and infiltration conditions stabilize.

Grain size analyses of soil samples collected from the aquifer and capillary fringe show the shallow aquifer beneath the Site contains beds of clayey silt, silty fine sand with clay, silty medium sand, medium sand with silt and clay, medium sand with gravel silt and clay, coarse sand with gravel and gravelly medium sand with silt and clay. The test results are summarized in Table 5 and the full reports are included in Appendix D. Of the 16 soil samples analyzed for grain size, one is a clayey silt, six are silty fine sands with clay, one is a silty medium sand, four are medium sand with silt and/or clay, two are medium sand, one is gravelly medium sand with silt and clay and one is coarse sand with gravel (Table 5). Eight of the 16 soils are silty soils have silt and clay content of 19% to 85% (Table 5). These samples represent the silt and silty sand facies shown on the cross-sections (Figures 5 through 9). The other eight samples contain from 3% to 9% silt and clay and high percentages of medium sand and/or coarse sand and some gravel. These samples represent the sand and gravel facies shown on the cross-sections (Figures 5 through 9) and are typical of the permeable aquifer materials of the SVRP aquifer.

Hydraulic conductivity measurements collected from four aquifer and capillary fringe samples show calculated hydraulic conductivities of 1.36×10^{-2} cm (centimeters)/second in coarse sand to 1.99 x 10^{-6} centimeters per second (cm/second) in silt (38.54 to 0.006 feet per day). The test results are summarized in Table 6, and the full reports are included in Appendix D. Most of these samples were collected from beds of fine to medium sand containing silty sand interbeds. Because the measured hydraulic conductivities are from layers containing silty sand interbeds and from samples that previously contained LNAPL, they are two to three orders of magnitude lower than the hydraulic conductivities (12,000 feet per day) typically reported for the SVRP aquifer in the Hillyard Trough area. Although solvents are used to flush LNAPL from the undisturbed samples prior to conducting the hydraulic conductivity testing, complete removal of LNAPL from the soil is nearly impossible; this results in hydraulic conductivity test results that are biased low.

3.3.3 Groundwater Use and Potability

The SVRP aquifer is the water source for more than 500,000 people in Idaho and Washington. Because it supplies water to more than 80% of the population living near the aquifer, the USEPA designated the SVRP aquifer as a sole-source aquifer in 1978 (Kahle and Bartolino 2007).

A review of public drinking water systems located in the vicinity of the Site was completed to assess whether potential receptors and exposure pathways exist for groundwater. Public records and available technical reports were reviewed to identify active public drinking water supply wells located downgradient or cross-gradient of the Site. Because the groundwater flow direction is to the north, wells located to the east, west, and north of the Site were identified. A review of Ecology records for private wells located within 0.5 miles downgradient of the Site was also conducted to identify private wells located immediately downgradient of the Site. The following data sources were used in this review:

- Washington State Department of Health (WSDOH) drinking water databases, including the Washington State Water System data through the Sentry Internet and the SWAP (Source Water Assessment Program) Interactive GIS (Geographic Information System) Mapping Tool (WSDOH 2014a,b);
- Ecology well log viewer (Ecology 2014f); and
- Technical reports published by local and state entities, including the City of Spokane, the Spokane Aquifer Joint Board (CH2MHill 2000), City of Spokane (CH2MHill 1998), and the United States Geological Survey.

Public Drinking Water Systems. Results of the review identified the presence of seven active downgradient public drinking water systems within 6 miles of the Site. This included six systems with groundwater supply wells located between 2 and 6 miles of the Site, and one system (City of Spokane) that included two wells located between 0.8 and 1.8 miles of the Site in a cross-gradient or upgradient direction. A summary of the water systems identified is presented in Table 7, and the approximate locations of the wells are shown on Figure 16.

Ecology Well Log Review. Ecology's online well log viewer was used to identify wells located downgradient of the Site within 0.5 miles. Ecology's database divides wells into four categories: abandoned, resource protection wells, water wells, and multiple well types. No water wells were on file within 0.5 miles of the Site at the time of the review.

Due to the high transmissivity of the SVRP aquifer, capture zones for individual pumping wells are generally narrow and follow the direction of regional groundwater flow upgradient of the pumping well. Based on a review of capture zone delineations for nearby pumping wells presented in the above referenced sources, the Site does not appear to fall within the capture zones for the wells listed in Table 7.

4.0 REMEDIAL INVESTIGATION ACTIVITIES

The RI is the data-gathering phase of the RI/FS process and, as indicated in Section 1.2, the goal of the RI is to collect and evaluate sufficient data to characterize the Site conditions, the nature and extent of contamination, and the risk to human health and the environment. Because a significant amount of pre-RI Site data had been collected, the RI focused on collecting supplemental data to address the following objectives:

- Identifying constituents of potential concern (COPCs) and additional contaminant sources;
- Assessing Site hydrogeology, contaminant characteristics, and contaminant fate and transport;
- Assessing the extent and mobility of the LNAPL; and
- Evaluating the overall risk to human health and the environment.

The RI was completed in three phases (Phase I, II, and III). Phase I was initiated in March 2013 and completed in October 2014. The scope of Phase I was presented in the RI/FS Work Plan (ERM 2013a), SAP (ERM 2013b), and QAPP (ERM 2013c) and included:

- Validating and compiling the pre-RI Site data;
- Locating subsurface utilities and historical features at the Site;
- Excavating and sampling test pits and trenches in the vicinity of historical Site features to identify additional contaminant sources;
- Drilling and sampling soil borings to assess the Site hydrogeology, the vertical and lateral extent of impacted soil, and the physical and chemical characteristics of the LNAPL; and
- Installing and sampling monitoring wells to assess groundwater flow conditions and the extent and mobility of LNAPL and groundwater contamination.

Identifying the Site-related contaminants was one of the objectives of Phase I. This objective was satisfied by collecting samples of stained soil from test pits advanced in potential source areas and conducting the required testing for petroleum releases as specified in Table 830-1 of WAC 173-340-900 (see Section 4.7.1.1 for the list of required analyses and test methods). As specified in Section 5.2.2 of the RI/FS Work Plan (ERM 2013a), the laboratory results from this initial set of source area soil samples were summarized and reviewed with Ecology to determine potential Site-related contaminants. During the meeting with Ecology, which occurred on 5 November 2013, it was determined subsequent soil samples would be analyzed for the following:

- TPH-D/HO,
- BTEX,
- PAHs, and
- Cadmium and chromium.

To ensure the breadth of analytes were evaluated, LNAPL samples were analyzed for the above-listed constituents plus total petroleum hydrocarbons-gasoline range (TPH-G), PCBs, the full volatile organic compound (VOC) and semi-volatile organic compound (SVOC) scans, copper, lead, nickel, and zinc.

ERM summarized and evaluated the Phase I RI data collected through May 2014 and met with Ecology on 4 June 2014 to assess data gaps and discuss additional RI activities to address the data gaps. The following data gaps were identified.

Soil Contamination

- Source investigation in areas of asbestos-impacted soil located around the Sump and Black Tank Pump House and along the Black Tank oil pipeline west of the Sump.
- Vertical and lateral extent of impacted soil at the northern and southern ends of the Red Tank Dispenser pipeline.
- Vertical and lateral extent of impacted soil along the Black Tank and Chemical Solution Pipelines.

LNAPL

- Southern/southwestern extent of the LNAPL.
- Northeastern extent of the LNAPL.
- Source of LNAPL at MW-20.
- Composition of LNAPL in the southern and northeastern areas of the Site.
- Soil grain size and pore fluid saturation of specific intervals of the LNAPL smear zone.

Groundwater

- Northeastern extent of the TPH-D/HO in groundwater.
- Characterization of groundwater conditions beneath the LNAPL.

- Magnitude and extent of chromium and lead in groundwater.

ERM designed Phase II RI activities to address these data gaps and presented the proposed scope of work to Ecology in a letter dated 15 September 2014 (ERM 2014). Ecology approved the proposed scope of work in a letter dated 24 September 2014 (Ecology 2014d), but questioned the efficacy and usefulness of collecting groundwater samples from beneath viscous LNAPL using a bailer.

The Phase II RI activities were carried out between 22 September 2014 and 5 December 2014, and presented in a draft RI/FS report submitted in January 2015. Ecology provided comments on the draft RI/FS report in a letter dated 28 July 2015. The comments included identification of several gaps in the RI data, including:

LNAPL

- The western and northeastern extent of the LNAPL.
- More complete understanding of LNAPL mobility and recoverability.
- Quantitative evidence supporting NSZD and NSZD rates.

Groundwater

- Dissolved phase TPH-D/HO data from analyses without silica gel cleanup.
- PCB data using analyses having low detection levels.

On 10 September 2015, ERM and representatives from BNSF and Husky Oil Operations Limited met with Ecology to discuss Ecology's comments on the draft RI/FS report and to propose additional RI activities to address the data gaps.

ERM designed Phase III RI activities to address the data gaps identified in Ecology's comments as well as additional investigation to assess whether the cadmium concentrations in the Site soil had an adverse impact on groundwater. The proposed scope of work for the Phase III RI activities were presented to, and discussed with Ecology, between November 2015 and March 2016. A revised scope of work was presented to Ecology in a letter dated 3 March 2016 (ERM 2016), and Ecology approved the revised scope of work in a letter dated 10 March 2016 (Ecology 2016). The Phase III RI activities were carried out between 10 March 2016 and 24 June 2016 and the data from those activities are included in this report. Descriptions of the RI activities are presented in the following subsections. Additional detail regarding the data collection procedures can be found in the RI/FS Work Plan (ERM 2013a), SAP (ERM 2013b), QAPP

(ERM 2013c), Phase II letter (ERM 2014), and Final Draft Addendum for the RI/FS Project Plan (ERM 2016).

4.1 FIELDWORK PREPARATION ACTIVITIES

4.1.1 Pre-Mobilization Activities

Prior to performing any intrusive work at the Site, subsurface clearance activities were performed to avoid inadvertent contact with subsurface utilities. The proposed test pit, soil boring, and monitoring well locations were marked at the Site as required by the Revised Code of Washington (RCW) Section 19.122.030. *Call Before You Dig*, a public utility notification service, was notified of the drilling activities at the Site. Global Geophysics LLC of Redmond, Washington (a private utility locating service) surveyed proposed test pit, monitoring well, soil boring locations for underground utilities, subsurface structures, and historical buried pipelines with electromagnetic, radio frequency transmission, and/or other geophysical locating equipment.

Physical clearing of all ground disturbance locations for work performed in 2013 and 2014 was performed by Big Sky Industrial of Spokane, Washington, and by Able Cleanup Technologies of Spokane, Washington, as a subcontractor to Environmental West Exploration, Inc. (EWE) for work performed in 2016. Physical clearing was performed using an air knife/vacuum truck to check for the presence of active public or private utilities or other obstructions at proposed ground disturbance (i.e., drilling or excavating) locations. Soil borings located near identified underground utilities were repositioned, as necessary, to avoid contact with underground utilities.

Because some investigation work was performed on BNSF property, in close proximity to railroad tracks, Site personnel and subcontractors were required to completed BNSF's Contractor Safety and Security Training prior to working on the Site. Additionally, Site personnel coordinated with the Road Master in charge of the section of track at the Site prior to conducting investigation tasks within 25 feet of railroad tracks, or conducting any task that presents a potential to foul the tracks to arrange for access to the desired portion of the Site, and to arrange for flaggers and track closures as necessary to perform the work safely.

This task also included procuring the utility locating, drilling, test pitting, surveying, analytical laboratory, and waste disposal subcontractors for the project.

4.1.2 *Asbestos-Containing Material Removal*

During Site visits to identify and mark underground utilities and ground disturbance locations, pieces of pipe insulation were observed on the ground surface in the area of the Black Tank Pump House and Sump (Figure 2). On 28 June 2013, samples of the pipe insulation were collected and analyzed for asbestos using polarized light microscopy (USEPA Method 600/R-93/116). Asbestos was detected in the pipe insulation samples. Because asbestos-containing material (ACM) was present in proposed test pit investigation areas, investigation of those areas was postponed until ACM removal was completed. On 22 September 2014, Performance Abatement Services, Inc. (PAS) of Woodinville, Washington, a Washington State Department of Labor and Industries-certified asbestos abatement contractor, completed the removal of ACM and ACM-impacted soils near the Black Tank Pump House and Sump and encapsulated the ends of exposed piping having ACM pipe wrap. PAS filed a notice of intent with the Spokane Regional Clean Air Agency on 2 September 2014. PAS completed a thorough survey of the ACM areas, picking up pieces of pipe wrap found on the ground along with 1 to 2 inches of soil around each piece. PAS also used rakes to remove smaller pieces of ACM from the surface. ACM and soil was double-bagged and disposed off Site at the Wasco County Landfill in The Dalles, Oregon.

4.2 *HISTORICAL SITE FEATURES INVESTIGATION*

Historical tanks, pipelines, dispensers, loading/unloading racks, pump houses, and other features not previously removed during the Black Tank remedial excavation were investigated using test pits to assess the presence of unidentified contaminant point sources. Trenches and soil borings were advanced to define the lateral and vertical extent of contamination identified during test pit installation. Test pit and trench locations are presented on Figure 17, and soil boring locations are presented on Figure 18. Test pit and trench logs are provided in Appendix E, and soil boring logs are included in Appendix F.

4.2.1 *Test Pits*

A total of 111 test pits were excavated along the Black Tank, Red Tank, Liquid Asphalt, Oil, and Chemical Solution Pipelines between 14 October and 29 October 2013 (Figure 17). Six additional test pits were excavated along the Black Tank pipeline in the ACM removal area and five additional test pits were excavated along the Red Tank dispenser pipeline between 25 September and 26 September 2014. All of the test pits were excavated by Big Sky Industrial under the direction of ERM.

The RI/FS Work Plan (ERM 2013a) specified use of a backhoe or excavator to excavate test pits; however, because of the shallow depths of the historical features and concern that historical pipelines may contain residual petroleum product, test pits were excavated using low-impact methods such as an air knife/vacuum truck and hand-digging.

Pipeline alignments were located using standard subsurface clearance geophysical techniques, including ground-penetrating radar. Test pits were excavated at approximately 15-foot intervals along subsurface pipelines and 30-foot intervals along aboveground pipelines. Piping encountered in test pits was inspected for evidence of release points and soil surrounding the piping was field-screened for evidence of contaminant impacts. Field screening consisted of inspecting the soil for the presence of staining, sheen, and/or petroleum odor, and using a portable photoionization detector (PID) to detect the VOCs. If field screening indicated potential contaminant impact, a sample of the impacted soil was collected and submitted for laboratory analyses of COPCs.

If laboratory testing showed evidence of a release at a test pit, additional test pits or trenches were excavated around the impacted test pit to assess the horizontal and vertical (up to 15 ft bgs) extent of the contamination.

During the early stages of Phase I of the RI, laboratory analyses showed evidence of releases in the vicinity of the Red Tank, Liquid Asphalt Pipeline, and Black Tank pipeline. To assess the vertical and horizontal extent of this contamination, four trenches were excavated to depths up to 15 ft bgs near the impacted test pits. The trenches were excavated between 31 October and 4 November 2013 and their locations are shown as RT-TP-01-EX, LAPL-TP-06-EX, BT-TP-25-EX, and BT-TP-27-EX on Figure 17.

Subsequent laboratory analyses showed evidence of releases in the vicinity of the Red Tank dispensers and the need for additional assessment of the vertical and lateral extent of contamination in the vicinity of the Black Tank and Chemical Solution Pipelines. Five additional test pits (RT-TP-45A, RT-TP-45B, RT-TP-50A, RT-TP-50B, and RT-TP-50C) were excavated and sampled in the vicinity of the Red Tank dispensers on 25 September 2014. Three additional trenches (BT-TP-25A, BT-TP-27A, BT-TP-27B) were excavated near the Black Tank pipeline and two trenches (CSPL-TP-7A and CSPL-TP-7B) were excavated near the Chemical Solution Pipeline on 29 and 30 September 2014. These test pits and trenches were excavated and sampled to delineate the lateral limits of petroleum contamination in these areas (Figure 17).

Soil samples were collected from obviously contaminated areas where field screening identified the presence of contamination and submitted for laboratory analysis of COPCs to assess the nature and magnitude of the contaminant impact. Soil samples were also collected from immediately beneath or adjacent to areas of soil contamination and submitted for laboratory analysis of COPCs to assess the vertical and lateral extent of the contamination. In cases where test pits were expanded horizontally and vertically, discrete soil samples were collected from the bottom and/or sidewalls of the exploratory excavation to document the limits of the contamination. A total of 56 soil samples were collected from test pits for laboratory analysis.

Samples to be analyzed for TPH-G and/or VOC were collected using USEPA Method 5035. Samples to be analyzed for other parameters were collected using a clean, stainless steel trowel and were placed directly into labelled glass sample jars. Soil samples were transported under chain-of-custody procedures in chilled coolers to Pace Analytical in Minneapolis, Minnesota, for analysis as described in Section 4.7.1.

4.2.2 Soil Borings

Soil borings were advanced in the vicinity of the Red Tank dispensers (RT-SB-01) and the Black Tank and Chemical Solution Pipelines (BT-SB-01) to assess the vertical extent of contamination identified in test pits in those areas. Soil boring RT-SB-01 was advanced to a depth of 77 ft bgs at a location next to the Red Tank dispenser pipeline, immediately north of BT-TP-50 (Figure 18). Soil boring BT-SB-01 was advanced to a depth of 177 ft bgs at a location near the Black Tank and Chemical Solution Pipelines, between BT-TP-26 and BT-TP-27A (Figure 18).

These soil borings were advanced and sampled by EWE of Spokane, Washington, between 29 September 2014 and 2 October 2014, using rotosonic drilling methods. Soil samples were collected at 5-foot intervals using split-spoon samplers. Soil samples were evaluated for lithology, inspected for staining, sheen, and odor, and field screened for VOCs using a PID. Soil lithology was described using the Unified Soil Classification System, and descriptions of soil sample texture, composition, color, consistency, moisture content, recovery, odor, and staining were also documented. Soil samples were collected from selected intervals for laboratory analysis based on field screening results. Laboratory samples were collected, transported, and analyzed using the same procedures described for the test pit samples in Section 4.2.1. Sampling intervals, lithology, drilling observations, and screening results were recorded on the soil boring logs, which are included in Appendix F.

4.3 LNAPL INVESTIGATION

Fifteen soil borings (MW-16 through MW-30) were drilled and sampled at the locations shown on Figure 18 to assess the vertical and lateral extent of the

LNAPL smear zone, the hydrogeologic characteristics of the vadose zone and aquifer, and the physical and chemical characteristics of the LNAPL. Samples of subsurface soil and LNAPL were collected and submitted for laboratory analysis of the physical and chemical characteristics that control the mobility, transmissivity, and recoverability of LNAPL.

4.3.1 Soil Boring Installation and Sampling

The soil borings were installed by EWE, under the direction of ERM and Landau Associates, Inc., using rotosonic drilling methods. Borings MW-16 through MW-26 were drilled and sampled between 14 October and 17 November 2013, whereas MW-27 was drilled and sampled between 27 and 28 September 2014. MW-28 and MW-29 were drilled and sampled between 5 and 9 April 2016, and MW-30 was drilled and sampled between 20 and 22 June 2016.

Soil samples were collected continuously in 5- to 10-foot intervals to document soil lithology and to screen for contamination. The field screening and soil sampling were performed using the same methods described in Section 4.2.2. The borings range in depth from 177.5 to 188 ft bgs.

4.3.2 Soil Core Sampling and Sample Interval Selection

Five soil boring locations and depth intervals were selected for collection of undisturbed soil core samples for LNAPL mobility testing. The boring locations were selected to assess conditions at the core and margin of the LNAPL area. Cores were collected from the soil borings at MW-17 and MW-24 to assess conditions at the core of the LNAPL area, near each of two different source areas: the Black Tank, which primarily contained Bunker C and asphaltic oil, and the Red Tank, which primarily contained diesel. Cores were collected from soil borings MW-20, MW-28, MW-29, and MW-30 because of their locations near the margin of the LNAPL area. The undisturbed soil cores were collected from a soil interval extending from the approximate top of the LNAPL smear zone to at least 10 feet below the bottom of the smear zone.

The undisturbed core samples were collected in 5- to 10-foot intervals using a 4-inch diameter rotosonic core tube. The core was carefully vibrated from the core tube directly to plastic sample bags in 2.5-foot sections. The plastic sample bags were then placed in 2.5-foot lengths of Lexan sleeves to ensure that the shape was retained, capped at each end, taped, and immediately placed on dry ice for preservation. The cores were examined to confirm that they were fully frozen prior to shipment.

The cores were shipped under chain-of-custody control to PTS Laboratories, Inc. (PTS) in Santa Fe Springs, California, where they were photographed and analyzed for LNAPL mobility parameters. The soil cores were maintained in a frozen state to preserve their undisturbed condition, cut into two length-wise sections, photographed under visible light to identify changes in soil type (color and texture) and again under ultraviolet light to identify LNAPL via fluorescent aromatic hydrocarbons. ERM senior consultants examined the core photographs and selected intervals from each core, based on lithology and the presence of LNAPL, for analysis of the soil and soil-fluid interaction parameters described in Section 4.7.1.2. The core photographs and the results of the soil and LNAPL mobility testing are presented in Appendix D.

4.3.3 Physical and Chemical Characterization of LNAPL

The physical characteristics of the LNAPL beneath the Site were assessed by collecting samples of LNAPL and groundwater from selected monitoring wells using and analyzing the samples for the fluid properties described in Section 4.7.2.1. LNAPL and groundwater samples were collected from monitoring wells MW-01, MW-03, and MW-18 because they were capable of producing sufficient sample volume for the requested analyses and they potentially yielded LNAPL from different sources and having different compositions. MW-01 potentially contained LNAPL sourced from the SemMaterials site and/or the Liquid Asphalt Pipeline, whereas MW-03 likely contained LNAPL sourced from the Black Tank system and piping, and MW-18 likely contained LNAPL sourced from the Red Tank system and piping. Samples of the groundwater and LNAPL were collected using disposable polyethylene bailers and dispensed directly to unpreserved sample containers prepared by the laboratory. The results of the fluids property testing are presented in Appendix G.

The chemical composition(s) of the LNAPL beneath the Site was assessed by collecting LNAPL samples from selected monitoring wells and running chemical fingerprint analyses on each sample. LNAPL samples were collected from nine monitoring wells (MW01 through MW05, MW07, and MW18 through MW20) dispersed across the LNAPL area. The samples were submitted to Pace Analytical for analysis of the chemical fingerprint parameters described in Section 4.7.2.2. Fingerprint analyses were performed to assess the type or types of petroleum LNAPL released at the Site, and the chemical composition, weathering, and location of each LNAPL type. Mixed LNAPL and groundwater samples were collected from Site monitoring wells in December 2013 (MW01, MW02, MW09, and MW19) and October 2014 (MW01 through MW03, MW09, MW17 through MW20, and MW23) to collect separate samples of either LNAPL or "groundwater beneath the LNAPL." During both sampling events, mixed LNAPL and groundwater samples were obtained. LNAPL and mixed LNAPL and groundwater samples were collected using a disposable polyethylene bailer, placed in laboratory-provided containers, and stored on ice immediately after collection and during transport to the laboratory. The mixed LNAPL and groundwater samples are the result of: (1) the sampling methodology not allowing for separation of LNAPL from groundwater samples, and (2) there being insufficient LNAPL volume in the sample container to allow analysis of the LNAPL alone so the laboratory analyzed the mixed LNAPL and groundwater.

4.4 GROUNDWATER INVESTIGATION

Eight quarters of groundwater monitoring have been completed during the RI to evaluate seasonal variations and trends in fluid levels and groundwater quality across the Site. Groundwater samples were also collected from beneath the LNAPL in an attempt to assess dissolved phase contaminant impact to groundwater.

4.4.1 Monitoring Well Construction and Development

Permanent monitoring wells were constructed in each of the 15 soil borings described in Section 4.3. EWE constructed 11 of the monitoring wells (MW-16 through MW-26) between 16 October 2013 and 18 November 2013, one monitoring well (MW-27) on 28 and 29 September 2014, two monitoring wells (MW-28 and MW-29) between 7 and 9 April 2016, and one monitoring well (MW-30) on 21 and 22 June 2016. The locations of the monitoring wells, including pre-RI monitoring wells (MW-01 through MW-15), are shown on Figure 18.

Monitoring wells were constructed of 2-inch (nominal) threaded Schedule 40 polyvinyl chloride (PVC) casing and 0.010-inch slot size PVC screen installed to the target depth through a temporary steel casing. The new monitoring wells were screened over a 10- to 15-foot interval to bracket the known seasonally high and low groundwater table and the LNAPL smear zone. Monitoring wells were secured using flush-mount, locking steel monuments cemented in place where aboveground monuments were precluded. Other wells were finished aboveground with casings that extend about 2.5 feet above the ground then covered with a protective steel monument and surrounded with three bollards. Well construction logs are included in Appendix F, and the well construction details are summarized in Table 8.

Monitoring wells were developed, after allowing the cement grout to set for 24 hours, by surging and then purging groundwater from each well using a polyethylene bailer and a combination of bailer and stainless steel bladder pump for MW-21, MW-22, MW-26, MW-29, and MW-30 to remove drilling fines and to restore the hydraulic properties of the surrounding formation. Development continued until at least 5 to 10 well volumes were removed and particulates were reasonably cleared from the well. Monitoring well development logs are provided in Appendix H.

4.4.2 Static Water Level and LNAPL Thickness Measurements

Groundwater levels were measured on a quarterly basis in all Site monitoring wells to assess seasonal variations in the direction and gradient of groundwater flow. Two SemMaterials monitoring wells (GMW-05 and GMW-06) were included in the fourth quarterly monitoring event. LNAPL thickness was measured on a quarterly basis in all Site monitoring wells that contained LNAPL to allow correction of groundwater level measurements and assess potential changes in the LNAPL thickness. Quarterly monitoring was performed in December 2013, March 2014, July 2014, October 2014, March 2016, June 2016, September 2016 and December 2016. The measurements were obtained prior to the collection of groundwater samples during the first three and last three quarterly monitoring events, after the groundwater sampling for the fourth quarterly monitoring event, and both prior and after the groundwater sampling for the fifth quarterly monitoring event.

Depth to groundwater and LNAPL thickness measurements were collected using an oil-water interface probe and were measured to the nearest 0.01 foot relative to a surveyed reference point marked on each well. The measurements were taken in quick succession, generally within a 4-hour period, to minimize fluctuations resulting from changing environmental conditions (barometric pressure, precipitation, etc.). Reliable water level data was collected from wells that did not contain LNAPL; however, because of the high viscosity of the LNAPL, reliable LNAPL thickness and water level data could not be collected from wells containing LNAPL. Although reliable top of LNAPL measurements could be obtained, reliable depths to the underlying groundwater could not be obtained because when the oil-water interface probe passed through the LNAPL, it became coated with the viscous LNAPL and could not detect the underlying oil-water interface. The two oldest monitoring wells (MW-01 and MW-02) developed a coating of tar on the inside of the well casings, making passage of the oil-water interface probe difficult and collection of reliable water level and LNAPL data impossible. To address this issue, EWE pressure-washed and scrubbed the tarry coating from the inside of the well casings in September 2014, and the wells were unobstructed for the fourth quarter monitoring event. In general, the presence of viscous LNAPL in the monitoring wells likely resulted in over-estimates of the LNAPL thickness and non-reproducible data from those wells.

A revised LNAPL gauging method was developed before collection of the post-sampling fluid level measurements in March 2016. This method uses a thin layer of ice on a water level indicator probe to shield the probe's sensor for the LNAPL as the probe passes through the LNAPL layer into the underlying groundwater. After the ice on the probe has thawed, the audio indicator on the probe alarms, and the probe is slowly raised until the audio indicator stops sounding, which indicates it has encountered the bottom of the LNAPL layer. The method was used for the past four monitoring events and proved to be more reliable at identifying the LNAPL/water interface than the previous method.

4.4.3 Groundwater Sample Collection

Groundwater samples were collected on a quarterly basis from all Site monitoring wells that did not contain LNAPL at the time of sampling to assess dissolved phase contamination in groundwater. All groundwater samples were collected using low-flow purging and sampling procedures (USEPA 1996) to minimize disturbance and ensure samples were representative of groundwater within the formation. Pre-RI monitoring wells (MW-01 through MW-15) were purged and sampled using dedicated submersible pumps, whereas the RI monitoring wells (MW-16 through MW-27) were sampled using a stainless steel bladder pump with dedicated tubing for each well. An unsuccessful attempt to remove LNAPL from wells that contained measurable LNAPL and collect samples of groundwater from "beneath" the LNAPL that had accumulated in the wells was made during the October 2014 quarterly groundwater monitoring event. Ecology had advised that the sampling approach may be unsuccessful and that the resulting data should be used with caution. Ecology's concern was appropriate because incomplete removal of LNAPL and cross-contamination from the sampling device resulted in samples comprised of mixed LNAPL and groundwater that are not representative of dissolved phase groundwater conditions. The mixed LNAPL and groundwater sample data are used to characterize the LNAPL.

Field parameters (specific conductance, temperature, dissolved oxygen [DO], oxygen [O_2] reduction potential, and pH) were measured during purging and sampling using a field-calibrated water quality meter equipped with a flow-through cell. Purging continued until water quality parameters stabilized in accordance with the parameters established in the SAP (ERM 2013b). Logs of the groundwater purge and sampling for each well are included as Appendix I, and a summary of the groundwater quality parameter data is included as Table 9. Groundwater samples were collected by slowly dispensing the water directly from the pump tubing into the appropriate laboratory-provided sample containers, taking precautions to minimize aeration. Containers used to collect groundwater for VOC analysis were completely filled, so that no headspace remained. Groundwater samples were transported under chain-of-custody procedures in chilled coolers to Pace Analytical for the analyses described in Section 4.7.3.

Additional groundwater samples were collected in June 2014 from MW-1, MW-2, MW-18, and MW-19 for the purpose of obtaining lower detection limits for PCB analysis to verify that PCBs are not a COPC at the Site. Groundwater samples were collected after LNAPL had been removed to the extent practicable; however, the analytical data indicate the samples were mixed LNAPL and groundwater. Although lower detection limits for PCBs were obtained, the detection limits were not sufficiently low to evaluate compliance with MTCA groundwater cleanup criteria. Therefore, additional groundwater samples were collected during fifth monitoring event and analyzed for PCBs using even lower detection limits. The groundwater samples were collected from four monitoring wells that do not contain LNAPL: one upgradient well (MW-6) and three downgradient wells (MW-21, MW-22, and MW-29). The necessary lower detection limits for PCBs were obtained during the fifth monitoring event.

Groundwater samples collected from MW-19, MW-20, and MW-23 in June 2014 were analyzed for total and dissolved chromium and lead. The additional data were collected to investigate potential impact to groundwater based on the presence of these metals in mixed LNAPL and groundwater samples collected from these wells in December 2013. During the fifth monitoring event, groundwater samples were collected from all wells not containing LNAPL and analyzed for total cadmium to evaluate potential groundwater impacts from cadmium concentrations detected in Site soil.

4.5 LNAPL RECOVERY TESTING

In March 2016, manual LNAPL skimming tests were conducted in 12 monitoring wells as described in Attachment E of the Final Draft Addendum for the RI/FS Project Plan (ERM 2016). The purpose of the testing was to semi-quantitatively assess LNAPL recoverability at the Site. The manual LNAPL skimming tests included collecting fluid level measurements from LNAPL-containing monitoring wells then removing LNAPL using a disposable bailer until LNAPL was no longer present in the well. The process was then repeated and the volume of LNAPL recovered each time was recorded. Precautions were taken to minimize water removal, which would artificially induce drawdown in the monitoring well. The volume of LNAPL and water removed from each monitoring well was measured using a graduated cylinder instead of the 5-gallon bucket described in the Final Draft Addendum for the RI/FS Project Plan (ERM 2016). ERM attempted to gauge fluid levels in the monitoring wells after each LNAPL recovery event as described in the Final Draft Addendum; however, LNAPL spilled onto the well casing which made reliably measuring fluid levels difficult because the LNAPL and water-level indicator probes would stick to the LNAPL that had accumulated on the inside of the well casing during LNAPL removal.

Recovery tests were initially attempted at MW-1 through MW-5, MW-7, MW-9, MW-17 through MW-20, and MW-23. Sufficient LNAPL to provide a reliable estimate of recoverability (i.e., at least 6 inches) was not present in seven of these monitoring wells; therefore, subsequent LNAPL recovery testing focused only on monitoring wells having a sufficiently thick layer of LNAPL (i.e., MW-3, MW-4, MW-7, MW-17, and MW-20).

4.6 NATURAL SOURCE ZONE DEPLETION TESTING

The occurrence and rate of NSZD at the Site was evaluated by measuring carbon dioxide (CO_2) soil flux, conducting down-well metabolic gas monitoring, and collecting groundwater samples for analysis of NSZD parameters. The NSZD testing methodologies and the procedures used to evaluate the NSZD data are described below and in Attachment F of the Final Draft Addendum for the RI/FS Project Plan (ERM 2016).

4.6.1 Carbon Traps

On 23 March 2016, ERM deployed four carbon traps using the at-grade method at the locations shown on Figure 19. The traps were recovered on 5 April 2016 (after approximately 2 weeks deployment) and shipped to E-Flux in Fort Collins, Colorado, for analysis. E-Flux analyzed the samples for total sorbed CO_2 to evaluate the total CO_2 soil flux and performed C^{14} carbon dating to assess the fraction of CO_2 soil flux attributable to petroleum degradation. NSZD rates were estimated by stoichiometric conversion of the CO_2 flux to petroleum hydrocarbons as decane ($C_{10}H_{22}$) with a density of 0.97 grams per milliliter.

4.6.2 Carbon Flux Chambers

ERM installed carbon flux chamber monitoring stations at the 20 locations shown on Figure 19. Monitoring stations were installed at locations upgradient, downgradient, cross-gradient, and within the extent of the LNAPL to assess carbon flux across the entire Site. To minimize the contribution of root respiration and maximize sensitivity to contaminant-related soil respiration, 10 cm of topsoil was removed at each survey location. Subsequently, PVC collars (10 cm inner diameter) were placed at the survey location such that approximately 4 cm remained above ground surface. Soil collars were positioned within an approximate 1 meter radius of an existing monitoring well, with the exception of the MW-19/LI-19 location, which was positioned approximately 4 meters from the well to avoid placing it in railroad ballast. After collar placement, ERM allowed a minimum of 24 hours of time to elapse to allow stabilization of the CO_2 soil flux before initiating data collection.

CO_2 flux measurements were collected between 17 March 2016 and 11 April 2016. Measurements were collected by attaching a soil carbon flux measurement system consisting of a survey chamber and soil analyzer to the monitoring station. The soil analyzer control unit draws soil gas through the survey chamber and analyzes the CO_2 content and records the data for later download.

The CO_2 production rates attributable to biodegradation of petroleum hydrocarbons (i.e., background corrected flux) were calculated by subtracting the background CO_2 soil flux measured at a location upgradient of the known TPH impacts. Background measurements were collected at the beginning and end of each set of measurements, and background measurements were applied for corrections according to the time of each individual measurement. Soil flux measurements from LI-06 near MW-06 were considered representative of background conditions (i.e., natural CO_2 respiration). NSZD rates were estimated by stoichiometric conversion of the background corrected CO_2 flux to petroleum hydrocarbons as decane ($C_{10}H_{22}$) with a density of 0.97 grams per milliliter.

4.6.3 Metabolic Gas Monitoring

Metabolic gas monitoring measures respiration parameters (O_2, CO_2, and methane [CH_4]) associated with biodegradation of petroleum in soil gas obtained from vadose zone soil immediately above the air/LNAPL interface or air/groundwater interface. Between 17 and 21 March 2016, ERM performed metabolic gas monitoring at one upgradient well (MW-6), eight wells within the LNAPL footprint (MW-4, MW-5, MW-7, MW-16, MW17, MW-18, MW-20, and MW-23), and two downgradient wells (MW-11 and MW-22). The monitoring locations are shown on Figure 19. The well volume (i.e., volume of air in each well casing) was calculated based on well diameter and depth to groundwater data. Each monitoring well was capped using a Fernco pipe fitting equipped with a sampling port, then sample tubing was attached to the sampling port on the Fernco and connected with a sample chamber. Air was purged from the well while periodically collecting CH_4, O_2, CO_2, and VOC measurements until the readings stabilized and at least one well volume had been purged. Measurements were collected by filling a 1-liter Teflon bag from the sample port on the sample chamber. The soil gas monitors used for collecting measurements included a Landtec GEM-2000 Field Gas Meter for measuring CH_4, O_2, and CO_2 concentrations; and a MultiRAE IR Meter equipped with PID for measuring CO_2 and VOC concentrations in ppm. After readings on the soil gas meters stabilized to within ± 10%, a final set of CH_4, O_2, CO_2, and PID measurements was collected and documented.

4.6.4 Saturated Zone NSZD

Groundwater samples were collected from one upgradient well (MW-6) and three downgradient wells (MW-10, MW-11, and MW-22) on 16 March 2016 for analysis of NSZD parameters (DO, CH_4, nitrate, sulfate, iron, and manganese).

The changes in dissolved concentrations of O_2, CH_4, nitrate, sulfate, iron, and manganese from the upgradient well to the downgradient wells were used to approximate the rate of saturated zone NSZD in accordance with the April 2009 Interstate Technology & Regulatory Council (ITRC) guidance for "Evaluating Natural Source Zone Depletion at Sites with LNAPL" (ITRC 2009a).

4.7 LABORATORY ANALYSES

4.7.1 Soil

4.7.1.1 Chemical Analysis

The initial set of soil samples from the Phase I test pits and soil borings were analyzed for the following:

- TPH-D/HO using Ecology Method NWTPH-Dx;
- VOCs using USEPA Method 8260;
- PAHs using USEPA Method 8270 (selected ion monitoring [SIM] analysis was used as necessary to provide laboratory reporting limits at or below applicable screening levels);
- PCBs using USEPA Method 8082; and
- Cadmium, chromium, copper, lead, nickel, and zinc using USEPA Method 6010/7000.

As indicated in Section 4.0, after reviewing the preliminary analytical results from the initial soil samples (source area samples), Ecology determined that subsequent soil samples would be analyzed for the following COPCs:

- TPH-D/HO;
- BTEX;
- PAHs; and
- Cadmium and chromium.

The petroleum analyses are consistent with the required analyses for diesel and heavy oil specified in MTCA Table 830-1. As specified in Sections 3.2 and 4.2 of the SAP (ERM 2013b), an acid/silica gel cleanup was applied to all soil samples collected from the test pits/trenches and to soil samples collected from less than 10 ft bgs in the soil borings prior to analyzing the samples for TPH-D/HO.

To facilitate the calculation of Site-specific petroleum hydrocarbon CULs, soil samples containing obvious petroleum hydrocarbon contamination (based on field screening data) were analyzed for extractable petroleum hydrocarbons (EPH), volatile petroleum hydrocarbons (VPH), and associated compounds using Ecology Methods EPH and VPH by Fremont Analytical of Seattle, Washington, under a subcontract with Pace Analytical. A total of 12 surface (less than 15 ft bgs) and 11 subsurface (greater than 15 ft bgs) soil samples were analyzed for EPH and VPH.

4.7.1.2 LNAPL Mobility Parameter Testing

LNAPL mobility testing, consisting of general soil properties (grain size distribution, bulk density, and porosity), in-situ pore fluid saturations, and soil-fluid interaction properties, was conducted on selected intervals of the LNAPL smear zone. The soil core intervals were selected for analysis as described in Section 4.3.2. All tests were conducted by PTS on plug samples drilled out of the frozen cores by PTS. The objective of the analysis was to obtain quantitative estimates of LNAPL saturation versus depth and grain size as well as estimates of the LNAPL mobility and recoverability.

The following sections describe the specific tests and methods performed by PTS. The results of LNAPL mobility evaluations are summarized in the PTS laboratory data reports included in Appendix D.

4.7.1.2.1 Soil Grain Size Distribution

Grain size distribution tests were performed on selected soil samples to provide quantitative data regarding soil type. The soil grain size distributions of particle sizes larger than 75 micrometers; retained by the No. 200 sieve) were evaluated by sieving following ASTM International (ASTM) Method D422. The grain-size distributions of particle sizes finer than 75 micrometers (passing the No. 200 sieve) were evaluated using a laser method (ASTM Method D4464M).

4.7.1.2.2 Dean-Stark Analyses

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

4.7.1.2.3 *LNAPL Mobility (1,000G Centrifuge) Testing*

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

4.7.1.2.4 *Capillary Pressure Analyses*

Capillary pressure versus saturation analyses are performed to give an indication of the LNAPL saturation for a given capillary pressure. Air/water drainage capillary pressure versus saturation curves and LNAPL/water drainage capillary pressure versus saturation curves were measured using the centrifugal technique following ASTM Method D425M. These data supplement the measured saturation profile by providing an additional means to estimate the vertical distribution of LNAPL saturation within the interval of potentially mobile LNAPL. Therefore, they are used as an independent dataset from the pore fluid saturation data determined by the Dean-Stark analyses. These data can be used to develop models of LNAPL behavior using the API LNAPL Distribution and Recovery Model (LDRM). These analyses were performed on sample intervals: (1) estimated to represent the potentially mobile LNAPL in the formation and (2) the formations types in which LNAPL resides.

4.7.2 *LNAPL*

4.7.2.1 *Physical Parameters*

LNAPL and groundwater samples were collected and submitted to PTS for fluid properties analysis. The fluid properties analysis provided data that was used to support development of an LDRM to estimate the recoverability of LNAPL and to evaluate the degree of weathering of the LNAPL.

The fluid samples were analyzed for density and viscosity by ASTM Method D445 and API Publication Method RP-40 (API RP 40). They were also analyzed for LNAPL-water interfacial tension and LNAPL and groundwater surface tensions by a DuNouy ring tensiometer using ASTM Method D971. Laboratory report summaries of fluid properties are provided in Appendix G.

4.7.2.2 *Chemical Analysis*

The chemical composition(s) of the LNAPL beneath the Site was assessed by analyzing LNAPL samples for chemical fingerprint parameters. Fingerprint analyses included:

- TPH-G using Method NWTPH-Gx;
- TPH-D/HO using Method NWTPH-Dx;
- VOCs (full scan) using Method 8260;
- SVOCs (full scan) using Method 8270;
- PCBs using Method 8082; and
- Cadmium, chromium, copper, lead, nickel, and zinc using Methods 6010/7000.

The organic analytical results were provided with chromatograms to determine the composition and weathering of the samples for comparison against various fuel standards.

4.7.3 *Groundwater*

Groundwater samples were analyzed for petroleum hydrocarbons and related petroleum compounds, in accordance with requirements summarized in MTCA Table 830-1 and the RI/FS Work Plan (ERM 2013a). Each sample was analyzed using the following:

- TPH-D/HO using Ecology Method NWTPH-Dx,
- BTEX using USEPA Method 8260, and
- cPAHs using USEPA Method 8270-SIM.

All of the pre-RI and the first four rounds of RI groundwater samples collected in 2014 were analyzed for TPH-D/HO following an acid/silica gel cleanup. Groundwater samples collected in March and December 2016 were analyzed for TPH-D/HO both with and without an acid/silica gel cleanup, and samples collected in June 2016 and September 2016 were analyzed for TPH-D/HO without an acid/silica gel cleanup. The TPH-D/HO data from groundwater samples analyzed for TPH-D/HO both with and without an acid/silica gel cleanup were evaluated to assess the impact of using acid/silica gel cleanup on the results of groundwater samples analyzed for TPH-D/HO.

Select groundwater samples collected during the March 2016 monitoring event were analyzed for the parameters listed below using the laboratory methods listed below:

- PCBs by USEPA Method 8082A,
- Total cadmium by USEPA Method 6010,
- Sulfate by USEPA Method 9056,
- Nitrate and nitrite by E353.2,
- Ferrous iron by SM 3500-Fe-D-Modified,
- Total organic carbon by USEPA 9060,
- Dissolved CH_4 by USEPA Compendium Method RSK-175, and
- Total alkalinity by USEPA Method 310.1.

4.8 DATA VALIDATION

Laboratory analytical data were evaluated in accordance with applicable portions of the *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA 1999) and a *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (USEPA 2004). The following parameters were evaluated:

- Chain-of-custody records;
- Holding times;
- Blank results (laboratory method, field, and trip);
- Surrogate recoveries;
- Matrix spike/matrix spike duplicate and laboratory duplicate results;
- Laboratory control sample and laboratory control sample duplicate results;
- Audit/corrective action records; and
- Completeness and overall data quality.

Data validation qualifiers were added to samples based on the evaluation of data quality. The absence of a data qualifier indicates that the reported result is acceptable without qualification. Data quality evaluation (i.e., validation) memoranda were prepared for each laboratory analytical report. The data validation memoranda and laboratory analytical reports for soil, LNAPL, and groundwater samples are included as Appendix J.

4.9 LOCATION AND ELEVATION SURVEY

True North Land Surveying, Inc., a Washington State-licensed land surveyor, surveyed the locations and ground elevations of the completed test pits, trenches, and soil borings. True North Land Surveying, Inc. also surveyed the horizontal locations and top of casing elevations of the 15 new monitoring wells. The elevation and horizontal position of each well was obtained from the north rim of each well casing utilizing Washington State Plane coordinates and elevation. Horizontal location was established to an accuracy of 0.1 foot and elevation was established to an accuracy of 0.01 foot. Survey data are provided in Appendix K, and summarized for the monitoring wells in Table 8.

4.10 INVESTIGATION-DERIVED WASTE MANAGEMENT

4.10.1 Soils

Suspected contaminated soil encountered during the soil test pit, trenching, and soil boring activities was temporarily stockpiled on Site. The stockpiles were constructed on the concrete pad that forms the floor and apron around the former warehouse building. The stockpiles were placed on and covered with plastic sheeting (10 millimeter minimum thickness). Berms were constructed around the stockpiles to mitigate migration of contaminated soil via storm water runoff. The soil was profiled for disposal using analytical results from the RI soil samples. Based on the profiling results, clean stockpiled soils were used as backfill for the on-Site test pits and trenches. The contaminated investigation derived waste (IDW) soil stockpiles will be transported and disposed of at a BNSF-approved Subtitle D landfill. Disposal of the contaminated IDW soil may occur as part of implementation of the selected cleanup action.

4.10.2 Water

Well development, purge, and decontamination water were temporarily stored in steel 55-gallon drums and a 2,000-gallon polyethylene holding tank on Site. The waste containers were properly labeled and stored, pending waste profiling and disposal. Water containing obvious LNAPL was stored in drums, whereas water containing no obvious LNAPL was stored in the tank. Analytical results from the LNAPL and water samples were used for profiling the IDW water for disposal. NRC Environmental Services, Inc. of Spokane, Washington, conducted the transportation and coordinated the disposal of the IDW water as non-hazardous oily water in accordance with applicable regulations. IDW water was transported from the Site on 11 December 2014 and 20 January 2017 to PRS Group, Inc. in Tacoma, Washington, for treatment and disposal.

5.0 DEVELOPMENT OF PRELIMINARY CLEANUP STANDARDS

Cleanup standards are developed to evaluate whether contaminant concentrations at a particular site are compliant with the MTCA regulation. Per WAC 173-340-700 (3), establishment of cleanup standards requires specification of: (1) CULs (i.e., the concentration of a hazardous substance that is protective of human health and the environment) for each COC, and (2) the location on the site where the CULs must be attained, the point of compliance. Establishment of CULs must consider, for each impacted media, the potential exposure pathways based on highest beneficial use and reasonable maximum exposure.

The MTCA regulation provides three methods of cleanup standard development: Methods A, B, and C. MTCA Method A CULs are conservative lookup levels with broad applicability as outlined in Chapter 173-340-704 WAC. They are intended for sites having few contaminant types and exposure pathways and are commonly used for petroleum sites. MTCA Method B CULs include lookup levels as well as calculated risk-based levels that have broad applicability, including non-industrial sites, as outlined in Chapter 173-340-705 WAC. MTCA Method C CULs are calculated risk-based levels applicable only to industrial sites meeting a very specific set of requirements as described in Chapter 173-340-706 WAC. MTCA Methods B and C can be used for sites having multiple contaminant types and exposure pathways, and both may be applied by using default assumptions in MTCA or by using site-specific data.

This section presents an evaluation of receptors and exposure pathways that potentially exist based on current and future land use and Site conditions. Identified potential receptors and exposure pathways are then used to develop preliminary CULs and points of compliance using MTCA-compliance CUL methodologies. The preliminary CULs and points of compliance presented herein may not represent the final cleanup standards for the Site. Additional information may be collected or identified after completion of the RI that impacts the establishment of final cleanup standards. Final cleanup standards will be established by Ecology in the CAP.

5.1 RECEPTORS

The Site is currently accessed by industrial/commercial workers, including construction workers, and the general public.

Although the final alignment and configuration of the NSC project components (i.e., highway, railroad, corridor, and pedestrian path) in the vicinity of the Site has not been determined, the future land use of the Site will remain as a transportation corridor. Moreover, the people accessing the Site are unlikely to change (i.e., primarily industrial/commercial workers, including construction workers and secondarily the general public). Based on these current and future land uses, the following potential receptors were considered in the CSM:

- Human receptors:
  - Current and future on-Site industrial workers, including construction workers,
  - Current and future general public as users of the transportation corridor, and
  - Future off-Site drinking water users.
- Ecological receptors:
  - Terrestrial wildlife and plants, and
  - Aquatic life.

Each of these potential receptors is evaluated further in the following sections.

5.1.1 *Human Receptors*

5.1.1.1 *Current and Future On-Site Industrial Worker*

On-Site workers have the most potential for exposure based on proximity to the Site contamination. Industrial workers include current railroad operational employees and future railroad and highway construction and operational workers. Construction of the proposed highway and potential realignment of the rail lines may involve excavation of Site soils; therefore, future on-Site construction workers represent the most likely potential receptor for exposure to contaminated soil through the direct contact pathway. On-Site groundwater is not currently used and based on the planned future use of the Site it is unlikely to be used in the future. However, future use of on-Site groundwater is considered a potential exposure pathway.

5.1.1.2 *Current and Future General Public*

Although access to the Site by the general public is and likely will remain limited and controlled by structural elements surrounding the property (i.e., industrial properties having fences and gated access and large scale rail and vehicular transportation infrastructure), it is not strictly prohibited or severely limited as defined in WAC 173-340-200. As indicated in Section 2.1.4, the LI and CC2 zoning of the Site parcels includes land uses (e.g., transportation, commercial, schools, parks, commercial, office, and residential) that allow direct access by the general public. Therefore, MTCA requires evaluation of potential exposure by the general public to contaminated surface soil at the Site via the direct contact pathway.

5.1.1.3 *Future Off-Site Drinking Water*

The only potential future off-Site receptors of contamination from the Site are groundwater users. As indicated in Section 3.3.3, the SVRP aquifer is a federally classified, sole-source aquifer that is used for human consumption. Although the Site is not within the capture zone of any known users of the SVRP aquifer, there is a potential for future development of the aquifer downgradient of the Site. Recent Site data suggests that the downgradient extent of the dissolved phase groundwater plume is not defined throughout the year because petroleum metabolites were seasonally detected in one of the two northern-most monitoring well locations on the Site. However, petroleum metabolites are highly degradable, the monitoring well is located approximately 100 feet south of the northern Site boundary, and there are no data documenting the presence of Site-related contaminants beyond the northern Site boundary. Therefore, current human users of the SVRP aquifer are not considered receptors, but potential future human users of the SVRP aquifer for drinking water are considered potential future receptors.

5.1.2 *Ecological Receptors*

Two potential ecological receptors are considered for the Site: aquatic life and terrestrial wildlife and plants. As described in Section 3.1.3, there is no surface water on or near the Site. The nearest surface water hydraulically downgradient of the Site is the Little Spokane River, which is approximately 6 miles from the Site. Based on the lack of on-Site surface water and the large distance to off-Site surface water, aquatic life and other users of surface water are not considered potential receptors.

The potential exposure pathway for ecological receptors is through direct contact with soil. As described in Sections 3.1.4 and 3.1.5, the Site is sparsely vegetated and although it is accessible to terrestrial wildlife, it does not offer high quality habitat that would attract wildlife. To evaluate risks to ecological receptors at the Site, a Terrestrial Ecological Evaluation (TEE) was completed for the Site in accordance with WAC 173-340-7490 because the Site does not qualify for a TEE-exclusion under WAC 173-340-7491(1).

5.1.2.1 *Terrestrial Ecological Evaluation*

The goal of the TEE is to evaluate potential threats to terrestrial ecological receptors from exposure to contaminated Site soil having a potential to cause significant adverse effects. For sites that do not qualify for a TEE-exclusion, either a simplified TEE or a site-specific TEE must be conducted to determine if a threat to terrestrial ecological receptors exists or if the site can be removed from further ecological consideration during the RI and cleanup process. ERM determined that the Site does not exhibit any of the characteristics identified in WAC 173-340-7491(2)(a) that would require a Site-specific TEE. Moreover, ERM determined that the Site is developed property historically used for transportation purposes with no known usage by threatened or endangered species and without managed vegetation areas as defined in WAC 173-340-7490 (3)(b). Therefore, the Site qualifies for a simplified TEE that only evaluates future potential exposure to soil by terrestrial wildlife.

The process for conducting a simplified TEE includes an evaluation of the extent of exposure, exposure pathways, and type of contaminants present. Under the simplified TEE process, the evaluation ends if any one of the exposure evaluations determines that there is not a substantial threat of significant adverse effects to terrestrial ecological receptors.

ERM completed an exposure analysis based in Table 749-1 Simplified TEE Exposure Analysis Procedure under WAC 173-340-749(2)(a)(ii). A copy of the analysis is provided in Appendix L. The Site is a developed property having low quality habitat and none of the contaminants identified in question 5. Based on the results of this evaluation, further TEE is not necessary and wildlife is not considered a potential receptor.

5.2 EXPOSURE PATHWAYS

Exposure pathways involve four necessary elements. These are: (1) a source and mechanism of chemical release to the environment, (2) an environmental transport medium, (3) a point of potential receptor contact with the medium containing the site-related chemical, and (4) a receptor intake route at the contact point. Whenever one or more of these elements are missing in an exposure pathway, the pathway is incomplete and there is no potential for exposure and therefore no risk.

5.2.1 Soil Exposure Pathways

Based on the receptor evaluation, the following potential exposure pathways for Site soil were evaluated:

- Direct contact (dermal contact and incidental ingestion) by current and future on-Site industrial workers and the general public as users of the transportation corridor;
- Leaching to groundwater; and

- Volatilization to air.

The direct contact pathway is considered a potentially complete exposure pathway because Site soils ≤15 ft bgs contain elevated concentrations of petroleum hydrocarbons and on-Site industrial workers (particularly construction workers) and the general public under current and future conditions are potential receptors under this pathway. A future pedestrian trail associated with the planned NSC project may be located in the vicinity of the Site. Its location has not yet been finalized, but the original plan showed it to the west of the Site, beyond the Site boundary.

The soil-to-groundwater pathway is also considered a potentially complete exposure pathway under both current and future conditions. Site soils contain elevated concentrations of petroleum, and leaching of contamination via storm water infiltration and groundwater elevation fluctuations are viable mechanisms for contaminant transport to groundwater. Drinking water is the highest beneficial use of the underlying SVRP aquifer.

The soil-to-air pathway is not considered a current or future potentially complete exposure pathway per WAC 173-340-740 (3)(c)(iv)(B) for the following reasons:

- Based on areal extent and concentrations detected, TPH-D/HO, which has low volatility, is the predominant petroleum hydrocarbon detected in the Site soils. Evaluation of the TPH-D/HO data (i.e., concentrations by fraction and chromatograms) from the soil samples show that TPH-D (diesel) and TPH-HO (Bunker C and asphaltic oil) are generally collocated, the releases are old, and the residual petroleum hydrocarbons are weathered. Although some soil samples contain TPH-D/HO concentrations greater than 10,000 mg/kg, those concentrations are comprised predominantly of heavier, less volatile, constituents.
- TPH-G and VOCs are not present in Site soil at concentrations exceeding protection of groundwater standards.
- PAH and naphthalene concentrations in soil are relatively low.
- Human receptors at the Site are limited to industrial workers, primarily construction workers, and the general public who infrequently occupy the Site for short durations. As indicated above, a future pedestrian trail associated with the planned NSC project may be located in the vicinity of the Site. No long-term, full-day worker or general public exposure scenarios exist under current or future land use and Site conditions.
- No structures capable of creating indoor vapor intrusion conditions currently exist at the Site or are planned under the future use scenario. Therefore, exposure to airborne contaminants is exclusively under open air conditions.

- Current and anticipated future operations at the Site involve the operation of gasoline- and diesel-fired engines for rail, truck, and automobile transportation. Potential concentrations of petroleum constituents released to ambient air via vapor migration from the Site soils are expected to be much lower than background petroleum concentrations resulting from the current and anticipated future use of the Site as a transportation corridor.

5.2.2 *Groundwater Exposure Pathways*

Based on the receptor evaluation, the following potential exposure pathways for Site groundwater were evaluated:

- Direct contact and ingestion by future on-Site industrial workers, and
- Direct contact and ingestion by future off-Site human receptors.

As discussed in Section 3.3.3, groundwater at the Site is part of the SVRP aquifer, which is a federally classified, sole-source aquifer that is used for human consumption in the region. The potential exposure pathways to contaminated groundwater include human exposure through use as a potable water source. There are no potable supply wells on the Site and the Site is not located within the capture zone of any known domestic or industrial water supply wells located within 1 mile downgradient of the Site (Section 3.3.3). Because there is a potential for future development of the groundwater beneath and downgradient of the Site for drinking water and some recent data suggests that the dissolved phase groundwater plume extends to the northern-most Site monitoring well on a seasonal basis, the potential exists for the dissolved phase plume to temporarily extend slightly beyond the current downgradient Site boundary on a seasonal basis. Therefore, the future groundwater exposure pathway for on-Site and off-Site human receptors is considered a potentially complete pathway.

5.3 *PRELIMINARY CLEANUP LEVELS*

This section describes the preliminary CULs developed for evaluating contamination in Site groundwater and soil based on the potential exposure pathways and receptors. Preliminary CULs are summarized in Table 10.

As discussed in Section 5.4.1, TPH-D and TPH-HO are both present in the Site soils and although variations in petroleum composition (i.e., the percent TPH-D to TPH-H) exist in the soil, the differences diminish with depth and the subsurface soils contain a relatively uniform mixture of TPH-D and TPH-HO. Moreover, the petroleum products are broadly comingled and their individual concentrations cannot be readily differentiated via laboratory analysis because their chromatographic signatures overlap. Therefore, CULs were developed for the combined TPH-D/HO concentrations.

5.3.1 Groundwater Cleanup Levels

MTCA Method A groundwater CULs are selected as the preliminary CULs for groundwater at the Site (Table 10). Method A CULs are considered applicable for the Site because:

- The Site has few hazardous substances,
- The highest beneficial use and reasonable maximum exposure scenario for Site groundwater is as a drinking water source, and
- Numerical standards are available on WAC Table 720-1 for all indicator hazardous substances in groundwater at the Site.

These conditions meet the criteria for use of MTCA Method A specified in WAC 173-340-704.

5.3.2 Soil Cleanup Levels

CULs for COPCs identified in Site soils were developed based on the potential exposure pathways and receptors. For soil CULs developed to be protective of human receptors based on the direct contact exposure pathway, the reasonable estimate of the depth of soil that someone could be exposed to as a result of Site development activities is 15 ft bgs. For soil CULs based on protection of groundwater quality, it is assumed that all Site soils can contribute to a complete exposure pathway.

The CUL methodology used for surface soils (i.e., soils ≤15 ft bgs) is different than for subsurface soils (i.e., soils >15 ft bgs) because the CULs for surface soils must be protective of both groundwater and the direct contact pathway for human receptors, whereas the CULs for subsurface soils must only address protection of groundwater.

5.3.2.1 Surface Soil Cleanup Levels

MTCA Method A soil CULs for unrestricted land use are selected as the preliminary CULs for surface soils at the Site (Table 10). The Method A soil CULs are protective of all exposure pathways (direct contact, protection of groundwater, and vapor intrusion). In addition to the conditions specified in Section 5.3.1, MTCA Method A CULs are considered applicable for the Site because they address the soil exposure pathways and receptors of concern for both the current and future land use and conditions. The MTCA Method A CULs for unrestricted land use are look-up values in WAC Table 740-1.

The standard MTCA Method B soil CUL for the direct contact exposure route is adopted for cadmium in surface soil at the Site because, as later described in Section 5.3.2.2.3, an empirical demonstration has been made that cadmium concentrations in Site soil will not cause an exceedance of the applicable MTCA Method A groundwater CUL and no MTCA Method A soil CUL for direct contact alone has been established. Therefore, cadmium concentrations in the surface soil are compared to the standard MTCA Method B soil CUL for the direct contact exposure route of 80 mg/kg.

5.3.2.2 *Subsurface Soil Cleanup Levels*

MTCA Method B soil CULs are selected as the preliminary CULs for subsurface soils (i.e., soils >15 ft bgs) at the Site (Table 10). Because protection of groundwater is the only exposure pathway for which the subsurface soil CULs are intended, MTCA Method B is the applicable standard. Ecology's *Guidance for Remediation of Petroleum Contaminated Sites* (Ecology 2016) was used to calculate Method B soil CULs for TPH. Site-specific CULs were derived for all COPCs in subsurface soil using the fixed parameter three-phase partitioning model described (Equation 747-1) in WAC 173-340-747(4). Subsurface soil CULs are summarized in Table 10.

5.3.2.2.1 *Cleanup Level for Total Petroleum Hydrocarbons*

Development of preliminary CULs for subsurface soils requires assessing both the toxicity and the risk of NAPL generation (i.e., residual saturation). The following sections describe the approach used to generate a single Site-wide CUL for TPH-D/HO in subsurface soil. The proposed single Site-wide CUL for TPH-D/HO is driven by the residual saturation assessment and not the toxicity assessment.

Toxicity Assessment

MTCA Method B protection of groundwater CULs for TPH constituent mixtures (including cPAHs) were calculated using Ecology's MTCATPH 11.1 Workbook Tool. MTCA Method B soil CULs protective of the groundwater pathway are presented in Table 10, the sample data used in the MTCATPH 11.1 Workbook and the resulting calculations are summarized in Table 11, and the MTCATPH 11.1 calculation worksheets are included as Appendix M.

The MTCATPH 11.1 Workbook was populated using data from 10 subsurface soil samples analyzed for EPH, VPH, BTEX, and cPAHs (including naphthalene) as well as available Site-specific hydrogeological data, and the MTCA Method A groundwater CUL. If Site-specific hydrogeological data were not available, then MTCA default values were used. The subsurface soil samples analyzed for EPH and VPH and used in the CUL calculations were selected because they contained obvious TPH impact and were from depths at or near the LNAPL smear zone and represent conditions from multiple locations across the Site. Eight of the 10 subsurface soil samples analyzed for EPH and VPH were collected from the unsaturated zone, and for the evaluation of those samples, ERM used Ecology's default dilution factor for unsaturated soils of 20. For the two subsurface soil samples collected below the water table, ERM used Ecology's default dilution factor for saturated soils of 1 (Table 11).

Per Ecology guidance, the Method B protection of groundwater CUL for the Site is the median of the calculated CULs for all of the samples. As shown in Table 11, the median TPH-D/HO soil CUL for the protection of groundwater calculated for the Site is 62,164 mg/kg. The calculated Method B CULs for five of the 10 subsurface soil samples is equivalent to complete saturation of the soil with LNAPL (Table 11). In other words, these calculations show that concentration in soil needed to generate LNAPL is lower than the concentration needed to generate a dissolved phase toxicity risk to the groundwater. This finding is not unexpected because the petroleum hydrocarbons present at the Site are predominantly heavier aromatics compounds that have a low potential for leaching to groundwater. The calculated Method B soil concentrations protective of groundwater for the other five samples ranged from 9 to 62,164 mg/kg.

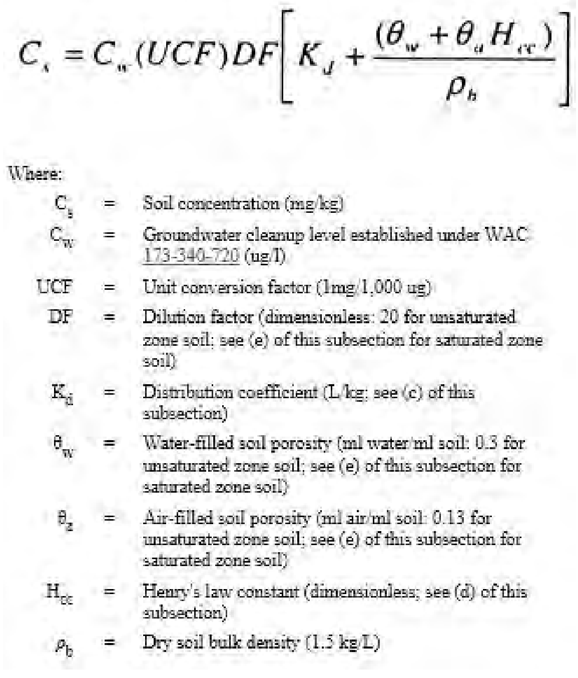
Residual Saturation Assessment

Development of numeric TPH concentrations protective of groundwater also requires an evaluation of LNAPL residual saturation, which is the saturation of LNAPL in the pore space below which LNAPL will be residual LNAPL and above which LNAPL will be mobile LNAPL. Note that mobile LNAPL is different than migrating LNAPL. Migrating LNAPL is both mobile and subject to a LNAPL pressure head that results in an expanding LNAPL footprint. Migrating LNAPL is not present at the Site as discussed in Section 6.3.3. The LNAPL residual saturation is dependent on the nature of the LNAPL, the type of soil in which the LNAPL is present, the LNAPL pressure head, and the initial LNAPL saturation. Because the nature of the LNAPL and the type of soil can vary vertically and laterally beneath the Site, the LNAPL residual saturation also varies. To estimate Site-specific LNAPL residual saturation values for the Site, ERM used the API Interactive LNAPL Guide, Version 2.0 TPH to NAPL Saturation Conversion Tool (Saturation Tool). The API Saturation Tool uses Site-specific soil bulk density, LNAPL density, soil porosity, and LNAPL saturation values to calculate LNAPL residual saturation for a specific LNAPL and soil combination. The input parameters needed for the API Saturation Tool were obtained for four subsurface soil samples analyzed as part of the LNAPL mobility testing described in Section 4.7.1.2. The Site-specific LNAPL and soil data for the four soil cores and the calculated residual saturation for each core are summarized in Table 12, and the API Saturation Tool worksheets used to calculate the residual saturation values are included as Appendix N. The calculated LNAPL residual saturations range from 17,000 mg/kg for diesel in medium sand to 70,000 mg/kg for mixed diesel and heavy oil in fine sand. As expected, LNAPL residual saturations are higher for higher viscosity LNAPL and finer-grained soils.

The low end of the calculated LNAPL residual saturation values at the Site (17,000 mg/kg) is below the median TPH-D/HO soil CUL for the protection of groundwater determined as part of the toxicity assessment (i.e., 62,164 mg/kg). It also represents the LNAPL residual saturation for the most mobile product and the most porous media tested at the Site. To account for the possibility that higher porosity soils and lower viscosity LNAPLs may exist at the Site, ERM applied a 20% safety factor to the low end of the LNAPL residual saturation values, which results in a LNAPL residual saturation value of 13,600 mg/kg. The proposed preliminary Site-specific CUL for TPH-D/HO in subsurface soil is appropriately protective of groundwater and the formation of LNAPL at the Site.

5.3.2.2.2 *Cleanup Levels for Other Constituents of Potential Concern*

Site-specific CULs were derived for all COPCs except TPH-D/HO in subsurface soil using the fixed parameter three-phase partitioning model described (Equation 747-1) in WAC 173-340-747(4). This model, presented below, is used to calculate soil CULs protective of groundwater.



$$C_s = C_w(UCF)DF\left[K_d + \frac{(\theta_w + \theta_a H_{cc})}{\rho_b}\right]$$

Where:

C_s = Soil concentration (mg/kg)

C_w = Groundwater cleanup level established under WAC 173-340-720 (ug/l)

UCF = Unit conversion factor (1mg/1,000 ug)

DF = Dilution factor (dimensionless: 20 for unsaturated zone soil; see (e) of this subsection for saturated zone soil)

K_d = Distribution coefficient (L/kg; see (c) of this subsection)

θ_w = Water-filled soil porosity (ml water/ml soil: 0.3 for unsaturated zone soil; see (e) of this subsection for saturated zone soil)

θ_a = Air-filled soil porosity (ml air/ml soil: 0.13 for unsaturated zone soil; see (e) of this subsection for saturated zone soil)

H_{cc} = Henry's law constant (dimensionless; see (d) of this subsection)

ρ_b = Dry soil bulk density (1.5 kg/L)

The model inputs and results are summarized in Table 13. Groundwater CULs (C_w) used in the equation are the MTCA Method A groundwater CULs published in WAC 173-340-900 Table 720-1. Default values were used for dry soil bulk density, as well as dilution factor, water-filled porosity, and air-filled porosity in unsaturated zone soil. For each organic COPC, the distribution coefficient published in WAC 173-340-900 Table 747-1 was used in the equation, unless the compound was not listed in the table. For those compounds, the distribution coefficients presented in Table 747-4 were used. For PCBs, the distribution coefficient for Arochlor-1016 was used because it would yield the most conservative CUL. For metals, the distribution coefficients published in WAC 173-340-900 Table 747-3 were used in the equation. Henry's law constants published in WAC 173-340-900 Table 747-4 for BTEXs, naphthalene, and methyl tert butyl ether and in the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (Appendix C, Exhibit C-1, USEPA 2002) for benzo(a)pyrene, methylene chloride, and trichloroethylene were used in the equation. A published Henry's law constant was not found for PCBs; therefore, it was set to zero based on the low volatility of PCBs. For metals, the Henry's law constant was set to zero in accordance with WAC 340-173-747(4)(d).

5.3.2.2.3 *Empirical Demonstration of Protection of Groundwater*

According to WAC 173-340-747(3)(f), for any hazardous substance, MTCA allows use of an empirical demonstration to show that detected soil concentrations will not cause an exceedance of the applicable groundwater CUL. The demonstration must utilize Site-specific soil and groundwater data. Per WAC 173-340-747(9), the empirical demonstration shall be based on methods approved by Ecology and must show:

- Groundwater concentrations are less than or equal to the applicable groundwater CUL; and
- The detected soil concentration will not cause a future exceedance of the applicable groundwater CUL.

This method is used to demonstrate that the cadmium concentrations detected in surface and subsurface soil at the Site has not and will not result in groundwater concentrations exceeding the preliminary groundwater CUL of 5 micrograms per liter (µg/L).

Cadmium was detected in 23 of the 35 surface soil samples analyzed for cadmium at concentrations ranging from 0.13 to 3.3 mg/kg. All of these cadmium concentrations are below the standard MTCA Method B CUL for protection of direct contact (80 mg/kg), but three of the samples had concentrations marginally higher than the calculated Method B CUL for protection of groundwater. The lack of a known source of cadmium at the Site, the low frequency of elevated cadmium concentrations in soil, and the low concentrations of cadmium relative to their CUL suggest the cadmium may be natural.

According to San Juan (1994), the mean and 90th percentile background cadmium concentrations are 0.63 mg/kg and 0.99 mg/kg, respectively, statewide, and 0.4 mg/kg and 0.72 mg/kg in the Spokane Basin, respectively. The cadmium concentrations detected in the Site soil are within the same order of magnitude as the background concentrations reported for the Spokane Basin. However, Site-specific background cadmium concentration data were not collected.

Groundwater samples collected during the fifth monitoring event were analyzed for cadmium to evaluate whether cadmium concentrations detected in surface and subsurface soil posed a risk to groundwater. Cadmium was detected in seven of the 16 groundwater samples analyzed at concentrations ranging from 0.03 to 0.73 µg/L, which are all below the MTCA Method A groundwater CUL of 5 µg/L. Analytical results of cadmium in groundwater are presented in Table P-3 in Appendix P.

These data empirically demonstrate that cadmium detected in Site soil does not pose a risk to groundwater; therefore, cadmium is not carried forward as a COC.

5.4 CONSTITUENTS OF CONCERN

In order to identify the constituents in Site media that contribute to greatest risk to human health and the environment, COCs or indicator hazardous substances per WAC 173-340-703 were identified using a two-step process.

The first step involved identifying all COPCs that were detected in soil and groundwater samples collected from the Site. The second step involved determining if COPCs detected in the samples exceeded preliminary cleanup standards identified in Section 5.3. COPCs that were detected in Site soil and groundwater exceeding preliminary CULs were carried forward as COCs.

5.4.1 Nature of Petroleum Hydrocarbon Contamination

Based on the interpretation of chromatograms generated by laboratory analyses of soil and LNAPL samples, the petroleum hydrocarbon contamination at the Site consists of TPH-D and TPH-HO. The source of these petroleum fractions appears to be two separate products, diesel fuel and heavy oil (from Bunker C and asphaltic oil), which each appear alone and mixed together in the sample set collected from the Site. As indicated by the evaluation described below, the LNAPL is predominantly a uniform mixture of diesel and heavy oil.

ERM reviewed available chromatograms to determine the appropriate approach for selection of MTCA TPH-D and TPH-HO CULs based on the requirements of the Ecology Implementation Memorandum #4 – Determining Compliance with Method A CULs for Diesel and Heavy Oil dated 17 June 2004 (Ecology 2004).

Note that the chromatograms for the petroleum hydrocarbon analysis by Ecology Method NWTPH-Dx provided by the laboratory could not be visually interpreted. The chromatograms generated for the SVOC analysis under USEPA Method 8270 SIM were used as a surrogate for the Ecology Method NWTPH-Dx chromatograms, as the general chromatographic response for the analyses are similar, and the SVOC analysis chromatograms could be visually interpreted.

Chromatograms for the petroleum hydrocarbons present in Site soil and LNAPL exhibited four general groups of chromatographic instrument response:

- A single peak in the diesel range, interpreted as areas of contamination by diesel fuel only;
- Two peaks, one in the diesel range and one in the heavy oil range, interpreted as mixed diesel and heavy oil (Bunker C and/or asphaltic oil);
- A single broad peak in the diesel range associated with a long shoulder in the heavy oil range, interpreted as mixed diesel and heavy oil, having a greater concentration of diesel; and
- A single peak in the heavy oil range, interpreted as heavy oil.

Example chromatograms are illustrated on Figure 20, a representative set of chromatograms is included as Appendix O, and the chromatogram analysis is summarized in Table 14. In addition to identifying the types of petroleum present in Site media, the chromatograms were used to evaluate changes in the hydrocarbon composition relative to the initial hydrocarbon composition (i.e., weathered versus un-weathered hydrocarbon). Gas chromatography is an effective tool in evaluating weathering of hydrocarbons in the natural environment (Belskoski, et. al. 2012). A change in hydrocarbon composition (i.e., weathering) is one line of evidence for NSZD, a combination of processes that reduce the mass of LNAPL in the subsurface (ITRC 2009a, 2009b). Comparison of the sample and calibration standard chromatograms (Figure 20) clearly shows weathering, most substantively in the diesel range and evidenced by the reduction or disappearance of the n-alkane series present in fresh diesel (personal communication with Alan Jeffrey, Pace/Zymax, 15 January 2015).

Although variations in petroleum composition (i.e., the percent heavy oil versus diesel) exist in the soil, the differences diminish with depth and the subsurface soils contain a relatively uniform mixture of diesel and heavy oil. Moreover, the two petroleum products are broadly comingled and their individual concentrations cannot be readily differentiated in many samples because their chromatographic signatures overlap. Therefore, the default assumption for evaluating compliance with numerical regulatory standards developed for the Site under MTCA will be to compare the sum of the TPH-D and TPH-HO fractions with the CUL. The sum of TPH-D and TPH-HO fractions (TPH-D/HO) is compared to the MTCA Method A levels of 500 µg/L for groundwater, and 2,000 mg/kg for surface soils (0 to 15 ft bgs), and the calculated MTCA Method B level for subsurface soils (greater than 15 ft bgs). This default compliance evaluation method is applied to soils and groundwater regardless of the relative amounts of diesel and heavy oil in the sample.

5.4.2 LNAPL

LNAPL consisting of diesel and/or heavy oil is present in Site soils, particularly in the smear zone at the groundwater table. As discussed in Section 6.3.3, both mobile and residual LNAPL is present at the Site, but there is no evidence of migrating LNAPL at the Site. WAC 173-340-360(2)(c)(ii) states, inter alia, "Treatment or removal of the source of the release shall be conducted for liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile hazardous substances, or hazardous substances that cannot be reliably contained. This includes removal of free product consisting of petroleum and other LNAPL from ground water using normally accepted engineering practices."

The hazardous characteristics of free product (mobile LNAPL) can be directly evaluated by collecting samples of it from monitoring wells and analyzing the LNAPL for chemical constituents. Twelve samples of mobile LNAPL (including mixed LNAPL/groundwater samples) were collected from Site monitoring wells and analyzed for toxic chemical concentrations. The results are presented in Section 6.3.1 and show that the mobile LNAPL contains high concentrations of TPH-D/HO, cPAHs, and/or naphthalenes. For these reasons, mobile LNAPL is considered a COC for the Site.

The hazardous characteristics of residual LNAPL can be evaluated via collection and analysis of soil samples in which the LNAPL resides. Therefore, residual LNAPL is not a distinct sample matrix and is not considered a COC. Instead, the hazardous substances in the residual LNAPL are the COCs and their concentrations are evaluated via soil samples and compared to the applicable soil CULs as described in the following sections.

5.4.3 Identification of Constituents of Concern

5.4.3.1 Surface Soil COCs

A total of 93 surface soil samples have been collected from the Site since 2007. TPH-D, TPH-HO, and selected metals, cPAHs, naphthalenes, non-carcinogenic PAHs, PCBs, SVOCs, and VOCs, including BTEX, have been detected in surface soil samples collected from the Site. Table 15 summarizes the number of surface soil samples analyzed, the number of samples containing detectable concentrations of COPCs, the range of concentrations detected, and the number of samples containing concentrations exceeding the preliminary CULs. Comparing the detected COPCs to the preliminary CULs, the following contaminants are carried forward as COCs:

- TPH-D/HO,
- Benzo(a)Pyrene,
- Benzo(a)Pyrene Toxic Equivalency Quotient (TEQ),
- Naphthalene, and
- Total Naphthalenes.

5.4.3.2 Subsurface Soil COCs

A total of 172 subsurface soil samples have been collected from the Site since 2007. TPH-G, TPH-D, TPH-HO, and selected metals, cPAHs, naphthalenes, non-carcinogenic PAHs, and VOCs, including BTEX, have been detected in subsurface soil samples collected from the Site. Table 16 summarizes the number of subsurface soil samples analyzed, the number of samples containing detectable concentrations of COPCs, the range of concentrations detected, and the number of samples containing concentrations exceeding the preliminary CULs. Comparing the detected COPCs to the preliminary CULs, the following contaminant is carried forward as a COC: TPH-D/HO.

5.4.3.3 Groundwater COCs

A total of 139 groundwater samples have been collected from monitoring wells at the Site not containing LNAPL since 2008. TPH-G, TPH-D, TPH-HO, metals, cPAHs, naphthalenes, non-carcinogenic PAHs, SVOCs, and VOCs, including BTEX, have been detected in groundwater samples collected from the Site.

Table 17 summarizes the number of groundwater samples analyzed, the number of samples containing detectable concentrations of COPCs, the range of concentrations detected, and the number of samples containing concentrations exceeding the preliminary CULs. Comparing the detected COPCs to the preliminary CULs, the following contaminants are carried forward as dissolved phase COCs in groundwater:

- TPH-D/HO,
- Benzo(a)Pyrene, and
- Benzo(a)Pyrene TEQ.

5.5 PRELIMINARY POINTS OF COMPLIANCE

5.5.1 Surface Soil

According to WAC 173-340-740(6)(d), the standard point of compliance for protection of human health from direct contact with contaminated soil is soils throughout the Site from ground surface to 15 ft bgs.

5.5.2 Subsurface Soil

According to WAC 173-340-740(6)(b), the standard point of compliance for protection of groundwater are soils greater than 15 ft bgs throughout the Site.

5.5.3 Groundwater

According to WAC 173-340-720(8), the standard point of compliance for groundwater is all groundwater throughout the Site.

6.0 NATURE AND EXTENT OF CONTAMINATION

This section describes the nature and extent of contaminants identified in Site soils, groundwater, and LNAPL. This evaluation utilizes all the pre-RI and RI data.

6.1 SOILS

As indicated in Section 5.2.1, contaminants in surface soil pose direct contact risks to human health that are not posed by contaminants in subsurface soils. Therefore, the nature and extent of contaminants in the surface soils (0 to 15 ft bgs) are evaluated separately from the subsurface soils (greater than 15 ft bgs).

6.1.1 Surface Soil (≤15 ft bgs)

Analytical data from surface soil samples collected from the Site show five localized areas of contaminant impact exceeding the applicable MTCA Method A CULs for unrestricted land use. Those areas of impact are situated in the vicinity of the:

- Black Tank Sump (SSA-1),
- Black Tank and Chemical Solution Pipelines (SSA-2),
- Red Tank Dispensers (SSA-3),
- Liquid Asphalt Pipeline (SSA-4), and
- Black Tank (SSA-5).

Field screening and laboratory analyses of soil samples collected from test pits, excavations, and/or soil borings from the other potential source areas at the Site (i.e., the oil pipeline and the Red Tank and associated piping) showed no indication of contaminant impact above the applicable CULs.

The areas of surface soil impacts and the sample concentrations exceeding the CULs are shown on Figure 21 for TPH-D/HO and on Figure 22 for cPAHs, naphthalenes, and metals. The analytical data for the COCs in the surface soil samples are summarized in Table 18, and the complete set of analytical data for surface soil samples is provided as Table P-1 in Appendix P. Laboratory analytical reports and data validation memoranda for the surface soil samples are included in Appendix J.

The COCs in surface soil are TPH-D/HO, benzo(a)pyrene, benzo(a)pyrene TEQ, naphthalene, and total naphthalenes (Tables 15 and 18). Of the 92 surface soil samples analyzed for TPH-D/HO, 64 contained detectable concentrations of TPH-D/HO and 25 contained concentrations exceeding the CUL (Table 15). The detected TPH-D/HO concentrations range from 10.4 to 152,000 mg/kg (Table 15).

All 61 surface soil samples analyzed for cPAHs and naphthalenes contained detectable concentrations of benzo(a)pyrene TEQ and total naphthalenes, but only 18 contained detectable concentrations of benzo(a)pyrene and 25 contained detectable concentrations of naphthalene (Table 15). Fourteen samples had calculated benzo(a)pyrene TEQ concentrations (based on non-detect [ND] values set to zero [ND=0]) exceeding the CUL, and 13 samples contained total naphthalene concentrations exceeding the CUL (Table 18). An additional 13 samples contained calculated benzo(a)pyrene TEQ concentrations (based on ND values calculated as one-half the laboratory detection limit [ND=1/2DL]) exceeding the CUL (Table 18). Because these calculated TEQ concentrations are driven primarily by ND, the calculated benzo(a)pyrene TEQ concentrations from these 13 samples are not used to identify surface soil requiring cleanup. The detected concentration ranges for benzo(a)pyrene TEQ are 0.00755 to 13.7 mg/kg (Table 15). The detected concentration ranges for total naphthalenes are 0 to 159 mg/kg (Table 15). The highest concentrations of TPH-D/HO, benzo(a)pyrene, and benzo(a)pyrene TEQ were detected in the Black Tank and Chemical Solution Pipelines area at a depth of 2 ft bgs (CSPL-TP-7B-2N).

The five areas of surface soil containing COC concentrations exceeding the CULs are described below.

Black Tank Sump Area (SSA-1). This area is located in the central portion of the Site adjacent to the former Black Tank Sump (Figures 21 and 22). TPH-D/HO and/or cPAHs were detected in soil borings B-14 and B-16 and excavation sidewall sample GE-SW-3 in this area at concentrations exceeding preliminary CULs (Table 18). This contamination area is bounded on the north and east by compliant soil samples from soil borings B-13 and B-15, respectively. It is bound to the west by a series of test pits that showed no evidence of contamination. To the south, it is bound by the north sidewall of the former Black Tank excavation. Contaminant concentrations exceeding the CULs extend to a depth of at least 10 ft bgs. The estimated size of the Black Tank Sump area is 3,200 square feet, and assuming a maximum contamination depth of 15 ft bgs, the estimated volume of soil potentially requiring remediation is 1,800 cubic yards.

Black Tank and Chemical Solution Pipelines Area (SSA-2). This area is located to the southwest of the Black Tank Sump area and directly west of the former Black Tank excavation (Figures 21 and 22). It includes the former Black Tank and

Chemical Solution Pipelines, which extends to the west from former Tank #2 (Figure 2). TPH-D/HO, benzo(a)pyrene TEQ, and/or total naphthalenes were detected in 15 test pit or trench samples from this area at concentrations exceeding their CULs (Table 18). This contamination area is bounded horizontally by compliant test pit soil samples to the north (BT-TP-25-14, BT-TP-27A-4N, and BT-TP-27B-5N), east (CSPL-TP-7A-4E), south (CSPL-TP-7B-6S, BT-TP-27A-4.5S, and BT-TP-27B, 5S), and west (BT-TP-30-2.5). However, the test pit sample (BT-TP-30-2.5) defining the westerly limit of the TPH-D/HO and benzo(a)pyrene TEQ contamination exceeds the CUL for total naphthalenes. Based on data from soil boring BT-SB-01, contamination exceeding the CULs in this area extends to the 15 ft bgs standard point of compliance. The estimated size of the Black Tank and Chemical Solution Pipelines area is 3,700 square feet, and assuming a contamination depth of 15 ft bgs, the estimated volume of soil potentially requiring remediation is 2,050 cubic yards.

Red Tank Dispensers Area (SSA-3). This area is located in the southwest portion of the Site, at the location of the dispensers for the former Red Tank system (Figure 22). Benzo(a)pyrene TEQs and/or naphthalenes were detected in four test pit samples (RT-T-45, RT-TP-45B, RT-TP-50, and RT-TP-50B) from this area at concentrations exceeding their CULs (Table 18). This contamination area is bounded horizontally by compliant test pit soil samples to the east (RT-TP-45A and RT-TP-50A) and south (RT-TP-50C). Confirmation samples were not collected to the north and west, but field screening in RT-TP-44 and MW-19 defines the northern extent of the petroleum in this area. Contamination was not observed at depths greater than 4 ft bgs. The estimated size of the Red Tank Dispensers area is 2,800 square feet, and assuming a maximum contamination depth of 4 ft bgs, the estimated volume of soil potentially requiring remediation is 400 cubic yards.

Liquid Asphalt Pipeline Area (SSA-4). This area is located along the southern Site boundary, where the former Liquid Asphalt Pipeline turns to the northeast along the property boundary with SemMaterials (Figures 21 and 22). TPH-D/HO and benzo(a)pyrene TEQ are the only COCs exceeding their CULs in this area (Table 18). The horizontal extent of contamination is bounded by compliant soil samples to the north (LAPL-TP-05-1.5), east (LAPL-TP-6-S1.5), south (LAPL-TP-08-1.25), and west (LAPL-TP-6-15). Based on data from test pit LAPL-TP-6, contamination exceeding the CULs in this area extends to the 15 ft bgs standard point of compliance. The estimated size of the Liquid Asphalt Pipeline area is 790 square feet, and assuming a maximum contaminant depth of 15 ft bgs, the estimated volume of soil potentially requiring remediation is 450 cubic yards.

Black Tank Area (SSA-5). This area is located beneath the former Black Tank, at the base of the former Black Tank excavation (Figure 21). TPH-D/HO is the only COC exceeding its CUL in this area (Table 18). The horizontal extent of contamination is bounded by compliant excavation confirmation soil samples to the north, east, south, and west (Figure 21). The vertical extent of contamination exceeding the CUL is not defined by compliant soil samples; however, soil screening at MW-17 indicates no significant contamination at shallow depths beneath the former Black Tank excavation (Appendix F). The estimated size of the Black Tank area is 970 square feet, and assuming a maximum contaminant depth of 5 ft bgs, the estimated volume of soil potentially requiring remediation is 200 cubic yards.

6.1.2 *Subsurface Soils (>15 ft bgs)*

For the purpose of evaluating the nature and extent of contamination, the subsurface soils are subdivided into intermediate soils and smear zone soils.

Intermediate Soils

Intermediate soils are vadose zone soils that extend from below the surface soils (i.e., >15 ft bgs) to the top of the smear zone, which is situated at approximately 156 ft bgs (1,883 feet amsl).

Analytical data from intermediate soil samples show one area of TPH-D/HO impact exceeding the preliminary CUL for TPH-D/HO (Figure 23). The area encompasses the Black Tank and Chemical Solution Pipelines and the Black Tank Sump, and is immediately north of the former Black Tank (Figure 23). Field screening and laboratory analyses of soil samples collected from soil borings from beneath the other potential source areas at the Site showed no TPH-D/HO concentrations above the preliminary CULs.

The analytical data for the COCs in the intermediate soil samples are summarized in Table 19, and the complete set of analytical data for intermediate soil samples is provided as Table P-2 in Appendix P. Laboratory analytical reports and data validation memoranda for the intermediate soil samples are included in Appendix J.

The COCs in intermediate soil are limited to TPH-D/HO. Of the 85 intermediate soil samples analyzed for TPH-D/HO, 48 contained detectable concentrations of TPH-D/HO, but only three contained concentrations exceeding the preliminary CUL of 13,600 mg/kg (Tables 16 and 19). The detected TPH-D/HO concentrations range from 11.6 to 67,500 mg/kg (Table 16). The highest concentration of TPH-D/HO was detected beneath the Black Tank and Chemical Solution Pipelines area at a depth of 116 to 117 ft bgs (BT-SB-01[116-117]). As shown on Figures 6 and 23, two intervals of intermediate soil show TPH-D/HO concentrations above the preliminary CUL of 13,600, one at a depth of 66 to 67 ft bgs and the other at 116 to 117 ft bgs. The horizontal extent of the intermediate soil contamination is bounded by MW-04 and B-12 to the north; B-05, B-06, and MW-25 to the east; B-7, MW-17, and B-10 to the south; and B-18 and MW-20 to the west (Figure 23 and 24).

Smear Zone Soils

Smear zone soils are capillary fringe and saturated soils that have been impacted by LNAPL (defined by the presence of petroleum staining and/or TPH-D/HO impacts). The smear zone soils were identified by evaluating the Site soil boring logs and TPH-D/HO laboratory data for soil samples collected from depths near the groundwater table. The smear zone data, which is summarized in Table 3, shows the smear zone is thickest (approximately 30 feet) at MW-3, where it extends from 156 to 186 ft bgs (1,883 to 1,853 feet amsl). MW-3 is situated immediately downgradient, but not within the petroleum release area; therefore, it is a good indicator of the likely maximum smear zone thickness. A contour map of the smear zone thickness (Figure 25) shows that the smear zone is thickest immediately below the impacted intermediate soils (and the primary source area: the Black Tank Sump, Black Tank and Chemical Solution Pipelines, and the Black Tank) and thins radially to less than 1 foot at its perimeter.

Analytical data from the smear zone soil samples show a contiguous area of TPH-D/HO impact exceeding the preliminary CUL of 13,600 mg/kg. The area of smear zone soil impacts and the sample concentrations exceeding the preliminary CUL for TPH-D/HO are shown on Figure 23. The analytical data for the COCs in the smear zone soil samples are summarized in Table 19, and the complete set of analytical data for smear zone soil samples is provided as Table P-2 in Appendix P. Laboratory analytical reports and data validation memoranda for the smear zone soil samples are included in Appendix J.

The COCs in the smear zone soil are limited to TPH-D/HO. Of the 86 smear zone soil samples analyzed for TPH-D/HO, 51 contained detectable concentrations of TPH-D/HO and 17 contained concentrations exceeding the preliminary CUL of 13,600 mg/kg (Tables 16 and 19). The detected TPH-D/HO concentrations range from 7.5 to 61,700 mg/kg (Table 16). The highest concentration of TPH-D/HO detected in the smear zone was at MW-21 in silt layer at a depth of 170 to 171 ft bgs (Figure 23). The horizontal extent of the smear zone soil contamination is bounded by MW-12, MW-22, and MW-29 to the north; MW-15, MW-24, and GMW-5 to the east; B-25 and MW-6 to the south; and MW-27 and MW-30 to the west. The footprint of the smear zone soils is interpreted to be the maximum extent of the residual LNAPL (Figures 23 and 25).

Data from soil borings where soil samples were collected at multiple intervals through the smear zone show large variations in TPH-D/HO concentrations across the smear zone. Commonly, the data show a soil interval containing TPH-

D/HO concentrations above the CUL (residual saturation) sandwiched between intervals having TPH-D/HO concentrations below the CUL (see MW-3, MW-7, MW-14, MW-16, MW-18, MW-20, MW-21, MW-23, MW-26 and MW-28 on Table 19). These data show that under current conditions, only a small part of the smear zone (in cross-sectional view) exceeds residual saturation and has the potential to contain mobile LNAPL. Most of the smear zone soils (particularly at the top and bottom of the smear zone) contain TPH-D/HO concentrations below residual saturation, indicating that the LNAPL is residual and not mobile. When plotted in cross-sectional view, the data show that over 86% of the soil in the smear zone is below residual saturation.

It is noteworthy that some monitoring wells exhibiting gauged LNAPL have no smear zone soil samples exceeding the residual-saturation based TPH-D/HO CUL and other monitoring wells have soil samples exceeding the residual saturation based TPH-D/HO CUL, but no gauged LNAPL in the well. The first condition is the result of not having collected soil samples from the intervals that produced mobile LNAPL. This may have occurred because of poor sample recovery during drilling, an incorrect field interpretation of the productive soil interval, and/or limitations on the number of soil samples to be collected from each boring. The second condition is the result of having a conservative residual-saturation based TPH-D/HO CUL (i.e, based on the soils that exhibited the lowest residual saturations and a 20% safety factor). This conservative approach will inevitably yield situations where soils exceeding the CUL don't produce mobile LNAPL.

6.2 GROUNDWATER

Analytical data from groundwater samples collected from the Site show COCs are rarely detected in groundwater at concentrations exceeding the MTCA Method A CULs. Only five of 123 groundwater samples collected from the Site and one of 16 groundwater samples collected from upgradient of the Site contain COC concentrations exceeding their preliminary CULs. The monitoring wells and sample concentrations exceeding the preliminary CULs are shown on Figures 26 and 27, the analytical data for COCs in groundwater are summarized in Table 20, and the complete set of analytical data for groundwater samples is provided as Table P-3 in Appendix P. Laboratory analytical reports and data validation memoranda for groundwater samples are included in Appendix J. Only groundwater samples from monitoring wells without measurable LNAPL at the time of the sampling are included in the groundwater dataset; samples collected from wells that contained LNAPL at the time of sampling are included in the LNAPL dataset.

6.2.1 *Groundwater Geochemistry*

The results of the water quality parameter measurements (i.e., pH, temperature, specific conductance, DO, and redox potential) obtained during groundwater monitoring events are summarized in Table 9. Site groundwater has slightly acidic (4.65) to slightly basic (8.34) pH range and a near-neutral (7.19) average pH. The oxidation-reduction potential values for Site groundwater ranges from reducing (-401 millivolts [mV]) to oxidizing (+337 mV), with a slightly oxidizing average oxidation-reduction potential of 125 mV. DO measured in Site groundwater has ranged from 0.21 milligrams per liter (mg/L) to 10.09 mg/L, with an average of 5.27 mg/L. The specific conductivity of the groundwater ranged from 0.01 microsiemens per centimeter (µS/cm) to 0.6 µS/cm, with an average of 0.25 µS/cm. Groundwater temperatures fluctuate seasonally between 4.11 degrees Celsius (°C) in the winter and 17.95 °C in the summer. The average groundwater temperature is 11.89 °C.

6.2.2 *TPH-D/HO and cPAHs*

The COCs detected in groundwater are TPH-D/HO, benzo(a)pyrene, and benzo(a)pyrene TEQ (Tables 17 and 20). Groundwater samples collected prior to March 2016 were analyzed for TPH-D/HO with silica gel cleanup, whereas groundwater samples collected in March and December 2016 were analyzed for TPH-D/HO with and without silica gel cleanup and groundwater samples collected in June and September 2016 were analyzed for TPH-D/HO without silica gel cleanup. The results of both types of TPH-D/HO analyses as well as the results of the cPAH analyses are described below.

6.2.2.1 *TPH-D/HO without Silica Gel Cleanup*

Of the 63 groundwater samples analyzed for TPH-D/HO without silica gel cleanup, 32 contained detectable concentrations of TPH-D/HO, and three contained concentrations exceeding the preliminary CUL (Table 17 and Figure 26). The detected TPH-D/HO concentrations range from 22 to 2,200 µg/L (Tables 17 and 20).

6.2.2.2 *TPH-D/HO with Silica Gel Cleanup*

Of the 139 groundwater samples analyzed for TPH-D/HO with silica gel cleanup, 15 contained detectable concentrations of TPH-D/HO, and two contained concentrations exceeding the preliminary CUL (Table 17). The detected TPH-D/HO concentrations range from 7.8 to 1,150 µg/L (Table 17). As shown in Table 20 and on Figure 27, the TPH-D/HO exceedances occurred at MW-06 (1,100 µg/L) on 6 March 2014 and at MW-24 (1,150 µg/L) on 5 December

2013. MW-06 is an off-Site upgradient well; therefore, contamination detected in that well is not representative of contamination from the Site.

6.2.2.3 *cPAHs*

Of the 109 groundwater samples analyzed for cPAHs, one contained a detectable concentration of benzo(a)pyrene, and three contained detectable concentrations of benzo(a)pyrene TEQ (Table 17). One sample (MW-12) contained benzo(a)pyrene and benzo(a)pyrene TEQ concentrations that exceeded the preliminary CULs (Table 17). Benzo(a)pyrene was detected in one sample at a concentration of 0.11 μg/L, and the detected concentration range for benzo(a)pyrene TEQ is 0.0119 to 0.15 μg/L (Table 17). The benzo(a)pyrene and benzo(a)pyrene TEQ exceedances occurred at MW-12 (0.11 μg/L and 0.15 μg/L, respectively) on 4 December 2013 (Table 20 and Figure 27). Given the low cPAH concentrations in the LNAPL itself, most, if not all, of the cPAH detections in groundwater are likely above their effective solubility. Therefore, the detected cPAH concentrations likely are not dissolved concentrations, but concentrations resulting from either micro emulsions of the LNAPL or cPAHs attached to particles in the groundwater samples.

6.2.2.4 *Data Evaluation*

The groundwater data from the off-Site, upgradient monitoring well (MW-06) indicate that a small, detached dissolved phase petroleum plume from an upgradient, off-Site source migrated toward the Site in 2014. Specifically, the March 2014 groundwater sample collected from MW-06 contained a TPH-D/HO contaminant concentration (1,100 μg/L) exceeding the preliminary CUL (Table 20 and Figure 27). All of the other 16 samples collected from that well showed no detectable petroleum-related constituents. As shown on Figures 12 and 27, MW-06 is situated approximately 140 feet to the south of the SemMaterials and Black Tank sites and groundwater flow was toward the north in March 2014. Moreover, the groundwater elevation at MW-06 was approximately 2.5 feet higher than the groundwater elevations measured in MW-26 and MW-27, which situated near the southern boundary of the Black Tank site, in March 2014. These data demonstrate that the SemMaterials and Black Tank sites are located downgradient of MW-06. Because dissolved phase groundwater contamination moves in the direction of groundwater flow, the source of the dissolved phase petroleum contamination detected in MW-06 must have been upgradient (i.e., south) of MW-06 and both the SemMaterials site and the Black Tank site. The single detection of petroleum in the well over a 7-year period suggests the dissolved phase petroleum plume was small and detached (Figure 27).

The groundwater data from the on-Site monitoring wells shows that dissolved phase petroleum has been inconsistently detected in groundwater samples collected from monitoring wells situated below and/or beyond the footprint of the LNAPL (Figures 26 and 27). Since groundwater sampling at the Site began in 2008, only five of the 139 groundwater samples (<4%) collected from on-Site monitoring wells beyond the footprint of the LNAPL exhibited petroleum constituent concentrations exceeding the preliminary CULs. The CUL exceedances include:

- A December 2013 sample from MW-24 that contained 1,150 μg/L TPH-D/HO based on an analysis with silica gel cleanup;
- A December 2013 sample from MW-12 that contained 0.11 μg/L benzo(a)pyrene and 0.15 μg/L benzo(a)pyrene TEQ exceedances;
- A June 2016 sample from MW-26 that contained 990j μg/L TPH-D/HO based on an analysis without silica gel cleanup; and
- June and September 2016 samples from MW-11 that contained 2,200j and 650j μg/L TPH-D/HO, respectively, based on analyses without silica gel cleanup (Table 20 and Figures 26 and 27).

Because three of the five groundwater samples exceeding the preliminary CUL are based on TPH-G/HO analyses without silica gel cleanup (Figure 26), ERM evaluated the data from groundwater samples analyzed for TPH-D/HO with and without silica gel cleanup to determine if the analytical method impacted the sample results. ERM concluded that all of the data are useful for evaluating the nature, magnitude, and extent of dissolved phase TPH-D/HO at the Site; however, the data from samples analyzed without silica gel cleanup are more relevant because: (1) Ecology requires analysis without silica gel cleanup for evaluation of compliance with groundwater standards, and (2) some of the data from Site samples analyzed without silica gel cleanup show higher concentrations of TPH-D/HO than samples analyzed with silica gel cleanup.

As shown on Figure 27, the long-term trend of TPH-D/HO (analyzed with silica gel cleanup) and cPAH data from the on-Site monitoring wells show consistently low and ND concentrations that generally peaked in early 2011 and have steadily decreased in concentration since then. Although the recent TPH-D/HO data analyzed without silica gel cleanup suggests that the TPH-D/HO data analyzed with silica gel cleanup may be biased low, particularly during the summer and fall sampling events, it nonetheless shows an overall long-term trend of low and decreasing concentrations that is still relevant for evaluating the nature and magnitude of the dissolved phase TPH-D/HO plume at the site. Silica gel cleanup removes biogenic organic compounds and petroleum metabolites (San Francisco Bay Regional Water Quality Control Board 2016). The fact that TPH-D/HO concentrations exceeding the CUL are generally limited to samples analyzed without silica gel cleanup and collected from wells located downgradient of the core of the LNAPL plume suggests that petroleum metabolites generated by biodegradation in the core of the LNAPL plume is the source of the elevated TPH-D/HO concentrations. Therefore, the data from TPH-D/HO analyses with silica gel cleanup provide valuable information regarding the extent to which petroleum hydrocarbons (without biogenic organic compounds and petroleum metabolites) are leaching from the LNAPL and migrating in groundwater and the data from TPH-D/HO analyses without silica gel cleanup provide valuable information regarding the extent to which biogenic organic compounds and/or petroleum metabolites are impacting and migrating in groundwater.

As shown on Figure 26, the groundwater samples analyzed without silica gel cleanup that contain TPH-D/HO concentrations exceeding the preliminary CUL are all situated downgradient of the LNAPL plume. Moreover, the time-series plots shown on Figure 26 illustrate the following trends:

- No detectable TPH-D/HO in the upgradient monitoring well (MW-06).
- No exceedances of the TPH-D/HO CUL occurred during the spring (March) and winter (December) sampling events when the water table was high or rising.
- Exceedances of the TPH-D/HO CUL occurred in the summer (June) and fall (September) sampling events when the water was falling or low.

Petroleum metabolites generated from biodegradation of the LNAPL plume are believed to be the source of the elevated TPH-D/HO concentrations detected in the downgradient monitoring wells samples. Since December 2013, only samples analyzed without silica gel cleanup and only samples taken from wells downgradient of the LNAPL plume show elevated concentrations of TPH-D/HO. If natural biogenic organic compounds in the groundwater were the source of the elevated TPH-D/HO concentrations in the downgradient wells, samples from the upgradient background well (MW-6) would show similar concentrations of TPH-D/HO when analyzed without silica gel cleanup. However, the MW-6 samples analyzed for TPH-D/HO without silica gel cleanup are ND. If dissolution of petroleum hydrocarbons from the LNAPL plume were the source of the elevated TPH-D/HO concentrations in the downgradient wells, then analyses with and without silica gel cleanup would result in similar TPH-D/HO concentrations. However, the non-silica gel cleanup samples consistently show higher TPH-D/HO concentrations than the silica gel cleanup samples. Therefore, petroleum metabolites from degradation of the LNAPL plume are the most likely source of the elevated TPH-D/HO concentrations detected in the downgradient monitoring wells.

The dissolved-phase TPH-D/HO plume appears to expand and contract in response to seasonal fluctuations in the water table. Specifically, the dissolved-phase TPH-D/HO plume expands in the summer and fall when the water table drops and then contracts in the winter and spring when the water table is high. Seasonal release of petroleum metabolites during periods of falling water table levels has been observed at other LNAPL sites (San Francisco Bay Regional Water Quality Control Board, 2016).

The known extent of the dissolved phase TPH-D/HO (without silica gel cleanup) plume is illustrated on Figure 26; however, there are no data to define the downgradient (northern) extent of the dissolved phase plume in the summer and fall. It is, however, defined in the winter and spring. This finding is based on one year of seasonal data from samples analyzed without silica gel cleanup. It is well understood that petroleum metabolites are highly degradable and are unlikely to persist at concentrations exceeding the CULs much beyond MW-11. Although these data show some seasonal variation in the downgradient extent of the dissolved phase petroleum contamination, the long-term trend of low to non-detection of TPH-D/HO (using silica gel cleanup data) and other petroleum constituents in the downgradient wells suggest that downgradient groundwater conditions are and will be compliant with preliminary CULs. Further, these data suggest that leaching of residual petroleum constituents from the LNAPL to the groundwater at the Site is limited by: (1) the low solubility of the LNAPL constituents, (2) the low permeability of the silt and silty sand facies in which much of the LNAPL resides, and/or (3) LNAPL blocking interconnected pore space through which groundwater might otherwise leach contaminants. A thin dissolved phase plume may exist within the footprint of the LNAPL, but its presence cannot be confirmed via groundwater sampling because of the presence of LNAPL in the monitoring wells. Groundwater samples from MW-13 and MW-14, which are screened below the LNAPL smear zone (approximately 5 and 20 feet, respectively) have been sampled since 2010 and shown no exceedances of the CULs (with or without silica gel cleanup) during that period. These data suggest that the dissolved phase TPH-D/HO plume doesn't extend downward into the aquifer a significant distance (i.e., it appears to be a water table plume).

6.3 LNAPL

LNAPL at the Site is present as both mobile LNAPL and residual LNAPL. The lateral extent of residual LNAPL and mobile LNAPL at the Site is shown on Figure 28, and the vertical extent of the residual and mobile LNAPL at the Site is illustrated on Figure 29.

Extent of Residual LNAPL

The extent of residual LNAPL is based on the presence of LNAPL in subsurface soils as documented on soil boring logs (i.e., the smear zone as defined in Section 6.1.2 and shown on Figure 29).

The lateral extent of the residual LNAPL is bounded by MW-10, MW-11, MW-12, and MW-29 to the north; GMW-5 to the east; GMW-6 and MW-6 to the south; and MW-27 and MW-30 to the west. The footprint of the smear zone soils (MW-26) is interpreted to be coincident with the maximum extent of the residual LNAPL (Figures 23 and 28). As illustrated on Figures 25 and 28, the residual LNAPL may extend a short distance onto the SemMaterials property; however, there is no confirmation of LNAPL on that property. As illustrated on Figure 25, the smear zone thins toward the SemMaterials property so it is unlikely that residual LNAPL extends a significant distance onto that property. Based on Figure 29, approximately 86% of the total LNAPL cross-section area is residual LNAPL. The estimated lateral extent of the residual LNAPL area is 9.7 acres.

Extent of Mobile LNAPL

The extent of mobile LNAPL is based on observations of LNAPL in groundwater monitoring wells and/or where laboratory analytical data suggest mobile LNAPL may be present.

LNAPL measurements obtained during the groundwater sampling events show that mobile LNAPL has been identified in 14 Site monitoring wells (Table 4 and Figure 28). Twelve monitoring wells (MW-1 to MW-5, MW-7, MW-9, MW-17 to MW-20, and MW-28) have consistently shown a gauged thickness of LNAPL, whereas two wells (MW-16 and MW-23) show periodic gauged thicknesses of LNAPL.

The lateral extent of mobile LNAPL was estimated based the gauged LNAPL thicknesses observed during quarterly groundwater monitoring conducted in December 2013; March, June, and October 2014; and March and June 2016. The lateral extent of mobile LNAPL was interpreted to be near wells having a sheen or very thin gauged thickness of LNAPL and a thin smear zone (i.e., MW-1, MW-16, and MW-23) and further away from wells having greater gauged thicknesses of LNAPL and thicker smear zones (MW-9, MW-19, and MW-28). The vertical extent of mobile LNAPL was estimated based on the observed air/LNAPL interface and LNAPL/water interface.

The LNAPL gauging data used to develop the mobile LNAPL extent showed little variability in LNAPL presence. Only MW-16 and MW-23, which are situated on the lateral margin of the mobile LNAPL area, showed inconsistency in the presence of a gauged thickness of LNAPL. In the seven monitoring events since its construction in 2013, MW-16 has shown a sheen of LNAPL once (June 2014) and no detectable LNAPL the other six events (Table 4). In the seven monitoring events since its construction in 2013, MW-23 shows no LNAPL twice (December 2013 and June 2014) and thin gauged thicknesses in the other five events (Table 4). These data suggest that these wells are situated near the lateral margins of the mobile LNAPL area (Figure 28).

Two separate areas of mobile LNAPL are present at the Site: a main mobile LNAPL area and a smaller southeast mobile LNAPL area (Figure 28).

1. The lateral extent of the main mobile LNAPL area is bounded to the north by MW-22, northeast by MW-29, east by MW-15, MW-24, and MW-25, southeast by MW-26, southwest by MW-27, west by MW-30, and northwest by MW-21. None of these wells show gauged thicknesses of LNAPL. As illustrated on Figure 28, the main mobile LNAPL area may extend to and possibly across the SemMaterials property boundary. However, as indicated previously, there is no confirmation of LNAPL (mobile or residual) on the SemMaterials property and the smear zone thins toward that property (Figure 25) suggesting that LNAPL would not extend a significant distance onto that property.
2. The southeast mobile LNAPL area is bounded to the east by MW-16, which has shown no gauged thickness of LNAPL since June 2014, to the south by GMW-6, southwest by MW-26, and northwest by MW-25. None of these wells show gauged thicknesses of LNAPL.

Based on Figure 29, approximately 14% of the total LNAPL cross-section area is mobile LNAPL. The estimated areas of the main mobile LNAPL area and the southeast mobile LNAPL area are 5.8 and 0.24 acres, respectively.

6.3.1 *LNAPL Chemical Constituents*

Analytical data for LNAPL (including mixed LNAPL and groundwater) samples collected from the Site show the LNAPL is primarily diesel and heavy oil (Bunker C and asphaltic oil). The analytical data for the TPH, metals, cPAHs, PCBs, and BTEX in LNAPL are summarized in Table 21, and the complete sets of analytical data for LNAPL and groundwater samples are included as Tables P-5 and P-4 in Appendix P. Laboratory analytical reports and data validation memoranda for groundwater samples are included in Appendix J. All liquid samples collected from monitoring wells containing measurable LNAPL at the time of the sampling are part of the LNAPL dataset because the sampling methodologies yielded mixed LNAPL and groundwater samples from which LNAPL samples could be decanted and analyzed or the mixed samples were analyzed. The results of the mixed samples are only used to establish relative concentrations of constituents in each LNAPL sample (e.g., percent of TPH-D to TPH-H) for use in qualitatively describing the nature of the LNAPL (percentage of diesel to heavy oil). The results from the mixed samples are not used for any other purpose in the RI/FS because they contain varying amounts of groundwater, so the absolute chemical concentrations reported for the samples are not useful for quantitative assessment of the magnitude of contaminant concentrations.

6.3.1.1 *Total Petroleum Hydrocarbons*

The nine LNAPL samples submitted for laboratory analysis during the RI consisted of 25.3% to 97.5% TPH-D/HO (Table 21). Based on the concentration split between TPH-D and TPH-HO, heavy oil comprises approximately 51% to 72% of the LNAPL. Most samples contain a fairly even split of diesel and heavy oil; however, the samples from MW-3 and MW-4 contain significantly higher percentages of heavy oil. The LNAPL samples contain from 0.1% to 1.1% TPH-G; however, because gasoline was not stored or handled in significant quantities at the Site, the detected TPH-G concentrations likely represent the lighter end of diesel. The 28 mixed LNAPL and groundwater samples collected from the Site show the same general TPH composition as the LNAPL samples, but at lower concentrations. These data indicate that most of the LNAPL plume is comprised of a relatively even mix of diesel and heavy oil (Bunker C and asphaltic oils).

6.3.1.2 *Carcinogenic Polycyclic Aromatic Hydrocarbons*

LNAPL samples from the Site show a low frequency of cPAH detections (Table 21). Of the nine LNAPL samples analyzed for cPAHs, one contained benzo(a)anthracene, one contained benzo(k)fluoranthene, and five contained chrysene. Concentrations of cPAHs in the LNAPL samples ranged from ND to 10.1 mg/kg for benzo(a)anthracene, ND to 6.82 mg/kg for benzo(k)fluoranthene, and ND to 107 mg/kg for chrysene. The 28 mixed LNAPL and groundwater samples collected from the Site show a similarly low frequency of cPAH detects (Table 21). The same three cPAHs were detected, but benzo(a)pyrene and benzo(b)fluoranthene also were detected in one sample each.

6.3.1.3 *Naphthalenes*

Specific naphthalenes (1-methylnaphthalene and 2-methylnaphthalene) were detected in eight of the nine LNAPL samples. Conversely, naphthalene was detected in only one LNAPL sample. Total naphthalene concentrations range from ND to 1,240 mg/kg in the nine LNAPL samples. The 28 mixed LNAPL and groundwater samples collected from the Site show a lower frequency of naphthalene detections (Table 21). 1-methylnaphthalene and

2-methylnaphthalene were detected most frequently, but at approximately half the frequency that they were detected in the LNAPL samples.

6.3.1.4 Non-Carcinogenic PAHs and Semi-Volatile Organic Compounds

The following non-carcinogenic PAHs were detected in one or more of the nine LNAPL samples collected from the Site: acenaphthene, acenaphthylene, anthracene, fluoranthene, fluorine, phenanthrene, and pyrene (Table P-5 in Appendix P). Only fluorene and phenanthrene were consistently detected in the LNAPL samples. Concentrations of individual non-carcinogenic PAHs ranged from ND to 332 mg/kg for phenathrene. None of the other SVOCs analyzed for in the LNAPL samples were detected (Table P-5 in Appendix P). The 28 mixed LNAPL and groundwater samples collected from the Site show a similar frequency of non-carcinogenic PAH detects (Table P-5 in Appendix P). The main difference is that in addition to fluorene and phenanthrene, acenaphthene is consistently detected in the mixed LNAPL and groundwater samples.

6.3.1.5 Volatile Organic Compounds

The following VOCs were detected in one or more of the nine LNAPL samples: 1,2,4-trimethylbenzene; 1,3,5-trimethylbenzene; 2-butanone; 2-phenylbutane; cumene; cymene; n-butylbenzene; n-propylbenzene; and tert-butylbenzene (Table P-5 in Appendix P). Only 2-phenylbutane, cumene, cymene, n-butylbenzene, n-propylbenzene, and tert-butylbenzene were detected relatively consistently (>50%) in the samples. Concentrations of individual VOCs detected in the LNAPL samples ranged from 0.41 to 33.6 mg/kg.

All 28 of the mixed LNAPL and groundwater samples were analyzed for BTEX, but only seven of the samples were analyzed for the full VOC scan (Table P-5 in Appendix P). VOCs detected in one or more of the mixed LNAPL and groundwater samples include: 2-phenylbutane, cumene, cymene, n-butylbenzene, and n-propylbenzene, all of which were also detected in the LNAPL samples. However, two of the mixed LNAPL and groundwater samples contained benzene and/or toluene, and three of the mixed LNAPL and groundwater samples contained ethylbenzene and/or xylenes. Concentrations of individual VOCs detected in the mixed LNAPL and groundwater samples ranged from 0.837 to 10.6 μg/L.

6.3.1.6 PCBs

Aroclor 1254 was detected in one of the nine LNAPL samples, at a concentration of 6,190 μg/kg, below the MTCA Method B soil CUL for the protection of groundwater. No other Aroclors were detected in LNAPL samples. No PCBs were detected in any of the 28 mixed LNAPL and groundwater samples.

6.3.1.7 *Metals*

As shown in Table 21, the following metals were detected in one or more of the LNAPL samples collected from the Site: cadmium (one sample), chromium, (one sample), copper (nine samples), lead (two samples), nickel (nine samples), and zinc (three samples). The metals concentrations ranged from a minimum of 0.028 mg/kg for cadmium to a maximum of 30.6 mg/kg for nickel. None of the detected metals concentrations in the LNAPL samples exceed the MTCA Method A CULs for soil or the Site-specific MTCA Method B soil CULs for the protection of groundwater.

Chromium and lead were the only metals detected in the 28 mixed LNAPL and groundwater samples collected at the Site. Total chromium and/or lead concentrations detected in one or more of the mixed LNAPL and groundwater samples exceeded the MTCA Method A groundwater CULs. However, the same wells that contained the elevated total chromium and lead concentrations were subsequently sampled and analyzed for dissolved chromium and lead, and detected concentrations are well below the MTCA Method A groundwater CULs, indicating that the presence of total chromium and lead is the result of particulates in the original samples (Table 21).

6.3.2 *LNAPL Fluid Properties*

The results of density, viscosity, and interfacial tension analyses conducted on samples of LNAPL and groundwater collected from monitoring wells MW-1, MW-3, and MW-18 are summarized in Table 22. The LNAPL density, viscosity, and surface/interfacial tension ranges indicate that the Site LNAPL has characteristics similar to heavy fuel oil (i.e., heavy oil and diesel). The LNAPL fluid properties are fairly consistent across each of the three sample locations, suggesting that the LNAPL is fairly consistent across the Site. The slight variability in LNAPL fluid properties is likely due to variability in the amount of diesel and heavy oil at each well location. The fluid properties laboratory analytical report is provided as Appendix G.

6.3.3 *LNAPL Stability and Mobility*

6.3.3.1 *Core Logs and Sample Selection*

Descriptive summaries of the undisturbed cores collected from soil borings MW-17, MW-20, MW-24, MW-28, and MW-29 for use in evaluating LNAPL mobility are included as Tables 23 to 27. The core descriptions are based on photographs of each core under both natural and ultraviolet light. The core photography logs were provided to ERM for review, and are included in Appendix D.

Based on the logs, intervals of the cores were selected for further analysis. A summary of the selected core sample intervals, testing parameters, and the rationale for each of the selected sample interval and testing parameters is provided in Table 28.

6.3.3.2 Soil Properties and Hydraulic Conductivity

Grain-size data show that subsurface lithology ranges from gravel with sand to silt. Soils in the smear zone (i.e., 156 to 185 ft bgs) consist primarily of a mixture of fine to medium sand having varying concentrations of silts and clays (Table 5). The percentage of silts and clays (fine-grained material) within the soils varied at each location.

- MW-17 had fine-grained material ranging from 9.05% at 154.0 ft bgs (1,876.78 feet amsl) to 39.07% at 162.2 ft bgs (1,868.58 feet amsl).
- MW-20 had fine-grained material ranging from 2.98% at 168.2 ft bgs (1,870.91 feet amsl) to 38.84% at 171.0 ft bgs (1,868.11 feet amsl).
- MW-24 had fine-grained material ranging from 2.98% at 175.8 ft bgs (1,864.61 feet amsl) to 7.38% at 171.8 ft bgs (1,868.61 feet amsl).
- MW-28 had fine-grained material ranging from 6.95% at 167.2 ft bgs (1,873.26 feet amsl) to 34.6% at 169.8 ft bgs (1,870.66 feet amsl).
- MW-29 had fine-grained material ranging from 84.92% at 173.3 ft bgs (1,865.24 feet amsl) to 2.08% at 179 ft bgs (1,859.54 feet amsl).

These data verify that the soils in the smear zone are interbedded gravels, sands and silty sands, and silts.

The calculated horizontal hydraulic conductivity of the soils in the vicinity of the smear zone ranged from 1.36 x 10^{-2} cm/second (38.55 feet per day) in coarse sand to 1.91 x 10^{-6} cm/second (0.0056 feet per day) in silt (Table 6). The horizontal hydraulic conductivity of the fine to medium sands were between 3.37 x 10^{-4} cm/second (0.96 feet per day) in medium sand to 9.94 x 10^{-5} cm/second (0.28 feet per day) in fine sand with silt (Table 6).

6.3.3.3 Pore Fluid Saturations and Laboratory LNAPL Mobility Testing

The pore fluid saturations within the subsurface were quantified using the Dean-Stark analyses. LNAPL mobility testing includes measuring the initial LNAPL saturation by Dean-Stark analysis then spinning the sample in a centrifuge at a 1,000g to release the LNAPL and water, and reanalyzing the LNAPL saturation by Dean-Stark analysis. These data provide an estimation of the residual LNAPL and water saturations. The residual LNAPL saturation is the portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients. Residual LNAPL possesses an LNAPL transmissivity of zero. A summary of the results of the pore fluid saturation analysis and LNAPL mobility testing are provided in Table 29 and Figure 30. Samples for laboratory LNAPL mobility testing were selected from intervals with the high LNAPL fluorescence to understand the percentage of mobile LNAPL and residual LNAPL at these sample intervals.

Total pore fluid saturations (water saturation plus LNAPL saturation) were between 26% and 86%. Total pore fluid saturations generally indicated that fluids were successfully retained in place. However, saturations were lower than expected at MW-20F at 177.0 ft bgs and MW-24F at 177.0 ft bgs, and indicate that fluid drainage may have occurred during core removal due the gravelly nature of these sample intervals. The in-place subsurface LNAPL saturations varied at each location.

- LNAPL saturations in the fine-medium sands in the vicinity of MW-17 ranged from 46.0% to 58.6%. The residual LNAPL saturation at 160.0 ft bgs (1,870.78 feet amsl) was 23.4%.
- LNAPL saturations in the fine-medium sands in the vicinity of MW-20 ranged from 11.1% to 29.9%. The residual LNAPL saturations ranged from 11.1% to 12.3%.
- LNAPL saturations in the fine-medium sands in the vicinity of MW-24 ranged from 2.8% to 12.9%. The residual LNAPL saturation at 176.0 ft bgs (1,864.41 feet amsl) was 7.5%.
- LNAPL saturations in the fine to medium sands in the vicinity of MW-28 ranged from 2.9% to 19%. The residual LNAPL saturation at 168.5 ft bgs (1,871.86 feet amsl) was 18.2%, and at 170 ft bgs (1,870.36 feet amsl) was 18%.

Based on the LNAPL mobility testing, the residual LNAPL saturation as determined in the laboratory ranged from 7.5% to 23.4%, and the mobile LNAPL saturations ranged from 0% to 35.2%.

The range in residual and mobile LNAPL saturations is the result of variations in the soil type, the maximum capillary pressure head of LNAPL at a given interval, and the high density of the LNAPL (between approximately 0.96 to 0.98 grams per cubic centimeter [g/cc]) along with the high viscosity values (between 1660 to 5570 centistoke). This supports the assumption and observation that there is variability in LNAPL residual saturation across the Site. Figure 30 illustrates the variability in mobile LNAPL saturation and residual LNAPL saturations based on the laboratory data and compares the laboratory measured residual LNAPL saturations to the preliminary TPH-D/HO CUL of 13,600 mg/kg, which is based on a calculated LNAPL residual saturation for the Site. The data and calculations used to generate Figure 30 are summarized in Table 30. As illustrated on Figure 30 and in Table 30, the preliminary TPH-D/HO CUL of 13,600 mg/kg is lower than the LNAPL residual saturations observed in the laboratory samples.

Laboratory-derived values for residual saturation provide a valuable line of evidence to support understanding of LNAPL behavior and conditions when evaluated with empirical site observation. Examples of where the laboratory LNAPL mobility analysis agrees with gauged LNAPL thicknesses include:

- At MW-20, dark brown LNAPL was produced from the sample collected at 168.4 ft bgs located within the gauged LNAPL thickness and both lines of evidence indicate mobile LNAPL is present at that interval in the formation.
- At MW-20, no LNAPL was produced from the sample collected at 177.0 ft bgs located below the gauged LNAPL thickness and both lines of evidence indicate residual LNAPL is present at that sample interval.

Examples of where the laboratory LNAPL mobility analysis does not agree with gauged LNAPL thicknesses includes:

- At MW-24, dark brown LNAPL was produced from the sample collected at 176.0 ft bgs; however, no LNAPL has accumulated in the well suggesting that LNAPL in the vicinity of the well is residual LNAPL.

Overall, the laboratory data suggest that the residual LNAPL saturation in the smear zone generally ranges from 10% to 20% of the pore space.

6.3.3.4 *Location-Specific LNAPL Vertical Profiles*

LNAPL Vertical Profiles (LVPs) were developed for the vicinity of MW-17, MW-20, and MW-24 to understand the vertical distribution of LNAPL in the subsurface based on the data collected.

MW-17

The LVP for the vicinity of MW-17 is illustrated using a hydrograph containing gauging data for well MW-17, soil core fluorescence data, LNAPL saturation data, soil core photography data, well screen interval, and subsurface soil characterization data based on lithological logging and is provided on Figure Q-1 in Appendix Q.

Evaluation of the LVP data indicates that LNAPL exists primarily within the native silt and silty sand facies (photographs of the core show primarily silty sand with intervals of deformed silt beds [it is unknown whether the deformation is natural or induced by drilling/sample collection]) at elevations from approximately 1,863 to 1,878 feet amsl. Soil samples were collected from the frozen soil cores and analyzed for LNAPL saturation and mobility at two locations within the interval of LNAPL. LNAPL saturations were quantified to be from 46.0% to 58.6%. The soil sample collected at 1,868.08 feet amsl for LNAPL mobility analysis was located within the interval of mobile LNAPL based on gauging data and produced dark brown LNAPL.

There is limited historical gauging data available for MW-17. The air/LNAPL interface was observed between 1,863 and 1,869 feet amsl since the construction of the well in November of 2013. Both the air/LNAPL interface and the LNAPL/water interface have generally remained within the screened interval since the installation of the well. By June 2014, the LNAPL/water interface dropped very near the bottom of the screened interval; however, this is likely an erroneous measurement resulting from the high viscosity LNAPL sticking to the interface probe beyond the actual depth of the LNAPL/water interface. This interpretation is supported by the fact that there is no core fluorescence in the formation at that elevation. Gauging data collected prior to June 2014, likely reflects conditions that had not reached equilibrium following well installation and indicate that LNAPL recovery into the well is very slow.

LNAPL in the formation in the vicinity of MW-17 is primarily located above the gauged air/LNAPL interface, but within the screened interval of the well, based on the core fluorescence. This indicates that the LNAPL between 1,869 and 1,878 feet amsl is trapped in the silty sands and deformed silt beds and exists as residual LNAPL as it does not flow into the monitoring well screen. The mobile LNAPL interval is observed between 1,863 and 1,869 feet amsl. The gauging data suggest that the mobile LNAPL is present in unconfined conditions.

In conclusion, the LNAPL present at MW-17 is both residual LNAPL held up in the silty sands and deformed silt beds, and unconfined mobile LNAPL in the lower portions of the silty sands, deformed silt beds and underlying medium to coarse sand.

MW-20

The LVP for the vicinity of MW-20 is illustrated using a hydrograph containing gauging data for well MW-20, soil core fluorescence data, LNAPL saturation data, soil core photography data, well screen interval, and subsurface soil characterization data based on lithological logging, and is provided on Figure Q-2 in Appendix Q.

Evaluation of the LVP data indicates that LNAPL exists within native interbedded silt and silty sand at elevations from approximately 1,879 to

1,876 feet amsl, within native fine- to medium-grained sands at elevations from approximately 1,874 to 1,867 feet amsl, and within the gravels and coarse-grained sands at elevations of approximately 1,865 to 1,862 feet amsl. Soil samples were collected from the frozen soil cores and analyzed for LNAPL saturation and mobility at multiple locations within the interval of LNAPL. LNAPL saturations were quantified to be from 11.1% to 29.9%. The soil sample collected at 1,871.08 feet amsl for LNAPL mobility analysis was located within the interval of mobile LNAPL based on gauging data and produced dark brown LNAPL. The soil sample collected at 1,862.48 feet amsl for LNAPL mobility analysis was located below the mobile LNAPL interval based on gauging data and did not produce LNAPL.

There is limited historical gauging data available for MW-20. The air/LNAPL interface stayed at an elevation between approximately 1,871 to 1,873 feet amsl from the time of well installation in October 2013 to present. The air/LNAPL interface has stayed at or above the top of the screened interval. The LNAPL/water interface has remained within the screened interval between approximately 1,872 and 1,867 feet amsl. The mobile LNAPL interval is observed between 1,874 and 1,867 feet amsl. The gauging data suggest that the mobile LNAPL is present in unconfined conditions.

LNAPL in the formation in the vicinity of MW-20 is also located above the mobile interval of LNAPL within interbedded silts and silty sands and below the mobile interval of LNAPL in the gravel and coarse sands. This indicates that the LNAPL is trapped in these intervals and exists as residual LNAPL. In conclusion, the LNAPL at MW-20 appears to be present in three intervals. Residual LNAPL is present in the vadose zone above the interval of mobile LNAPL in the silts and silty sands, and below the interval of mobile LNAPL in the saturated zone comprised of gravels and coarse sands. The mobile LNAPL interval is in coarse sands and interbedded silts and silty sands, but appears to be generally in unconfined conditions.

MW-24

The LVP for the vicinity of MW-24 is illustrated using a hydrograph containing gauging data for well MW-24, soil core fluorescence data, LNAPL saturation data, soil core photography data, well screen interval, and subsurface soil characterization data based on lithological logging, and is provided on Figure Q-3 in Appendix Q.

Evaluation of the LVP data indicates that LNAPL exists primarily within the medium to coarse-grained sands and gravel at elevations from approximately 1,870 to 1,860 feet amsl. Soil samples were collected from the frozen soil cores and analyzed for LNAPL saturation and mobility at multiple locations within the interval of LNAPL. LNAPL saturations were quantified to be from 2.8% to 12.9%. The soil sample collected at 1,861.77 feet amsl for LNAPL mobility analysis was located within the interval of highest core fluorescence and produced dark brown LNAPL.

Although LNAPL was observed in the soil core fluorescence data and generated by the laboratory LNAPL mobility test, no gauged LNAPL has been observed in the monitoring well in over 2 years since MW-24 was constructed. The air/water interface has stayed between approximately 173 and 176 ft bgs since the installation of the well in November 2013 and has remained within the screened interval of the well. The gauged water level has fluctuated within the interval of LNAPL observed in the core fluorescence data, yet no LNAPL has been detected in the monitoring well. This suggests the LNAPL in the vicinity of MW-24 is residual LNAPL. The low LNAPL saturation percentages observed in the soil samples collected within the interval (from 2.8% to 12.9%) further support that the LNAPL is residual LNAPL.

In conclusion, soil core fluorescence data indicates there is approximately 8 feet of residual LNAPL in the formation near MW-24. The lack of gauged LNAPL in the well and the relatively low LNAPL saturations further supports that only residual LNAPL is present in the vicinity of MW-24. This location demonstrates that portions of the Site where LNAPL had previously migrated have subsequently become residual LNAPL. This supports the concept that the overall extent of mobile LNAPL is shrinking.

In summary, the LVPs developed support that both mobile LNAPL and residual LNAPL are present at the Site. As evidenced by MW-24, a significant portion of the LNAPL in the subsurface is present as residual LNAPL and will not appear in a monitoring well. LNAPL residual saturation values are variable due to variations in the LNAPL physical properties, the formation type and soil properties, and initial LNAPL conditions following the release.

6.3.3.5 *LNAPL Recoverability Testing and Transmissivity Assessment*

LNAPL recovery is frequently required to the "extent practicable," which is more accurately assessed according to LNAPL transmissivity rather than LNAPL thickness. LNAPL transmissivity is different than thickness in that it accounts for different hydrogeologic conditions, soil types, and LNAPL characteristics; it better represents changes in LNAPL mobility and saturation; and it incorporates the formation thickness of LNAPL. In addition, unlike LNAPL recovery rate, LNAPL transmissivity can be applicable across differing cleanup technologies.

According to the ASTM Standard Guide for Estimation of LNAPL Transmissivity (E2856-13, 2013), hereinafter "ASTM 2013," the transmissivity of LNAPL represents the volume of LNAPL that can go through a unit width of aquifer per unit time per unit of drawdown, as such it has units of feet squared per day (feet^2/day). ASTM 2013 methods were used to estimate the transmissivity of the LNAPL found at the Site. The LNAPL recoverability and transmissivity evaluation included the following activities:

- Fluid level gauging,
- LNAPL manual skimming testing, and
- Estimation of LNAPL transmissivity.

In addition to ASTM methods, the LNAPL transmissivity was also estimated using laboratory and field data and the API LDRM.

6.3.3.6 *Fluid Level Gauging*

Fluid level gauging was performed at all monitoring wells with a gauged LNAPL thickness in March and June 2016 as described in Section 4.4.2. A total of 12 wells had a gauged LNAPL thickness (see Table 4). Using data from the March 2016 gauging event, ERM selected monitoring wells with the greatest LNAPL thicknesses (MW-3, MW-4, MW-7, MW-17, and MW-20) to attempt LNAPL manual skimming tests. Manual skimming testing methods were used due to significant difficulties in gauging the LNAPL/water interface that precluded conducting LNAPL baildown tests.

6.3.3.7 *Manual Skimming Testing*

Manual skimming tests were performed using a weighted bailer to remove LNAPL. A weighted bailer was required because of the high viscosity and depth of the LNAPL. The procedure involved removing all LNAPL in the well (to the extent practicable to minimize groundwater removal), then repeating the removal at periodic intervals and recording the volume of LNAPL that had recovered back into the well. Ideally, the manual skimming test is concluded when three or four consecutive well recharge rates are within 25% of each other and no consistently decreasing trend is observed, or if there is insignificant LNAPL recovery between events. Because of the very slow rate of LNAPL recovery, only a limited number of LNAPL recovery events were performed at each well.

The LNAPL manual skimming tests were analyzed using calculations as specified in ASTM 2013. Equations 16 and 17 of the ASTM standard were used as the basis for quantification of LNAPL transmissivity.

Equation 16:

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

where:
T_n = LNAPL transmissivity (L^2/t),
Q_n = measured LNAPL recovery rate (L^3/t),
R_{oi} = radius of influence (L), and
r_w = well radius (L).

Equation 17:

$$s_{n_{unconfined}} = b_n(1 - \rho_r)$$

Where:
s_n – LNAPL drawdown at time t (L)
b^n – formation LNAPL thickness (L)

In accordance with ASTM guidance, $\ln(R_{oi}/r_w)$ was assumed to equal 4.6. Values for b^n were estimated based on the gauged thickness of LNAPL in each monitoring well. LNAPL recovery testing data and transmissivity calculations for MW-3, MW-4, MW-7, MW-17, and MW-20 are provided in Appendix R.

The estimated LNAPL transmissivities based on the manual skimming testing ranged from 0.0006 to 0.0981 feet^2/day and are shown on Figure 31.

6.3.3.8 LNAPL Distribution and Recovery Modelling

Prior to conducting LNAPL manual skimming testing, the LNAPL transmissivity was estimated using laboratory-derived data and the API LDRM. A vertical distribution model was developed for MW-17 and MW-20 based on the maximum gauged LNAPL thickness observed and the laboratory-derived saturation data and other parameters. The vertical distribution model then calculates the LNAPL saturation, mobile fraction of the LNAPL in the formation, and the LNAPL transmissivity. A LDRM model could not be developed for MW-24 because the well contained no gauged LNAPL. The LDRM input parameters include the following:

- Soil characteristics within the interval of mobile LNAPL,
- The maximum gauged LNAPL thickness,
- Corrected groundwater elevation,
- Soil characteristics,

- Porosity,
- van Genuchten parameters “N” and “α,”
- Irreducible water saturation,
- Residual LNAPL saturation,
- Fluid characteristics,
- LNAPL density,
- Air/water surface tension,
- Air/LNAPL surface tension, and
- LNAPL/water interfacial tension.

Values for the input parameters for each of the wells were derived from field measurements and observations, laboratory analytical results, reference values, and professional judgment, and are provided in Appendix Q. LNAPL fluid elevation data was based on field observations, LNAPL characteristics (density, viscosity and interfacial tension) were based on PTS analytical data for representative LNAPL, soil grain size, porosity, conductivity, and residual LNAPL saturation were based on location specific soil core PTS analytical data, and van Genuchten parameters and irreducible water saturation based on the mean published values for Sand (Carsell and Parish 1988) and referenced in the LDRM model guidance. The LDRM was calibrated using soil core analytical results. LNAPL saturation data obtained from the soil core analyses by PTS were imported into the LDRM and visually overlaid on the modelled vertical profile. The predicted LDRM saturation profiles are generally consistent with the measured values from the soil cores as shown on Figures Q-4 and Q-5 in Appendix Q.

Figures Q4 and Q5 illustrate the modelled vertical distribution of LNAPL at MW-17 and MW-20, respectively. The solid red line “Sn” represents how the modelled LNAPL saturation varies across the mobile interval of LNAPL. The green dots represent the actual measured LNAPL saturation based on the PTS testing data. The blue line “Sw” represents how the modelled water saturation varies across the mobile interval of LNAPL, and the dashed red line “Snr” represents the residual LNAP saturation based on the PTS testing data.

The raw output from the LDRM is also provided in Appendix Q. “Do,” or “Dn” as referenced in the raw output data, is the specific thickness of LNAPL (feet^3/foot^2) per unit surface area and represents the quantity of LNAPL in the formation. The LNAPL specific thickness for MW-17 was 1.7 feet and for MW-20 was 0.17 feet. The mobile portion of the LNAPL specific yield “Rn” based on the model for MW-17 was 0.96 feet and for MW-20 was 0.04 feet. Overall, the calculated specific thicknesses and mobile portion suggest that the majority of LNAPL in the subsurface is not mobile LNAPL, but immobile and residual. It is important to note that these results do not account for residual LNAPL outside of the mobile interval in the vicinity of MW-17 and MW-20.

The modelled LNAPL transmissivity values for MW-17 and MW-20 are 0.03 feet^2/day and less than 0.01 feet^2/day, respectively. These modelled LNAPL transmissivity values are compared to transmissivity values provided in the ITRC LNAPL guidance documents (ITRC 2009b and 2009c) to provide an understanding of the feasibility of hydraulic recovery of LNAPL. The ITRC LNAPL transmissivity range (0.1 to 0.8 feet^2/day) is based on review of multiple sites where asymptotic LNAPL recovery was observed and agreement was reached that LNAPL recovery was no longer practicable. The range is not intended to be definitive limits, but provides guidance from which to evaluate LNAPL transmissivities within the context of Site-specific conditions.

In both wells, the LNAPL transmissivities are significantly below the lower end of the ITRC range of 0.1 to 0.8 feet^2/day, and are generally consistent with the LNAPL manual skimming test observations that LNAPL recovery is very slow due to the high viscosity and density of the LNAPL (Figure 31).

Based on the results of the manual skimming testing and LDRM modelling, hydraulic recovery of LNAPL via skimming, pumping, or other hydraulic methods is not practicable at the Site.

7.0 CONCEPTUAL SITE MODEL

This section provides a CSM that summarizes the origin and current occurrence of contamination in soil and groundwater at the Site, describes the fate and transport of the COCs, and presents potential receptors and exposure pathways to the COCs. A summary map showing areas of Site contamination exceeding the preliminary CULs is provided as Figure 32, and an illustration of the CSM is provided as Figure 33.

7.1 PRIMARY SOURCES OF CONTAMINATION AND RELEASE MECHANISMS

Historical Site operations included the storage and transfer of heavy oil (Bunker C or asphaltic oil) and diesel in the Black Tank and Red Tank systems, respectively. Operations also included the transfer via the Liquid Asphalt Pipeline of heavy oils used for asphalt- and petroleum-related activities at the neighboring SemMaterials facility. RI and pre-RI data indicate releases of petroleum occurred to surface soils in the general vicinity of the:

- Black Tank,
- Black Tank Sump,
- Black Tank and Chemical Solution Pipelines,
- Red Tank Dispensers, and
- Liquid Asphalt Pipeline.

All of the COCs (TPH-D/HO, benzo[a]pyrene, benzo[a]pyrene TEQ, naphthalene, and total naphthalenes) identified at the Site are consistent with releases of diesel, Bunker C, and/or asphaltic oils from one or more of these areas. Based on historical accounts of the Site operations and releases, observations from historical aerial photographs, and inspection of the Site facilities during the RI and pre-RI investigations, petroleum releases occurred to the ground surface and surface soils in these areas via spills, overfills, and/or leaking pipelines. Based on the available records, Site operations that could have resulted in releases of petroleum hydrocarbons began approximately 100 years ago and ceased approximately 30 years ago.

7.2 *CONTAMINANT IMPACTS AND MIGRATION*

7.2.1 *Vadose Zone Soil*

Soil sampling data show that the petroleum product releases in the vicinity of the Black Tank, Red Tank dispensers, and Liquid Asphalt Pipeline were generally limited to surface soils and did not migrate to groundwater. Heavy oil (Bunker C and/or heavier asphaltic oil) was released in the vicinity of the Black Tank and Liquid Asphalt Pipeline, which accounts for the minimal vertical migration. The limited migration of the petroleum releases in these areas is illustrated on Figures 32 and 33.

In the vicinity of the Black Tank Sump and the Blank Tank and Chemical Solution Pipelines, the soil sampling data indicate that petroleum products migrated from the surface soil to the groundwater table at approximately 175 ft bgs. Analyses of soil and LNAPL samples collected in these areas indicate that the LNAPL is a mixture of heavy oil and diesel, with diesel comprising 28% to 49% of the mixture. The Site data indicate that a sufficient volume of petroleum products were released in the vicinity of the Black Tank Sump and Black Tank and Chemical Solution Pipelines to migrate downward as an LNAPL due to gravimetric (its own head) and capillary forces to the groundwater. Based on the viscosity and density of the petroleum products released at the Site, it appears that the presence of diesel was critical to facilitating the vertical migration of the heavy oil.

As illustrated on Figures 29 and 33, petroleum releases that migrated to groundwater exhibit limited lateral migration in the vadose zone. The narrow vertical columns of impacted soil are the result of migration through the coarse sands and gravels that comprise most of the vadose zone soils. Lenses of the silt and silty sand facies are scattered throughout the coarse sands and gravels of the vadose zone, and where encountered, it appears that the LNAPL migrated into the lenses, resulting in elevated TPH-D/HO concentrations in these intervals. Based on the period of operation at the facility and evaluations of TPH-D/HO residual saturation in the Site soils, most of the LNAPL in the vadose zone soil is likely to be residual (i.e., immobile because it is below residual saturation concentrations). As shown on Figures 29 and 33, two intervals of intermediate soil show TPH-D/HO concentrations above the residual-saturation-based preliminary CUL of 13,600: one at a depth of 66 to 67 ft bgs and the other at 116 to 117 ft bgs. These lenses of potentially mobile LNAPL in the intermediate soil are thin, associated with silt or silty sand, and have a limited horizontal extent (Figures 23, 24, 29, 32, and 33).

7.2.2 *Capillary Fringe/LNAPL Smear Zone*

The shape of the LNAPL smear zone indicates that the LNAPL migrated downward through the capillary fringe and a short distance below the water table under gravimetric and capillary forces and laterally to the maximum extent of the LNAPL shown on Figures 32 and 33. The capillary fringe/LNAPL smear zone is comprised of medium to coarse sand with a bed of the silt and silty sand facies near the groundwater table. The bed of silt and silty sand facies is generally 1 to 6 feet thick and was identified in most of the Site soil borings. The combination of the low permeability silt and silty sand facies at the groundwater table and the presence of water-filled pores below the groundwater table probably slowed the vertical migration of the LNAPL, causing it to mound and spread laterally. Gravimetric forces, fluctuations in groundwater level and interbedded sands, silts, and silty sands produced a complex LNAPL smear zone that extends several feet above and below the groundwater table. Consistent with LNAPL CSMs presented in the scientific literature (ITRC 2009b), the LNAPL smear zone is thickest beneath the primary sources (i.e., the Black Tank Sump and the Blank Tank and Chemical Solution Pipelines) and thins radially. The vertical head would be highest where the releases occurred (in the vicinity of the primary sources), which would account for the LNAPL migrating through the silt and silty sand facies and penetrating deepest into the aquifer in the area below the primary sources (Figures 25, 29, and 33). Near the lateral margins of the smear zone (particularly to the southeast, south, southwest, west, and northwest), where the vertical head would be much lower, it appears that the LNAPL didn’t penetrate the silt and silty sand facies and the aquifer as much as below the primary sources.

It appears that the thickness and topography of the top of the silt and silty sand facies layer also influenced the migration of the LNAPL. As illustrated on Figure 10, the top of the silt and silty sand facies layer exhibits more than 18 feet of relief across the Site, and in at least three areas (i.e., near MW-10, MW-12, and MW-15), the silt and silty sand facies layer is not present. Where the silt and silty sand facies layer is not present within the footprint of the LNAPL (e.g., near MW-15, it appears the LNAPL migrated downward through the hole in the silt and silty sand facies layer and then laterally to the north, where it appears to be trapped beneath the silt and silty sand facies layer near MW-23 (Figures 7 and 10). The top of the silt and silty sand facies layer appears to form two ridges that are approximately 10 feet higher than the surrounding areas (Figure 10). One ridge is to the southeast of the primary source area and encompasses MW-17, MW-25, and MW-26. The other ridge is to the west of the primary source area and encompasses MW-14 and MW-20. Based on the distribution of the LNAPL in the smear zone, it appears that the ridge to the southeast may have limited LNAPL migration in that direction and isolated the southeast mobile LNAPL area from the main mobile LNAPL area (Figures 8 and 9). Conversely, it appears that the

LNAPL migrated into the ridge to the west, which consists of more than 20 feet of the silt and silty sand facies (Figures 9 and 10). Consequently, the thickness of the smear zone and the mass of LNAPL in that area is higher than at the other LNAPL margin areas.

The lateral and vertical extents of mobile LNAPL and residual LNAPL in the smear zone are illustrated on Figures 29 and 32, and the CSM is illustrated on Figure 33. Mobile LNAPL in the smear zone was identified based on accumulations of LNAPL in monitoring wells (MW-1 through MW-5, MW-7 through MW-9, MW-17 through MW-20, and MW-28). LNAPL in the smear zone is generally unconfined LNAPL, and the vertical distribution of mobile LNAPL is illustrated on Figures 29 and 33. Although mobile LNAPL was observed at these wells, evidence of residual LNAPL was also observed both above and below the interval of mobile LNAPL based on the gauged interval of LNAPL. To further understand the mobile interval of LNAPL, LNAPL mobility testing and Dean-Stark analysis was performed on soils with evidence of mobile LNAPL to quantify the fraction of mobile LNAPL and residual LNAPL within these soils. These data indicate that the fraction of mobile LNAPL in these soils is relatively small as compared to the fraction of residual LNAPL in these soils.

Residual LNAPL in the smear zone was also identified during installation of monitoring wells where petroleum staining and detectable TPH-D/HO concentrations in the soil were observed, but LNAPL from those soils did not accumulate in the monitoring well. Evidence of only residual LNAPL was observed in monitoring wells located at or near the perimeter of the LNAPL extent (MW-15, MW-16, MW-21, MW-22, MW-24, MW-25, and MW-26). The vertical and horizontal distribution of LNAPL, as shown on Figures 29 and 32, indicates that mobile LNAPL comprises less than 14% of the total LNAPL mass and residual LNAPL comprises more than 86% of the total LNAPL-impacted soil at the Site.

7.2.3 *Groundwater*

LNAPL is present at the groundwater table and a thin dissolved phase TPH-D/HO plume is situated beneath the LNAPL and appears to periodically extend downgradient of the LNAPL on a seasonal basis (Figures 32 and 33). Although the groundwater data from on-Site monitoring wells have only rarely and inconsistently shown dissolved phase petroleum concentrations above the preliminary CULs (Figure 27), two of the past four groundwater monitoring events have shown TPH-D/HO concentrations (based on analyses without silica gel cleanup) exceeding the CULs in one or two downgradient monitoring wells (Figure 26). TPH-D/HO analyses performed with silica gel cleanup on samples from these same wells do not show elevated TPH-D/HO concentrations. Petroleum metabolites generated from biodegradation of the LNAPL plume are believed to be the source of the elevated TPH-D/HO concentrations (from analyses without silica gel cleanup) detected in the downgradient monitoring wells samples because these compounds are removed by silica gel cleanup. As discussed in Section 6.2.2, the TPH-D/HO exceedances were observed to occur during the summer and fall monitoring events when groundwater elevations were decreasing. No exceedances of the TPH-D/HO CUL were observed in the winter and spring monitoring events when the groundwater elevations were increasing. This seasonal expansion and contraction of the dissolved phase TPH-D/HO plume appears to be related to the release of petroleum metabolites during periods of falling water table levels, a phenomenon that has been observed at other LNAPL sites (San Francisco Bay Regional Water Quality Control Board 2016).

The long-term trend of TPH-D/HO (using silica gel cleanup data) and cPAH data from the on-Site monitoring wells show consistently low and ND concentrations that generally peaked in early 2011 and have steadily decreased in concentration since then (Figure 27). TPH-D/HO data from samples analyzed without silica gel cleanup show that the downgradient extent of the dissolved phase plume is not defined in the summer and fall, but is defined in the winter and spring (Figures 26 and 32). This finding is based on 1 year of seasonal data from samples analyzed without silica gel cleanup. Although these data show some seasonal variation in the downgradient extent of the dissolved phase petroleum contamination, the long-term trend of low to non-detection of TPH-D/HO (using silica gel cleanup data) and other petroleum constituents in the downgradient wells suggest that downgradient groundwater conditions are generally stable and/or decreasing. It is well understood that petroleum metabolites are highly degradable and are unlikely to persist at concentrations exceeding the CULs much beyond the Site boundary. A thin dissolved phase plume may exist within the footprint of the LNAPL, but its presence cannot be confirmed via groundwater sampling because of the presence of LNAPL in the monitoring wells interferes with our ability to collect and analyze groundwater samples that don’t contain LNAPL.

Lastly, the concentrations of TPH-D/HO in the groundwater are very low considering that LNAPL is present at the Site. The low TPH-D/HO concentrations in the groundwater suggest that leaching of residual petroleum constituents from the LNAPL to the groundwater at the Site is limited. Possible reasons for the limited leaching include: (1) the low solubility of the LNAPL constituents, (2) the low permeability of the silt and silty sand facies in which much of the LNAPL resides, and/or (3) low-solubility LNAPL blocking interconnected pore space through which groundwater might otherwise leach contaminants.

7.3 CONTAMINANT FATE AND TRANSPORT

NSZD, commonly referred to as weathering, changes the composition of LNAPL residues in the subsurface over time. NSZD occurs as a result of natural processes that include:

- Dissolution of LNAPL constituents into the saturated zone,
- Volatilization of LNAPL constituents into the vadose zone, and
- Biodegradation of LNAPL constituents in both zones.

These mechanisms are well known to occur and, in part, underlie the scientific rationale for monitored natural attenuation in groundwater for which Ecology issued guidance in 2005 (Ecology 2005). The combined influences of these mechanisms can result in substantial changes in LNAPL composition and reduction in LNAPL mass (ITRC 2009a). NSZD can generally be expected to occur faster and with greater mass-reduction effect for lighter, lower molecular weight LNAPLs. Although the LNAPL at the Site is a higher molecular weight LNAPL (i.e., a combination of diesel and heavy oil), the rate and extent of NSZD is quantitatively shown to be significant.

Most bacteria degrade organic compounds by taking up compounds that are dissolved in the water that surrounds the cell. However, the water solubility of high-molecular-weight petroleum hydrocarbons is so low that uptake from water is not feasible. To degrade the high-molecular-weight hydrocarbons, the bacteria must be in direct contact with the oily phase hydrocarbon (Ron and Rosenberg, 2002; Hua and Wang, 2013).

Bacteria that degrade petroleum hydrocarbons prefer the compounds with a simple structure and a low molecular weight. As bacteria act to biodegrade petroleum hydrocarbons in the smear zone, the smaller and simpler components in the blend of hydrocarbons are degraded first. As a result, the residual hydrocarbon is less amenable to biodegradation and if other factors remain the same, the rate of biodegradation would be expected to slow. However, there is a counter-acting process. To allow better access to oily phase hydrocarbons, and to give them a competitive advantage in the degradation of oily phase hydrocarbons, many bacteria synthesize and excrete high-molecular-weight biosurfactants that act to emulsify the oil (Ron and Rosenberg 2001; Ron and Rosenberg 2002). This increases the surface area of the oil that can be colonized by bacteria, which increases the rate of degradation of the oil (Shreve et al., 1995). As the bacteria grow in the smear zone and excrete more biosurfactants, the biosurfactants can be expected to accumulate over time and increase the rate of biodegradation of the residual oil.

As the water table moves up and down, the capillary force acting on the oily phase hydrocarbon will decrease and increase. This change in the capillary force on the oily phase hydrocarbon will change the shape and distribution of the oily phase hydrocarbon and facilitate emulsification. An increase in emulsification will facilitate the biodegradation of the hydrocarbon.

Evidence for NSZD at the Site includes data generated as part of the NSZD rate assessment testing and comparison of sample TPH chromatography against representative standards and evaluation of LNAPL conditions.

7.3.1 *Natural Source Zone Depletion Evaluation*

Data collected by CO_2 soil flux monitoring, metabolic gas monitoring, and analysis of groundwater samples for NSZD parameters document the occurrence of NSZD at the Site. The data indicate that the majority of NSZD is occurring through biodegradation in the vadose zone. The results from the NSZD investigation activities are presented in the following sections.

7.3.1.1 Carbon Trap Results

CO_2 soil flux monitoring results and corresponding biodegradation rate calculations are summarized in Table 31. Calculated LNAPL biodegradation rates with LNAPL extent observations are shown on Figure 34. Results from carbon trap CO_2 flux monitoring show:

- A biodegradation rate range of 229 to 1,681 gallons of hydrocarbons per acre per year (gal HC/ac-yr); and
- A Site-wide average biodegradation rate of 791 gal HC/ac-yr.

7.3.1.2 Carbon Chamber Results

CO_2 soil flux monitoring results and corresponding biodegradation rate calculations are summarized in Table 32. Calculated LNAPL biodegradation rates with LNAPL extent observations are shown on Figure 35. Results from carbon chamber CO_2 flux monitoring show:

- The standard deviation of each triplicate experimental flux measurement was generally low, with the exception of one set of measurements at LI-15 on 5 April 2016 at 15:45 (Table 32). The low variability observed in experimental flux measurements is an indicator that the data quality is acceptable for decision-making purposes.
- Background corrected fluxes indicate that NSZD is resulting in petroleum hydrocarbon degradation rates that range from 48 to 1,111 gal HC/ac-yr and average 255 gal HC/ac-yr (Table 32).

7.3.1.3 *Metabolic Gas Monitoring*

Metabolic gas monitoring results are summarized in Table 33. The monitoring results show:

- PID measurements correlate with the flux observations. Higher volatility may result in more easily available hydrocarbons in the vadose zone and higher degradation rates.
- CH_4 is present in three of 13 monitoring locations (MW-17, MW-18, and MW-20) at concentrations ranging from 0.2% to 2.8%.

7.3.1.4 *Saturated Zone NSZD*

The NSZD parameter analytical results from four monitoring wells (MW-06, MW-10, MW-11, and MW-22) sampled in March 2016 are summarized in Table 34, and laboratory analytical reports are included in Appendix S. Based on the results of the field and laboratory quality assurance/quality control samples, data quality are acceptable for decision-making purposes.

The changes in dissolved concentrations of O_2, CH_4, nitrate, sulfate, iron, and manganese from MW-06 to MW-10, MW-11, and MW-22 were used to approximate the rate of saturated zone NSZD using the approach provided in the ITRC guidance for *Evaluating Natural Source Zone Depletion at Sites with LNAPL* (ITRC 2009a). This analysis shows that the estimated hydrocarbon reduction in the saturated zone ranges from approximately 6.4 to 73 gal HC/ac-yr, and, on average, 92% of hydrocarbon reductions observed in the saturated zone are attributable to biodegradation. The calculated NSZD rates for saturated zone NSZD are summarized in Table 35. Saturated zone NSZD calculations are provided in Appendix S. It is important to note that some and perhaps most of the biodegradation that takes place in the saturated zone results in the release of gaseous methane or carbon dioxide to the unsaturated zone. This is then measured as vadose zone NSZD. For this reason NSZD measurements typically underestimate biodegradation in the saturated zone.

7.3.2 *Chromatography*

As described in Section 5.4.1 and illustrated on Figure 20, evaluation of chromatograms shows the lighter ends of the petroleum are diminished in concentration relative to the representative standards, indicating "weathered" petroleum. This is another line of evidence that NSZD has reduced concentrations of petroleum hydrocarbons at the Site via biodegradation, dissolution, and/or volatilization.

7.3.3 Data Evaluation

Based on the NSZD data collected from the Site, 800 gal HC/ac-yr appears to be a reasonable average NSZD rate for the Site. It was developed by summing the Site-wide average vadose zone NSZD rate of 791 gal HC/ac-yr (from the carbon trap analyses) and the average saturated zone NSZD rate of 43 gal HC/ac-yr and rounding down. The site-specific NSZD rate was determined based on the following conservative assumptions:

- The NSZD carbon flux measurements were made in the spring, under high water levels, which results in lower measured rates than during lower water table conditions when more source material is exposed to O_2. The average rate is higher than those measured during high water table conditions. This results in an underestimation of NSZD.
- The NSZD carbon flux is assumed to express itself at the surface in the same footprint as the LNAPL (i.e., CO_2 does not spread laterally due to diffusion). In reality, carbon flux occurs over a much larger footprint due to diffusion of CO_2 in the vadose zone. The result is an underestimate of NSZD.
- The calculation of NSZD rates assumes a 100% efficient stoichiometric conversion of hydrocarbon to CO_2. However, there is less than 100% conversion since some of the hydrocarbon is converted to microbial biomass. The result is an underestimate of NSZD.
- The calculation conservatively assumes all of the CO_2 created by biodegradation makes its way in gaseous form to the surface. However, CO_2 can dissolve into pore water and be converted to carbonate minerals. To the extent that these processes occur, NSZD rates will be underestimated.

Field measurements of the vadose zone NSZD rate include a portion of NSZD that occurs in the saturated zone. This is because CO_2 and CH4 (which will degrade to CO_2) in the saturated zone will rise up through the vadose zone and be incorporated in the carbon trap data. The saturated zone NSZD rates are based on TPH concentrations in the groundwater (indicating source depletion through dissolution, and terminal electron acceptors, indicating source depletion through degradation) and groundwater flow rate estimates. Dissolution refers to TPH or metabolic byproducts that have dissolved but not yet biodegraded. In any stable plume, this dissolved material biodegrades downgradient of where it is measured. The saturated zone NSZD rates do not include any CO_2 or CH4 gas loss to the unsaturated zone. Therefore, the saturated zone NSZD estimates can be added to the vadose zone NSZD estimates to develop an average NSZD rate for the Site without risk of double counting.

As shown on Table 36, similar heavy hydrocarbon sites have reported NSZD rates ranging from 510 to 7,700 gal HC/ac-yr, making a rate of 800 gal HC/ac-yr reasonable and conservative when compared with the NSZD rates reported for these similar sites.

7.3.4 LNAPL Conditions

The LNAPL conditions (e.g., residual, mobile, migrating) at the Site are illustrated on Figure 28. Several lines of evidence indicate the lateral extent of the mobile LNAPL is stable or decreasing. These lines of evidence include:

- Data collected from multiple rounds of groundwater monitoring show LNAPL has not appeared in any of the "clean" monitoring wells (i.e., wells that did not show evidence of a smear zone LNAPL when installed).
- There are no known areas of mobile LNAPL at the margins of the smear zone and instead it appears that the area of mobile LNAPL is surrounded by residual LNAPL, which is clear indication the LNAPL body is receding, not expanding.
- Based on Site-specific viscosity measurements, the Site LNAPL would move between 1,590 and 5,470 times slower than groundwater, all conditions being equal (saturation, gradient, relative permeability).
- The Site LNAPL has a density of 0.955 g/cc, which is very close to that of water; therefore, it very likely exists at capillary pressures less than the LNAPL-water entry pressure and LNAPL can only displace water if the capillary pressure exceeds the entry pressure. Calculations performed by Kueper (2016) show that 5 feet of Black Tank LNAPL can only generate a capillary pressure of 642 Pa (very small). By comparison, 5 feet of fresh gasoline (density = 0.78 g/cc) can generate a capillary pressure of 3,257 Pa (much higher than can be generated by the Site LNAPL).
- LNAPL transmissivity values calculated for the Site LNAPL are between 0.0006 and 0.098 ft2/day. These values are close to and below the threshold values for recoverability (ITRC 2009b and 2009c). The calculated LNAPL transmissivity values demonstrate that LNAPL migration under current conditions, if it were occurring, would be extremely slow.

These lines of evidence are clear indicators that the LNAPL is not migrating and NSZD is likely reducing the mass of LNAPL. This is consistent with the Site operational history, which shows that petroleum releases at the Site stopped at least 30 years ago, when the petroleum storage and transfer operations at the Site ceased. Without a continuing source, the LNAPL head dissipated over time and the LNAPL ceased migrating vertically and laterally.

The location of the mobile portion of the LNAPL relative to the groundwater table is an important consideration in evaluating cleanup actions for the Site. The mobile LNAPL exists in the smear zone, which consists of saturated, capillary fringe, and unsaturated segments (see Section 7.2.2 and Figure 29). The relative thicknesses of these segments vary with annual and cyclic fluctuations of the groundwater table. Under static conditions, mobile LNAPL is by definition above the groundwater table. However, the conditions at the Site are not static and the viscosity of the LNAPL is sufficiently high that LNAPL migration can't always keep pace with groundwater elevation changes.

Therefore, ERM interpreted intervals of the smear zone that contain or may contain mobile LNAPL using: (1) field observations of soil samples collected during drilling of the borings, (2) TPH-D/HO concentrations exceeding the preliminary CUL in soil samples collected from the smear zone, (3) observations of LNAPL in photographs of soil cores collected from the smear zone, (4) the results of Dean-Starks analyses of soil samples collected from the smear zone and (5) gauged LNAPL thickness data from the monitoring wells. The interpreted location of the mobile LNAPL zone shown on Figure 29 illustrates that most of mobile LNAPL is situated between the low and high groundwater levels measured at the Site and is thus exposed to vadose zone conditions part of the year. The evaluation shows the following:

- A few areas of the Site (MW-19) have the top and bottom of the mobile LNAPL zone above the water table most of the year;
- Some areas of the Site (MW-3, MW-5 and MW-7) have the top of the mobile LNAPL zone above the water table most of the year and the bottom of the mobile LNAPL zone above the water table part of the year;
- Most areas of the Site (MW-1, MW-2, BT-SB-01, MW-9, MW-17, MW-23 and MW-28) have the top and bottom of the mobile LNAPL zone above the water table only part of the year; and
- A few areas of the Site (MW-4, MW-18 and MW-20) have the bottom of the mobile LNAPL below the water table throughout most of the year. Basic physics makes this condition unsustainable, which suggests that the concentrations detected in the soil are actually below residual saturation, but we're comparing them to a preliminary CUL that is based on a conservative residual saturation concentration that is not representative of the fine-grained soils at these locations.

Based on a plot of the average groundwater level for the Site from March 2016 through March 2017 over the mobile LNAPL zone for the Site, it is estimated that over the course of a year, an average of 66% of the mobile LNAPL zone is above the water table (Figure 36). The plot shows that the portion of the mobile LNAPL zone above the water table ranges from approximately 30% in spring to 100% in fall. This is an average for the Site based on 2016 data and the actual conditions will vary across the Site and from year to year.

7.4 POTENTIAL PATHWAYS AND RECEPTORS

The Site is and will remain a transportation corridor and the Site and surrounding properties are zoned LI and CC2, having permitted uses that include transportation, light-industrial, commercial, schools, parks, office, residential, parks, and open spaces. The receptor evaluation (Section 5.1) determined that potential human receptors associated with the Site contamination include current and future on-Site workers, the general public, and future on-Site and off-Site groundwater users. Potential aquatic and terrestrial ecological receptors were evaluated and neither is considered receptors for the Site.

The direct contact pathway is considered a potentially complete exposure pathway because Site soils less than 15 ft bgs contain elevated concentrations of petroleum and on-Site industrial workers (particularly construction workers) under current conditions and future conditions are potential receptors under this pathway. The soil-to-groundwater pathway is also considered a potentially complete exposure pathway under both current and future conditions because Site soils contain elevated concentrations of petroleum, leaching of contamination via storm water infiltration, and groundwater elevation fluctuations is a viable mechanism for contaminant transport to groundwater, and drinking water is the highest beneficial use of the underlying SVRP aquifer.

Much of the contaminated surface soil at the Site was removed during the Black Tank excavation activities; however, the RI and pre-RI data show five areas of surface (<15 ft bgs) soil contain COC concentrations exceeding the MTCA Method A standards, which are protective of the direct contact exposure pathway, remain at the Site. Those areas include surface soil in the vicinity of the:

- Black Tank Sump (SSA-1),
- Blank Tank and Chemical Solution Pipelines (SSA-2),
- Red Tank Dispensers (SSA-3),
- Liquid Asphalt Pipeline (SSA-4), and
- Residual contaminated soil at the base of the Black Tank excavation (SSA-5).

The locations of these areas of soil that pose a potential risk via the direct contact pathway to current and future on-Site workers and the general public are shown on Figure 32.

Analytical data from subsurface soil samples collected from the Site show TPH-D/HO impacts exceeding the preliminary CUL are present in the intermediate soils (between 15 ft bgs and the top of the smear zone soils). As shown on Figure

32, the area of TPH-D/HO impacted intermediate soils underlies the Black Tank Sump and portions of the Black Tank excavation and Black Tank and Chemical Solution Pipeline areas.

As shown on Figures 32 and 33, residual and mobile LNAPL are present in the smear zone at the groundwater table beneath a portion of the Site. The Site data show no evidence of downward migration of LNAPL to lower portions of the SVRP aquifer, as supported by the lower density of the LNAPL relative to water. The density of LNAPL at the Site varies from 0.955 g/cc to 0.9814 g/cc at 70 degrees Fahrenheit (°F) (Table 21), whereas the density of water at the Site ranges between 0.998 g/cc to 1.001 g/cc at 70 °F. Site-specific groundwater and LNAPL densities at groundwater temperatures measured at the Site would be slightly higher than the densities reported at 70 °F.

Groundwater beneath the Site is part of the SVRP aquifer, which is a sole-source of drinking water to residents within the city of Spokane and Spokane County. Therefore, potential human receptors include those that consume or come into contact with groundwater pumped from wells near the Site. Seven active downgradient public drinking water systems are situated within 6 miles of the Site; six systems have groundwater supply wells 2 and 6 miles from the Site, and one system has two wells located within 2 miles of the Site, but in a cross-gradient or upgradient direction. The two wells are situated at distances of 1.8 and 0.8 miles from the Site. No water wells were on Ecology's online well log viewer file within 0.5 miles of the Site at the time of the review.

As stated in Section 3.3.3, there are no active pumping wells on the Site and the Site is not located within the capture zone of any known nearby pumping wells in the SVRP aquifer. However, there is a potential for future development of the aquifer on and downgradient of the Site. Therefore, potential future human users of the SVRP aquifer for drinking water are considered potential future receptors. Because areas of mobile and residual LNAPL occur at the Site, development of on-Site water resources would require well design considerations (i.e., the placement of surface casings through the LNAPL smear zone) to prevent mobilizing LNAPL in the immediate vicinity of an installed production well.

8.0 FEASIBILITY STUDY

The purpose of the FS is to develop and evaluate cleanup actions for the Site. The FS identifies applicable regulatory requirements, cleanup standards that are protective of human health and the environment, and a recommended Site-wide cleanup action using applicable cleanup technologies that have the potential to achieve cleanup standards.

Once the FS is finalized, Ecology will select the cleanup standards and cleanup action for the Site. These decisions will be documented in a draft CAP. Following public review of the draft CAP, the project will advance into engineering design, permitting, construction, operation, and monitoring (as applicable).

Implementing a cleanup action at the Site may be influenced by construction of the NSC highway project (see Section 2.1.4 and Figure 3). However, as of this writing, a specific alignment has not been selected and a final design does not exist. For purposes of this FS, the cleanup actions are evaluated assuming WSDOT's 2014 proposed alignment of the NSC through the Site. It is understood that this is likely a worse-case condition because WSDOT is evaluating alternative alignments that would allow access to most areas requiring active cleanup.

8.1 MTCA REQUIREMENTS

MTCA specifies several requirements for cleanup actions. This section presents and discusses these requirements in relation to the Site. The cleanup actions presented in Section 9.0 are evaluated against these requirements to understand their adequacy with respect to the regulation and to enable objective comparison of their relative benefits to human health and the environment.

8.1.1 Threshold Requirements

As specified in WAC 173-340-360(2)(a), all cleanup actions are required to meet the following threshold requirements:

- Protect human health and the environment,
- Comply with cleanup standards specified under MTCA,
- Comply with applicable state and federal laws, and
- Provide for compliance monitoring.

The cleanup actions presented in this FS are all expected to meet these threshold requirements even though some actions may take many years to do so.

The following state and federal laws or associated regulations are considered applicable to Site cleanup:

- Federal Maximum Contaminant Levels (40 CFR Part 141) – Considered in establishing groundwater CULs (MTCA Method A).
- Groundwater Quality Standards (Chapter 173-200 WAC) – Considered in establishing groundwater CULs (MTCA Method A).
- Surface Water Quality Standards (Chapter 173-201A WAC) – Not applicable because the nearest surface water is 6 miles from the Site.
- Solid and Hazardous Waste Management (RCW 70.105; Chapter 173-303 WAC; 40 CFR 241, 257; Chapter 173-350 and 173-351 WAC) and Land Disposal Restrictions (40 CFR 268; WAC 173-303-340) – Not applicable because contamination at the Site is not Hazardous or Dangerous Waste.
- Washington Industrial Safety and Health Act (RCW 49.17) and the Federal Occupational Safety and Health Act (29 CFR 1910, 1926) – Occupational health and safety will be addressed as part of cleanup action planning.
- State Environmental Policy Act (RCW 43.21C and Chapter 197-11 WAC) – State Environmental Policy Act requirements will be addressed concurrent with cleanup action permitting.
- Construction Storm Water General Permit (RCW 90.48) (33 U.S.C. Section 1251 et seq.) – Construction and other storm water requirements will be addressed concurrent with cleanup action permitting.
- Dangerous Waste Regulations (Chapter 173-303 WAC) – Not applicable because contamination at the Site is not Hazardous or Dangerous Waste.

8.1.2 Other MTCA Requirements for Cleanup Actions

As specified in WAC 173-340-360(2)(b) and (c) and discussed below, all cleanup actions are required to meet the following other requirements:

- Use permanent solutions to the maximum extent practicable,
- Provide for a reasonable restoration timeframe (RTF),
- Consider public concerns, and
- Meet specific expectations for groundwater sites where LNAPL is present.

8.1.2.1 Requirement for Permanent Solution to the Maximum Extent Practicable

WAC 173-340-200 defines a permanent solution as one in which cleanup standards can be met without further action. Ecology recognizes that permanent solutions may not be practicable for all sites. In these cases (and for this Site), potential cleanup actions are evaluated relative to the following additional criteria to determine whether the actions are permanent to the "maximum extent practicable" (WAC 173-340-360[3][f]):

- ***Overall protectiveness*** of human health and the environment, including the degree to which existing risks are reduced, the time required to reduce the existing risks and attain cleanup standards, risks from implementation, and improvement of overall environmental quality.
- ***Permanence***, as the degree of reduction in toxicity, mobility, and volume of hazardous substances, including the adequacy of the cleanup action in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.
- ***Cost***, including capital costs and operation and maintenance costs.
- ***Long-term effectiveness***, including the degree of certainty that the cleanup action will be successful, long-term reliability, the magnitude of residual risk, and the effectiveness of controls required to manage treatment residues and remaining waste.
- ***Management of short-term risks***, including the protection of human health and the environment associated with the cleanup action during construction and implementation.
- ***Implementability***, including consideration of whether the cleanup action is technically possible, availability of necessary off-Site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.
- ***Consideration of public concerns***, including the extent to which the cleanup action addresses such concerns. This process includes identifying and addressing concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the Site.

MTCA prescribes an evaluation methodology termed a disproportionate cost analysis (DCA) that compares cleanup actions using the above criteria to determine whether a cleanup action is permanent to the maximum extent practicable. The DCA methodology assesses the incremental increase in cost of a cleanup action over that of a lower cost cleanup action relative to the differences in performance (i.e., differences in benefits to human health and the environment). If the incremental increase in costs is disproportionate to the incremental benefits, then the more costly cleanup action can be viewed as disproportionately costly and the lower cost cleanup action can be selected as being permanent to the maximum extent practicable. This methodology balances the permanence of a cleanup action with costs while ensuring that cleanup action protects human health and the environment.

8.1.2.2 Requirement for a Reasonable Restoration Timeframe

WAC 173-340-360(4)(b) specifies that the following factors be considered when determining whether a cleanup action provides for a reasonable RTF:

- Potential risks to human health and the environment;
- Practicability of achieving a shorter RTF;
- Current use of the Site, surrounding areas, and associated resources that are or may be affected by releases from the Site;
- Availability of alternate water supplies;
- Likely effectiveness and reliability of institutional controls;
- Ability to control and monitor migration of hazardous substances from the Site;
- Toxicity of the hazardous substances at the Site; and
- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the Site or under similar Site conditions.

MTCA expects relatively short RTFs for sites that compare unfavorably to these factors. Conversely, sites that compare favorably to these factors are candidates for cleanup actions having relatively long RTFs. Existing Site conditions are described in terms of these MTCA RTF factors to establish context for the forthcoming discussion of cleanup actions.

<u>*Potential Risk*</u>s – Contaminated surface soil is currently accessible to the general public where it poses a potential risk to human health. TPH-D/HO and cPAHs exist in the surface soil at concentrations exceeding preliminary CULs based on toxicity. RI data indicate that deep contamination in the form of mobile LNAPL and the dissolved-phase groundwater plume is stable (i.e., not expanding; See Section 7.2.3), is inaccessible to the general public without drilling deep wells and thereby poses little immediate risk to human health and the environment.

Institutional controls prohibiting access to the contaminated portion of the aquifer can mitigate any residual exposure risk while cleanup is occurring.

Current Site Use – The current use of the Site (i.e., as a transportation corridor), surrounding areas, and associated resources are not imminently threatened by further releases from the Site because the primary sources of contamination (i.e., the ASTs, sumps, and piping) are no longer operational and, with the exception of some piping, have been removed. Additionally, secondary sources of contamination (shallow soil, intermediate soil, and LNAPL) and the dissolved phase groundwater plume are stable or decreasing in concentration.

Water Supplies – Groundwater at the Site is part of a sole-source aquifer. However, the area of impacted groundwater is stable, limited to the Site (and if the dissolved phase TPH-D/HO plume is shown to extend off-site, the Site will be expanded to encompass the entire groundwater plume), and alternative water supplies (public water supplies) sourced from areas of the aquifer beyond the Site are readily available. There are no plans now nor are plans likely to be developed in the foreseeable future to place a groundwater production (drinking water) well at this Site.

Institutional Controls – Institutional controls in the form of environmental covenants coupled with access restrictions are effective and reliable for managing risks from weathered diesel/heavy oil contamination in surface soil particularly in the context of this Site's land use (i.e., as a transportation corridor). Similarly, institutional controls alone can effectively prohibit access and exposure to the deep contamination in both soil and groundwater.

Ability to Control and Monitor – As previously discussed, the RI data suggest that the mobile LNAPL and dissolved-phase plumes are stable, meaning that they are naturally controlled by hydrogeologic and biological conditions in the subsurface. Monitoring is feasible and an existing network of monitoring wells installed during the RI is being used to track conditions.

Toxicity –Toxic concentrations of TPH-D/HO and cPAHs exist in the surface soil and deep contamination areas. Surface soil contaminant concentrations exceed levels protective of human health via direct contact. The deep soil/LNAPL contamination has a relatively low toxicity as evidenced by the preliminary CULs for subsurface soil and LNAPL being based on residual saturation rather than toxicity. Dissolved-phase TPH-D/HO concentrations downgradient of the LNAPL plume have been documented to exceed the preliminary CULs on a seasonal basis; however, the detected constituents are petroleum metabolites resulting from the biodegradation of the LNAPL and are themselves highly degradable.

<u>Natural Processes</u> – The NSZD evaluation conducted at the Site shows that natural processes are actively reducing concentrations of hazardous substances in the subsurface.

Based on the foregoing evaluation, the nature of contamination (viscous diesel and heavy oil) in surface soil, the risk that it poses, and the unobstructed physical setting in which the soil resides suggest that achieving cleanup in a relatively short period of time is both practicable and warranted.

With respect to the deep contamination, the evaluation supports a relatively long RTF. The contamination is neither readily accessible nor migrating, and short-term risks can be managed with institutional controls while cleanup is occurring.

8.1.2.3 *Requirement for Consideration of Public Concerns*

Consideration of public concerns is part of the Site cleanup process and Ecology's responsibilities under MTCA (see WAC 173-340-600). Consideration of public concerns is one factor in the DCA evaluation of permanency described above in Section 8.1.2.1. Additionally, Ecology will publish a notice in the Site Register when the draft CAP is received (WAC 173-340-515[4][d]). There will be a formal public review and comment period of 30 days for the draft CAP, during which time comments from the public may be submitted. Those comments will be considered and addressed as applicable in the final CAP.

8.1.2.4 *Requirement for Sites with Contaminated Groundwater*

Another key MTCA requirement contained in WAC 173-340-360 (2)(c) pertains to sites with contaminated groundwater where LNAPL is present. The regulation requires that *"the cleanup action treat or remove liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile hazardous substances, or hazardous substances that cannot be reliably contained. This includes removing free product consisting of [LNAPL] from the ground water using normally accepted engineering practices."* There is no specific guidance from Ecology on the meaning or interpretation of the phrase "*…normally accepted engineering practices*" in WAC 173-340-360 (2)(c). Literal interpretation of the phrase suggests a degree of flexibility in decision-making for groundwater sites with LNAPL wherein some sites may not warrant cleanups using out-of-the-ordinary engineering practices. The ITRC methodology for evaluating LNAPL recoverability (Section 6.3.3.8) determined that mobile LNAPL at the Site is not recoverable using conventional recovery technologies such as skimming, dual-phase, or total fluids extraction under ambient conditions.

Unless Ecology utilizes its flexibility in this situation, the principle ramification of this requirement for cleanup of the Site is that Ecology does not consider

NSZD alone an acceptable cleanup action at LNAPL sites. WAC 173-340-370(7) states four conditions wherein reliance on natural processes alone may be appropriate:

- Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable;
- Leaving contaminants on Site during the RTF does not pose an unacceptable threat to human health or the environment;
- There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the Site; and
- Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected.

While it is reasonable to suggest that the last three conditions are or can be met at the Site, the first condition requires some form of active intervention to the maximum extent practicable simply because LNAPL is present. Therefore, ongoing depletion of LNAPL at the Site, as supported by the NSZD evaluation discussed in Section 7.3.1, cannot by itself be used as a cleanup action.

8.2 ZONES OF CONTAMINATION REQUIRING CLEANUP

For FS discussion purposes and consistent with the CSM (Section 7.0), contamination at the Site exceeding proposed CULs may be partitioned into the following four spatial/media zones:

- Surface Soil,
- Intermediate Soil,
- LNAPL, and
- Groundwater.

Surface Soil (≤15 ft bgs): As discussed in Section 6.1.1, there are five areas of surface soil contamination (SSA-1 through SSA-5; TPH-D/HO and/or cPAH concentrations in these areas exceed the applicable MTCA Method A CULs. The combined surface area of SSA-1 through SSA-5 is 11,460 square feet. The combined volume of contaminated soil is 6,400 cubic yards assuming rectangular prisms from ground surface to a depth of 15 ft bgs.

Where the NSC passes over surface soil areas requiring cleanup, WSDOT would be consulted to determine the finished elevation of the road surface and adjust the localized point of compliance depth as necessary.

<u>*Intermediate Soil (>15 ft bgs)*</u>*:* Contaminated soil extending from the base of the surface soil areas to the smear zone soil is referred to as intermediate soil. Analytical data from intermediate soil samples show one area of TPH-D/HO impact exceeding the preliminary CUL for TPH-D/HO (Figure 37). The intermediate soil area shown on Figure 37 encompasses the former Black Tank, Black Tank Sump, and Black Tank and Chemical Solution Pipelines, which are believed to have been the primary sources of petroleum releases at the Site. Although contaminant impacts to the intermediate soil extend from immediately below the surface soil (15 ft bgs) to the top of the smear zone (approximately 156 ft bgs), the two intervals containing TPH-D/HO concentrations exceeding the preliminary CUL occur at approximately 66 and 116 ft bgs (i.e., approximately 1,960 and 1,910 feet amsl).

<u>*LNAPL (and Smear Zone Soil)*</u>*:* The footprint of the smear zone soil (i.e., capillary fringe and saturated soils that have been impacted by LNAPL) is coincident with the footprint of residual LNAPL (Figure 32). As described in Section 6.1.2, the smear zone is approximately 30 feet thick below the intermediate soils (the primary release area) and thins radially to less than 1 foot at its perimeter. Section 6.3 shows that some of the LNAPL in the smear zone is mobile; the rest is residual. Because the preliminary CUL for TPH-D/HO in subsurface soil is based on the residual saturation of the LNAPL and the preliminary CUL for LNAPL is based on removal of mobile LNAPL using normally accepted engineering practices (Table 10 and Section 5.4.2), cleanup of smear zone soils focuses on mobile LNAPL and the soils that yield them.

Figure 32 shows the estimated extent of mobile and residual LNAPL at the Site. The total LNAPL footprint covers an area of approximately 9.7 acres. Approximately 6.0 acres of the total LNAPL footprint contains both mobile and residual LNAPL and that area is surrounded by a band of residual LNAPL. In cross-sectional view (Figure 29), the mobile LNAPL occurs as a thin layer situated near the groundwater table. Based on measured thicknesses in monitoring wells, the layer of mobile LNAPL ranges from a sheen to 8.5 feet (Table 4). In total, mobile LNAPL comprises less than 14% of the total LNAPL cross-sectional area and residual LNAPL comprises greater than 86% of the LNAPL cross-sectional area.

<u>*Groundwater*</u>*:* Based on groundwater data presented in Section 6.2, the areal extent of dissolved phase TPH-D/HO concentrations exceeding preliminary CULs in groundwater is similar to the area occupied by mobile LNAPL during the winter and spring seasons, but expands a short distance downgradient of the mobile LNAPL plume during the summer and fall seasons (see Figure 32). Additional groundwater monitoring data is needed to more fully define the downgradient extent of the dissolved-phase groundwater plume. Data from monitoring wells screened below the LNAPL show that the dissolved phase

plume does not extend downward more than a few feet below the base of the smear zone..

The zones of contamination described above and depicted on Figure 32 are referenced throughout the remainder of the FS in the context of the forthcoming cleanup action discussions.

8.3 CLEANUP STANDARDS

MTCA cleanup standards are comprised of media-specific CULs, points of compliance, and a requirement that cleanup actions comply with all relevant local, state, and federal laws and associated regulations.

Preliminary CULs for soil, LNAPL, and groundwater are discussed in Section 5.0 and summarized in Table 10.

Proposed points of compliance for soil, LNAPL, and groundwater are as follows:

- Surface Soil – ground surface to 15 ft bgs for direct contact and protection of groundwater;[iv]
- Intermediate Soil – throughout the Site for protection of groundwater;
- Mobile LNAPL – throughout the Site for protection of groundwater; and
- Groundwater (Dissolved Phase) – throughout the Site.

8.4 REMEDIATION LEVELS

MTCA defines a remediation level as a concentration or other metric of a hazardous substance in environmental media above or below which a particular cleanup action component is required as part of an overall cleanup action. Remediation levels are not the same as CULs. A CUL defines the concentration of hazardous substances above which a contaminated medium (e.g., soil) must be remediated. Remediation levels are set at concentrations higher than CULs and are used to determine where and when a transition can be made from one

---

[iv] Where the NSC passes over surface soil areas requiring cleanup, WSDOT would be consulted to determine the finished elevation of the road surface and adjust the localized point of compliance depth as necessary.

cleanup technology to another. A common example is a site where groundwater is contaminated with petroleum hydrocarbons and active remediation (e.g., groundwater extraction and treatment) is required until dissolved phase contaminant concentrations diminish to a prescribed remediation level at which point the active system can be shut down and natural mechanisms (e.g., dispersion, diffusion, adsorption, and biodegradation) are relied upon to further reduce concentrations over time to the CULs.

A remediation level is proposed herein to divide the mobile LNAPL area into two zones; one to be remediated by NSZD and another that requires active remediation. The proposed remediation level required by Ecology that delineates these two areas is one-foot of measurable LNAPL thickness in a monitoring well. This remediation level is based on Ecology's evaluation of the RI data and NSZD rates.[v] Existing LNAPL gauging data was used to approximate a theoretical one-foot LNAPL isopleth illustrating what may accumulate in a well if it were installed at that location (Figure 37).

The area to be remediated using NSZD is referred to as the Low RTF LNAPL Area (Figure 37). The area to be remediated using active cleanup methods (i.e., where mobile LNAPL accumulations exceed 1-foot) is divided into two areas, a Medium RTF LNAPL area and a High RTF LNAPL area (Figure 37). This division is based on the concept that a more aggressive cleanup technology (and/or contingent cleanup technologies) may be applied to the area with the highest accumulations of mobile LNAPL and a less aggressive cleanup technology may be applied to the area with lesser accumulations of mobile LNAPL. The Medium RTF LNAPL area has lesser accumulations of mobile LNAPL and, thus, would receive a less aggressive cleanup technology. The High RTF LNAPL area encompasses the primary source area and historically has had the highest accumulations of mobile LNAPL; therefore, it would receive a more aggressive cleanup technology and/or contingent cleanup technologies, if needed, to achieve the CULs.

The cleanup actions developed for this FS are organized around the application of remedial technologies to the Low, Medium and High RTF LNAPL areas.

---

[v] The Ecology recommendation for this remediation level was provided in their 4 January 2017 comments to the September 2016 draft RI/FS.

9.0 CLEANUP ACTION TECHNOLOGIES AND ACTION

Cleanup actions suitable for application to the Site were identified and selected by drawing on national guidance, best professional judgment, and the national experience base for cleaning up sites with similar contaminants, geology, and hydrogeology. Cleanup actions for the Site surface soil are evaluated separately from cleanup actions for the deep contamination (i.e., intermediate soil, LNAPL, and groundwater) because cleanup of the surface soil is independent of the cleanup of the deep contamination, but cleanup of the deep contamination requires an integrated approach for dealing with all three media (intermediate soil, LNAPL, and groundwater). The cleanup action that Ecology selects for the Site will combine an action for surface soil with actions for the deep contamination as discussed in Section 10.

9.1 SURFACE SOIL

Table 37 presents an evaluation of potential cleanup technologies for surface soil, and identifies three viable and commonly practiced cleanup technologies (the highlighted rows) for TPH-D/HO contamination in surface soil: excavation, capping, and institutional controls. Soil vapor extraction (SVE), bioventing, and NSZD cannot reduce TPH-D/HO concentrations to the preliminary CUL of 2,000 mg/kg within a reasonable RTF. Therefore, these technologies are not considered further for surface soil cleanup. The cleanup actions proposed for surface soil areas SSA-1 through SSA-5 are:

- Capping and institutional controls, and
- Excavation.

9.1.1 Capping and Institutional Controls

The purpose of a cap at the Site is to protect humans from direct contact with contamination in surface soil (i.e., SSA-1 through SSA-5; Figure 37). Caps designed to protect humans from direct contact act as a physical separation layer with thicknesses typically ranging from 2 to 3 feet. For FS purposes, the fundamental design assumption is construction of a 3-foot cap with clean imported soil while preserving the existing surface grade. To preserve existing grade, approximately 3 feet of contaminated soil will be excavated and sent off Site for disposal at a landfill. In addition, remaining underground piping (approximately 1,600 linear feet) and infrastructure (one sump, and two pump houses) that may contain oil (Figure 37) will be demolished (removed and disposed at an off-Site landfill) as part of the cleanup action. This ensures that all remaining primary sources of oil at the Site are addressed.

The cumulative area occupied by the five surface soil areas is approximately 11,500 square feet and the estimated volume of soil that would be removed and disposed off-Site is 1,280 cubic yards.

Capping is a viable cleanup action for the surface soil at the Site. Where the NSC passes over surface soil areas requiring cleanup, WSDOT would be consulted to determine the finished elevation of the road surface or other subsurface infrastructure and adjust the localized finished elevation of the cap as necessary. Additional cut and fill work (followed by off-site disposal of contaminated soil) may also be required to establish appropriate sub-grade for highway construction and protect workers.[vi]

There are no identifiable technical or administrative obstacles to capping. Capping would require establishing institutional controls such as access restrictions and an environmental covenant on the deed for the impacted properties to document, monitor, and manage the long-term risks associated with the residual contaminated soil beneath the caps. If the NSC alignment extends through the Site, then the surface soil cleanup work needs to be coordinated with WSDOT and must take place before highway construction commences.

9.1.2 *Excavation*

Excavation and off-Site disposal at a Subtitle D landfill is a common practice for cleaning up accessible petroleum contaminated soil in the State of Washington. Excavation of the five surface soil areas SSA-1 through SSA-5 (Figure 37) would protect humans and ecological receptors from direct contact risks. Conventional construction equipment and shoring methods could be employed for this work. The estimated combined volume of soil that would be removed from the five areas to the standard point of compliance depth of 15 ft bgs is 6,400 cubic yards. All excavations would be backfilled (and compacted) with clean imported fill soil.[vii] Excavated soil exceeding CULs would be transported to a permitted regional Subtitle D landfill for disposal.

[vi] Backfill and compaction of excavations would be coordinated with WSDOT to assure consistency with WSDOT earthwork requirements.

[vii] Backfill and compaction would be coordinated with WSDOT to assure consistency with WSDOT earthwork requirements.

As discussed above for capping, remaining underground piping and infrastructure (sump, pump houses) at the Site that may contain oil will be demolished. These features are illustrated on Figure 37.

There are no identifiable technical or administrative obstacles to implementing this cleanup action for the five shallow soil areas and remaining infrastructure that may contain oil. Excavation below 15 feet may also be undertaken if high-concentration source material is encountered and readily accessible without resorting to extraordinary shoring measures.

The NSC project has no practical bearing on this cleanup action except for timing. Excavation of surface soil would need to be coordinated with WSDOT and take place before highway construction commences in the area.

9.2 DEEP CONTAMINATION (INTERMEDIATE SOIL, LNAPL, AND GROUNDWATER)

Table 38 presents technologies for cleaning up intermediate soil, LNAPL, and groundwater. The highlighted rows in Table 38 identify the cleanup action technologies retained for development into cleanup actions. Detailed explanations of technologies potentially applicable to the LNAPL can be found in numerous online resources, in particular, LNAPL guidance (ITRC 2009c) from the ITRC.

It is important to note that excavation of the deep contamination (including mobile LNAPL) is not included as a viable cleanup action technology for the Site. This is because of the extreme depths at which the contamination resides (i.e., as low as 170 to 180 ft bgs). Excavating to this depth would require the employment of extraordinary shoring measures; for example, a vertical shoring wall constructed of overlapping deep soil mix pilings. Non-standard construction equipment and logistics would be needed to remove material at the extreme depths. Dewatering to lower the water table would likely be necessary to support removing material in the smear zone. Because much of the soil overlying the mobile LNAPL is below CULs, a vast area for staging this clean soil for use later as backfill would be required. An excavation of this size, depth, and complexity would require shutting down the existing active rail corridor and possibly some neighboring business activities for a significant period of time, thereby disrupting commerce. Long-term settling of backfill would be expected in an excavation of this depth, potentially complicating the construction of transportation infrastructure overlying the excavation. Lastly, these extraordinary conditions, use of non-standard construction equipment and techniques and vast volumes of soil to be moved/ transported, significantly increase risks to the health and safety of Site workers as well as the public situated along transportation routes. For these reasons, deep excavation of mobile LNAPL is not considered further.

Table 39 identifies five cleanup actions proposed for the deep contamination. The cleanup actions are assemblages of the retained cleanup technologies presented above in Table 38. Table 39 aligns the technologies with the areas of contamination to which the technologies apply. All cleanup actions include NSZD as the lone cleanup technology for the Low RTF LNAPL area (see Section 8.4). Similarly, all cleanup actions include groundwater monitoring and institutional controls.

Note that the primary differences between the cleanup actions are the technologies applied to the Medium and High RTF LNAPL areas.[viii] Cleanup Action A uses NSZD for both areas. Cleanup Actions B, C and D apply bioventing and biosparging to both areas. The differentiating feature of these three cleanup actions is the addition of another technology for the High RTF LNAPL area. Cleanup Action C includes Manual LNAPL recovery, and Cleanup Action D includes steam enhanced LNAPL extraction (SEE). As will be discussed further below, the primary LNAPL removal mechanism in Cleanup Action C is bioventing and biosparging. Manual LNAPL removal is predicted to provide marginal benefits, at best, in terms of LNAPL depletion. Bioventing and biosparging are included along with SEE in Cleanup Action D because, as discussed below, some tertiary LNAPL depletion would be necessary following SEE; i.e., SEE alone will not be 100% effective. Cleanup Action E applies smoldering combustion to the Medium and High RTF LNAPL areas.

The remainder of this section describes the elements of each cleanup action and presents conceptual-level information on how they would be implemented.

9.2.1 *Cleanup Action A – Natural Source Zone Depletion*

Cleanup Action A applies NSZD throughout the mobile LNAPL area and Intermediate Soil. As noted in Table 39, Cleanup Action A is included here for informational purposes only. It does not meet the MTCA threshold requirement that prohibits reliance on natural processes alone to cleanup LNAPL sites (see Section 8.1.2.4). Nevertheless, it provides useful context for evaluating the performance of the other cleanup actions for deep contamination. While NSZD is expected to eventually eliminate mobile LNAPL, the rate of LNAPL depletion (see Section 7.3.3) is such that attainment of the CUL (i.e., no LNAPL

[viii] Cleanup of intermediate soil contamination is addressed by the technologies implemented in the High RTF LNAPL area because the two zones approximately overlap.

accumulation in monitoring wells) would take much longer than 100 years. The NSC project would have no impact on implementation of NSZD at the Site.

9.2.2 Cleanup Action B – Bioventing/Biosparging

Cleanup Action B applies bioventing and biosparging to both the Medium and High RTF LNAPL areas. Bioventing is intended to deplete LNAPL in the smear and vadose zones at higher rates than are achievable by NZSD. Biosparging operations would focus on areas of the smear zone where mobile LNAPL may be trapped below the layer of silt and silty sand facies (e.g., near MW-20 and MW-4). Cleanup of the Low RTF LNAPL area would occur via NSZD.

Applicability of Bioventing and Biosparging to the Site

O_2 is the most thermodynamically favorable electron acceptor for petroleum biodegradation in natural systems. Where large masses of hydrocarbons (e.g., LNAPL) exist in the subsurface, O_2 demand by microbes exceeds natural O_2 replacement mechanisms. Under these conditions, the microbial ecosystem goes anearobic and alternate electron acceptors (e.g., nitrate, sulfate, ferric iron) are utilized for petroluem biodegradation. The NSZD evaluation discussed in Section 7.3.1 indicates that this has occurred at the Site.

Bioventing and biosparging encourage aerobic biodegradation of petroleum hydrocarbons by promoting the movement of air (with O_2 as the electron acceptor) through the unsaturated and saturated zones of the formation respectively. Initially, both technologies are expected to convert portions of the formation currently depleting hydrocarbons under anaerobic conditions to aerobic biodegradation. It should be noted that excess O_2 is required to move the system to aerobic conditions in the beginning as some O_2 will be funneled to other processes, such as oxidizing reduced metal species (e.g., iron and manganese).

The fluctuating groundwater table at the Site is expected to seasonally disperse LNAPL across the smear zone, particularly within the granular soil above the layer of silt and silty sand facies (Figure 29). The relative permeability of this layer makes it conducive to circulating air via bioventing. Further, the LNAPL smearing brought about by the seasonal water table fluctuation (which is at least 7 feet based on RI data, but may be up to 15 feet based on the smear zone thickness) is expected to increase mass transfer of hydrocarbons into biologically active micro-zones within the formation. As the water table moves up and down, the capillary force acting on the petroleum hydrocarbon LNAPL will decrease and increase, which will change the shape and distribution of the petroleum hydrocarbon LNAPL and facilitate emulsification. An increase in emulsification will facilitate the biodegradation of the petroleum hydrocarbon. As indicated in

Section 7.3, many bacteria synthesize and excrete high-molecular-weight biosurfactants that act to emulsify the petroleum hydrocarbon LNAPL, thereby increasing the surface area of the LNAPL that can be colonized by bacteria, which increases the rate of degradation of the oil. Bioventing has been shown to be effective at treating or removing petroleum hydrocarbon LNAPL present as free product. Table 40 presents representative case studies of LNAPL sites that have been treated using bioventing or SVE. The table includes SVE because it is well understood that biodegradation (i.e., bioventing) is a significant component of SVE treatment of petroleum hydrocarbons. Johnson et al. (1990) demonstrated that mass was removed from a "free-liquid gasoline" during SVE. Another example is found in Trowbridge and Malot (1990) which states: "The vacuum extraction process [SVE] can be an effective technique for the removal of free product floating on the water table." USEPA reported that, "Available evidence indicates that SVE is very effective for removing those fractions of contamination located in the vapor and free-liquid phases or adsorbed to the external surfaces of the soil matrix" (USEPA 1996).

Recent experience by Dr. Rob Hinchee showed that bioventing resulted in the complete treatment of mobile LNAPL at a jet fuel site. The treatment occurred in 5 years without any active LNAPL extraction (Hinchee, 2016). According to Hinchee (2016), a site having a 30-acre LNAPL plume is being treated using bioventing and after 8 years, the LNAPL plume has been reduced to a single well with only 0.16 feet of measureable LNAPL. According Dr. John Wilson, bioventing removed the mobile LNAPL in a very few years from one of the USEPA's early bioventing sites at Traverse City, Michigan. Lastly, during the 21 December 2016 meeting to discuss major technical and regulatory issues identified by Ecology in the September 2016 draft RI/FS, the PLP's technical team presented information on a BNSF site where successful implementation of bioventing virtually eliminated measurable weathered diesel LNAPL thicknesses in most monitoring wells within a period of approximately 3 years.

The same mechanisms that successfully treated the petroleum LNAPL in the bioventing case studies identified above would work for the LNAPL at the Black Tank site, albeit at lower rates because the Black Tank LNAPL is comprised of heavier and less volatile hydrocarbons. Nonetheless, bioventing and biosparging are expected to change the composition and physical properties of the mobile LNAPL at the Black Tank site based on loss of the more soluble, volatile, and biodegradable hydrocarbons. The changes in composition are expected to accelerate weathering to a more viscous and less mobile material. These changes to residual LNAPL properties will reduce the remediation timeframe, but are not accounted for in the RI/FS RTF estimates.

Seasonal fluctuations in the water table are expected to alter the volume of smear zone media that is amenable to bioventing. As a result, bioventing's effectiveness will be lower in the winter and spring when the water table is high and higher in the summer and fall when the water table is low. The water table fluctuations will replenish LNAPL in the upper portion of the smear zone where bioventing stimulates aerobic biodegradation. Bioventing has been used as a standalone cleanup technology for LNAPL removal, including residual and free product LNAPL, at hundreds of other sites.

Table 40 shows that bioventing has proven effective for heavy hydrocarbons, such as Bunker C, with reported bioventing degradation rates ranging from 0.6 to 5 mg/kg-day. The applicability of bioventing to heavy oils and Bunker C is supported by the hydrocarbon volatility and solubility graph (Figure 38) from the USEPA Bioventing Manual (USEPA 1995a and 1995b).

The Site is amenable to bioventing because O_2-limited conditions have been observed (see Table 33; 0.6% O_2 in MW-4; 5% O_2 in MW-17). It should be noted that the wells in Table 33 were not constructed for vapor sampling and are, therefore, likely to leak and show higher O_2 conditions than actually exist. The presence of CH_4 in some soil vapor and groundwater samples further confirms the presence of O_2-limiting conditions. The vadose NSZD carbon trap data obtained from the Site demonstrates that vadose zone biodegradation is occurring even under O_2-limited conditions. These observations provide supporting evidence that addition of O_2 via bioventing would further stimulate biodegradation that treats and removes LNAPL.

Implementation Approach

The rate of LNAPL depletion by NSZD is expected to be sufficient to eliminate mobile LNAPL in the Low RTF LNAPL area in a reasonable period of time (see RTF discussion below). For FS purposes, the following NSZD testing would be undertaken annually to track changes in NSZD rates (see Sections 4.6 and 7.3.1 for details):

- CO_2 soil flux via flux chambers or carbon traps (four carbon traps for 2 weeks),
- In situ respiration (ISR) testing in four monitoring wells, and
- Analysis of groundwater samples from four monitoring wells for NSZD parameters.

Because LNAPL in monitoring wells may be isolated from the natural processes of NSZD, the LNAPL in the wells would be removed (e.g., semiannually) to allow a more representative evaluation of the performance of NSZD in the surrounding formation.

The NSC project does not significantly impact implementation of NSZD at the Site because sufficient area should be available for NSZD monitoring regardless of the alignment (Figure 37).

Bioventing and biosparging at the Site would be accomplished by promoting the movement air in the subsurface. For bioventing, either a vacuum or pressure would be placed on an appropriately spaced well network to draw or push air through the formation. The wells would be screened into but not below the layer of silt and silty sand facies and to an elevation above the seasonal high water table. The number of wells and rates of air flow would be calculated and adjusted to provide what is needed to maintain oxygenated conditions in the targeted remediation zone. Soil gas monitoring would be undertaken to monitor conditions and provide data for estimating degradation rates. Periodically, air flow could be terminated for short periods to allow manual removal of LNAPL from wells situated in the High RTF LNAPL area.

For FS purposes, an array of 7 wells would be constructed based on an assumed 100-foot radius of influence across the Medium and High RTF LNAPL Areas (Figure 39). This is a reasonable spacing given the granular nature of the soil in which the mobile LNAPL resides above the layer of silt and silty sand facies (Figure 29) and industry experience. Note that the configuration avoids placement of any wells or equipment in the footprint of WSDOT’s 2014 proposed NSC alignment. However, if necessary, it would be technically feasible to use angle drilling to locate operable bioventing and biosparging wells within the highway footprint.

Actual well spacing, vacuum pressures and flow rates, and a determination regarding the need for a soil gas collection and treatment system would be determined via a pre-design pilot test. Piping between process equipment and each well would be buried below ground. The configuration shown in Figure 39 avoids having remediation equipment or infrastructure in the NSC footprint (i.e., paved or constructed areas). Three independently operated equipment enclosures containing the blower (for vacuum), ancillary equipment and instrumentation would be used to service the biovent wells. This configuration alleviates having to cross under or over the NSC with utility corridors.

Figure 39 also shows the placement of 7 biosparging wells. Five wells are clustered around MW-20 and two in the High RTF LNAPL area to address potential zones of mobile LNAPL situated near the bottom of typical annual water table fluctuations. The wells would therefore be screened below the water table, and compressed air would be injected into the wells to oxygenate groundwater and promote aerobic biodegradation of LNAPL residues. Design information for the biosparging would be obtained as part of the pilot test program.

For performance monitoring, the bioventing system would temporarily be shut down to allow LNAPL gauging in the wells.

Estimated Remediation Timeframe

Estimation of RTF requires consideration of degradation of both the mobile LNAPL in the smear zone and residual LNAPL above the smear zone. Some of the LNAPL above the smear zone is biodegradable; however, it is to be expected that this shallower residual LNAPL is less biodegradable than the mobile LNAPL, because it is more highly weathered and in a dryer setting; less amenable to biodegradation. Table 41 contains an estimate of RTFs that include contributions from both sources of LNAPL. The calculation assumes that residual LNAPL in the unsaturated zone would degrade at half the rate of the more biodegradable mobile LNAPL. The results show that mobile LNAPL is still the dominant fraction of LNAPL that will be removed. The calculations and assumptions are included as Appendix T.

It is important to recognize that the effect of continued and enhanced weathering of the heavy oils at the site will shorten remediation timeframes due to the associated reduction in LNAPL mobility, which is a remediation goal. Linearity (i.e., use of a constant NSZD rate) was assumed to estimate RTF as there is no straightforward way of correcting for the changing composition of the hydrocarbon mixture over time in the calculation. Weathering will slow biodegradation over time, but it will also further decrease the residual LNAPL's mobility. It should be noted that the 655 gal/ac-yr NSZD estimate for highly weathered crude oil cited above (Lundegard and Johnson 2006) was for LNAPL that had been weathering over 100 years in a much warmer shallower site than the Black Tank Site. All mixed hydrocarbon LNAPLs weather (by volatilization, dissolution, and biodegradation), which concentrates the higher molecular weight compounds and increases viscosity. As the LNAPL becomes more viscous, the LNAPL becomes less mobile, eventually reaching a point where the LNAPL is no longer mobile (i.e., remediation endpoint). The loss of mobile LNAPL due to decreasing viscosity as weathering occurs compensates for any reduction of NSZD rates over time. It is also important to recognize that hydrocarbons in the free phase also biodegrade, which is not accounted for in the RTF estimates.[ix]

A bioventing rate for the Site was initially estimated based on multiplying the observed NSZD rate (800 gal/ac-yr) by a factor of 4 (yielding 3,200 gal/ac-yr).

[ix] See Appendix D, Direct Biodegradation of LNAPL in the ITRC NSZD guidance, http://www.itrcweb.org/GuidanceDocuments/LNAPL-1.pdf.

Hinchee (2016) recommends using a 1 mg/kg-day rate to estimate remediation timeframe at the Site. This rate is conservative because it falls well within and towards the lower end of the literature reported ranges. A rate of 1 mg/kg-day translates to a bioventing rate of 5,875 gal/ac-yr at the Site (i.e., 1 mg/kg-day multiplied by the estimated mass of contaminated soil). Based on this rate, 8 and 14 years of bioventing would be required to remediate mobile LNAPL in the Medium and High RTF areas, respectively (Table 41). It should be noted that any LNAPL residual in the shallower vadose zone would not impact this timeframe estimate. Similar operational durations are assumed for the biosparging wells. As shown in Table 41, NSZD over a period of 7 years is predicted to completely deplete the mobile LNAPL in the Low RTF LNAPL area.

Bioventing Performance Enhancement Options

The bioventing system described in the RI/FS is conceptual. The layout was based on currently available information and professional judgment. The bioventing system would be implemented in phases and information gained from initial phases would be used to inform and optimize subsequent phases. For example, shut-down ISR testing can be used to estimate actual biodegradation rates. If observed rates are deemed insufficient, enhancements could be progressively implemented to improve performance. Table 42 summarizes enhancements (i.e., optimization activities) that could be implemented as needed at the Black Tank site. These are all proven techniques to achieve cleanup in a reasonable period of time.

Infrastructure for all of the optimization enhancements listed in Table 42 can be designed and implemented so as not to interfere with the NSC project regardless of the alignment ultimately adopted by WSDOT.

Groundwater Monitoring

The dissolved phase plume is stable, appears to fluctuate seasonally, and generally coincides spatially with the LNAPL footprint. Groundwater monitoring data indicates that the dissolved-phase plume may extend a few hundred feet beyond the downgradient edge of the LNAPL area at concentrations exceeding the TPH-D/HO CUL (see Section 7.2.3).[x] Groundwater conditions at the periphery of the LNAPL will be monitored. An environmental covenant will be placed on the parcels that comprise the Site to prohibit development of groundwater for drinking water purposes. For Cleanup Action

---

[x] The full downgradient extent of the dissolved phase will be confirmed when the monitoring well network is expanded to the north during remedial design and implementation.

B, it was assumed that groundwater at 10 wells would be monitored for TPH; annually for 10 years and once every 5 years through year 30.

All proposed cleanup actions in Table 39 include provisions for groundwater monitoring and reporting. For FS purposes, the existing network of monitoring wells at the Site (Figure 40) is assumed sufficient. Monitoring will include gauging groundwater elevations, the presence/thickness of LNAPL, and collection of samples from selected wells for laboratory analytical testing. The frequency and duration of groundwater monitoring will vary depending on the cleanup actions taken and on the RTF.

Depending upon the final NSC alignment, some existing monitoring wells may need to be abandoned and new ones installed. For FS purposes, WSDOT's proposed 2014 alignment was assumed along with the following modifications to the monitoring well network:

- Ten to16 monitoring wells are abandoned because they are located in highway and rail construction project areas or currently defective in some manner, and
- Six to 12 new monitoring wells are installed in areas outside of active traffic following completion of the highway construction.

Alternative highway alignments that pass further to the west may also require abandonment, replacement, and/or retrofitting of monitoring wells; however, the impacts are significantly less.

9.2.3 Cleanup Action C – Manual LNAPL Removal

Cleanup Action C includes all the features of Cleanup Action B with the addition of a network of LNAPL removal wells in the High RTF LNAPL Area (Figure 41). Recovery of mobile LNAPL in most areas of the Site is not practical by means of pumping or dual-phase extraction because of the low transmissivity and low vapor pressure of the LNAPL. As detailed in Section 6.3, LNAPL transmissivities at the Site are extremely low and have been confirmed by field observations from manual skimming tests. LNAPL transmissivity is very low due to the high viscosity and density of the LNAPL and lower permeability of the silt and silty sand facies in which much of the mobile LNAPL resides. Enormous amounts of groundwater would need to be pumped with very little LNAPL volumes produced. However, manual recovery (e.g., bailing) of LNAPL from wells over a long period of time is a common practice at sites with low LNAPL recoverability and where the risks and potential for LNAPL or dissolved plume migration are low. The volumes of LNAPL recovered over time are generally low relative to the total mass present in the subsurface (i.e., low effectiveness), but can be viewed as supplementing other cleanup actions while also empirically reinforcing findings of the LNAPL transmissivity evaluations that predict low recoverability.

Cleanup Action C utilizes manual LNAPL removal from wells as a supplement to bioventing. As many as 62, 4-inch diameter wells could be spaced 30 feet on centers (i.e., approximately a 15-foot radius of influence) across the High RTF LNAPL area and screened across the smear zone (Figure 41). The wells would be gauged for the presence of LNAPL and manually bailed to remove LNAPL accumulations. The recovered petroleum would be recycled. For cost estimation purposes, it was assumed that manual LNAPL removal would occur quarterly for 2 years, annually for 3 years, and then once every 5 years until a remediation level is achieved. Groundwater monitoring for this cleanup action was assumed to be the same as previously described for Cleanup Action B: monitor 10 wells for TPH; annually for 10 years and once every 5 years through year 30.

The overall rate of LNAPL depletion would combine the contributions from bioventing, biosparging and manual LNAPL removal. As discussed previously for Cleanup Action B, bioventing and biosparging alone are expected to fully deplete mobile LNAPL in approximately 14 years. Estimates of the contribution from manual LNAPL removal using data from the RI suggest that no more than 100 additional gallons per year of LNAPL are likely to be manually recovered. This translates to a reduction in RTF of less than 1 year.

The extent to which manual LNAPL removal could be implemented in the High RTF LNAPL area depends upon the final NSC alignment. Manual LNAPL removal can be implemented up to, but not within, the active limited access highway area. The alternative NSC alignments being considered by WSDOT would make more of the High RTF LNAPL area available for manual LNAPL removal than the 2014 alignment.

9.2.4 Cleanup Action D – Steam Enhanced LNAPL Extraction (SEE)

Cleanup Action D includes all the features of Cleanup Action B with the additional application of SEE in the High RTF LNAPL Area (Figure 43). LNAPL removal using SEE involves injection of steam into the subsurface to modify LNAPL properties and improve recovery potential. Heating lowers LNAPL viscosity and increases both solubility and fluid transport properties. These property modifications enable recovery of LNAPL and groundwater by total fluids extraction and, in cases of LNAPLs with high vapor pressures, by vapor recovery.

The conduction of heat in earth materials is relatively slow. Therefore, efficient application of SEE depends on the effective delivery of heat into the subsurface. This is complicated by formation heterogeneity and LNAPL distribution. SEE is a complex technology to implement full-scale and therefore requires extensive laboratory and pilot testing before implementation.

Applicability of SEE to the Site

The primary recovery mechanism at the Site would be from total fluids extraction. The mobility of the weathered fuel oil at the Site can be potentially enhanced by taking advantage of the temperature-dependent reduction of LNAPL viscosity and density (see Appendix G) thereby enabling the potential for flow that does not now exist under ambient conditions. The composition and physical properties of LNAPL at the Site show that volatile components represent less than 2% of the mass. Therefore, the relative contribution of vaporization to LNAPL removal by SEE would be very low.

SEE has been applied at a number of environmental sites with varying results (Table 43). Of nine sites evaluated by US ACE (2014), none had the same combination of characteristics as the LNAPL at the Site (e.g., deep contamination, heavy oil, unsaturated/saturated zone interface). SEE has been shown to be effective for increasing mass removal of chlorinated solvents and lighter fuels and oils, such as JP-4, kerosene, gasoline, and motor oil. Most SEE sites involve cleanup of chlorinated solvents or other dense non-aqueous phase liquids in the saturated zone. Only three sites involved fuel oils in partially saturated soils and none of those were heavy oils. The data indicate that SEE is less effective for heavier oils because of their lower volatility and mobility as a fluid. Complete removal of mobile LNAPL comprised of heavy oil using SEE is impractical and was not achieved at any of the sites listed on Table 43. In the petroleum industry, steam injection is widely recognized to have removal efficiencies ranging from 30% to 60%. In other words, between 40% and 70% of the oil is likely to remain in the ground after steam injection.

While SEE is technically feasible to implement at the Site and could be expected to deplete mobile LNAPL to some extent, there is no evidence from previous applications of the technology that SEE alone can achieve the MTCA required CUL of no mobile LNAPL in monitoring wells. This is the basis for assuming that the bioventing and biosparging systems described previously for Alternative B will need to operate for some period of time following SEE to assure attainment of the CUL. There is also substantive evidence to suggest that the technology poses a risk with regard to causing dissolved phase contaminant mobilization and migration into the aquifer.

Important additional considerations for the effectiveness of SEE for the Site are:

- *Flux of groundwater though the SEE treatment zone* – The high specific heat capacity of water (four times higher than rock or soil matrix), influences the rate of heat lost. Thus, groundwater velocity is a key design factor in the design of a SEE system. At the Site, the sediment at the base of the LNAPL smear zone is coarse and groundwater velocities are high. This will decrease the effectiveness of steam injection in the saturated zone and increase the heating costs.

- *Temperature* – Formation temperatures that can be achieved by steam injection in the saturated zone are limited by the boiling point of water at atmospheric pressures.[xi] This temperature caps the extent to which LNAPL viscosity can be decreased. Because of the very high viscosity of the LNAPL at the site, the mobility of the LNAPL, which is 1590 to 5470 times slower than water at 70° F, may not be sufficiently enhanced to allow significant additional recovery. This is particularly an issue for the LNAPL in the silt and silty sand facies because there will be insufficient LNAPL head to overcome the capillary pressure and force displacement of the viscous LNAPL from the small pore spaces in these fine-grained deposits.
- *Geology* - Typically, sandy and gravelly, high permeability media are more easily treated by steam injection than silts and clays. The injection process requires permeability sufficient to achieve an adequate flow of the injected steam through media. Therefore, more permeable soils allow a faster introduction of heat. To some extent, heterogeneity (e.g., lenses of less permeable material) can be overcome by conduction of the heat into the less permeable lenses or by injecting steam below. This will be a potentially important mechanism at the Site because of the presence of the silt and silty sand facies at the base of the smear zone in the High RTF LNAPL area.

In most areas of the Site, there is no confining layer above the mobile LNAPL zone to keep injected steam from rising due to buoyancy. This condition would invariably lead to heat loss and inefficient or incomplete heating of the LNAPL target zone. Further, it would be very difficult to inject steam directly into the silt and silty sand facies where much of the LNAPL resides due to the fine-grained, low permeability nature of these soils. As discussed later in this section, pairs of injection wells with one screened below and one within the smear zone are proposed in an attempt to counter the aforementioned conditions and their influence on heating. However, it is important to understand that steam injected below the silt and silty sand facies will not form a continuous distribution.

[xi] Steam temperature and injection pressure are related. The pressure at which steam can be injected at the Site is governed by the injection elevation relative the water table. The injection elevation for steam at the Site would be near the water table such that the injection pressure would be close to atmospheric; and temperature near what occurs at atmospheric conditions.

Rather, the steam will migrate preferentially through higher permeability zones such as the sand and gravel layers encountered below the silt and silty sand facies. Oil industry experience also confirms that preferential flow of steam through higher permeability zones can halt the spread of steam into target areas (e.g., Xu et al. 2014). The implication of this at the Site is that steam may not enter the silt and silty sand facies where much of the LNAPL resides. Even if the silt and silty sand facies could be heated to steam temperature via conduction from above and below, there will be insufficient decrease in LNAPL viscosity and insufficient LNAPL head to overcome the capillary pressure and displace LNAPL from the silt and silty sand facies.

Preliminary Modelling

ERM ran a thermal model using the PC-based PetraSim software to support this FS-level evaluation of the use of steam injection at the Site (see details in Appendix U). The model was run assuming implementation of steam injection technology in the High RTF LNAPL area, and the model output was used to estimate the amount and distribution of steam and the time required to inject steam into the smear zone and reach a target temperature of 160 °F (71 °C). This target temperature is expected to decrease the viscosity and mobilize the types of LNAPL present in the smear zone. Four scenarios were modelled:

- Scenario 1: Steam injection flow rate – 5,000 kilograms per hour (kg/hr) of steam in total (a flow rate of 100 kg/hr per well).
- Scenario 2: Steam injection flow rate – 2,500 kg/hr of steam in total (a flow rate of 50 kg/hr per well).
- Scenario 3: Steam injection flow rate – 2,050 kg/hr of steam in total (a flow rate of 50 kg/hr per well). Increase radius of influence of steam injection wells (decreased number of wells).
- Scenario 4: Once a temperature of 160 ºF is reached in saturated zone (based on Scenario 3 inputs), then steam injection is ceased, with the recovery system continuing to run until temperatures had declined to between 77 ºF (25 °C) and 86 ºF (30 °C) within the vadose zone.

Each steam well was modelled to a depth of 10 feet beneath the water table (190 feet in total) with the screen section positioned from 185 to 190 feet. The recovery wells are modelled to the same depth with the screened section between 185 to 190 feet to simulate recovery from the capillary fringe and saturated zone. For FS-level conceptual design purposes, the results of Scenario 4 were selected wherein 160 ºF (71 °C) is predicted to be achieved after approximately 6 months of heating at a steam injection rate of 50 kg/hr per well. A total of 2 years of steam enhanced recovery operations were assumed for cost estimation purposes. The relative costs and benefits of alternative heating regimes would be further assessed during detailed design.

Implementation Approach

A pilot test of SEE would need to be performed to obtain design parameters and proof of concept. This would require assembly and operation of a complete, but smaller, version of a full-scale system. The pilot system would need to be of sufficient size that product recovery performance can be adequately evaluated.

For full-scale estimation purposes, pairs of steam injection wells would be located as shown on Figure 42. Each black colored well symbol in Figure 42 represents a pair of injection wells; one completed to 175 ft bgs with a 15 ft screen and one completed to 190 ft bgs with a 10 ft screen. Two steam injection intervals are recommended to facilitate the in-situ thermal desorption process. The injection interval ranging from 160-175 feet bgs was selected based on the site average low water table elevation of 175 feet bgs. This zone targets the largest LNAPL mass residing directly above the water table, up to the capillary fringe. A second, deeper injection interval is recommended for two reasons. First, injecting into the saturated zone will allow trapped immiscible LNAPL globules to be thermally desorbed from the soil, allowing for effective removal of the LNAPL through the liquids extraction system. The second reason for the deeper injection interval is to prevent heat loss from the upper injection interval downward through conduction to a fluctuating, unheated groundwater table. In essence, the steam injected into the lower interval migrates upward and prevents excessive condensation and heat loss, thereby enhancing LNAPL recovery from the upper zone.

The steam injection wells are arranged for an approximate 30-foot radius of influence. Multi-level temperature monitoring points (not shown in the figure) would also be installed to monitor the temperature propagation front. Once the LNAPL is heated and viscosity reduced, it would be recovered by total fluids extraction from an array of 12 recovery wells. Hydraulic containment of the steam-enhanced recovery system was predicted to be achieved using 12 wells at 60-feet spacing and flow rate of 3 gallons per minute per well (Appendix V). The predicted total flow rate of the 12-well system is approximately 36 gallons per minute. The water would be further pretreated, as necessary, and discharged to the municipal sewer under a City of Spokane discharge permit. For FS purposes, the assumed pretreatment is oil/water separation and dissolved air flotation, the latter to remove emulsified oil. The recovered oil would be recycled. Extraction and treatment of formation air is unlikely to be necessary for this cleanup action given the very low vapor pressure of the weathered oil. For Cleanup Action D, it was assumed that groundwater at 10 wells would be monitored for TPH; Quarterly for 2 years, semi-annually for 3 years, annually for 5 years, then once every 5 years through year 30.The greater frequency of monitoring during and immediately following steam-enhanced LNAPL is due to the potential for mobilizing LNAPL or increasing the size of the dissolved phase plume with this technology.

Figure 3 is a generalized schematic or equipment arrangement for a steam enhanced LNAPL removal system. Figure 44 is a representative process flow diagram for a typical steam system. In general, the system modules are 1) steam generation plant, 2) below ground systems (injection and extraction wells, temperature monitoring points), and 3) aboveground air, water, and LNAPL process equipment.

The extent to which SEE could be implemented in the High RTF LNAPL area depends upon the final NSC alignment and the construction schedule. SEE can be practically installed and operated up to, but not within, the active limited access highway area. The alternative NSC alignments being considered by WSDOT would make more of the High RTF LNAPL area available for SEE implementation than the 2014 alignment. Alternatively, implementation of SEE could potentially occur before construction of the NSC depending on WSDOT's schedule. As previously discussed for Cleanup Action B, bioventing and biosparging can be configured for implementation with WSDOT's 2014 proposed NSC alignment. If necessary, it would be technically feasible to use angle drilling to locate operable bioventing and biosparging wells within the highway footprint; however, this is not a viable option for LNAPL extraction wells using in a SEE system because those wells are equipped with down-hole pumps that must hang vertically.

Restoration Timeframe

Based on experience at other project sites, the following implementation timeline is assumed once the approval for construction is given:

- Three months for system construction and shakedown;
- Six months to achieve steam temperature in the formation;
- Twenty-four months of steam operations; and
- Six to 10 month cool-down period and continued LNAPL recovery.

Therefore, the time period for SEE implementation is anticipated to be on the order of 3 years. An overall RTF cannot be reliably estimated for SEE because SEE alone has not been proven effective at achieving the MTCA required endpoint (no mobile LNAPL; Table 43). Several more years of bioventing/biosparging would likely be necessary to fully achieve the CUL in the High RTF LNAPL area. Furthermore, for bioventing and biosparging to be effective, an unknown period of time would be needed to allow microbial recolonization of the essentially sterilized SEE treatment zone.

9.2.5 Cleanup Action E – Smoldering Combustion

Smoldering combustion thermally treats combustible materials (e.g., hydrocarbons) in situ wherein the contaminants serve as fuel. A patented version of the technology referred to as STAR (Self-sustaining Treatment for Active Remediation) is available from Savron Solutions (Savron Solutions n.d.). Figure 45 is a generalized schematic of a smoldering combustion system. The ignition source is a heater element situated inside an air injection well at an elevation commensurate with the treatment zone. Once ignition is achieved, combustion is sustained by injecting air into the treatment zone. Combustion propagates through the contaminated zone in a self-sustaining manner (i.e., no external energy or added fuel input following ignition) provided a sufficient flux of O_2 is supplied. The combustion front is controlled by the O_2 supply. The products of smoldering combustion are CO_2, carbon monoxide, and water.

Major components of the aboveground equipment set are compressors for subsurface air delivery, blowers for ground surface vapor collection, and emission control equipment (if needed). Ignition wells equipped with temporary in-well heaters, and multi-level thermocouple bundles form the main elements of subsurface equipment.

According to the vendor (Grant, et al. 2016), the following are key Site applicability considerations:

- The lower concentration limit of combustible material for application of the technology is between 3,000 and 5,000 mg/kg.
- The technology can be effective in soils ranging from silty sands to gravels. Less permeable soils make it difficult to deliver the air needed to sustain combustion.
- Some mobilization of LNAPL and increase in the dissolved phase plume may occur as temperatures in the formation increase.

Smoldering combustion is an innovative and developing technology that has not been implemented full-scale at the depths and for conditions comparable to those at the Site. Pilot testing the technology would be necessary to confirm implementability, effectiveness, and essential design information pertaining to ignition, propagation, the need for vapor collection/treatment, and the need for hydraulic controls.

For FS purposes, and based on consultations with the vendor, it is assumed that ignition/air injection wells arranged on 15-foot centers provide adequate coverage. Multi-level thermocouple wells would be installed to monitor the propagating combustion front. It may not be necessary to capture and treat combustion vapors (estimated at 1% of the total contaminant mass treated) given the depth interval and the attenuation buffer this depth affords. Groundwater monitoring for this cleanup action was assumed to be the same as previously described for Cleanup Action D; Quarterly for 2 years, semi-annually for 3 years, annually for 5 years, then once every 5 years through year 30. The greater frequency of monitoring during and immediately following active remediation is due to the potential for mobilizing LNAPL or increasing the size of the dissolved phase plume with this technology.

Based on the technology vendor's (Savron) recommendation, the duration of smoldering combustion is anticipated to be on the order of 1 year from system startup.

If WSDOT's proposed highway alignment extending through the Site is adopted, implementation (i.e., design, permitting, construction, and operation to completion) of this cleanup action would need to occur before construction of the highway at the Site commences. Depending on how the timelines for the highway project and the Site cleanup align, implementation of this cleanup action is possible. Installing a smoldering combustion system to operate during or after highway construction is not feasible because of the need to periodically access the network of ignition and instrumentation wells for servicing/maintenance.

9.3 INSTITUTIONAL CONTROLS

Regardless of the cleanup action selected, an environmental covenant on the impacted parcels would likely be necessary to: 1) acknowledge the presence of soil and groundwater that exceeds the applicable CULs, and 2) prohibit future groundwater development.

10.0 MTCA EVALUATION OF SURFACE SOIL CLEANUP ACTIONS

10.1 THRESHOLD REQUIREMENTS

The two cleanup actions proposed for contaminated surface soil (excavation and capping combined with institutional controls) meet MTCA threshold requirements. Both cleanup actions protect human health and the environment, comply with MTCA cleanup standards, are readily implemented, and can be undertaken in a manner that complies with applicable state and federal laws.

Excavation eliminates direct contact risks to humans by physically removing contaminated soil and disposing it off Site in an engineered and permitted landfill. No compliance monitoring, environmental covenants, or other institutional controls are necessary for surface soil following excavation.

Capping isolates the contaminated soil on Site to prevent direct contact exposures. The cap is periodically inspected and maintained. Institutional controls in the form of access restrictions, signage, and an environmental covenant are implemented to manage the residual risk. The covenant is placed on the property deed acknowledging that contamination remains beneath the cap and requiring Ecology approval if future property redevelopment plans require earthwork in the capped areas.

10.2 OTHER MTCA REQUIREMENTS FOR CLEANUP ACTIONS

Other MTCA requirements for cleanup of surface soil at the Site are:

- Use permanent solutions to the maximum extent practicable,
- Provide for a reasonable RTF, and
- Consider public concerns.

As discussed earlier in Section 8.1.2, a DCA can be used to compare how multiple cleanup actions address these requirements relative to various performance or benefit metrics and cost. Incremental increases in benefits of cleanup actions are compared to incremental increases in costs. If the incremental cost of a cleanup action is determined to be disproportionate to the corresponding incremental benefit, and all other MTCA requirements for cleanup actions are met, then the lower cost cleanup action may be judged acceptable and appropriate.

The following discussion considers the relative benefits of each surface soil cleanup action relative to the DCA evaluation factors (see Section 8.1.2.1) and compares the benefit outcomes to the estimated cleanup action costs.

Overall protectiveness: There is little difference between excavation and capping for this factor. Once designed and permitted, both excavation and capping can be implemented in a matter of a few months. There are no substantive differences in RTF. Capping has lower short-term risks (less exposure resulting from excavating and transporting the contamination), but excavation is more effective long term.

Permanence: The only relevant sub-factor in this case is reduction in toxicity mobility and volume. The mass and inherent toxicity of the contaminants are not altered by either cleanup action. Excavation reduces the volume of contaminated surface soil remaining at the site to a greater extent than capping.

Long-term effectiveness: Excavation is more favorable than capping for this factor because capping has higher residual risk. Contaminated soil remains at the Site with capping at elevations above the point of compliance. An environmental covenant is considered an effective means of preventing unauthorized earthwork that might damage the cap or result in exposure to contaminated soil, whereas excavation removes the contaminated soil and the residual risk from the Site.

Management of short-term risks: This factor addresses protection of human health and the environment associated with the cleanup action during construction and implementation. Capping of surface soil is more favorable than excavation for this factor because it carries lower risks to workers, community, and environment as a result of the lower amount of construction, road transport, and contaminated material handling.[xii]

Implementability: There are no significant implementability constraints for either capping or excavation. However, capping is viewed as slightly less favorable for this factor because the cap requires ongoing inspection and maintenance. Whether WSDOT's highway alignment extending through the Site is selected has little practical bearing on the implementability of either cleanup action.

[xii] While not explicitly accounted for in the DCA, capping is a more sustainable outcome. Less energy is consumed, less atmospheric pollution generated, and fewer short-term impacts to the community (e.g., construction noise, trucking on surface streets) by leaving material in place as opposed to removing it and transporting it to a different location.

<u>Consideration of public concerns</u>: This factor will be addressed when the public has the opportunity to review and comment on the draft CAP.

Both excavation and capping may be viewed similarly. Short-term impacts to the neighborhood from excavation and off-Site transport of contaminated soil could be viewed negatively. Similarly, leaving contaminated soil in place may be considered a negative.

<u>Cost</u>: The estimated cost for capping contaminated surface soil is approximately \$490,000. The total estimated cost for excavation and off-Site disposal of contaminated surface soil is approximately \$1,500,000. Detailed cost estimates for both cleanup actions are provided in Appendix W. Costs were estimated based on project experience at similar sites and contractor estimates.

The aggregate benefit of excavation is qualitatively greater than that for capping. This is primarily because all contaminated surface soil is removed from the Site. This benefit comes with an incremental cost premium of approximately \$1,000,000.

10.3 RECOMMENDED CLEANUP ACTION FOR SURFACE SOIL

The recommended cleanup action for surface soil is excavation and off-site disposal because compared to capping it has higher overall protectiveness, is a more permanent solution, has better long-term effectiveness and is more easily implement in conjunction with the NSC. Excavation will ensure that potential risks to human health and the environment posed by the surface soil contamination at the Site are eliminated. Part or all of the surface soil cleanup action could be implemented quickly as an interim action under MTCA if needed to accommodate NSC highway project scheduling.

11.0 MTCA EVALUATION OF DEEP CONTAMINATION CLEANUP ACTIONS

11.1 THRESHOLD REQUIREMENTS

Four of the five cleanup actions (Cleanup Actions B through E; bioventing/biosparging, manual LNAPL removal, SEE, and smoldering combustion) proposed for the deep contamination satisfy MTCA threshold requirements (Table 44). They protect human health and the environment, comply with MTCA cleanup standards, can be undertaken in a manner that complies with applicable state and federal laws, and provide for compliance monitoring. The four cleanup actions are expected to remove mobile LNAPL and reduce contaminant concentrations in the intermediate soil, smear zone soil, and groundwater at the Site to levels that meet the preliminary CULs within 20 years. During that period, human health and the environment would be protected by:

- Controlling access to the Site,
- Prohibiting development of groundwater at the Site through an environmental covenant, and
- Monitoring groundwater to ensure that the LNAPL and dissolved phase contaminant plumes decline in response to the cleanup actions.

Cleanup Action A relies on NSZD exclusively for LNAPL cleanup. This cleanup action would also be protective of human health and the environment, but it would take longer than 100 years to comply with the cleanup standards. During implementation, protectiveness would be secured using the same institutional measures and monitoring described above. However, by not including an active technology for LNAPL, Cleanup Action A may not meet the MTCA requirement for *"…treatment or removal of liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile hazardous substances, or hazardous substances that cannot be reliably contained. This includes removing free product consisting of [LNAPL] from the groundwater using normally accepted engineering practices."*[xiii] Ecology does not consider NSZD a normally accepted engineering practice for treatment or removal of LNAPL.

Importantly, multiple lines of evidence (Sections 7.2.2 and 7.3.4) show that LNAPL at the Site is not highly mobile, is not migrating and the observed extent of LNAPL is receding over time by NSZD. Although the groundwater data show

---

[xiii] Cleanup Actions B through E each include an active measure to reduce the mass of mobile LNAPL in the subsurface and thus meet this requirement.

some seasonal variation, the long-term trend of TPH-D/HO (using silica gel cleanup data) and cPAH data in the on-Site monitoring wells show consistently low and ND concentrations that generally peaked in early 2011 and have steadily decreased in concentration since then (Figure 27). The dissolved phase TPH-D/HO plume is thin, situated beneath the LNAPL and extends downgradient of the LNAPL on a seasonal basis. This seasonal expansion and contraction of the dissolved phase TPH-D/HO plume (without silica gel cleanup) appears to be related to the release of petroleum metabolites during periods of falling water table levels. It is well understood that petroleum metabolites are highly degradable and are unlikely to persist at concentrations exceeding the CULs much beyond the Site boundary (see Section 7.2.3). LNAPL stability and mobility testing demonstrated that LNAPL at the Site is generally not recoverable under ambient conditions using certain normally accepted engineering practices such as total fluids or dual-phase extraction. Under ambient conditions, technologies other than automated fluid extraction are necessary to actively remove mobile LNAPL.

11.2 OTHER MTCA REQUIREMENTS FOR CLEANUP ACTIONS

This section evaluates whether the cleanup actions proposed for the deep contamination use permanent solutions to the maximum extent practicable, provide for a reasonable RTF, and consider public concerns. The DCA described in Section 8.1.2.1 is the methodology used for this evaluation.

11.2.1 Permanent to Maximum Extent Practicable

Table 45 presents the DCA for the deep contamination cleanup actions. The cleanup actions are listed in order across the top (column identification) of the table and the DCA evaluation factors and sub-factors are listed on the left side (row identification) of the table. The narrative information in the table describes how the cleanup actions address the evaluation sub-factors and how they compare to each other.

In this DCA, a numeric scoring and ranking system is used. The scoring rubric attributes a value of one to 10 to each evaluation sub-factor. For example, the sub-factors of implementability are:

- Whether the cleanup action is technically possible;
- Availability of necessary off-Site facilities, services, and materials;
- Administrative and regulatory requirements;
- Scheduling, size, complexity;

- Monitoring requirements;
- Access for construction operations and monitoring;
- Integration with existing facility operations; and
- Integration with other current or potential remedial actions.

A value of one is the lowest score and value of 10 is the highest. Cleanup Actions B through E are then ranked from one to four for the given DCA evaluation factor based on the sum of scores for the individual sub-factors. Cleanup Action A is not scored or ranked because it does not meet all MTCA threshold requirements as discussed in Section 11.1. The rationale for the scoring of each sub-factor is provided in Table 45. The cumulative rank or sum of ranks for each evaluation factor is shown at the bottom of the table. A cleanup action with a relatively high rank is viewed as using permanent solutions to a greater extent than a cleanup action with relatively low rank.

Cleanup Action B received the highest rank (18). Cleanup Actions C, D, and E received lower cumulative ranks of 12, 11 and 9, respectively. Based on this evaluation, Cleanup Action B (bioventing/biosparging) uses permanent solutions to a greater practicable extent than the other cleanup actions because it possesses the following attributes:

- Medium-High overall protectiveness – all of the cleanup actions provide similar protectiveness, but bioventing/biosparging has the lowest risks from implementation.
- High permanence – utilizes in situ technologies that are proven to destroy hazardous substances and reduce the toxicity, mobility, and volume of contamination without generating treatment residuals.
  High for implementability – utilizes simple and conventional construction and operation technologies, has moderate permitting requirements, carries considerable design flexibility and modification potential, has few constraints regardless of the highway alignment,[xiv] and requires a simple pilot test.
- High long-term effectiveness – proven technology for petroleum at similar sites, modification and enhancement potential is high, and few uncertainties other than operational duration.

[xiv] While the final alignment is not yet known, WSDOT's 2014 proposed NSC highway alignment would complicate, but not preclude implementation of the recommended cleanup action. Initial design drawings for the highway alignment indicate construction would occur at or above grade. Conceptual design layouts indicate installation and operation of a bioventing/biosparging well system is feasible regardless of the NSC highway alignment.

- High for management of short-term risks – few construction and operation risks because of the simple and conventional technologies utilized and relatively low manpower requirements.

The other three cleanup actions (manual LNAPL removal, steam enhanced extraction, and smoldering combustion) have total DCA scores considerably lower than bioventing.

- Cleanup Action C (bioventing/biosparging and manual LNAPL removal) ranked lower primarily because it has lower-management of short-term risk and implementation scores. Manual LNAPL recovery has a high manpower requirement to install and service wells which increases the potential for injury and exposure to LNAPL and results in a low management of short-term risk score. The implementation score for this cleanup action is also lower because a NSC highway alignment that crosses all or part of the High RTF LNAPL area would conflict with the existence and servicing of LNAPL removal wells.
- Cleanup Action D (bioventing/biosparging and SEE) ranked lower because of its complexity, utilization of technologies that carry higher risks to public health (e.g., potential to cause dissolved phase contaminant migration into the aquifer), higher risks to worker health and safety, uncertainty of success given it's unproven track-record for similar sites, the impracticability of servicing critical infrastructure (i.e., wells) if the NSC highway alignment crosses all or part of the High RTF LNAPL area, and the high carbon footprint resulting from the need to generate large amounts of heat. Additionally, SEE scores relatively low on permanence because it generates considerable hazardous residuals rather than destroying the hazardous substances in situ and will not achieve MTCA required CULs without combining it with a follow-up technology. Total fluids extraction is necessary to remove the mobilized LNAPL and to control for concentration increases in groundwater during steam heating.
- Cleanup Action E (Smoldering combustion) ranked low for many of the same reasons cited above for SEE. In particular, smoldering combustion ranked low on long-term effectiveness and implementability because it is a new technology that is unproven at sites with similar conditions. Smoldering combustion has only been implemented full-scale on one site. Also, the technology possesses considerable uncertainty as to whether the distribution of LNAPL in the saturated zone is sufficiently continuous and concentrated to reliably promote advancement of the combustion front to all areas requiring cleanup. Until the self-propagation of the combustion front is fully understood and known to be controllable, it is not recommended for areas where there are nearby structures or residential areas. Smoldering combustion does have the theoretical potential of destroying the most

petroleum mass of all the alternatives, but is not well suited to this Site for the above reasons. Furthermore, because of its development status as a cleanup technology, smoldering combustion does not meet the MTCA requirement of *normally accepted engineering practice* for treatment or removal of LNAPL (see WAC 173-340-360 (2)(c)).

11.2.2 Restoration Timeframe

The estimated RTFs for the Cleanup Actions are shown in Table 46.

As indicated in Section 8.1.2.2, the current Site conditions are favorable for allowing a moderate RTF (~20 years). The evaluation of current Site conditions in relation to the MTCA factors for evaluating reasonableness of RTF indicates that a moderate RTF is justified because:

- The current use of the Site, surrounding areas, and associated resources are not imminently threatened by further releases from the Site because the primary sources of contamination (i.e., the ASTs, sumps, and piping) are no longer operational and, with the exception of some piping, have been removed;
- The impacted groundwater at the Site is part of a sole-source aquifer, but the area of impacted groundwater is limited to the Site itself and alternative water supplies (public water supplies) sourced from areas beyond the Site are readily available;
- The nature of the hazardous substances comprising the contamination (weathered TPH-D/HO and metabolites) and its existing physical condition (i.e., stable or decreasing concentrations) indicate that it can be readily controlled and monitored;
- NSZD is actively reducing concentrations of contamination at the Site;
- The deep contamination appears to be stable (i.e., not expanding) and inaccessible to the general public thereby posing little immediate risk to human health and the environment;
- The residual contamination has a relatively low toxicity as evidenced by the preliminary CULs for subsurface soil and LNAPL being based on residual saturation rather than toxicity; and
- Institutional controls are highly effective and reliable for managing risks from TPH-D/HO in soil and groundwater.

11.2.3 *Comparison of Cumulative DCA Ranks to Costs*

This section presents estimated costs for the deep contamination cleanup actions and compares the costs to the cumulative ranks obtained from the DCA.

Table 47 breaks total costs out by area/media and the action(s) taken for those areas. Note that the table includes costs for the recommended cleanup action for shallow soil (i.e., excavation). Appendix W contains the detailed cost estimation tables. Costs were estimated based on project experience at similar sites, contractor estimates where appropriate, and best professional judgment. The costs are a combination of capital and operating, the latter accounting for monitoring, inspections, maintenance, reporting over the applicable period of time during which the activities occur, and discounted to present value assuming a 3% discount rate. The cost estimates do not include potential impacts from construction of the NSC.

Table 48 summarizes the DCA results using symbols as an alternative visualization tool. Figure 46 charts both the cumulative DCA ranks (bottom of Table 48) and the total estimated costs for the deep contamination cleanup actions. The cumulative rank for Cleanup Action B (bioventing/biosparging) is substantially higher than ranks for the other cleanup actions. The estimated costs for steam enhanced LNAPL removal and smoldering combustion (Cleanup Actions D and E, respectively) are a factor of 3 to 4 times higher than for Cleanup Actions B.

11.3 *RECOMMENDED CLEANUP ACTION*

Based on the information and analysis provided above, the recommended cleanup action for the deep contamination (i.e., intermediate soil, LNAPL, and groundwater) is Cleanup Action B:

- Intermediate Soil: Bioventing
- Low RTF LNAPL Area: NSZD
- Medium and High RTF LNAPL Areas: Bioventing/Biosparging

Important to the success of bioventing will be coupling effective air distribution in the upper part of the smear zone with annual fluctuations in the water table. The water table fluctuation will aid in overcoming potential mass transfer limitations by bringing hydrocarbons into contact with naturally occurring microorganisms. Adding O_2 will encourage higher rates of biodegradation than what occurs now with NSZD. Biosparging will target LNAPL submerged below the silt and silty sand facies layer and aid in promoting delivery of O_2 into the smear zone. Specific design parameters to achieve the most effective air distribution and overall performance would be established during a pilot test program. Performance monitoring data would be used to determine whether and the extent to which enhancements (see Table 42) may be needed to ensure a reasonable RTF.

An NSC alignment through the Site might complicate, but would not preclude, implementation of the recommended cleanup action. The bioventing/ biosparging wells and associated equipment can be configured to avoid the highway infrastructure (see Figure 39). However, installation and operation of a bioventing/biosparging wells within the highway footprint is also technically feasible.

12.0 REFERENCES

Advanced Applied Technology Demonstration Facility for Environmental Technology (AATDF). 1997. *Technology Practices Manual for Surfactants and Cosolvents*. February 1997.

Air Force Center for Environmental Excellence (AFCEE). 1996. *A General Evaluation of Bioventing for Removal Actions at Air Force/Department of Defense Installations Nationwide, General Engineering Evaluation/Cost Analysis (EE/CA)*. AFCEE Technology Transfer Division. Brooks Air Force Base. San Antonio, Texas. June 1996.

Alleman, B.C, R.E. Hinchee, R.C. Brenner, P.T. McCauley. 1995. Bioventing PAH Contamination at the Reilly Tar Site, in In Situ Aeration: Air Sparging, Bioventing, and Related Remediation Processes, Hinchee et al., Ed., 473-482.

Aspect Consulting, Inc. (Aspect). January 2013. *SemMaterials L.P. Spokane Site Remedial Investigation/Feasibility Study Report – Public Review Draft*. Prepared for SemMaterials Potentially Liable Persons Group under Project No. 090190-003-07.

ASTM. 2013. *Standard Guide for Estimation of LNAPL Transmissivity*. Designation: E2856 – 13.

Atwater, B.F. 1986. *Pleistocene Glacial-Lake Deposits of the Sanpoil River Valley, Northeastern Washington.* U.S. Geological Survey Bulletin 1661.

Beckett, G.E., et al. 2006. "User Guide for Data Retrieval" *LNAPL Parameters Database.* American Petroleum Institute.

Belskoski, V.P., et al. 2012. *Chromatography in Environmental Sciences and Evaluation of Bioremediation in Gas Chromatography – Biochemicals, Narcotics and Essential Oils*. Salih, B (Ed.), ISBN: 978-953-51-0295-3. March 2012.

Beyke, G., and D. Fleming. 2005. "In-Situ Thermal Remediation of DNAPL and LNAPL Using Electrical Resistance Heating." *Remediation.* 15.3 (2005): 5-22. Published online in Wiley Online Library (wileyonlinelibrary.com).

Biestel. 2003 and 2004. Personal communication from David Biestel, Environmental Management, Eielson AFB 907-377-5209.

Boleneus, D.E., and R.E. Derkey. 1996. "Geohydrology of the Peone Prairie, Spokane County, Washington." *Washington Geologist*. Vol. 24. No. 1. March.

CH2MHill. 1998. *Wellhead protection Program Phase 1 Technical Assessment Prepared for the City of Spokane Planning and Engineering Services.* February.

CH2MHill. 2000. *Spokane Aquifer Joint Board Wellhead Protection Plan.*

Cline, D.R. 1969. *Ground-water Resources and Related Geology North-Central Spokane and Southeastern Stevens Counties of Washington.* Washington State Department of Water Resources Water Supply Bulletin No. 27.

Dasch, J.M., Abdul, A.S., Rai, D.N., Gibson, T.L., Grosvenor, N. 1997. Synergistic Application of Four Remedial Techniques at an Industrial Site, Ground Water Monitoring & Remediation, 17, no. 3, 194-209.

Derkey, R.E. 1997. *Geologic Map of the Mead 7.5 Minute Quadrangle, Spokane County, Washington*. Washington Division of Geology and Earth Resources Open File Report 97-3. June.

Derkey, R.E., et al. 1998. *Geologic Map of the Dartford 7.5 Minute Quadrangle, Spokane County, Washington*. Washington Division of Geology and Earth Resources Open File Report 98-6. June.

Drost, B.W., and H.R. Seitz. 1977. *Spokane Valley-Rathdrum Prairie Aquifer, Washington and Idaho.* U.S. Geological Survey Open-File Report: 77-829.ERM. 2013a. *Final Remedial Investigation/Feasibility Study Work Plan, BNSF Railway Black Tank Property, 3202 Wellesley Avenue, Spokane, Washington*. January.

ERM. 2013b. *Final Sampling and Analysis Plan: Remedial Investigation/ Feasibility Study, BNSF Railway Black Tank Property, 3202 Wellesley Avenue, Spokane, Washington*. January.

ERM. 2013c. *Final Quality Assurance Project Plan, BNSF Railway Black Tank Property, 3202 Wellesley Avenue, Spokane, Washington*. January.

ERM. 2013d. *Final Site-Specific Health and Safety Plan: Remedial Investigation/Feasibility Study, BNSF Railway Black Tank Property, Spokane, Washington.* Updated October 2013.

ERM. 2014. *Additional Remedial Investigation Data Collection Activities, BNSF Railway Black Tank Property Site, Spokane, Washington.* Letter from David Edwards of ERM to Jeremy Schmidt of Washington Department of Ecology. 15 September.

ERM. 2016. *Final Draft Addendum to the RI/FS Project Plan, BNSF Railway Black Tank Property Site, Spokane, Washington.* Letter from David Edwards of ERM to Jeremy Schmidt of Washington Department of Ecology. 3 March.

GeoEngineers. 2008. *Black Tank Removal, Remedial Excavation, and Supplemental Assessment Report*. May 14.

GeoEngineers. 2010. *Black Tank Supplemental Well Installation and Groundwater Monitoring Report*. August 5.

GeoEngineers. 2011a. *Supplemental Assessment Report*. February 1.

GeoEngineers. 2011b. *Groundwater Monitoring Report, Third and Fourth Quarters 2010*. March 28.

GeoEngineers. 2011c. *Groundwater Monitoring Report, First Quarter 2011*. July 8.

GeoEngineers. 2012. *Groundwater Monitoring Report, 2011 Annual Report*. June 4.

Golder Associates, Inc. 2008. Remedial Investigation/Feasibility Study Work Plan For the SemMaterials, L.P. Spokane Facility, 4327 North Thor Street Spokane, Washington, dated July 24, 2008.

Grant, G.P., et al. 2016. “Smoldering Combustion (STAR) for the Treatment of Contaminated Soils: Examining Limitations and Defining Success.” *Remediation.* 26.3 (2016): 27-51. Published online in Wiley Online Library (wileyonlinelibrary.com).

Griggs. 1973. *Geologic Map of the Spokane Quadrangle, Washington. Idaho, and Montana.* U.S. Geological Survey Miscellaneous Geological Investigations Map 1-768.

Hinchee, R., 2016. BNSF Black Tank Property Key NSZD and Bioventing Issues Presentation. Meeting with Washington State Department of Ecology. December 21, 2016.

Hsieh, P.A., et al. 2007. *Ground-water Flow Model for the Spokane Valley-Rathrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai*

Counties, Idaho. U.S. Geological Survey Scientific Investigations Report 2007-5044.

Hua, Fei and Hong Qi Wang. 2014. Uptake and trans-membrane transport of petroleum hydrocarbons by microorganisms. *Biotechnology & Biotechnological Equipment* 28(2):165-175.

Interstate Technology & Regulatory Council LNAPL Team (ITRC). 2009a. *Evaluating Natural Source Zone Depletion at Sites with LNAPL.* ITRC Document LNAPL-1. April 2009.

ITRC LNAPL Team. 2009b. *Evaluating LNAPL Remedial Technologies for Achieving Project Goals.* December 2009.

ITRC. 2009c. *Light Non-Aqueous Phase Liquids (LNAPLs) Documents.* Interstate Technology & Regulatory Council (ITRC). http://www.itrcweb.org/Guidance/ListDocuments?TopicID=13&SubTopicID=18.

ITRC. 2016. LNAPL Guidance/Training Workshop. http://wvbrownfields.org/wp-content/uploads/2016/09/Randy-Chapman_LNAPL-Guidance_LRS2016.pdf.

Johnson, P.C., Kemblowski, M.W., and Colthart, J.D. 1990. *Quantitative Analysis for the Cleanup of Hydrocarbon-contaminated Soils by In-Situ Soil Venting.* Ground Water, 28, no. 3, 413-429.

Johnson, P.C., P.D. Lundegard and Z. Liu. 2006. Source Zone Natural Attenuation at Petroleum Hydrocarbon Spill Sites – I: Site-Specific Assessment Approach, Ground Water Monitoring and Remediation, 26(4):82-92.

Jones & Stokes (J&S). 2007. Natural Resources along Urban Connector Alignment Map prepared for the Notice of Application, SEPA Environmental Checklist for the Bigelow Gulch Road/Forker Road Urban Connector project.

Joseph, N.L. 1990. *Geologic Map of the Spokane 1:100,000 Quadrangle, Washington – Idaho.* Washington State Department of Natural Resources Open File Report 90-17.

Kahle, S.C. and J.R. Bartolino. 2007. *Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County,* *Washington, and Bonner and Kootenai Counties, Idaho*. U.S. Geological Survey Scientific Investigations Report 2007–5041.

Kahle, et al. 2005. Compilation of Geologic, Hydrologic, and Ground-Water Flow Modeling Information for the Spokane Valley – Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. U.S. Geological Survey Scientific Investigation Report 2005-5227.

Kueper, B., 2016. BNSF Black Tank Property Key LNAPL and SEE Issues Presentation. Meeting with Washington State Department of Ecology. December 21, 2016.

Lee, J. et al. 2001. Evaluation of Soil Vapor Extraction and Bioventing for a Petroleum Contaminated Shallow Aquifer in Korea, Soil and Sediment Contamination, 10(4):439-458.

Lee, M.D. and M. Swindoll. 1993. Bioventing for In Situ Remediation, Hydrological Sciences, 38(4):273-282.

Leeson et al. 1995. Bioventing Feasibility Study at Eielson AFB, Alaska, Report to Armstrong Laboratory, USAF, AL/EQ-TR-95-21.

Lundegard, P.D. and P.C. Johnson. 2006. Source Zone Natural Attenuation at Petroleum Hydrocarbon Spill Sites – II: Application to a Former Oil Field, Ground Water Monitoring and Remediation, 26(4):93-106.

Lyverse, M. 2014. Natural Source Zone Depletion: Research Initiatives and Use of Results, Ninth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA.

McCoy, K., J. Simbron, T. Sale, and M. Lyverse. 2014. Measurement of Natural Losses of LNAPL Using CO2 Traps, Groundwater, doi: 10.1111/gwat. 12240 (electron printing).

Mercer, James W., and Robert M. Cohen (Mercer & Cohen). 1990. "A Review of Immiscible Fluids in the Subsurface: Properties, Models, Characterization, and Remediation." *Journal of Contaminant Hydrology*, Elsevier Science Publishers B.V., Amsterdam, 6 (1990) 107-163.

Palaia, T. et al. 2014. Variability in Flux Chamber-Based CO2 Efflux Measurements at Petroleum Remediation Sites, Ninth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA.

Reynolds, C.M. et al. 1997. Soil Remediation Demonstration Project: Biodegradation of Heavy Fuel Oils, US Army Corps of Engineers Cold Regions Research & Engineering Laboratory, Special Report 97-20.

Ron, Eliora Z. and Eugene Rosenberg. 2002. Biosurfactants and oil bioremediation. *Current Opinion in Biotechnology* 13:249-252.

Ron, Eliora Z. and Eugene Rosenberg. 2001. Minireview: Natural roles of biosurfactants. *Environmental Microbiology* 3(4):229-236.

San Juan, Charles (Washington State Department of Ecology, Toxics Cleanup Program). 1994. *Natural Background Soils Metals Concentrations in Washington State.* October, 1994; Publication No. 94-115.

San Francisco Bay Regional Water Quality Control Board. 2016. Petroleum Metabolites, Literature Review and Assessment Framework, Technical Resource Document 50p.

Savron Solutions. n.d. *Full-scale Implementation of STAR Technology.* Savron Solutions. http://savronsolutions.com/.

Schaap, M.G. 1999. *U.S. Salinities Laboratory Database.* Rosetta Model. http://www.ars.usda.gov/Services/docs.htm?docid=8953.

Shreve, G.S., S. Inguva and S. Gunnam. 1995. Rhamnolipid biosurfactant enhancement of hexadecane biodegradation by *Pseudomonas aeruginosa. Molecular Marine Biology and Biotechnology* 4(4):331-337.

Trowbridge, B.E., and Malot, J.J. 1990. *Soil Remediation and Free Product Removal Using In-Situ Vacuum Extraction with Catalytic Oxidation.* In Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring, and Geophysical Methods. Las Vegas, Nevada, May 14-17.

United States Department of Transportation. 2013. *Federal Highway Administration Design Manual: Deep Mixing for Embankment and Foundation Support.* Publication No. FHWA-HRT-13-046. October.

United States Environmental Protection Agency (USEPA). 1995a. Bioventing Principles and Practice, Volume I: Bioventing Principles, EPA/540/R-95/534a.

USEPA. 1995b. Bioventing Principles and Practice, Volume II: Bioventing Design, EPA/625/XXX/001.

USEPA. 1996a. Assessing UST Corrective Action Technologies: In Situ SVE-Based Systems for Free Product Recovery and Residual Hydrocarbon Removal, EPA/600/R-96/042.

USEPA. 1996b. *Groundwater Issue: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures.*USEPA. 1999. *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review.* United States Environmental Protection Agency.

USEPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*. Document No. OSWER 9355.4-24, December 2002.

USEPA. 2004. *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.* United States Environmental Protection Agency.

Washington State Department of Ecology (Ecology). 2000. Cleanup Action Plan, North Market Street Site, FS ID#: 667.

Ecology. 2004. *Ecology Implementation Memorandum #4 – Determining Compliance with Method A CULs for Diesel and Heavy Oil dated 17 June 2004.*

Ecology. 2005. *User's Manual: Natural Attenuation Analysis Tool Package for Petroleum-Contaminated Ground Water.* Washington State Department of Ecology, Toxics Cleanup Program Publication No. 05-09-091A (Version 1.0). July 2005.

Ecology. 2006. *Minimum Standards for Construction and Maintenance of Wells* (Chapter 173-160 WAC). Washington State Department of Ecology. Updated November.

Ecology. 2008. Periodic Review, North Market Street Site, FS ID#: 667.

Ecology. 2012. *Agreed Order No. 9188. In the Matter of Remedial Action at: BNSF Railway Black Tank Property, Spokane County, WA*. Signed August 2012.

Ecology. 2013. *SemMaterials Site Fact Sheet*. Accessed in March. https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=3229.

Ecology. 2014a. *Aluminum Recycling Corp* site information on the Department of Ecology website. Accessed 10 September 2014. https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=1133.

Ecology. 2014b. BNSF Hillyard Lead Soil Site information on the Department of Ecology website. Accessed 11 September 2014. https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=1371.

Ecology. 2014c. BNSF RR Bunker C Spill Area site information on the Department of Ecology website. Accessed 11 September 2014. https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=2829.

Ecology. 2014d. BNSF Railway Black Tank Property Site: Approval of Additional Remedial Investigation Data Collection Activities and RI/FS Submittal Extension. Letter from Jeremy Schmidt of Ecology to Bruce Sheppard of BNSF and Will Ratliffe of Husky Oil. 24 September.

Ecology. 2014e. Cleanup Levels and Risk Calculation (CLARC) data tables on the Department of Ecology website. https://fortress.wa.gov/ecy/clarc/CLARCDataTables.aspx.

Ecology. 2014f. Second Periodic Review, Washington Water Power Central Steam Plant, FS ID#: 726, Cleanup Site ID#: 682.Fam, S., et. al. 1995. Critical State of the Art Review of Vapor Extraction. In Proceedings of the Purdue Industrial Waste Conference, 50:137.

Ecology. 2014g. Washington State Well log Viewer. Accessed 19 November 2014. https://fortress.wa.gov/ecy/waterresources/map/WCLSWebMap/default.aspx.

Ecology. 2015. BNSF Railway Black Tank Property Site: Ecology Comments on RI/FS. Letter from Jeremy Schmidt of Ecology to Dave Edwards of ERM. July 28.

Ecology. 2016a. BNSF Railway Black Tank Property Site – Ecology Approval of Final Draft Addendum to the RI/FS Work Plan. Letter from Jeremy Schmidt of Ecology to Dave Edwards of ERM. March 10.

Ecology. 2016b. *Guidance for Remediation of Petroleum Contaminated Sites*. Washington State Department of Ecology, Toxics Cleanup Program Publication No. 10-09-057. September.

Washington State Department of Health (WDOH). March 2005. *Health Consultation, BNSF Hillyard Lead Site, Spokane, Spokane County, Washington, EPA Facility ID: WAD000812883.*

WSDOH. 2014a. Source Water Assessment Program (SWAP) Interactive GIS Mapping Tool. Accessed 18 November 2014. https://fortress.wa.gov/doh/eh/dw/swap/maps/.

WSDOH. 2014b. Washington State Water System Data Sentry Internet. Accessed 18 November 2014. https://fortress.wa.gov/doh/eh/portal/odw/si/Intro.aspx.

Washington State Department of Transportation (WSDOT). 2016. *North Spokane Corridor Quick Facts*. March.

Xu, J., Chen, Z.J., Cao, J. and Li, R. 2014. *Numerical study of the effects of lean zones on SAGD performance in periodically heterogeneous media.* SPE-170138-MS. Society of Petroleum Engineering.

Zeman, Natalie Rae. 2013. *Thermally Enhanced Bioremediation of LNAPL*. Thesis for the Degree of Master of Science, Colorado State University, Department of Civil and Environmental Engineering. Spring. Zemo, et al. 2013. *Nature and Estimated Human Toxicity of Polar Metabolite Mixtures in Groundwater Quantified as TPHd/DRO at Biodegrading Fuel Release Sites*. Ground Water Monitoring & Remediation, v33 n4: 44-56. DOI: 10.1111/gwmr.12030.

Zemo, et. al. 2014. *Nature and Estimated Toxicity of Polar Metabolite Mixtures in Groundwater Quantified as Extractable "TPH" at Biodegrading Fuel Release Sites*. NEBC Technical Seminar. October.

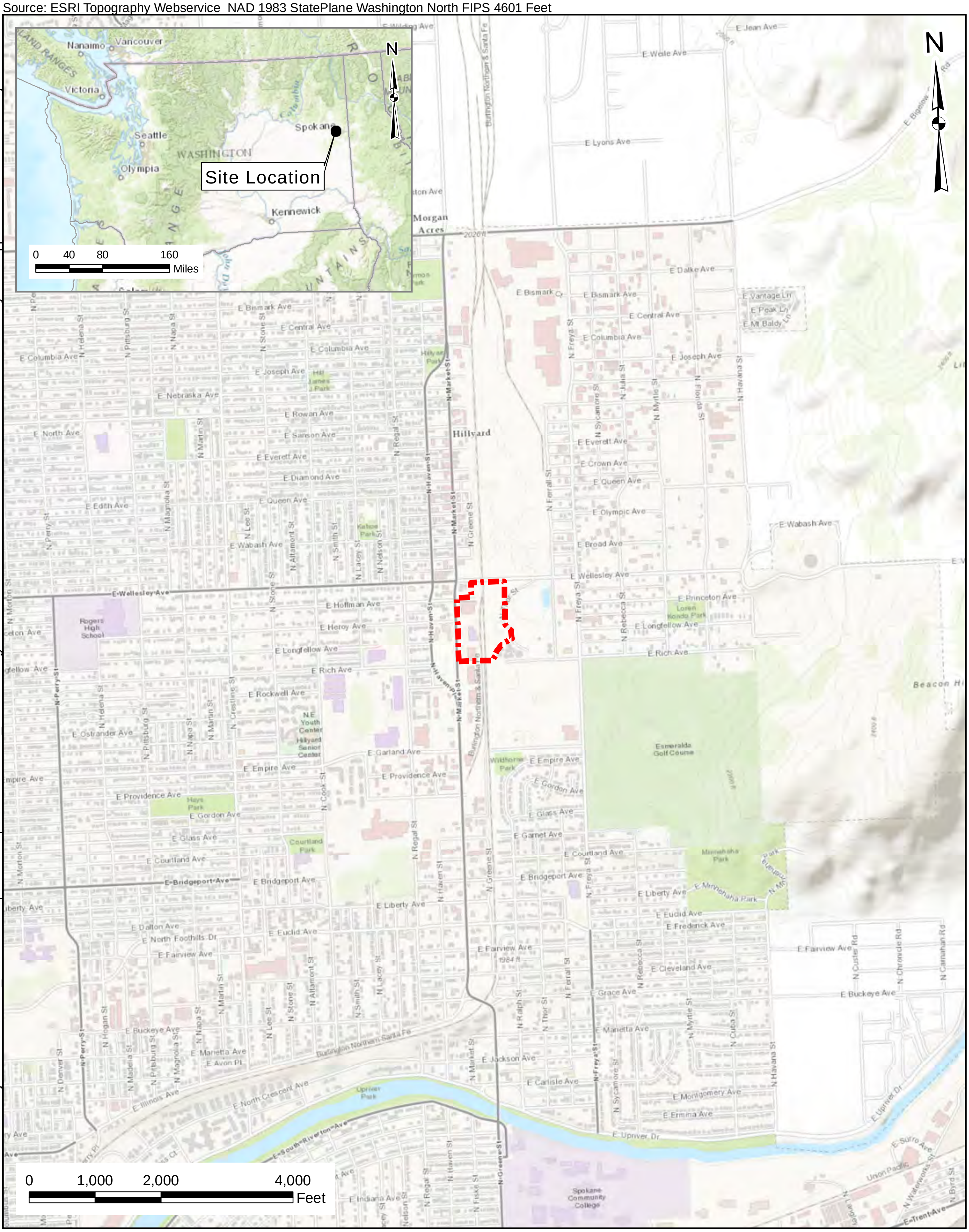
Zemo. 2015. *Work Shop: Nationwide Trends and Developments in Cleanup Levels for Petroleum Hydrocarbons "Drilling Down on Details."* Association for Environmental Health Sciences West Coast Conference. March 24.

Figures

DRAFT

Source: ESRI Topography Webservice NAD 1983 StatePlane Washington North FIPS 4601 Feet

\\WDWALVS02\Data\Projects\BNSF\BNSF BlackTank\maps\RIFS Report\RevisedDraft 2016June\Figure 1 Site Location.mxd Created By: Mike Appel Date: 7/1/2016 Project: 0197977



Legend

🟥 Proposed BNSF Black Tank Site Boundary

Environmental Resources Management
www.erm.com
ERM

Figure 1
Site Location
BNSF Black Tank
Spokane, Washington

DRAFT

\\WDWALVS02\Data\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 2 Site Layout.mxd

Drawn By: Austin Phelps Date: 7/14/2016 Project: 0197977

Legend

- SemMaterials Monitoring Well
- SemMaterials Direct-Push Boring
- SemMaterials L.P. Spokane Site Boundary
- Aluminum Recycling Corporation, BNSF Dross Cap Site Boundary
- BNSF Hillyard Lead Site
- Former Black Tank Excavation

Tax Parcel Ownership

- BNSF-Owned Properties
- Other-Owned Properties
- WSDOT-Owned Properties
- WSDOT-Managed Easements
- Proposed BNSF Black Tank Site Boundary
- Historical Aboveground Storage Tank
- Black Tank Oil Pipeline (1937)
- Red Tank Oil Pipeline (1937)
- Chemical Solution Pipeline (1937)
- Liquid Asphalt Pipeline (1956)
- Steam Pipeline
- Water Pipeline

N

0 60 120 240 Feet

Notes:
Aerial Photo: USGS, April 2012.

Figure 2

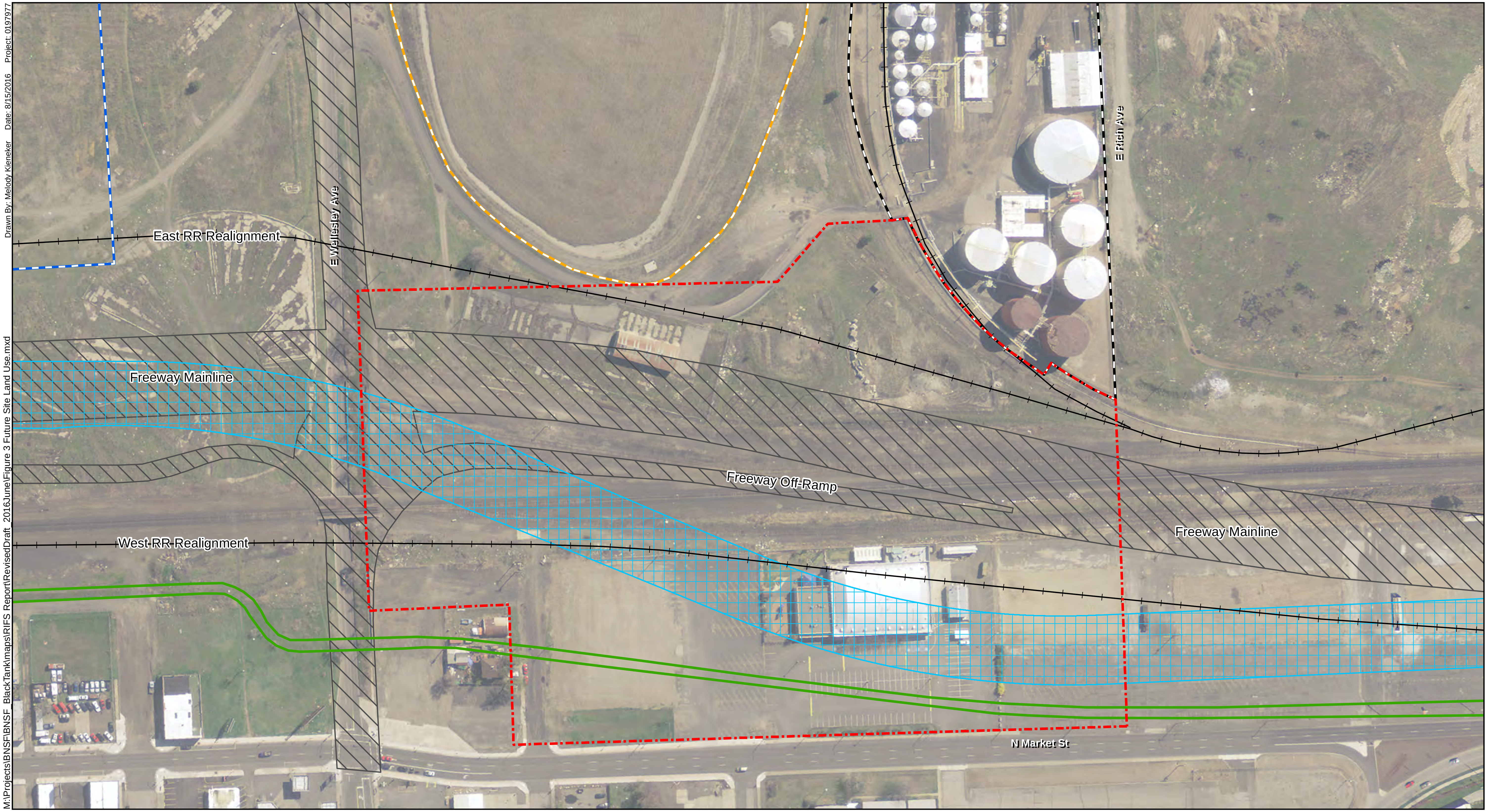
Site Layout and Tax Parcels
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 3 Future Site Land Use.mxd

Drawn By: Melody Kieneker Date: 8/15/2016 Project: 0197977



Legend

- SemMaterials L.P. Spokane Site Boundary
- Aluminum Recycling Corporation, BNSF Dross Cap Site Boundary
- BNSF Hillyard Lead Site
- Proposed BNSF Black Tank Site Boundary
- DOT Proposed Highway Alignment Option - 2016
- DOT Proposed Highway Alignment Option - 2014
- DOT Proposed Pedestrian Pathway - 2014
- DOT Proposed Railroad Realignment Option - 2014

N

0 75 150 300 Feet

Notes:
Aerial Photo: USGS, April 2012.
Source: Washington State Department of Transportation (WSDOT).
July 2014. North Spokane Corridor Quick Facts.
http://www.wsdot.wa.gov/Projects/US395/NorthSpokaneCorridor/nscdesignvix.htm

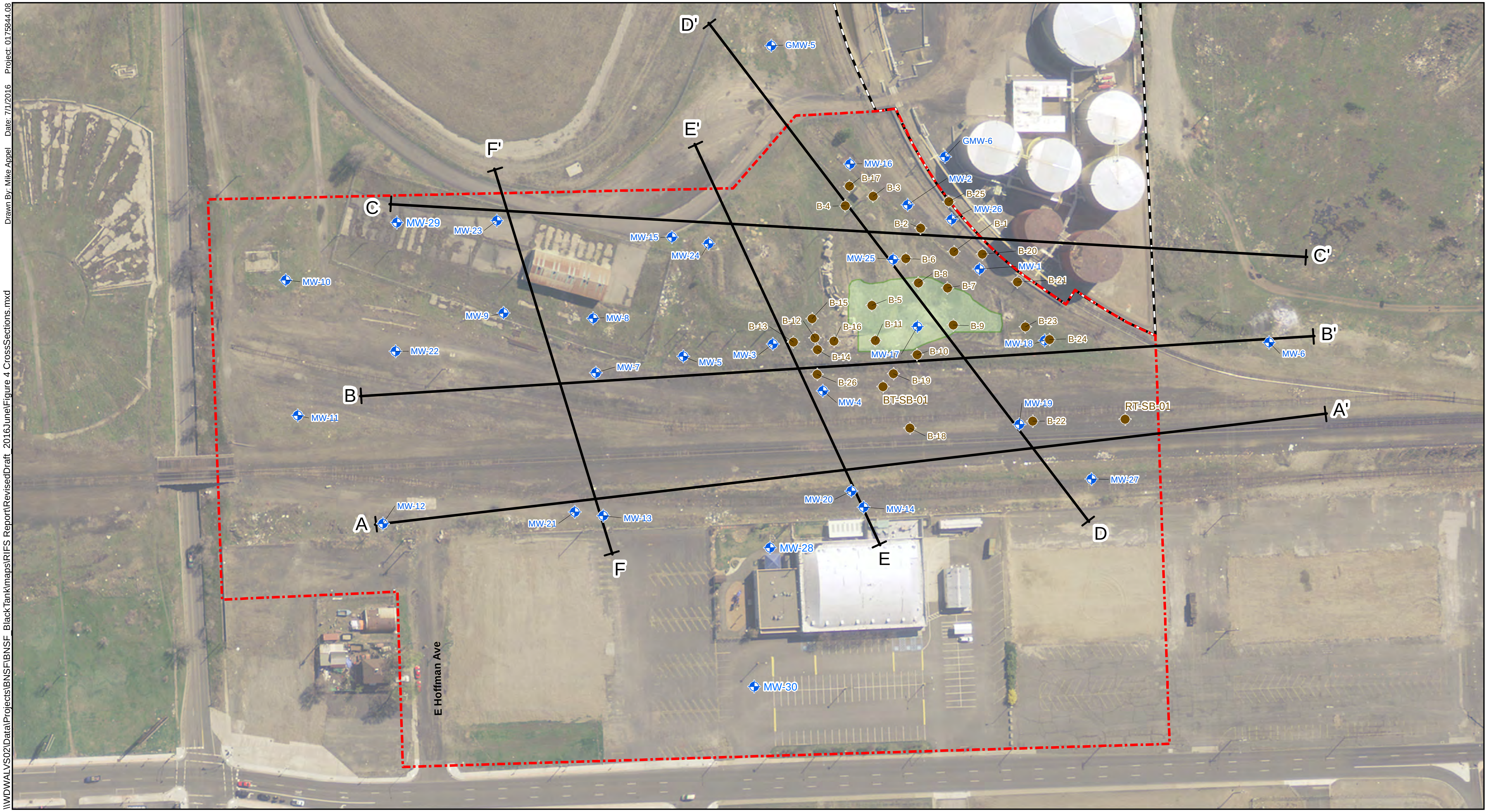
Figure 3

Future Site Land Use
Proposed Highway Alignments
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

\\WDWALVS02\Data\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 4 CrossSections.mxd Drawn By: Mike Appel Date: 7/1/2016 Project: 0175844.08



Legend

✦	Monitoring Well
●	Soil Boring
▭	Proposed BNSF Black Tank Site Boundary
▭	SemMaterials L.P. Spokane Site Boundary
🟩	Former Black Tank Excavation
⊢⊣	Cross Section Line

N

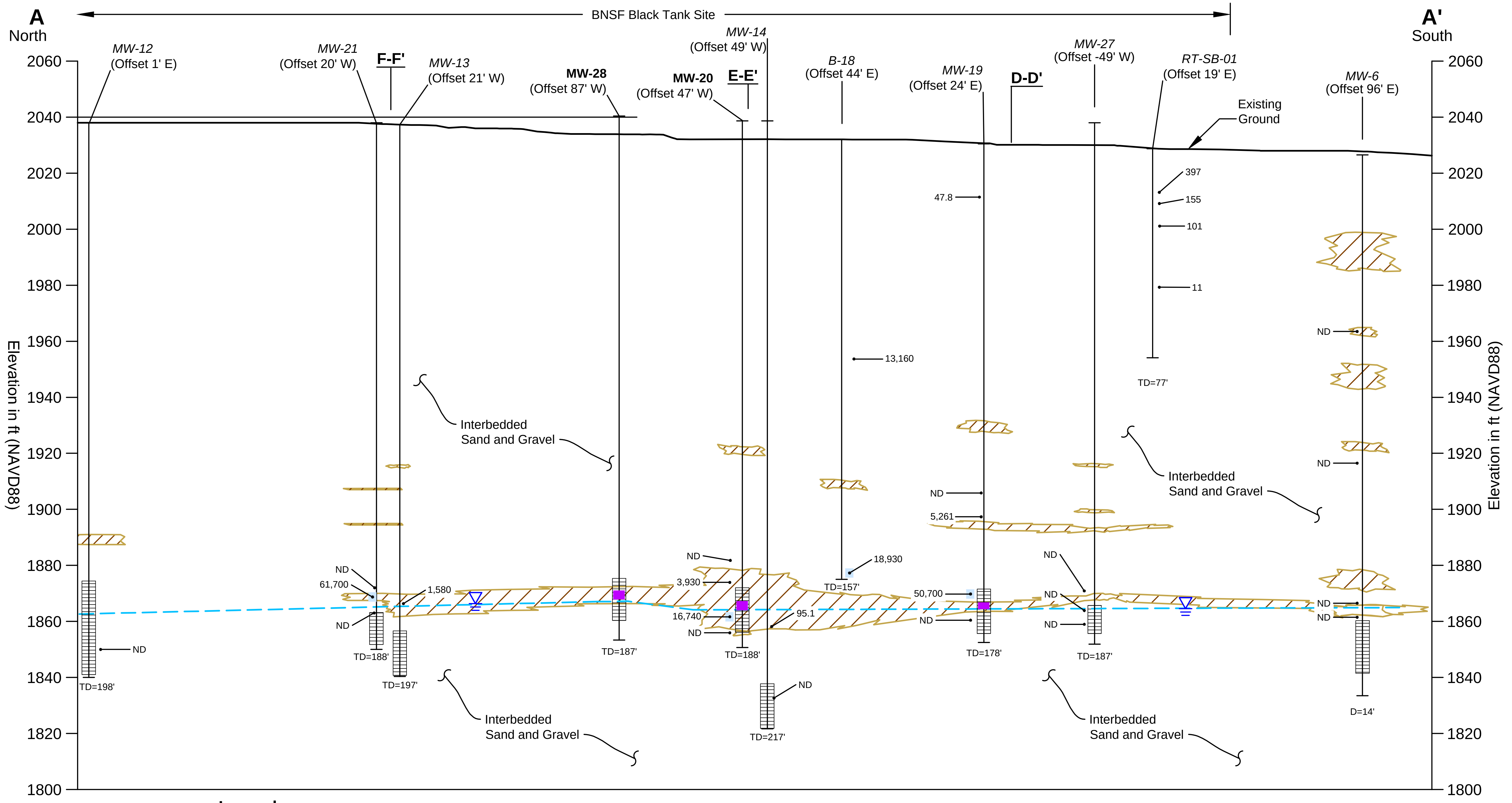
0 50 100 200 Feet

Notes:
LNAPL = Light Non-Aqueous Phase Liquid.
Aerial Photo: USGS, April 2012.

Figure 4
Cross Section Locations
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT



Legend

MW-18 — New Exploration Designation

MW-6 — Existing Exploration Designation

(Offset 22' W) — Offset Distance in Feet and Direction

Top of Exploration

Silt and Silty Sand Facies

Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level

Inferred Groundwater Table

Approximate Groundwater Level

397 — TPH-D/HO Concentration in Soil (mg/kg)

Well Screen Interval (If Installed)

LNAPL Present in Well

Bottom of Exploration

TD=193' — Total Depth of Exploration (feet BGS)

mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

(Vertical Exaggeration = 2.5X)

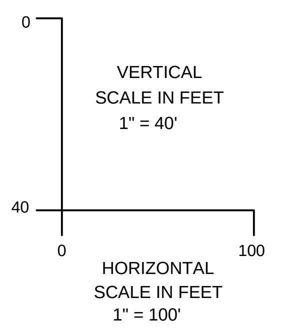
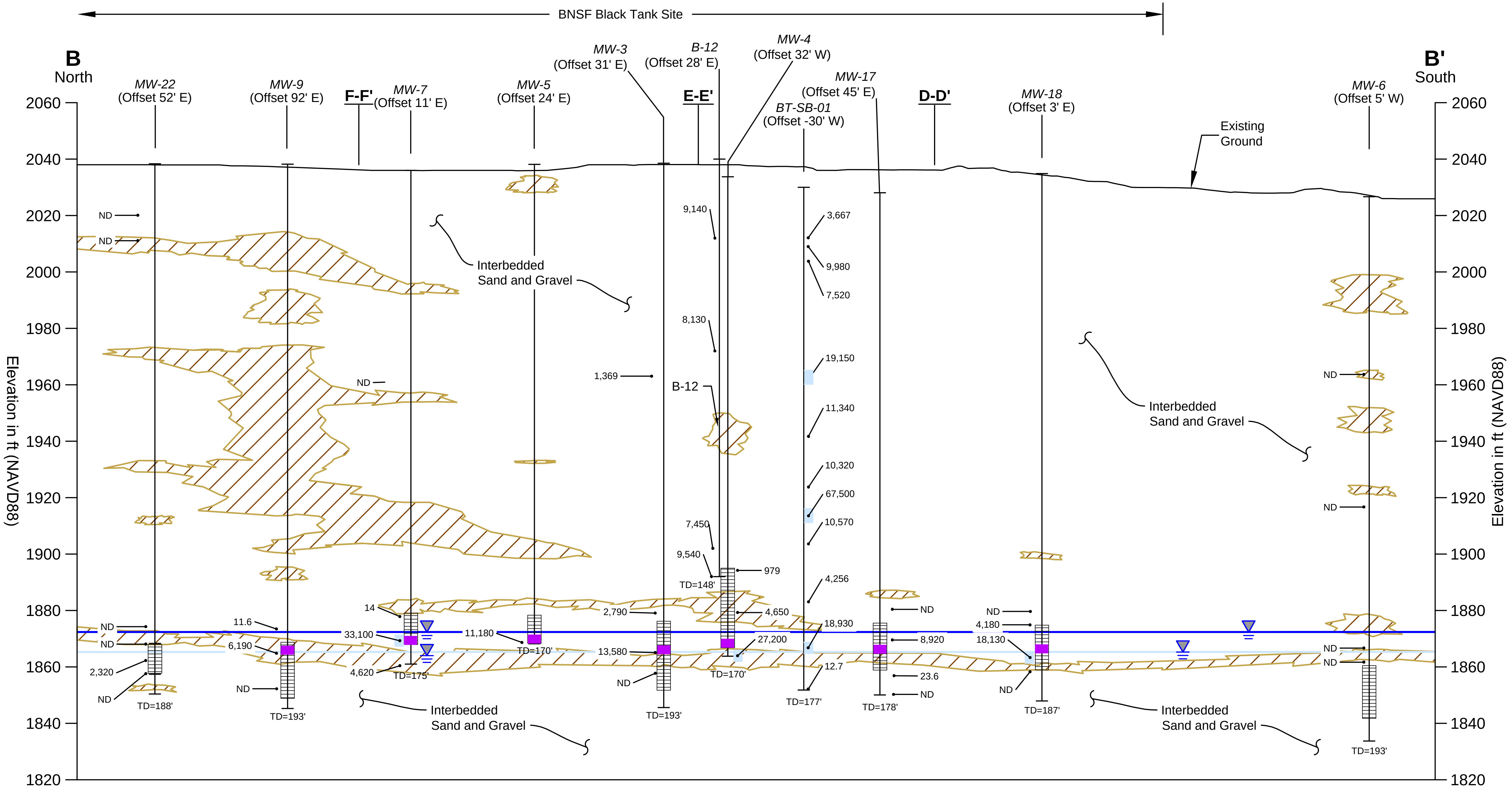


Figure 5
Geologic Profile A-A'
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

\\wdwalfs01\CAD\DWGS\0175844-BNSF Black Tanks\23\01758423-01.dwg
0175844.23
3/06/2017
R. Olson/JSE

DRAFT



Legend

MW-18 — New Exploration Designation
MW-6 — Existing Exploration Designation
(Offset 22' W) — Offset Distance in Feet and Direction
⊤ — Top of Exploration
▨ — Silt and Silty Sand Facies
▮ — Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level
— Approximate High Groundwater Level
— Approximate Low Groundwater Level
▽ — Approximate Groundwater Level
397 • — TPH-D/HO Concentration in Soil (mg/kg)
▤ — Well Screen Interval (If Installed)
■ — LNAPL Present in Well
⊥ — Bottom of Exploration
TD=193' — Total Depth of Exploration (feet BGS)

mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

(Vertical Exaggeration = 2.5X)

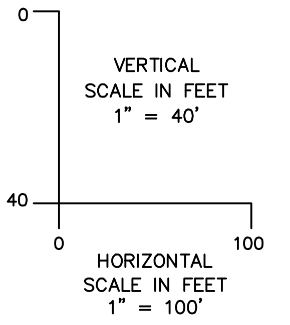
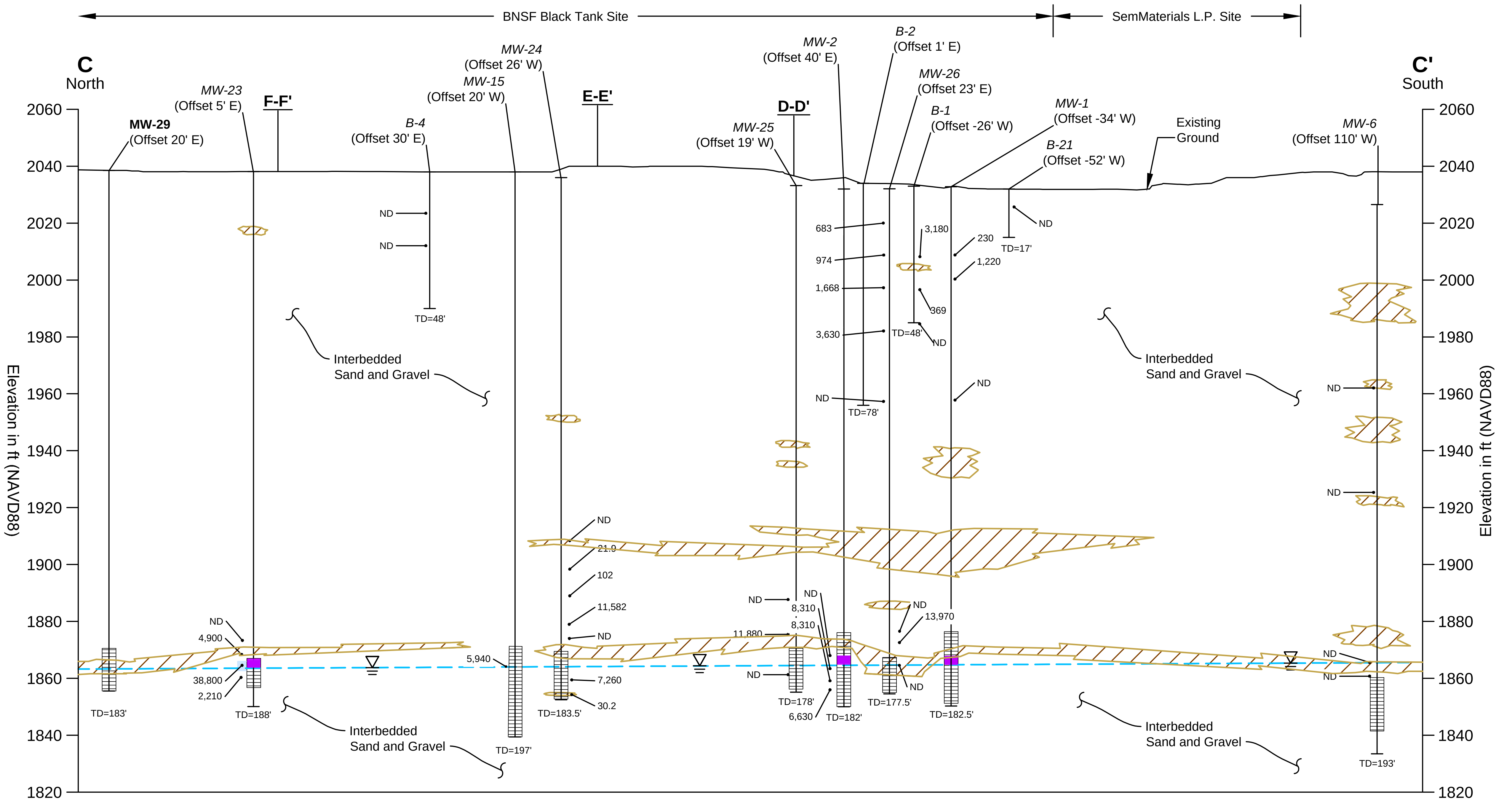


Figure 6
Geologic Profile B-B'
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

\\wdwalfs01\CAD\DWGS\0175844–BNSF Black Tanks\23\017584423–02.dwg
0175844.23
3/06/2017
R. Olson\jse

DRAFT



Legend

MW-18 — New Exploration Designation

MW-6 — Existing Exploration Designation

(Offset 22' W) — Offset Distance in Feet and Direction

— Top of Exploration

— Silt and Silty Sand Facies

— Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level

— Inferred Groundwater Table

— Approximate Groundwater Level

397 — TPH-D/HO Concentration in Soil (mg/kg)

— Well Screen Interval (If Installed)

— LNAPL Present in Well

— Bottom of Exploration

TD=193' — Total Depth of Exploration (feet BGS)

mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

(Vertical Exaggeration = 2.5X)

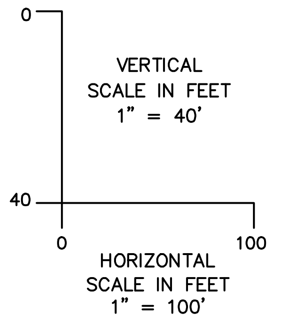


Figure 7

Geologic Profile C-C'
BNSF Black Tank
Spokane, Washington

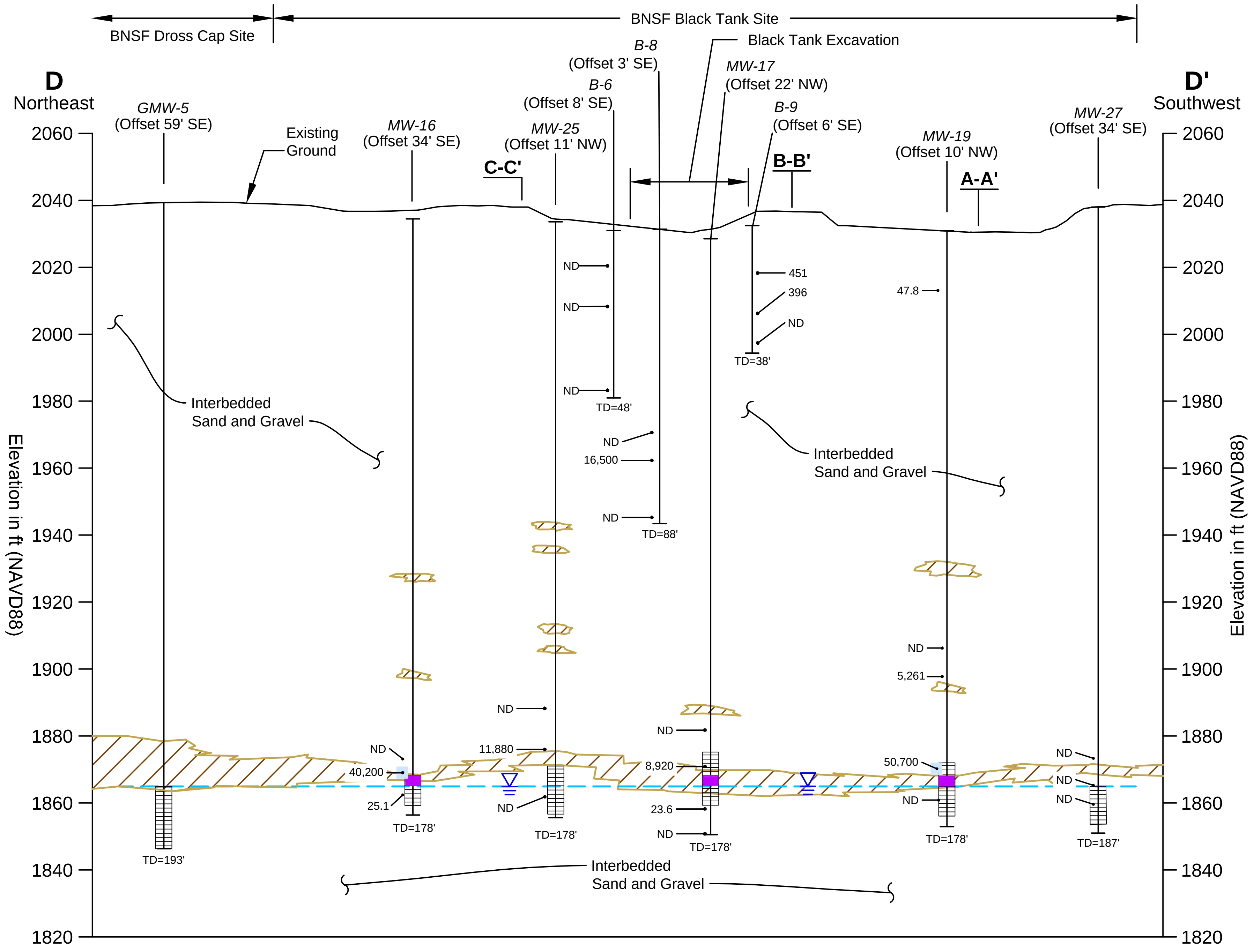
Environmental Resources Management
www.erm.com
ERM

\\wdalfs01\CAD\DWGS\0175844–BNSF Black Tanks\23\017584423–03.dwg

0175844.23

3/06/2017

R. Olson\jse



Legend

- MW-16 — Existing Exploration Designation
- (Offset 11' NW) — Offset Distance in Feet and Direction
- ⊤ — Top of Exploration
- ▨ — Silt and Silty Sand Facies
- ▯ — Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level
- \- - - — Inferred Groundwater Table
- ▽ — Approximate Groundwater Level
- 397 ● — TPH-D/HO Concentration in Soil (mg/kg)
- ▤ — Well Screen Interval (If Installed)
- ■ — LNAPL Present in Well
- ⊥ — Bottom of Exploration
- TD=193' — Total Depth of Exploration (feet BGS)

mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

(Vertical Exaggeration = 2.5X)

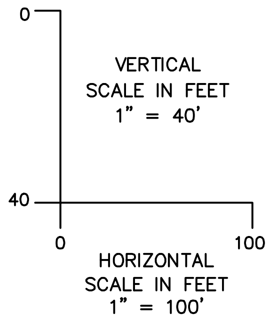
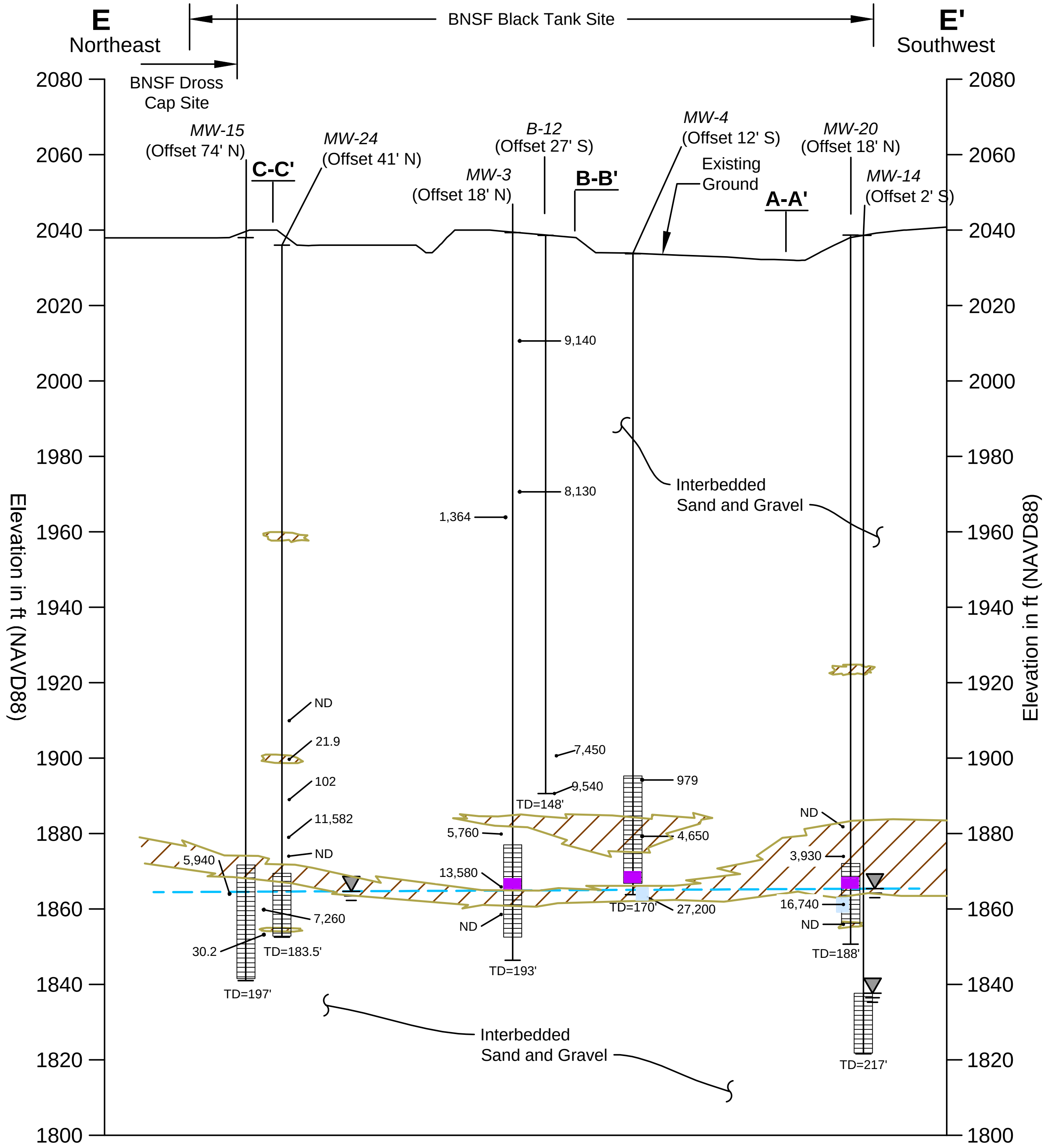


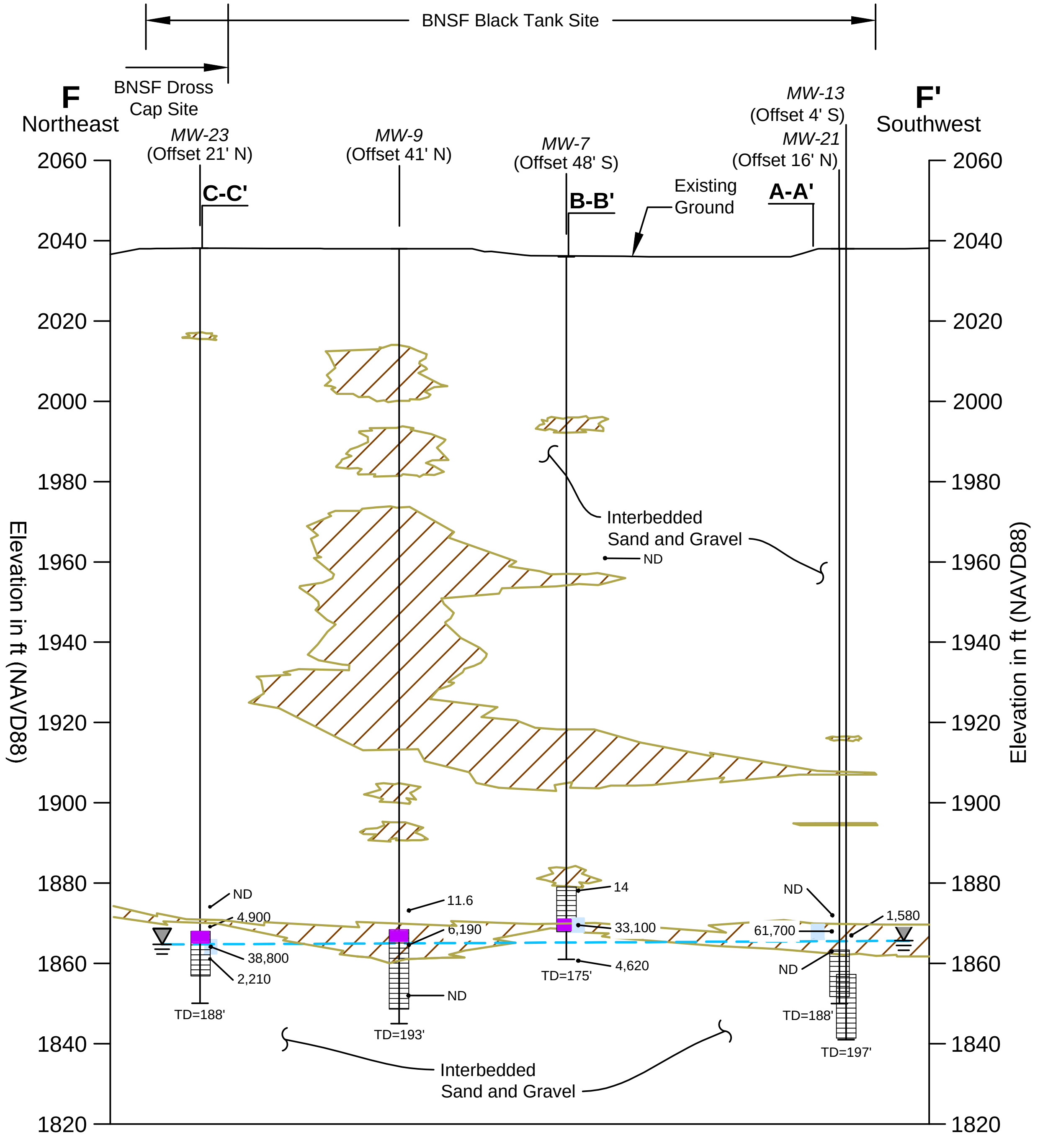
Figure 8
Geologic Profile D-D'
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

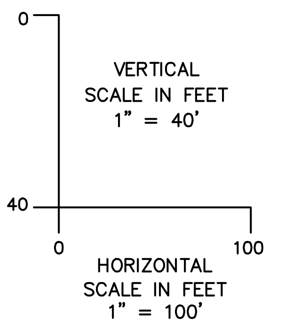
\\wdwalfs01\CAD\DWGS\0175844-BNSF Black Tanks\23\01758423-04.dwg
017584.23
3/06/2017
R. Olson\jse

DRAFT





(Vertical Exaggeration = 2.5X)



mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

Legend

MW-6	Existing Exploration Designation
(Offset 22' W)	Offset Distance in Feet and Direction
┬	Top of Exploration
▨	Silt and Silty Sand Facies
▯	Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level
— — —	Inferred Groundwater Table
▽	Approximate Groundwater Level
397 ●	TPH-D/HO Concentration in Soil (mg/kg)
▤	Well Screen Interval (If Installed)
■	LNAPL Present in Well
┴	Bottom of Exploration
TD=193'	Total Depth of Exploration (feet BGS)

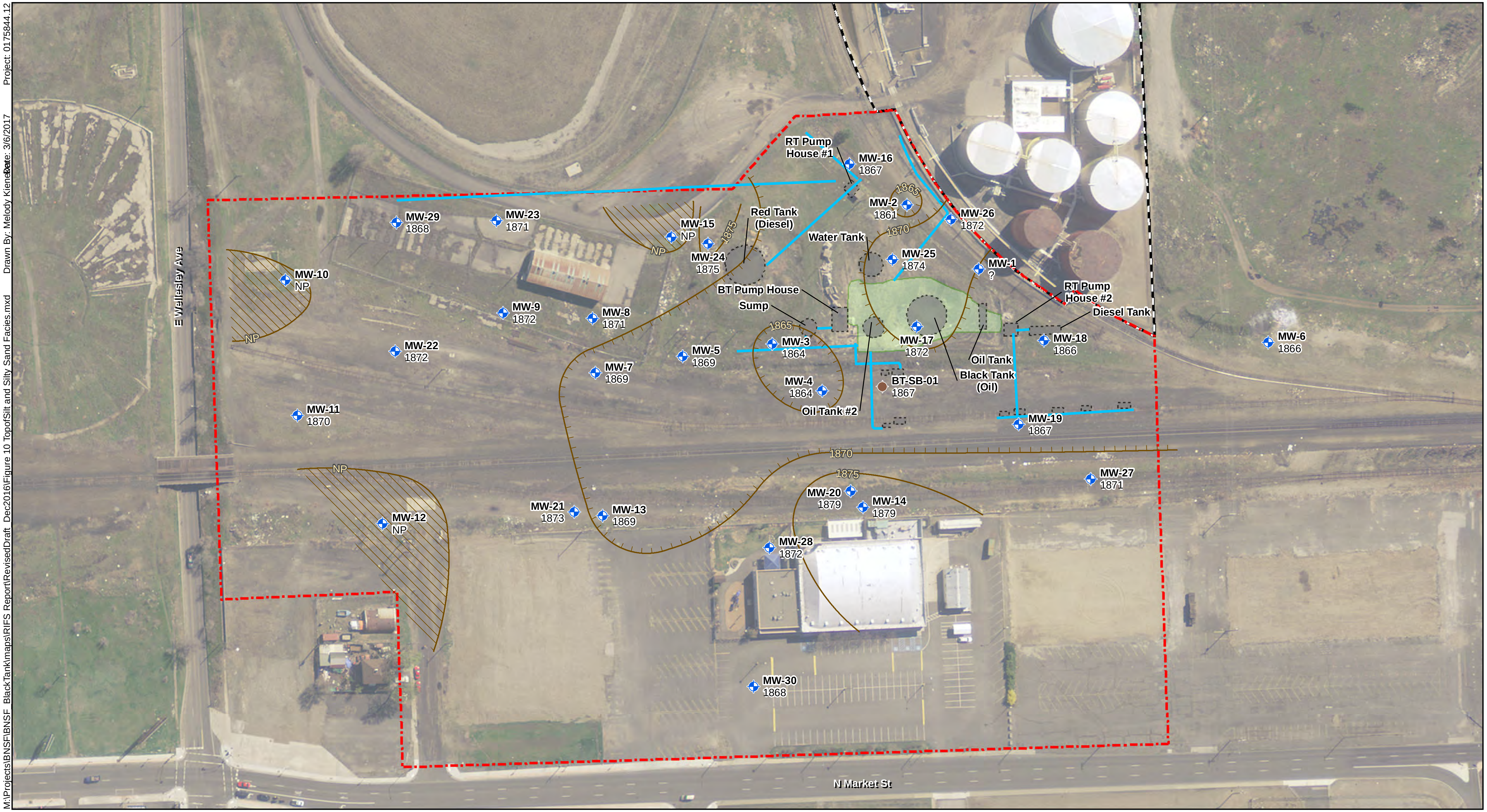
Figure 9
Geologic Profiles E-E' and F-F'
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

\\wdwalfs01\CAD\DWGS\0175844-BNSF Black Tanks\23\01758423-05.dwg
0175844.23
3/06/2017
R. Olson\jse

DRAFT

M:\Projects\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 10 TopofSilt and Silty Sand Facies.mxd Drawn By: Melody Kiene Date: 3/6/2017 Project: 0175844.12



Legend

⌖	Monitoring Well with Bottom of Smear Zone Elevation (ft amsl)	—	Top of Silt and Silty Sand Facies Layer Contour	▭	SemMaterials L.P. Spokane Site Boundary		
●	Soil Boring with Bottom of Smear Zone Elevation (ft amsl)	⊥⊥	Top of Silt and Silty Sand Facies Layer Depressional Contour	🟩	Former Black Tank Excavation		
—	Existing Piping (Petroleum and Chemical Solution)	▨	Silt and Silty Sand Facies Layer Not Present	▩	Historical Aboveground Storage Tank		
		▭	Proposed BNSF Black Tank Site Boundary				

Notes:
amsl = above mean sea level
BT = Black Tank System
ft = Feet
RT = Red Tank System
Aerial Photo: USGS, April 2012.

N

0 60 120 240
Feet

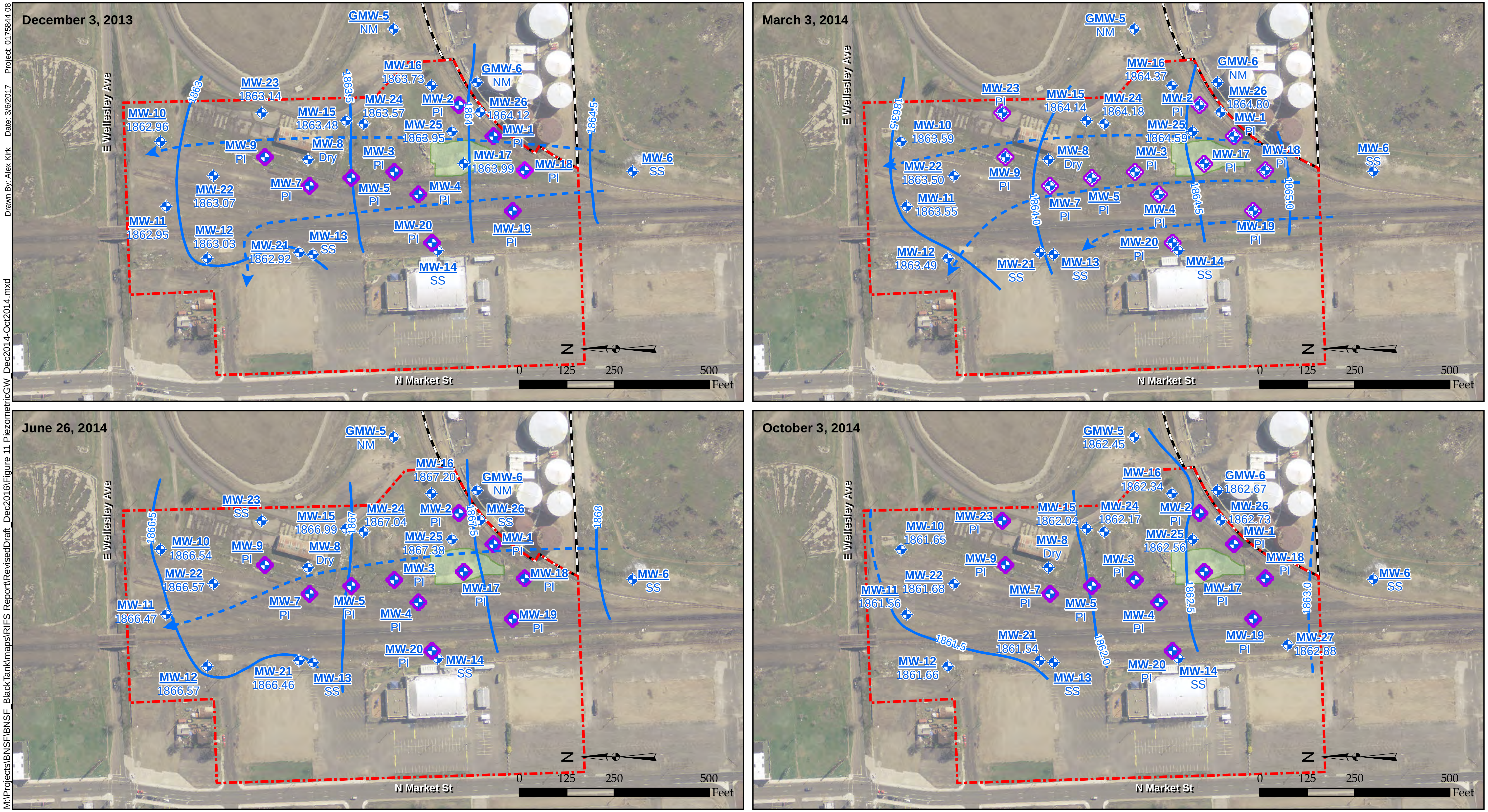
Figure 10

Top of Silt and Silty Sand Facies Layer Structure Contour Map
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 11 PiezometricGW_Dec2014-Oct2014.mxd Drawn By: Alex Kirk Date: 3/6/2017 Project: 0175844.08



Legend

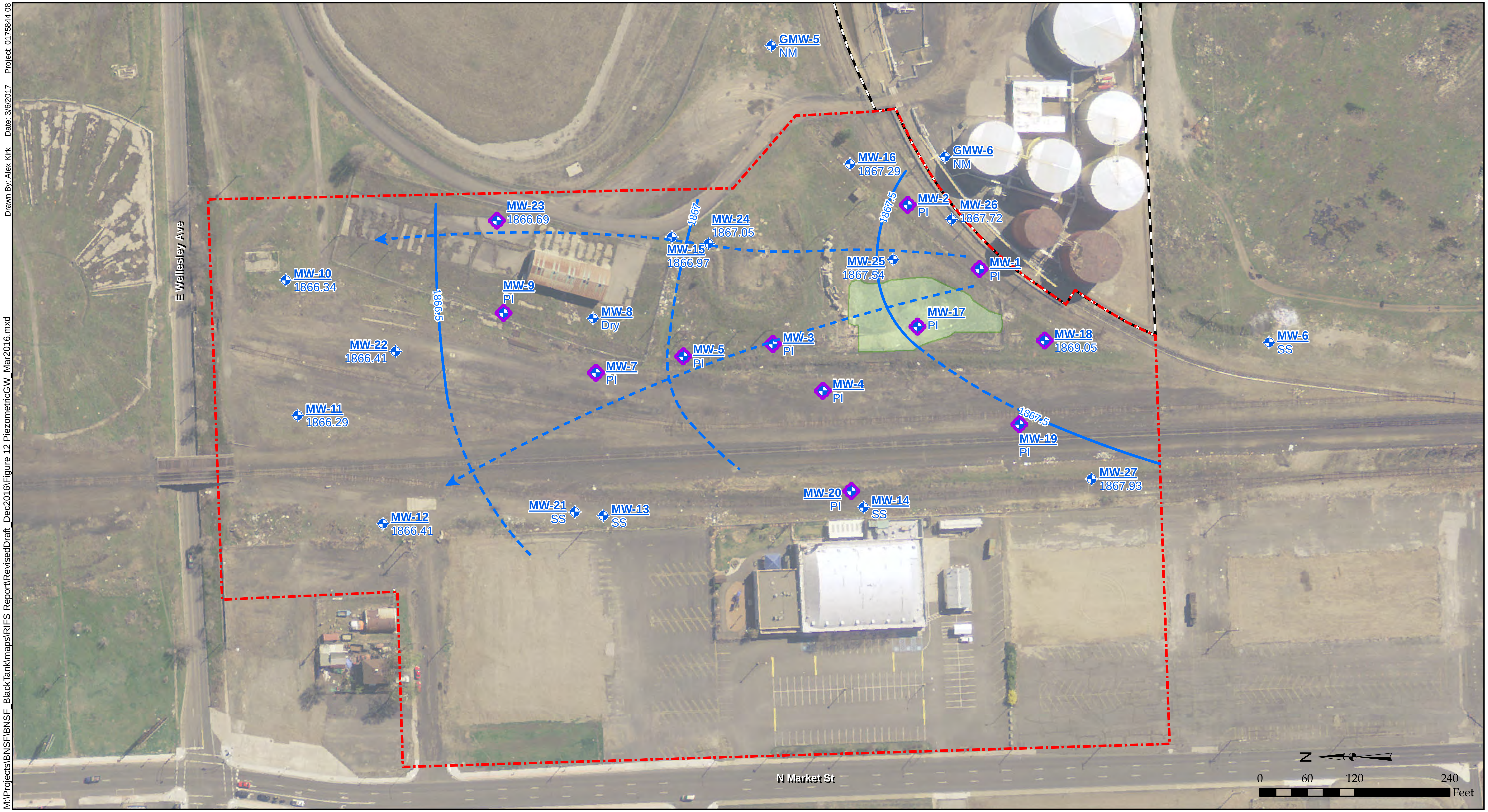
- ◆ Monitoring Well with Measurable LNAPL
- ⊕ Monitoring Well with Groundwater Elevation
- 🟩 Former Black Tank Excavation
- ▭ Proposed BNSF Black Tank Site Boundary
- ▭ SemMaterials L.P. Spokane Site Boundary
- ⁓ Confirmed Groundwater Elevation Contour
- ➜ Groundwater Flow Direction

Notes:
Dry = No water detected or water level was below screened interval.
LNAPL = Light Non-Aqueous Phase Liquid.
NM = Not Measured.
PI = Product interference precluded accurate water level measurement.
SS = Well screened below the water table; screen is submerged.
All elevations in Feet Above Mean Sea Level (ft. AMSL).
Contour Interval = 0.5 feet.
Aerial Photo: USGS, April 2012.

Figure 11
Piezometric Surface Map
Groundwater Monitoring
December 2013 to October 2014
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT



M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 12 PiezometricGW_Mar2016.mxd

Drawn By: Alex Kirk Date: 3/6/2017 Project: 0175844.08

Legend

- Monitoring Well with Measurable LNAPL
- Monitoring Well with Groundwater Elevation
- 🟩 Former Black Tank Excavation
- Proposed BNSF Black Tank Site Boundary
- SemMaterials L.P. Spokane Site Boundary
- Confirmed Groundwater Elevation Contour
- Inferred Groundwater Elevation Contour
- Groundwater Flow Direction

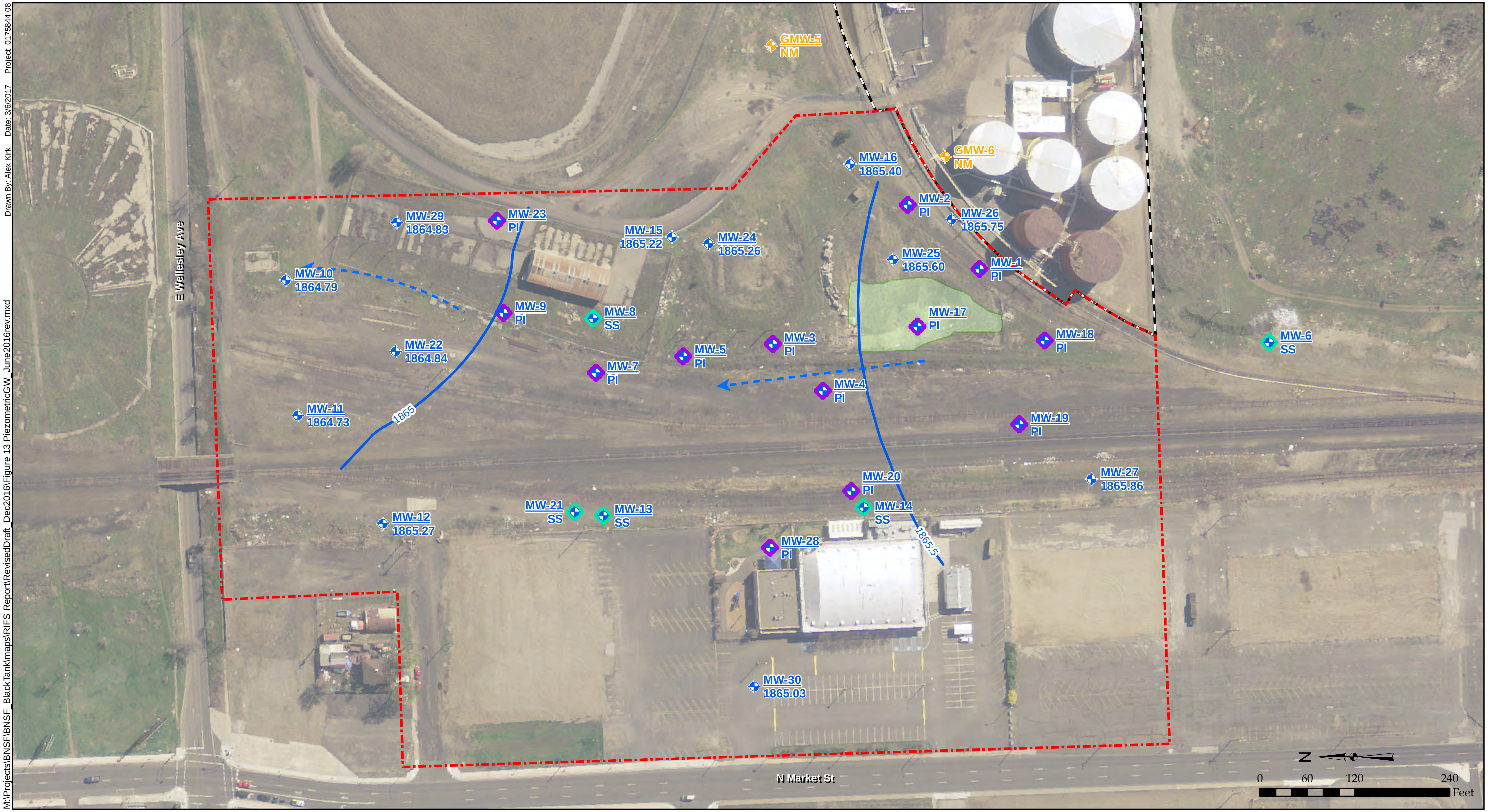
Notes:
Dry = No water detected or water level was below screened interval.
LNAPL = Light Non-Aqueous Phase Liquid.
NM = Not Measured.
PI = Product interference precluded accurate water level measurement.
SS = Well screened below the water table; screen is submerged.
All elevations in Feet Above Mean Sea Level (ft. AMSL).
Contour Interval = 0.5 feet.
Aerial Photo: USGS, April 2012.

Figure 12
Piezometric Surface Map
Groundwater Monitoring
March 10, 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 13 PiezometricGW_June2016rev.mxd Drawn By: Alex Kirk Date: 3/6/2017 Project: 0175844.08



Legend

- ◆ Monitoring Well with LNAPL
- ◆ Monitoring Well with Uncertain LNAPL Presence (Submerged Screen or Dry Well)
- ◆ Monitoring Well with No Measurable LNAPL
- ◆ SemMaterials Monitoring Well
- 🟩 Former Black Tank Excavation
- ▭ Proposed BNSF Black Tank Site Boundary
- ▭ SemMaterials L.P. Spokane Site Boundary
- — Groundwater Isocontour
- - -➤ Groundwater Flow Direction

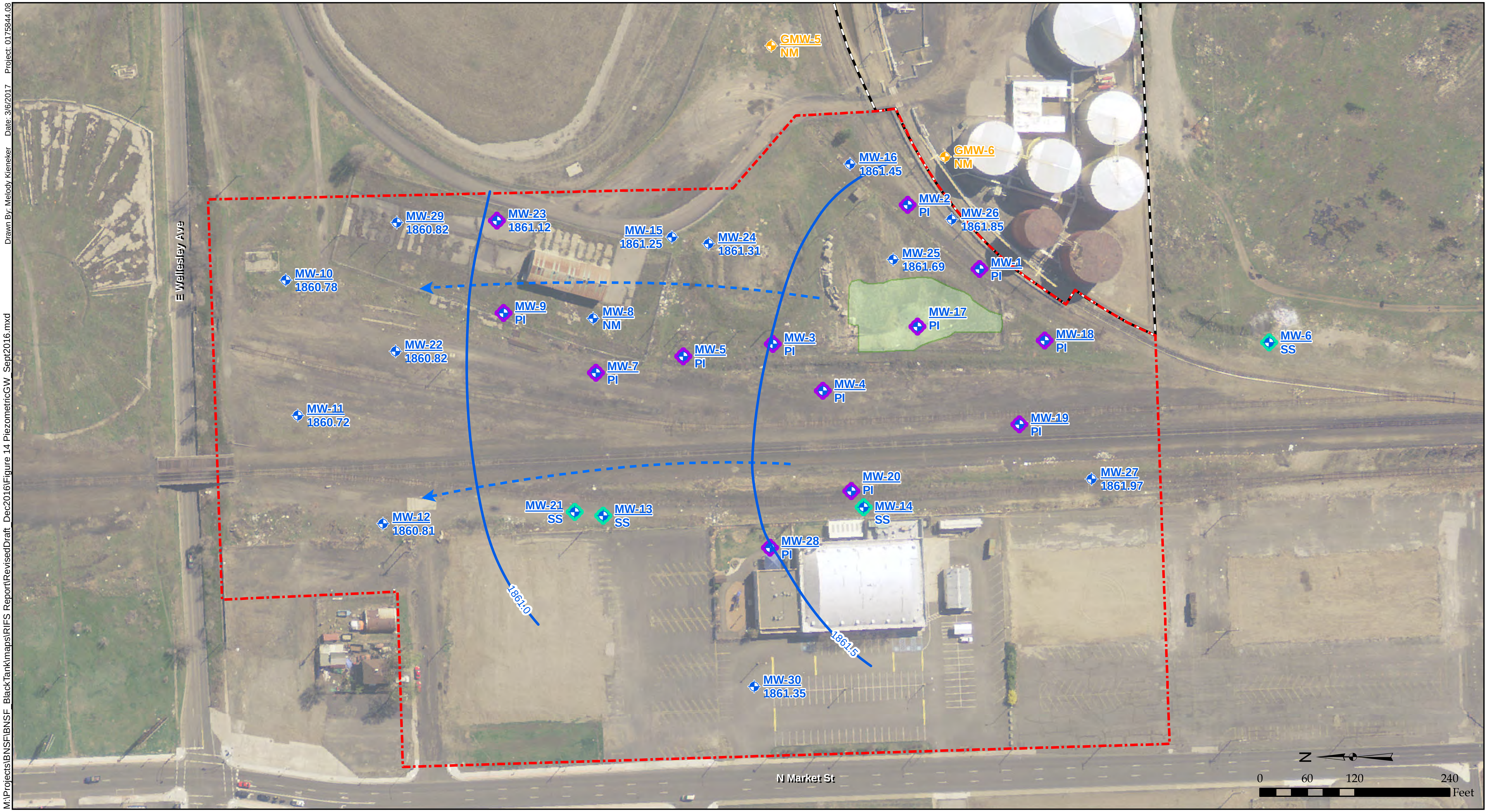
Notes:
Dry = No water detected or water level was below screened interval.
LNAPL = Light Non-Aqueous Phase Liquid.
NM = Not Measured.
PI = Product interference precluded accurate water level measurement.
SS = Well screened below the water table; screen is submerged.
All elevations in Feet Above Mean Sea Level (ft. AMSL).
Contour Interval = 0.5 feet.
MW-30 groundwater elevation taken 24 June 2016.
Aerial Photo: USGS, April 2012.

Figure 13
Piezometric Surface Map
Groundwater Monitoring
June 20, 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 14 PiezometricGW_Sept2016.mxd   Drawn By: Melody Kieneker   Date: 3/6/2017   Project: 0175844.08



Legend

- Monitoring Well with LNAPL
- Monitoring Well with Uncertain LNAPL Presence (Submerged Screen or Dry Well)
- Monitoring Well with No Measurable LNAPL
- SemMaterials Monitoring Well
- 🟩 Former Black Tank Excavation
- Proposed BNSF Black Tank Site Boundary
- SemMaterials L.P. Spokane Site Boundary
- Groundwater Isocontour
- Groundwater Flow Direction

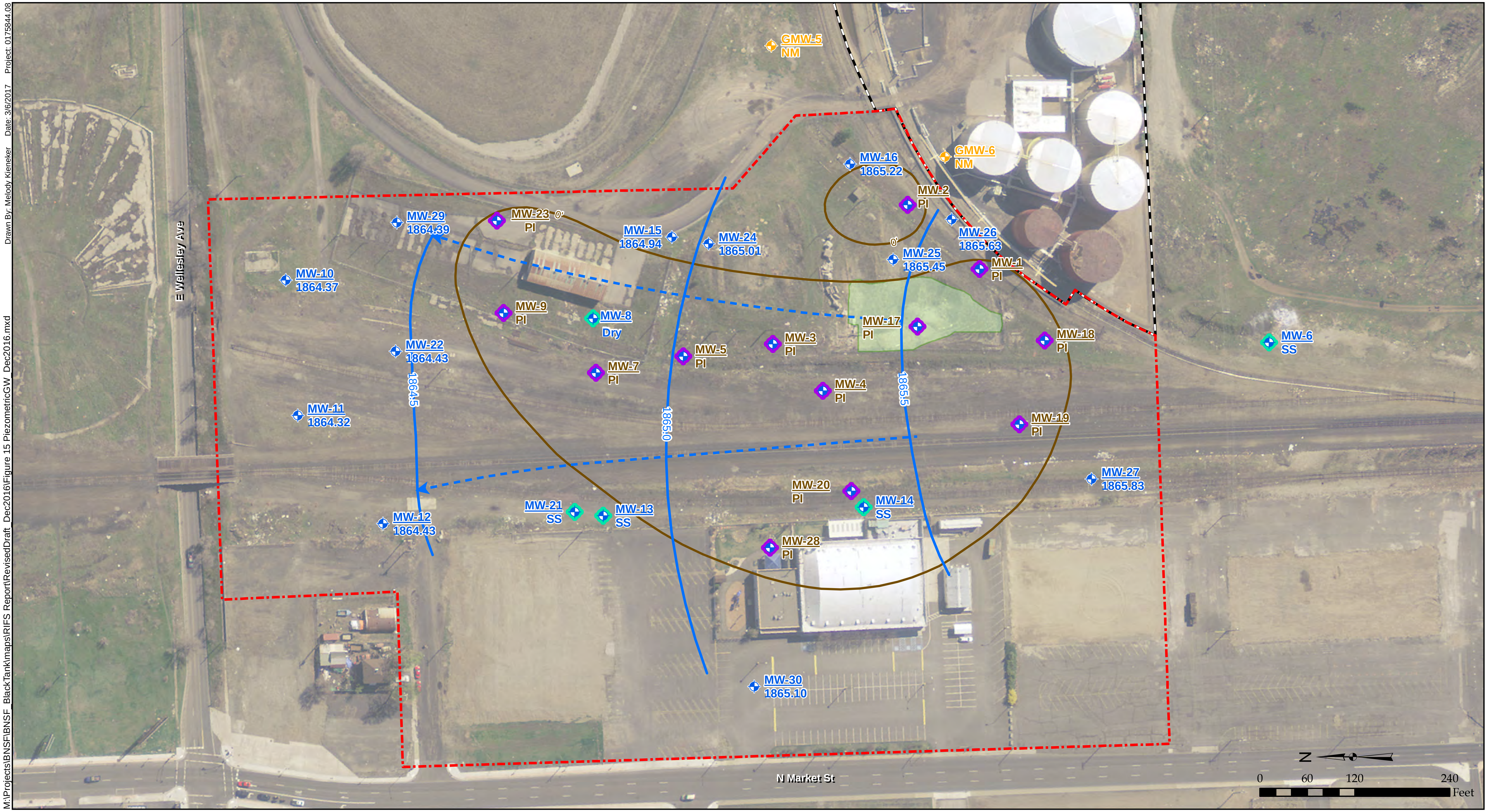
Notes:
Dry = No water detected or water level was below screened interval.
LNAPL = Light Non-Aqueous Phase Liquid.
NM = Not Measured.
PI = Product interference precluded accurate water level measurement.
SS = Well screened below the water table; screen is submerged.
All elevations in Feet Above Mean Sea Level (ft. AMSL).
Contour Interval = 0.5 feet.
Aerial Photo: USGS, April 2012.

Figure 14
Piezometric Surface Map
Groundwater Monitoring
September 20, 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 15 PiezometricGW_Dec2016.mxd Drawn By: Melody Kieneker Date: 3/6/2017 Project: 0175844.08



Legend

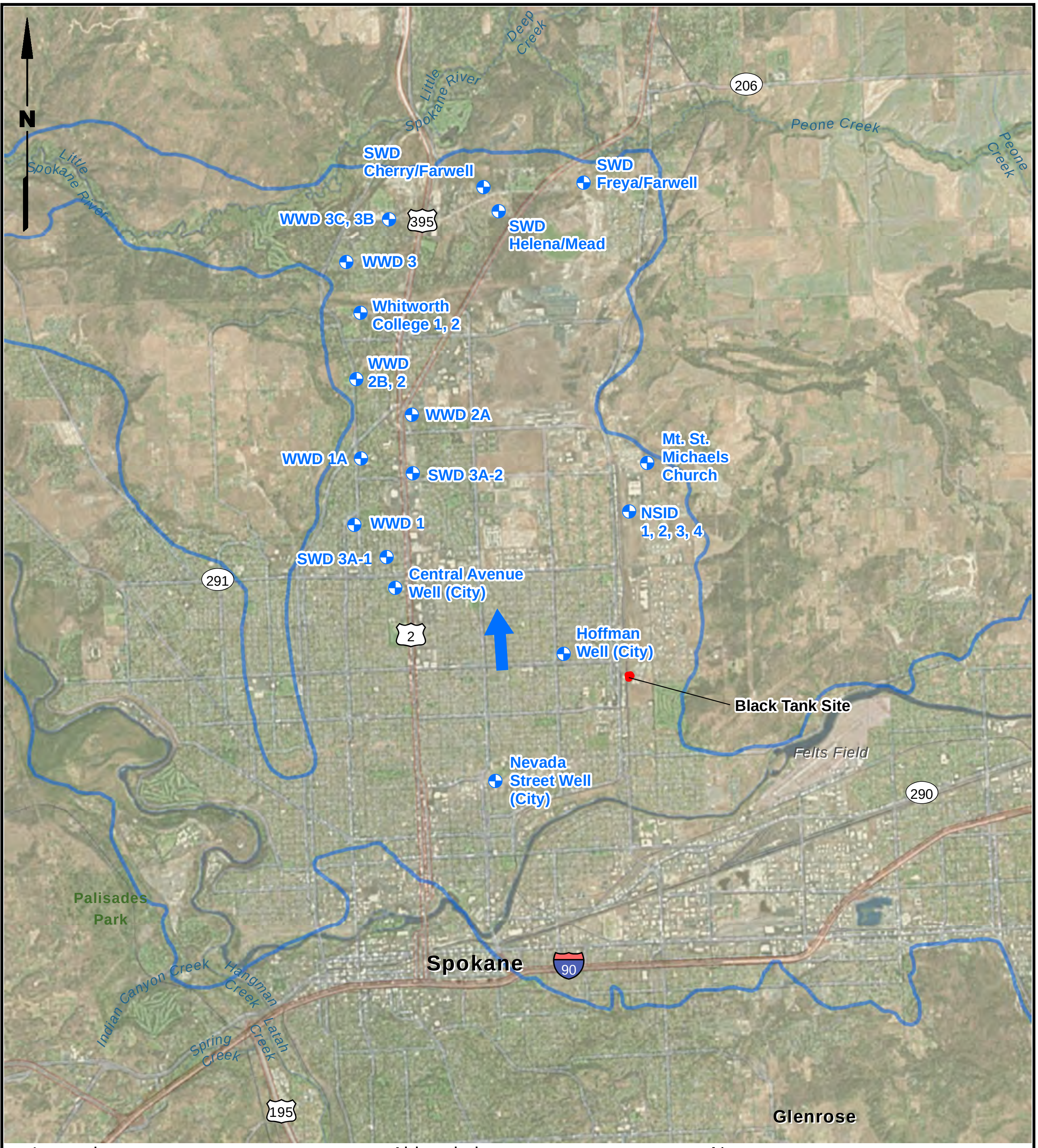
- Most Recent Approximate Extent of LNAPL, December 2016
- Monitoring Well with LNAPL
- Monitoring Well with Uncertain LNAPL Presence (Submerged Screen or Dry Well)
- Monitoring Well with No Measurable LNAPL
- SemMaterials Monitoring Well
- 🟩 Former Black Tank Excavation
- Proposed BNSF Black Tank Site Boundary
- SemMaterials L.P. Spokane Site Boundary
- Groundwater Isocontour
- Groundwater Flow Direction

Notes:
Lines dashed where Inferred.
Dry = No water detected or water level was below screened interval.
LNAPL = Light Non-Aqueous Phase Liquid.
NM = Not Measured.
PI = Product interference precluded accurate water level measurement.
SS = Well screened below the water table; screen is submerged.
All elevations in Feet Above Mean Sea Level (ft. AMSL).
Contour Interval = 0.5 feet.
Aerial Photo: USGS, April 2012.

Figure 15
Piezometric Surface Map
Groundwater Monitoring
December 5, 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT



Legend

🔵 Approximate Public Water Supply Well Location

▭ Spokane-Rathdrum Prairie Aquifer Boundary

➡ Approximate Direction of Regional Groundwater Flow

Abbreviations

SWD = Spokane Water District #3
WWD = Whitworth Water District #2
NSID = North Spokane Irrigation District
City = City of Spokane

Note

1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

0 1.5 3
Miles

Data Source: Esri World Imagery; City of Spokane GIS

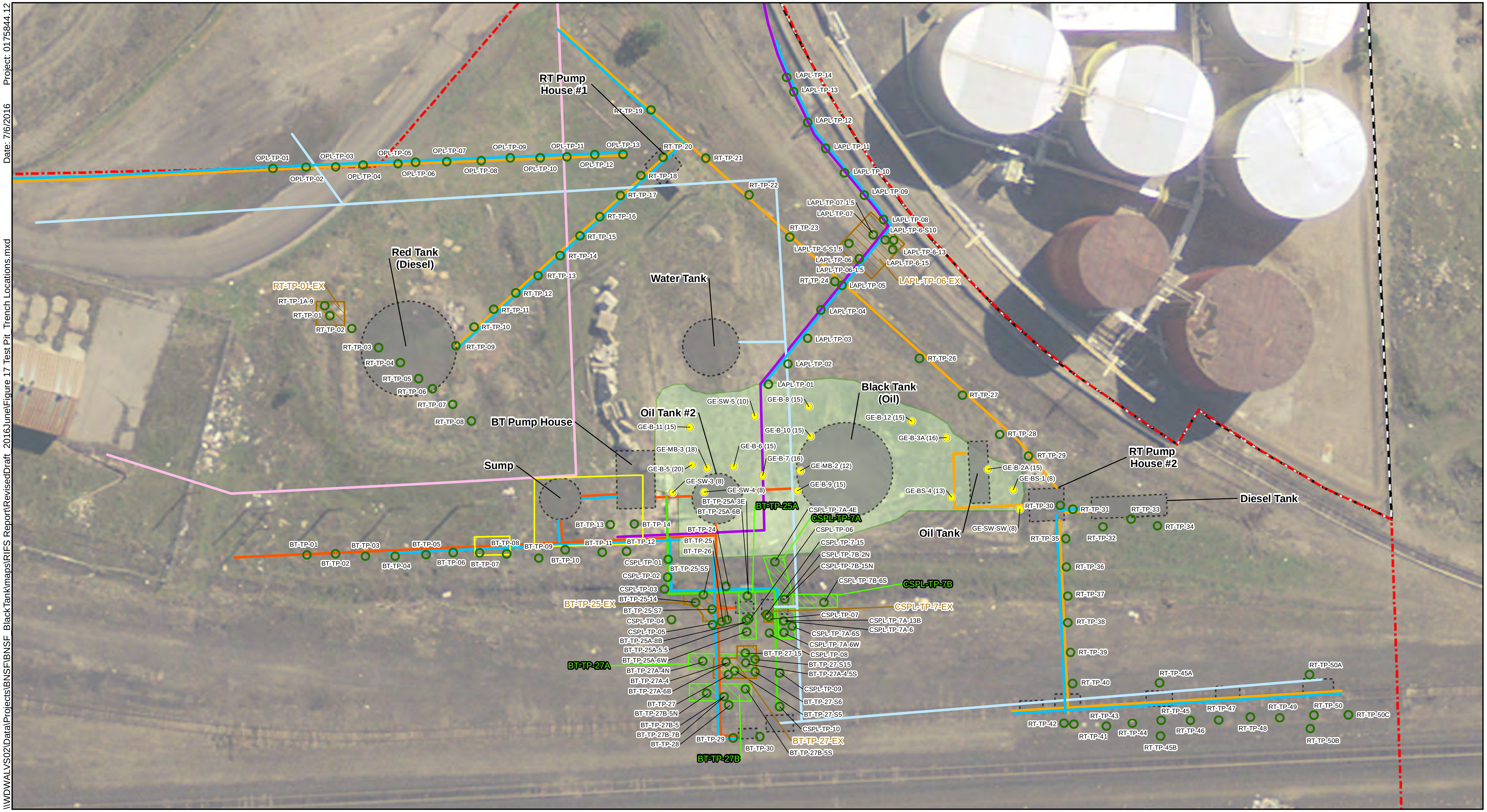
G:\Projects\1084\008\030\F16_PublicWells.mxd 3/6/2017 NAD 1983 StatePlane Washington North FIPS 4601 Feet

LANDAU ASSOCIATES

BNSF Black Tank Spokane, Washington	**Public Water Supply Well Locations**	Figure 16

DRAFT

\\WDWALVS02\Data\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 17 Test Pit_Trench Locations.mxd
Date: 7/6/2016
Project: 0175844.12



Legend

- ○ Test Pit
- ● GeoEngineers Black Tank Excavation Confirmation Sample
- ▭ Proposed BNSF Black Tank Site Boundary
- ▭ SemMaterials L.P. Spokane Site Boundary
- — Confirmed Residual Pipeline Location
- — Black Tank Oil Pipeline (1937)
- — Red Tank Oil Pipeline (1937)
- — Chemical Solution Pipeline (1937)
- — Liquid Asphalt Pipeline (1956)
- — Steam Pipeline
- — Water Pipeline
- ☐ ACM Abatement Area
- ▨ Historical Aboveground Storage Tank
- ☐ Former Black Tank Excavation
- ▨ Approximate Outline of 2013 Excavation Trenches
- ▨ Approximate Outline of 2014 Excavation Trenches

N

0 25 50 100
Feet

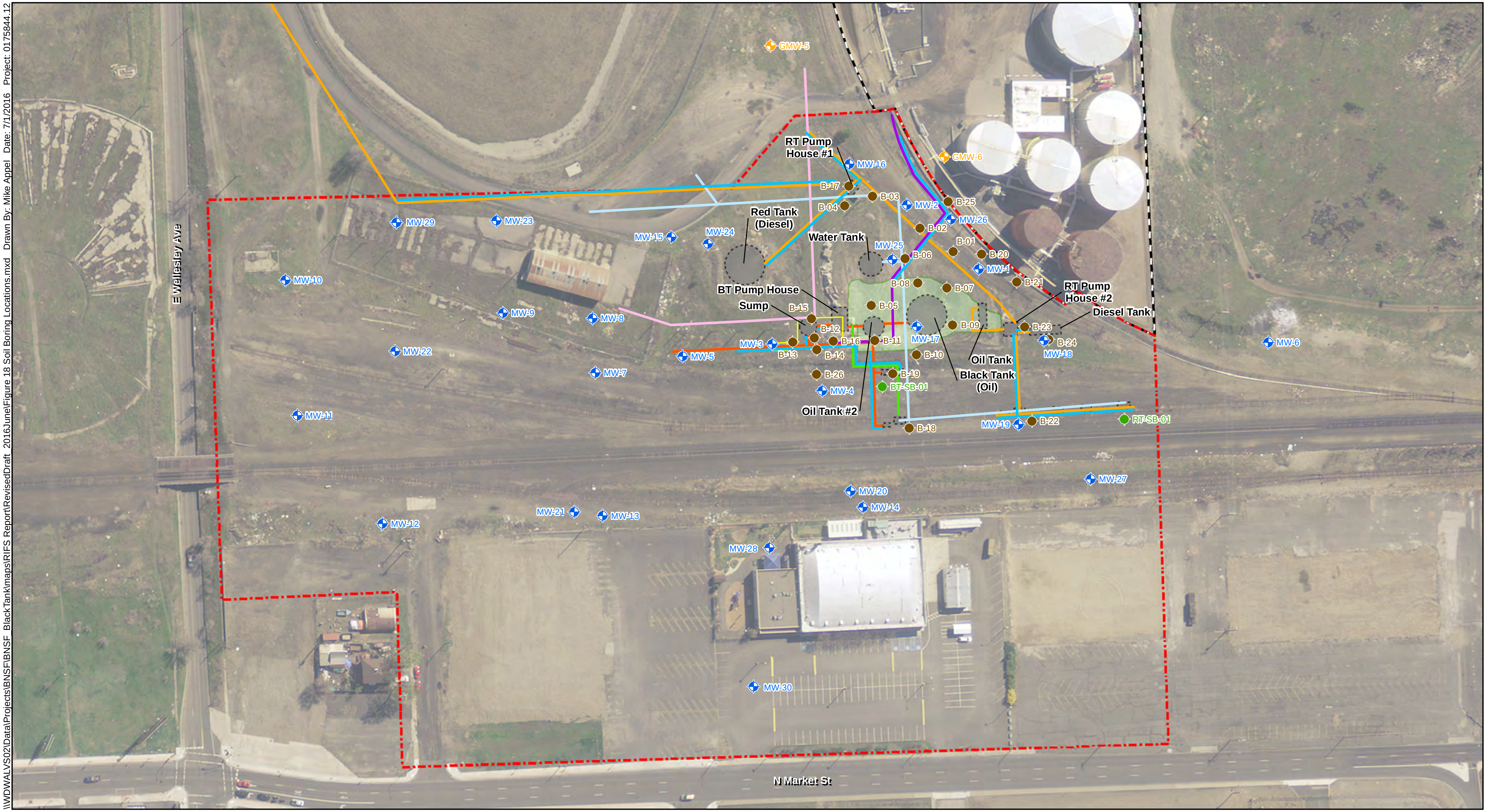
Notes:
ACM = Asbestos Containing Materials
BT = Black Tank System
CSPL = Chemical/Solution Pipeline
LAPL = Liquid Asphalt Pipeline
OPL = Oil Pipeline
RT = Red Tank System
TP = Test Pit
Aerial Photo: USGS, April 2012.

Figure 17
Test Pit and Trench Locations
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

\\WDWALVS02\Data\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 18 Soil Boring Locations.mxd Drawn By: Mike Appel Date: 7/1/2016 Project: 0175844.12



Legend

- ✥ Monitoring Well
- ✥ SemMaterials Monitoring Well
- ● GeoEngineers Soil Boring
- ● ERM Soil Boring
- — Confirmed Residual Pipeline Location
- — Black Tank Oil Pipeline (1937)
- — Red Tank Oil Pipeline (1937)
- — Chemical Solution Pipeline (1937)
- — Liquid Asphalt Pipeline (1956)
- — Steam Pipeline
- — Water Pipeline
- ☐ ACM Abatement Area
- ▨ Historical Aboveground Storage Tank
- 🟩 Former Black Tank Excavation
- ▭ Proposed BNSF Black Tank Site Boundary
- ▭ SemMaterials L.P. Spokane Site Boundary

N

0 60 120 240 Feet

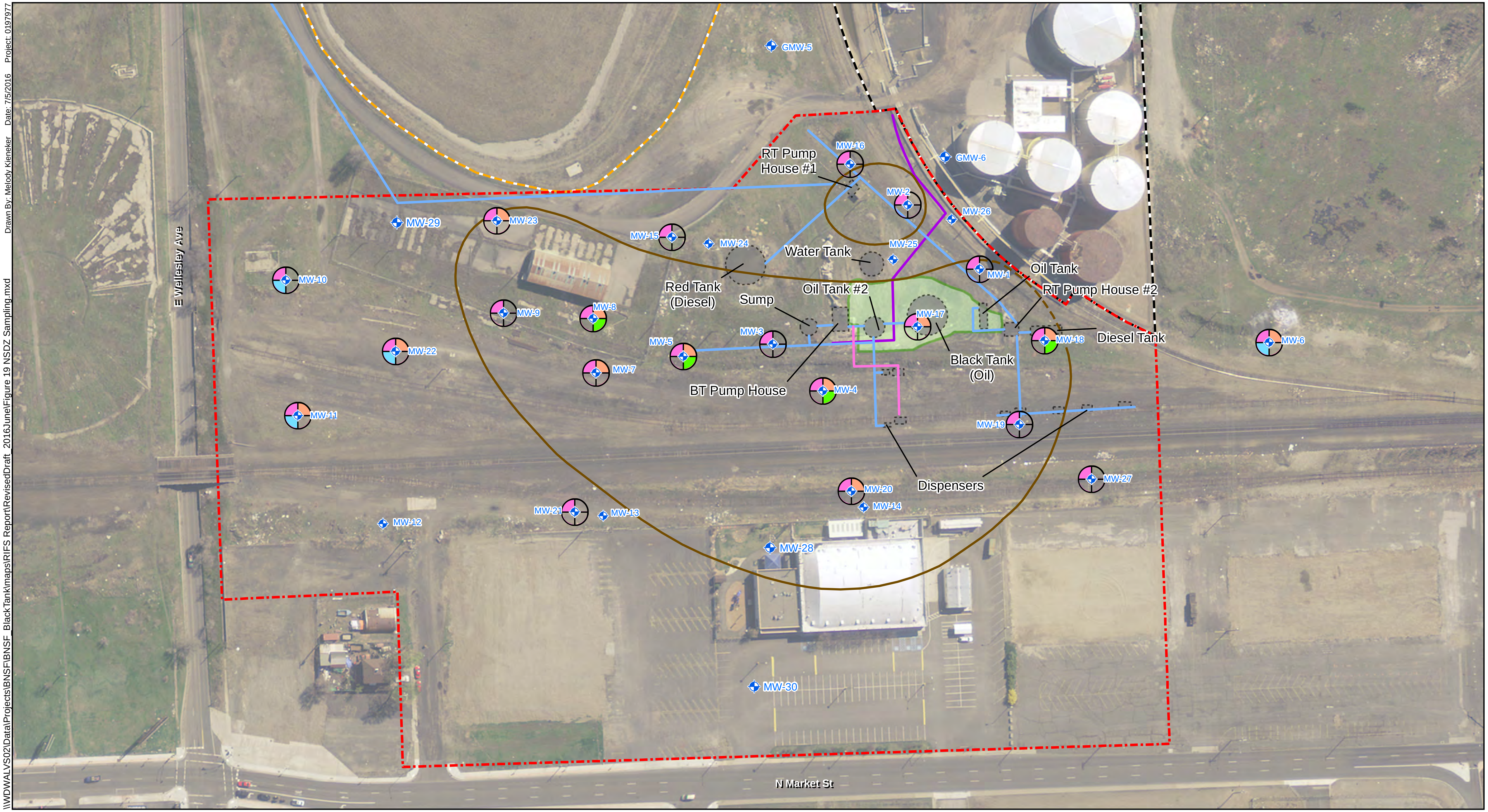
Notes:
ACM = Abestos-containing Material
BT = Black Tank System
CSPL = Chemical/Solution Pipeline
LAPL = Liquid Asphalt Pipeline
OPL = Oil Pipeline
RT = Red Tank System
TP = Test Pit
Aerial Photo: USGS, April 2012.

Figure 18
Soil Boring and Monitoring Well Locations
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

\\WDWALVS02\Data\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 19 NSZD Sampling.mxd Drawn By: Melody Kieneker Date: 7/5/2016 Project: 0197977



- Monitoring Well
- 🟩 Former Black Tank Excavation
- Proposed BNSF Black Tank Site Boundary
- L.P. Spokane Site Boundary
- SemMaterialsL.P. Spokane Site Boundary
- Liquid Asphalt Pipeline (1956)
- Historical Chemical Pipeline
- Historical Petroleum Pipeline
- Historical Aboveground Storage Tank
- Most Recent Inferred Extent of LNAPL, June 2016
- Most Recent Approximate Extent of LNAPL, June 2016

NSZD Sampling Details

Carbon Flux Chamber
In-situ Respiration Testing
NSZD Groundwater Sample
Carbon Trap

N

0 60 120 240 Feet

Notes:
NSZD = Natural Source Zone Depletion
CULs = Clean-Up Levels
LNAPL = Light Non-Aqueous Phase Liquid.
Data for GMW-5 and GMW-6 obtained from SemMaterials L.P. Spokane Site RI/FS Report, Public Review Draft, January 31, 2013.
Aerial Photo: USGS, April 2012.

Figure 19

Natural Source Zone Depletion
Monitoring Locations
BNSF Black Tank
Spokane, Washington

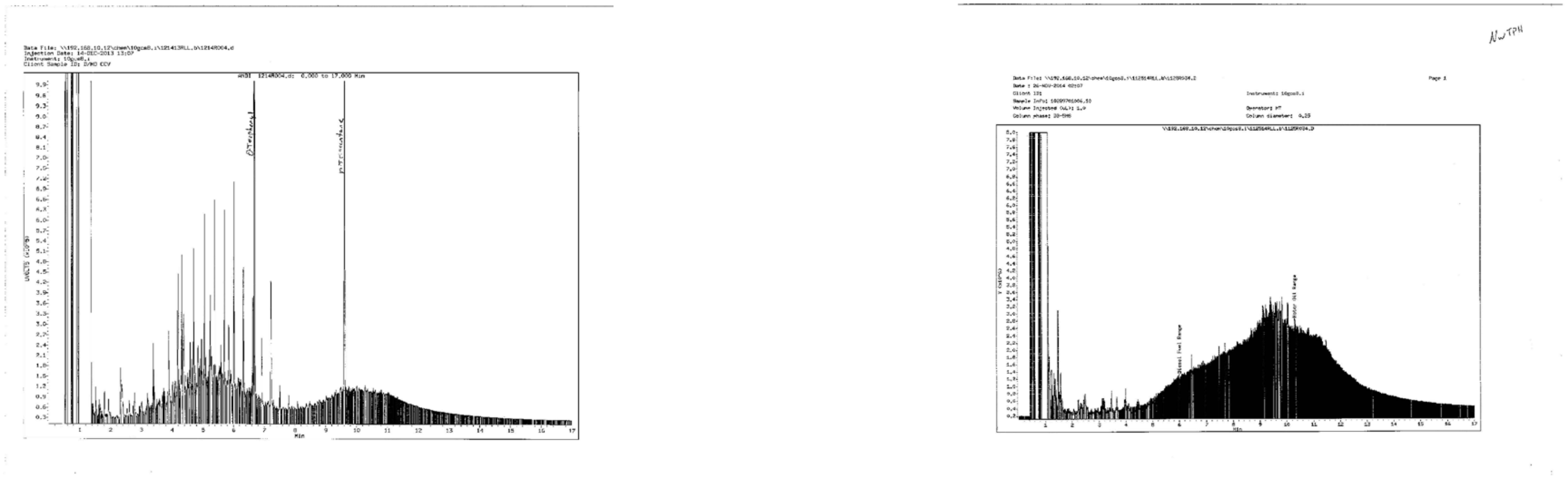
Environmental Resources Management
www.erm.com
ERM

DRAFT

\\WDWALVS02\Data\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 20 Chromatograms.mxd Drawn By: Austin Phelps Date: 7/1/2016 Project: 0175844.08

Calibration Standard (TPH-D = 300 mg/L; TPH-HO = 300 mg/L)

BT-SB-01(126-127 feet bgs) (TPH-D = 2,350 mg/kg; TPH-HO = 8,220 mg/kg)



MW18(160-161 feet bgs) (TPH-D = 1,410 mg/kg; TPH-HO = 3,160 mg/kg)

MW-23-(177-178 feet bgs) (TPH-D = 1,100 mg/kg; TPH-HO = 1,110 mg/kg)

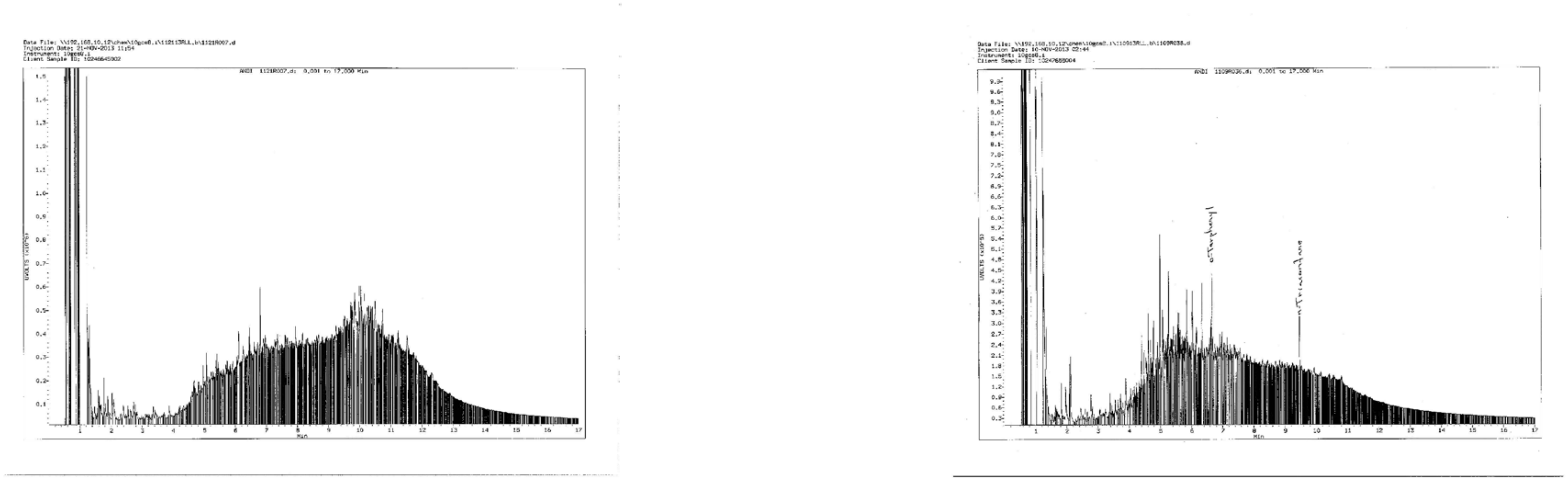
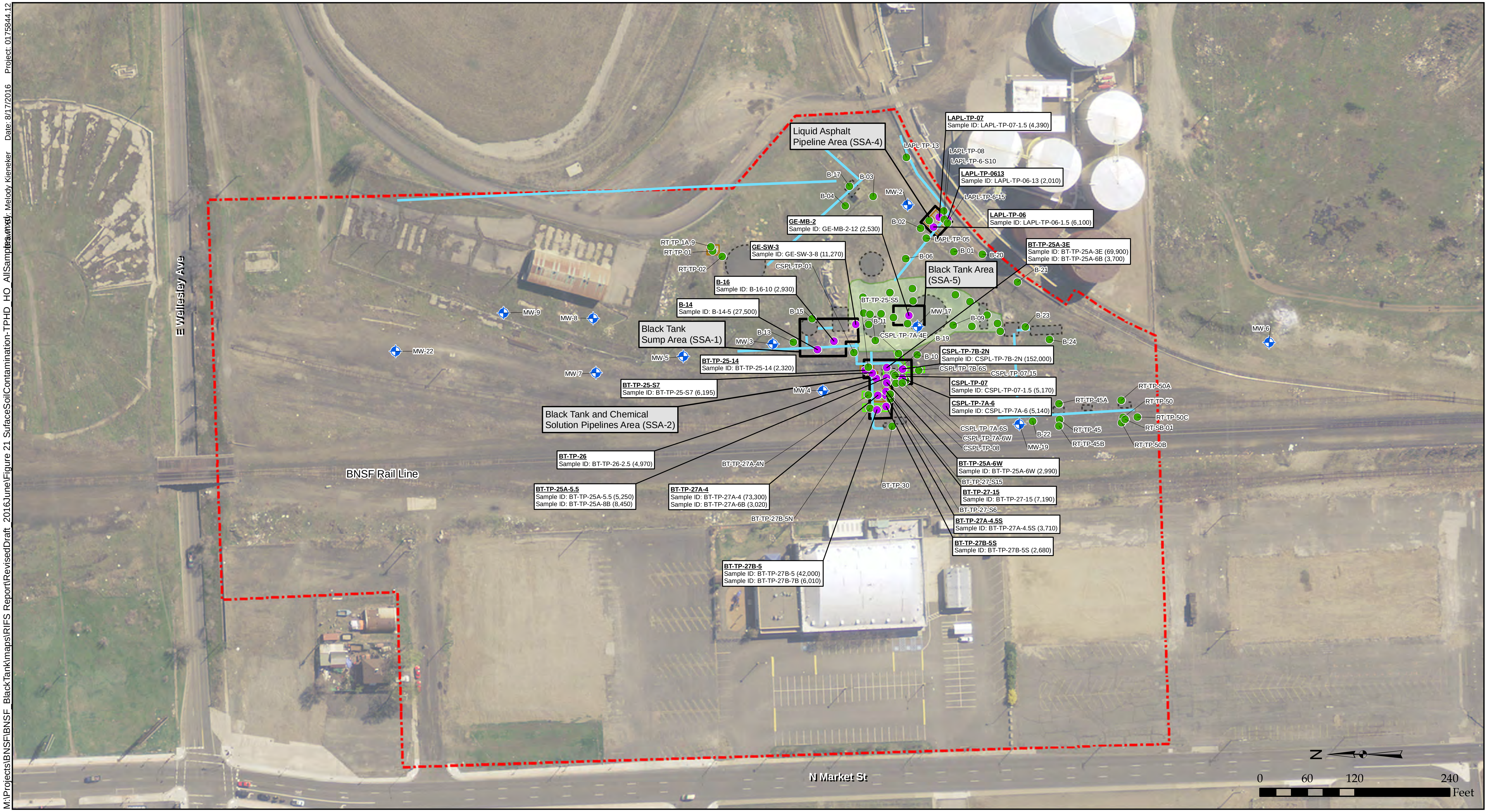


Figure 20
Comparison of Example Chromatograms
Petroleum Hydrocarbon Analysis
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 21 SufaceSoilContamination-TPHD_HO_AllSamples.mxd Drawn By: Melody Kieneker Date: 8/17/2016 Project: 0175844.12



Legend

● Soil Sample Location with Result Exceeding MTCA A Unrestricted CULs

● Soil Sample Location with No Exceedances

— Existing Piping (Petroleum and Chemical Solution)

▭ Proposed BNSF Black Tank Site Boundary

▭ Extent of TPH-D/HO Contamination

▨ Approximate Outline of 2013 Excavation Trenches

▨ Approximate Outline of 2014 Excavation Trenches

🟩 Former Black Tank Excavation

▨ Historical Aboveground Storage Tank

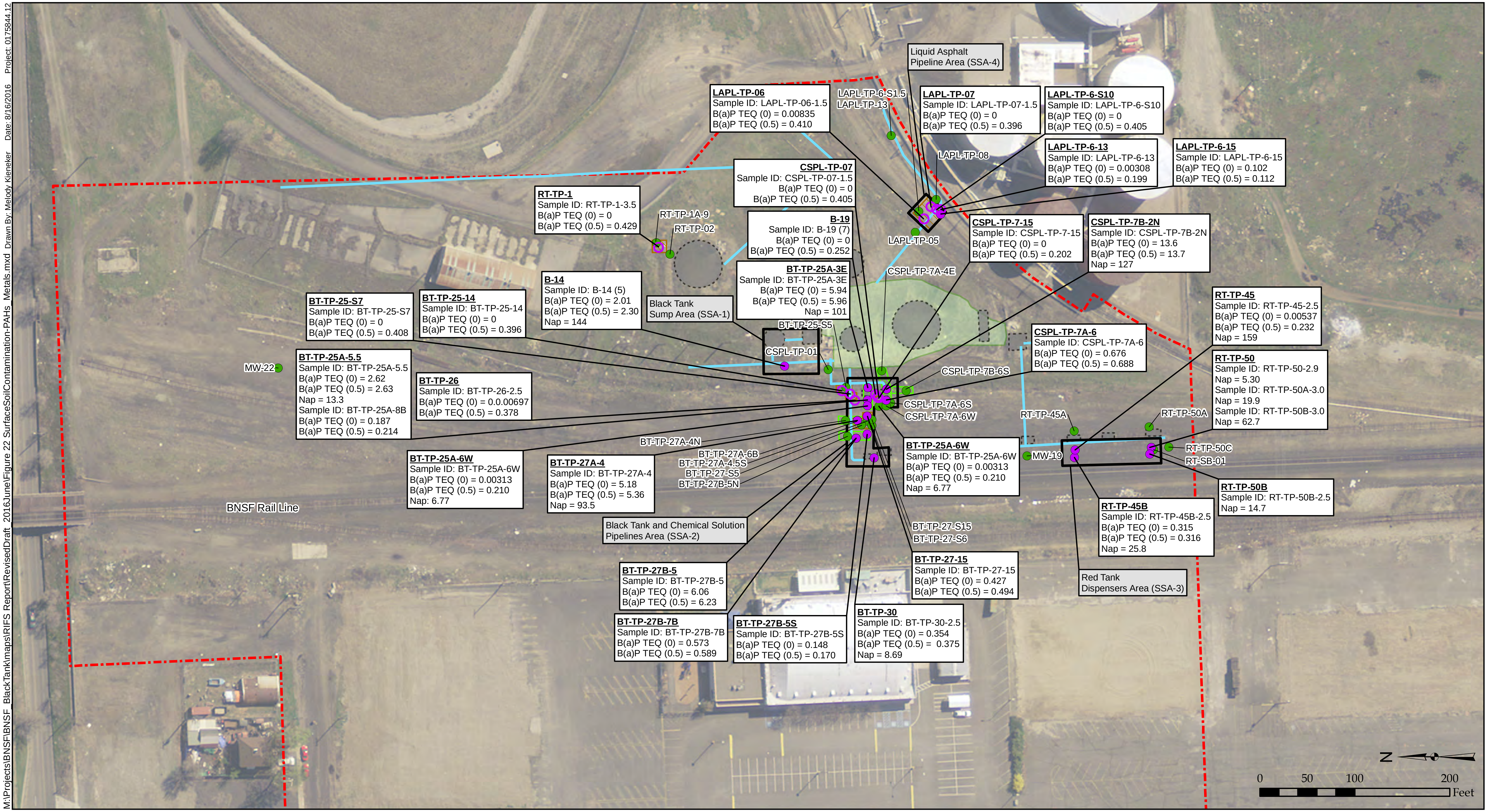
Notes:
CUL = Cleanup Level.
mg/kg = milligrams per kilogram.
(2,390) = TPH-D/HO Concentration in mg/kg.
MTCA A Unrestricted CULs
TPH-D/HO = 2,000 mg/kg.
Aerial Photo: USGS, April 2012.

Figure 21
Surface Soil Contamination
TPH-D/HO (0 to 15 feet bgs)
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
1218 3rd Avenue, Suite 1412
Seattle, Washington 98101
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 22 SurfaceSoilContamination-PAHs_Metals.mxd Drawn By: Melody Kieneker Date: 8/16/2016 Project: 0175844.12



Legend

- ● Sample that Exceeds Preliminary CULs
- ○ Sample that Exceeds Preliminary CULs Based on Detection Limits Exceeding the CULs.
- ● Sample with No Exceedances
- ― Existing Piping (Petroleum and Chemical Solution)
- ▭ Proposed BNSF Black Tank Site Boundary
- ▭ Extent of Surface Soil Contamination
- ▨ Approximate Outline of 2013 Excavation Trenches
- ▨ Approximate Outline of 2014 Excavation Trenches
- ▭ Former Black Tank Excavation
- ▨ Historical Aboveground Storage Tank

Notes:
B(a)P TEQ (0): Benzo(a)Pyrene TEQ using 0 for non-detects.
B(a)P TEQ (0.5): Benzo(a)Pyrene TEQ using 1/2 the detection limit for non-detects.
CUL = Cleanup Level.
mg/kg = milligrams per kilogram.
TEQ = Toxic Equivalency Quotient.
MTCA A Unrestricted CULs
B(a)P TEQ = 0.1 mg/kg
Total Naphthalene: (Nap) = 5 mg/kg
Aerial Photo: USGS, April 2012.

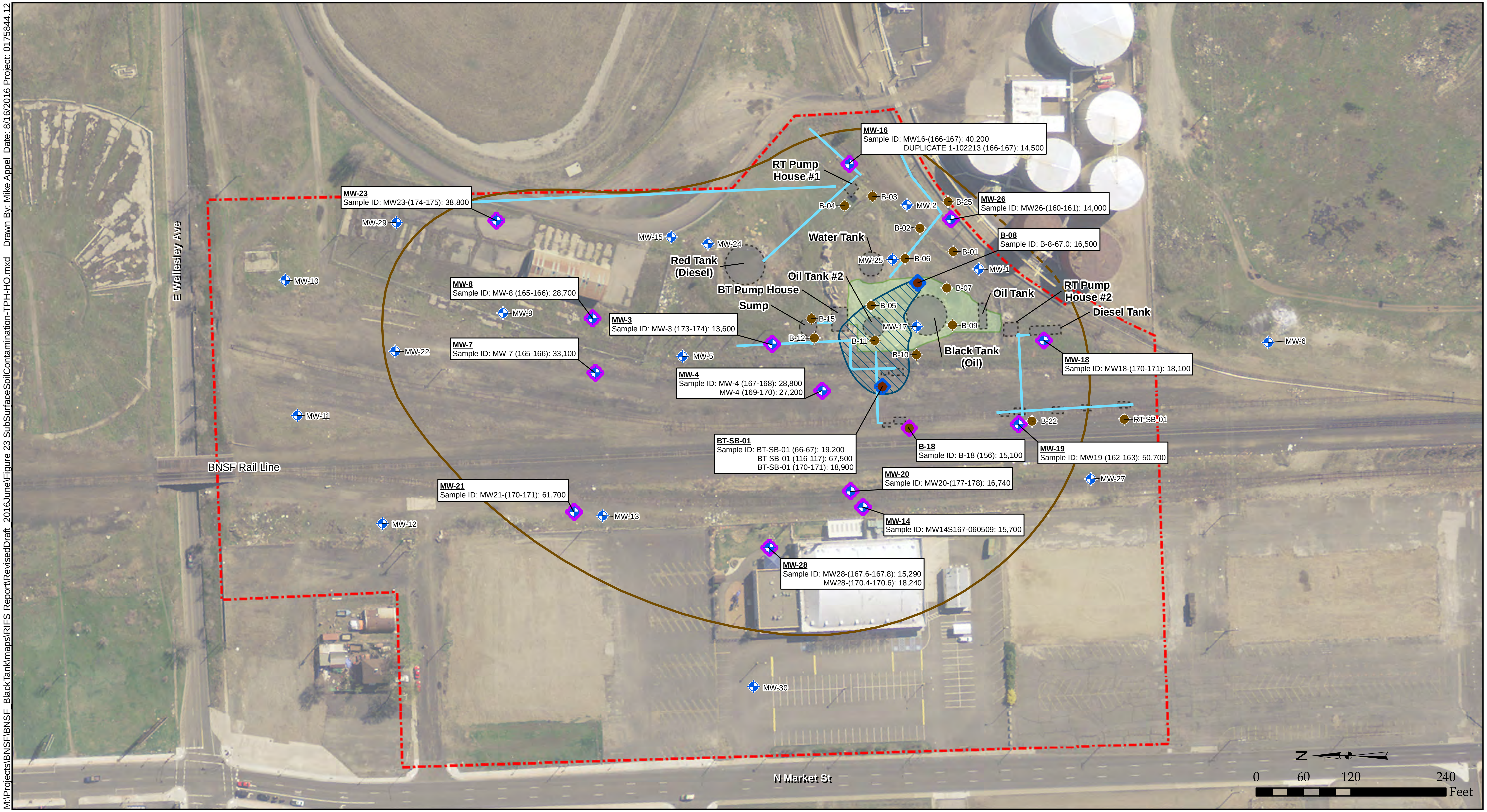
Figure 22

Surface Soil Contamination
cPAHs and Naphthalenes (0 to 15 feet bgs)
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 23 SubSurfaceSoilContamination-TPH-HO.mxd Drawn By: Mike Appel Date: 8/16/2016 Project: 0175844.12



Legend

- Soil Boring with Intermediate Soil Result that Exceeds the Preliminary CUL
- Soil Boring with Smear Zone Soil Result that Exceeds the Preliminary CUL
- Monitoring Well with Smear Zone Soil Result that Exceeds the Preliminary CUL
- Monitoring Well with No Soil Sample Exceedences
- Soil Boring with No Soil Exceedences
- Existing Piping (Petroleum and Chemical Solution)
- Most Recent Approximate Extent of Residual LNAPL, June 2016
- Most Recent Inferred Extent of Resdiual LNAPL, June 2016
- Proposed BNSF Black Tank Site Boundary
- ▨ TPH-D/HO in Subsurface Soil Exceeding the Preliminary CULs
- 🟩 Former Black Tank Excavation
- Historical Aboveground Storage Tank

Notes:
All Results in mg/kg
CUL = Cleanup Level
mg/kg = milligrams per kilogram.
(115-116): 17,000 = Depth:TPH-D/HO Concentration in mg/kg
Preliminary TPH-D/HO CUL = 13,600 mg/kg
Aerial Photo: USGS, April 2012.

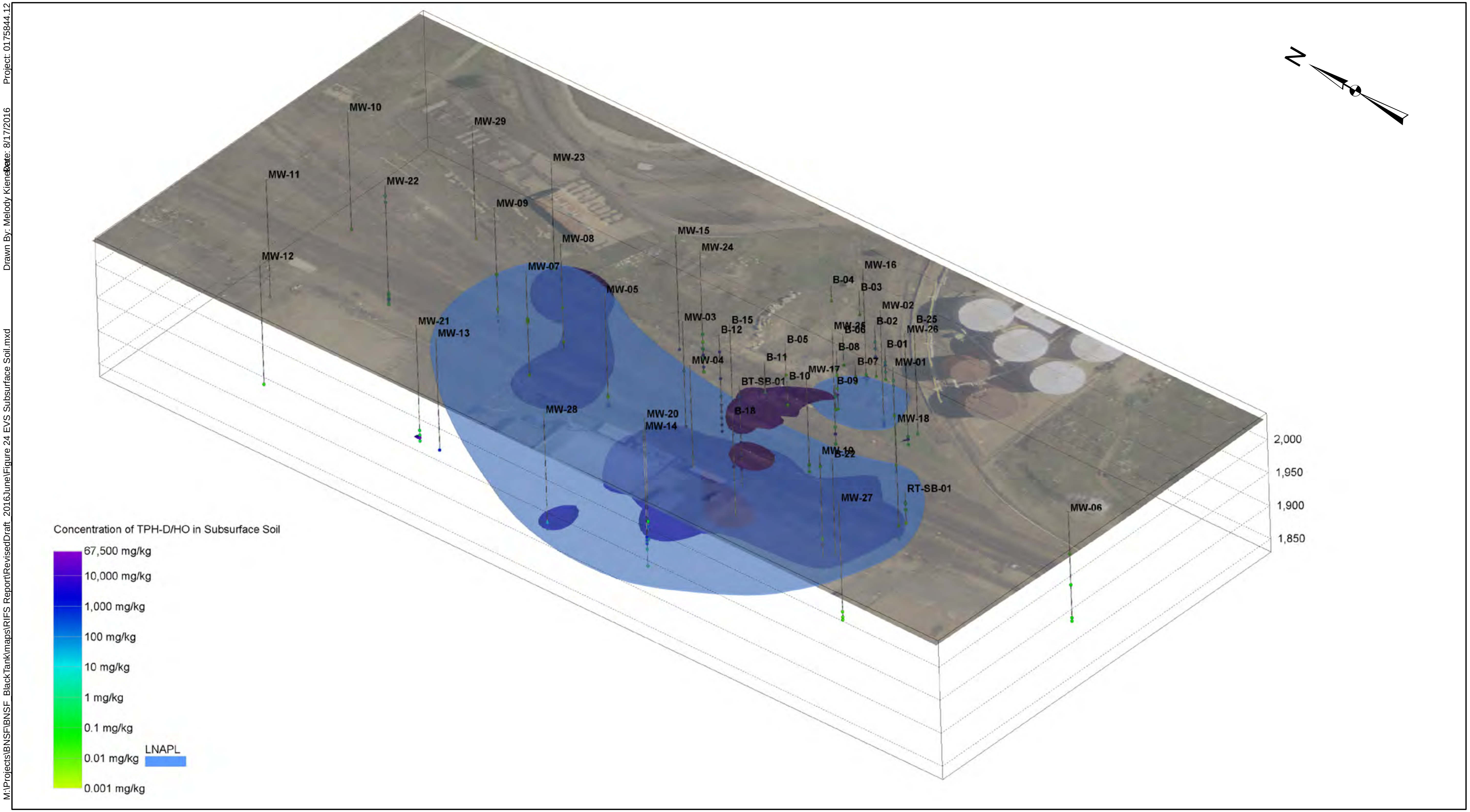
Figure 23

Subsurface Soil Contamination
TPH-D/HO (>15 ft bgs)
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 24 EVS Subsurface Soil.mxd Drawn By: Melody Kiener Date: 8/17/2016 Project: 0175844.12



Notes:
Image shows extent of TPH-D/HO impacts in subsurface soil as modeled using Mining Visualization System software.
Image also shows extent of mobile LNAPL in subsurface soil in relation to subsurface soil impacts.
CUL = Cleanup Level
LNAPL = Light Non-Aqueous Phase Liquid
mg/kg = milligram per kilogram
TPH-D/HO = Combined diesel-and heavy-oil range petroleum hydrocarbons
Preliminary TRH-D/HO CUL = 13,600 mg/kg

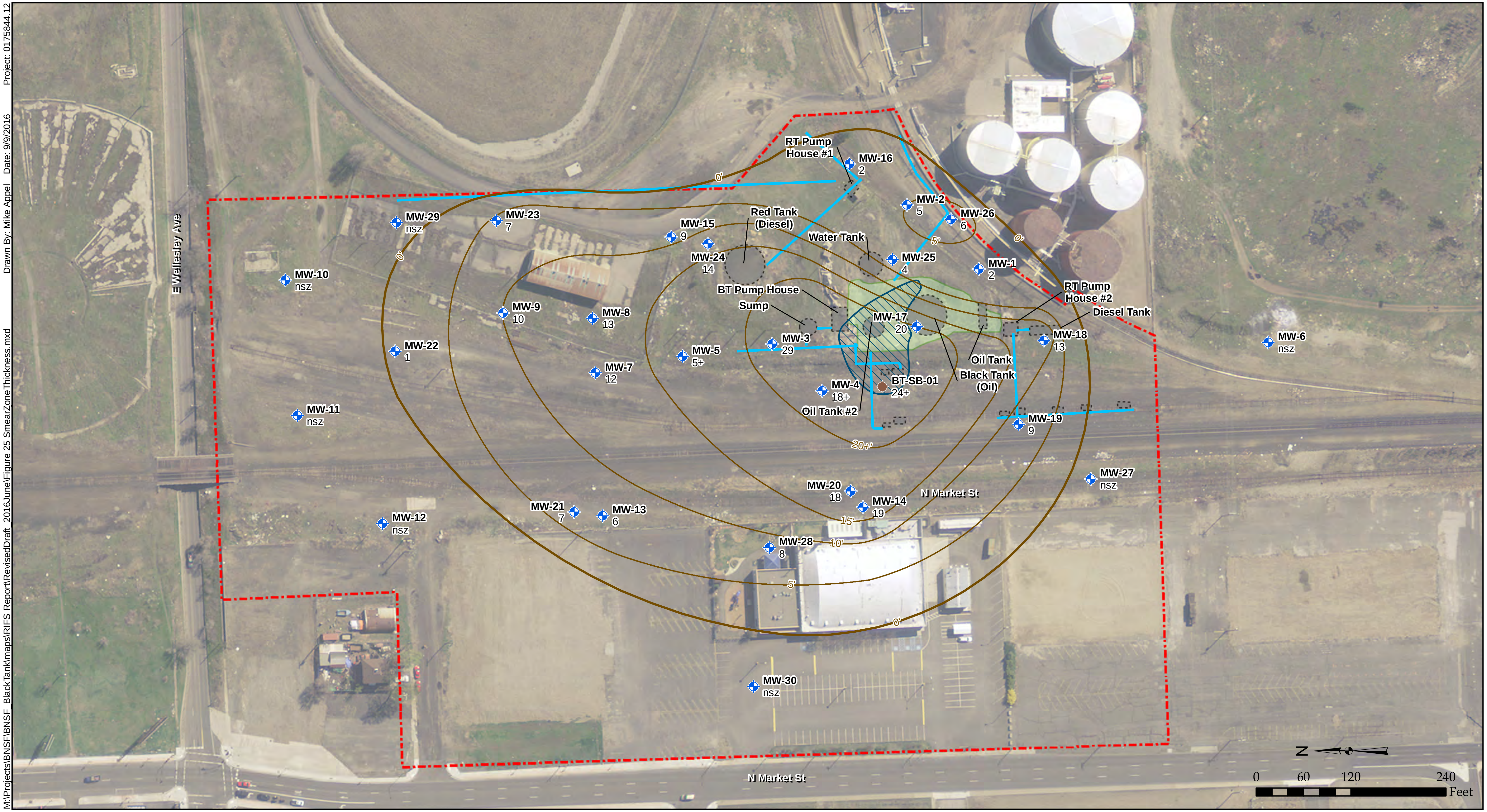
Figure 24

Subsurface Soil TPH-D/HO Impacts
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 25 SmearZoneThickness.mxd   Drawn By: Mike Appel   Date: 9/9/2016   Project: 0175844.12



Legend

⊕ Monitoring Well with Bottom of Smear Zone Thickness (ft)

● Soil Boring with Bottom of Smear Zone Thickness (ft)

— Confirmed Residual Pipeline Location

— Most Recent Approximate Extent of Residual LNAPL, June 2016

— Smear Zone Thickness Contour (ft)

▭ Proposed BNSF Black Tank Site Boundary

▨ TPH-D/HO in Subsurface Soil Exceeding the Preliminary CUL

🟩 Former Black Tank Excavation

▩ Historical Aboveground Storage Tank

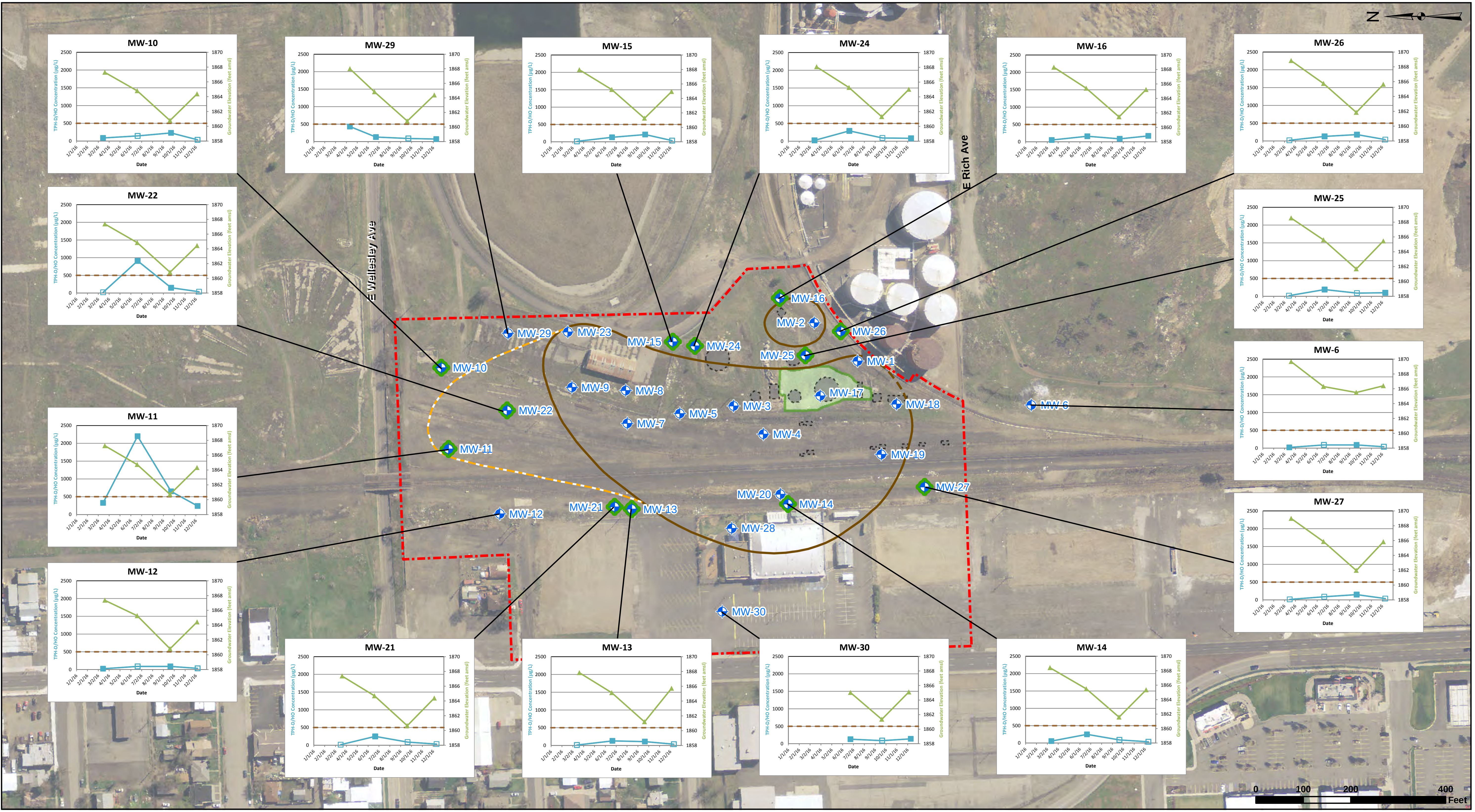
Notes:
Preliminary TPH-D/HO CUL = 13,600 mg/kg
CUL = Cleanup Level
ft = feet
mg/kg = milligram per kilogram
nsz = no smear zone
RT = Red Tank System
Aerial Photo: USGS, April 2012.

Figure 25
Smear Zone Thickness
Contour Map
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 26 Groundwater Analytical Summary - TPHDHO.mxd Drawn By: Melody Kieneker Date: 3/6/2017 Project: 0197977



Legend

- ⊕ Monitoring Well
- ⊕ Monitoring Well with Detectable Concentrations and Trendplot
- ▭ Proposed BNSF Black Tank Site Boundary
- 🟩 Former Black Tank Excavation
- ▨ Historical Aboveground Storage Tank
- - - Approximate Seasonal Maximum Extent of Dissolved Phase TPH-D/HO Plume
- - - Most Recent Inferred Extent of LNAPL, December 2016
- — Most Recent Approximate Extent of LNAPL, December 2016
- □ TPH-D/HO
- - - MTCA Method A TPH-D/HO Cleanup Level (500 µg/L)
- ▲ Groundwater Elevation

Notes:
All groundwater elevations measured on 3/21/16, 6/20/16, 9/20/16, and 12/5/16, except:
- MW-14 measured on 3/10/16 instead of 3/21/16;
- MW-29 measured on 4/12/16 instead of 3/21/16; and
- MW-30 measured on 6/24/16 instead of 6/20/16.

Groundwater TPH-D/HO data presented here was analyzed using NWTPH-Dx without Silica Gel Cleanup.
Hollow data points in well charts represent non-detect values.
Non-detects are charted as 1/2 the detection limit.
TPH-D/HO = Total Petroleum Hydrocarbons Diesel/Heavy Hydrocarbons
µg/L = micrograms per liter = Carcinogenic Polycyclic Aromatic Hydrocarbon
amsl = above mean sea level
LNAPL = Light Non-Aqueous Phase Liquid.
Aerial Photo: USGS, April 2012.

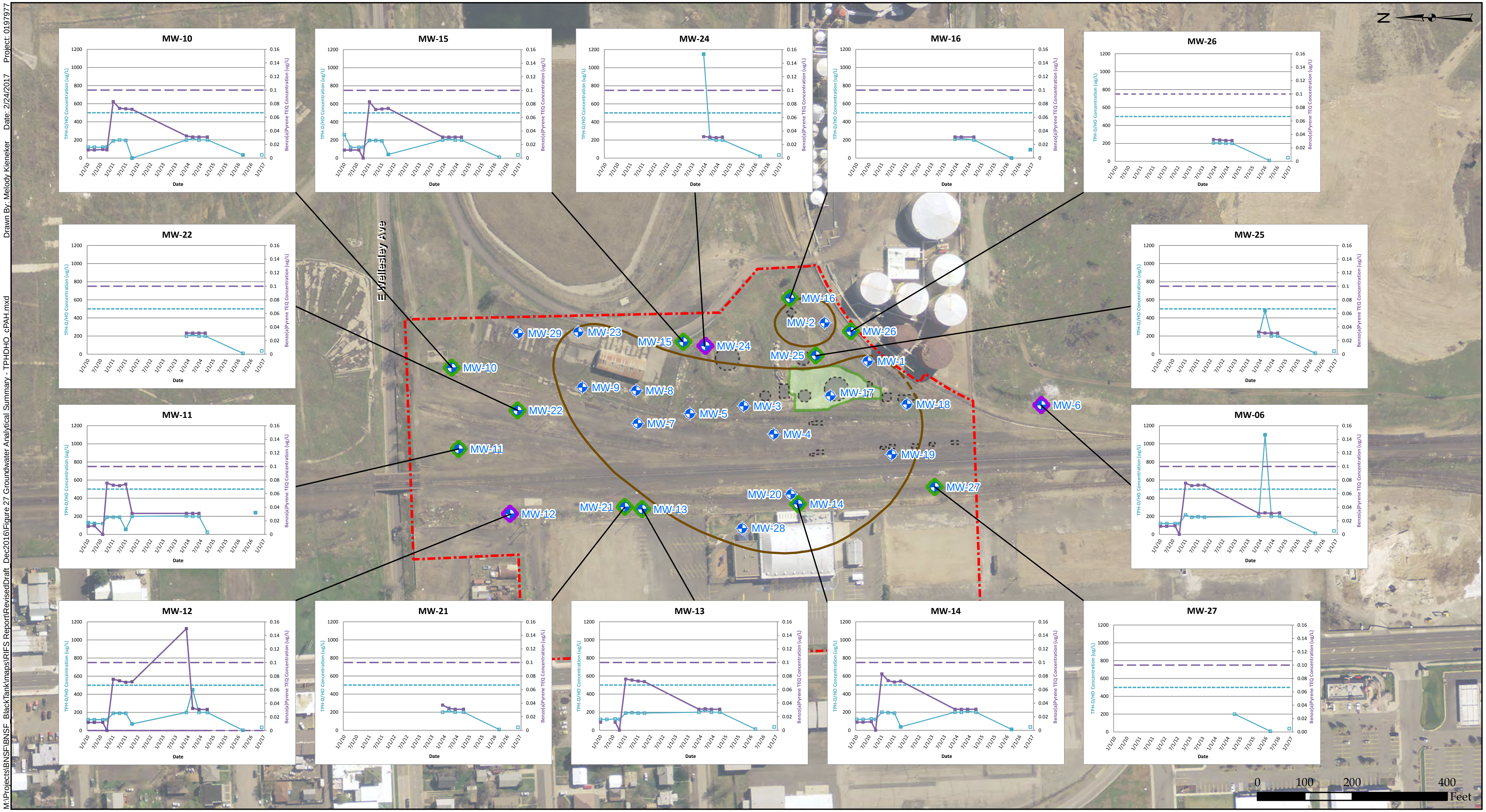
Figure 26

Groundwater Analytical Summary
TPH-D/HO without Silica Gel Cleanup
March 2016 - December 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 27 Groundwater Analytical Summary - TPHDHO_cPAH.mxd Drawn By: Melody Kieneker Date: 2/24/2017 Project: 0197977



Legend

- 🟪 Monitoring Well with Trendplot and CUL exceedances
- 🟩 Monitoring Well with Trendplot and No CUL Exceedances
- ⊕ Monitoring Well
- 🟥 Proposed BNSF Black Tank Site Boundary
- 🟩 Former Black Tank Excavation
- ▨ Historical Aboveground Storage Tank
- – – Most Recent Inferred Extent of LNAPL, June 2016
- —— Most Recent Approximate Extent of LNAPL, June 2016
- —■— TPH-D/HO, Silica Gel Treatment Results
- – – MTCA Method A TPH-D/HO Cleanup Level (500 µg/L)
- —■— Benzo(a)Pyrene TEQ Results
- – · MTCA Method A B(a)P TEQ Cleanup Level (0.1 µg/L)

Notes:
Groundwater TPH-D/HO data presented here was analyzed using NWTPH-Dx with Silica Gel Cleanup.
MW-29 groundwater sample in 2016 was non-detect for TPH-D/HO.
Hollow data points in well charts represent non-detect values.
Non-detects are charted as 1/2 the detection limit.
TPH-D/HO = Total Petroleum Hydrocarbons-Diesel/Heavy Hydrocarbons
cPAH = Carcinogenic Polycyclic Aromatic Hydrocarbon
TEQ = Toxic Equivalency Quotient
LNAPL = Light Non-Aqueous Phase Liquid.
Spokane Site RI/FS Report, Public Review Draft, January 31, 2013.
Aerial Photo: USGS, April 2012.

Figure 27

Groundwater Analytical Summary
TPH-D/HO with Silica Gel Cleanup &
cPAHs January 2010 - March 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 28 LNAPL June 2016.mxd Drawn By: Melody Kieneker Date: 8/23/2016 Project: 0197977

Legend

- ◆ Monitoring Well with Gauged LNAPL Thickness (ft)
- ◆ Monitoring Well with Uncertain Results (Submerged Screen or Dry Well)
- ◆ Monitoring Well with No Measureable LNAPL
- ◆ SemMaterials Monitoring Well with No Measurable LNAPL in Well
- ▭ Proposed BNSF Black Tank Site Boundary
- 🟩 Former Black Tank Excavation
- ▨ Historical Aboveground Storage Tank
- ▭ Residual LNAPL
- 🟨 Mobile and Residual LNAPL

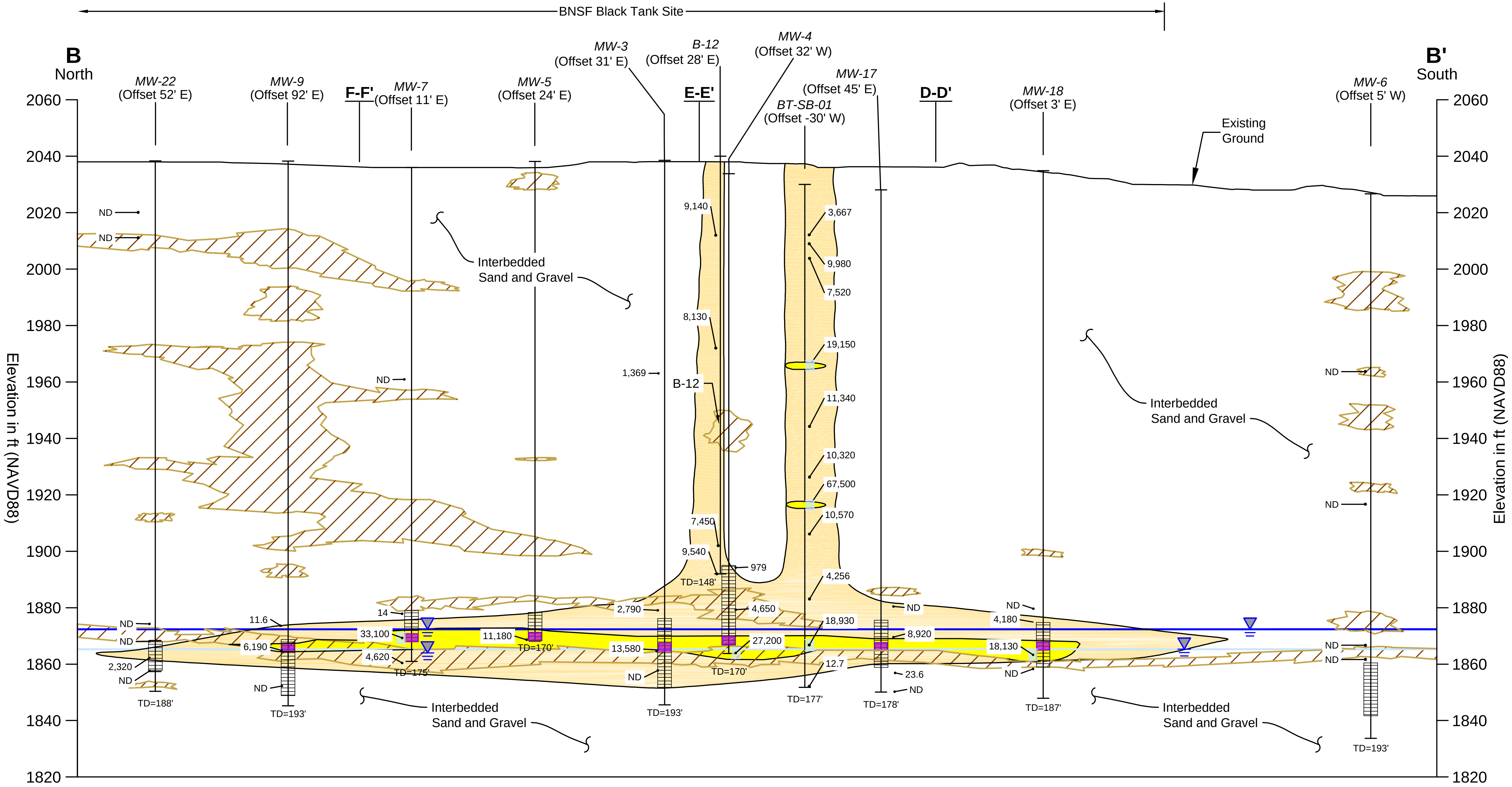
Notes:
Lines dashed where Inferred.
LNAPL Thicknesses gauged in June 2016, in feet.
ft = feet
LNAPL = Light Non-Aqueous Phase Liquid.
Mobile LNAPL = LNAPL that is interconnected in more space and has the potential to move under a hydraulic gradient.
Residual LNAPL = The potion of LNAPL that is hydraulically discontinuous and immobile to gravity drain force and hydraulic gradients.
Aerial Photo: USGS, April 2012.

Figure 28

Extent of LNAPL & Gauged LNAPL Thickness - June 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT



Legend

MW-6 — Exploration Designation
(Offset 22' W) — Offset Distance in Feet and Direction
Top of Exploration
Silt and Silty Sand Facies
Interval Having Diesel and Heavy Oil Range Petroleum Hydrocarbons (TPH-D/HO) above the Soil Cleanup Level
Approximate High Groundwater Level
Approximate Low Groundwater Level
Approximate Groundwater Level
397 — TPH-D/HO Concentration in Soil (mg/kg)
Well Screen Interval (If Installed)
LNAPL Present in Well
Bottom of Exploration
TD=193' — Total Depth of Exploration (feet BGS)

🟨 Mobile LNAPL

🟨 Residual LNAPL

mg/kg	Milligrams/Kilogram
ND	Not Detected
TPH-D/HO	Total Petroleum Hydrocarbon-Diesel/ Heating Oil
BGS	Below Ground Surface

Note:
1. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

2. TPH-D/HO Soil Cleanup Level = 13,600 mg/kg

Drawing Source:
Landau Associates, Figure 6, 1/14/15.

(Vertical Exaggeration = 2.5X)

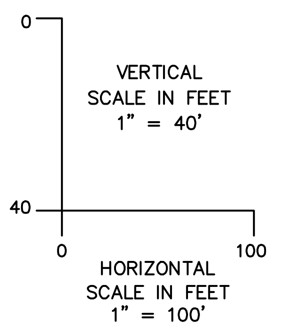


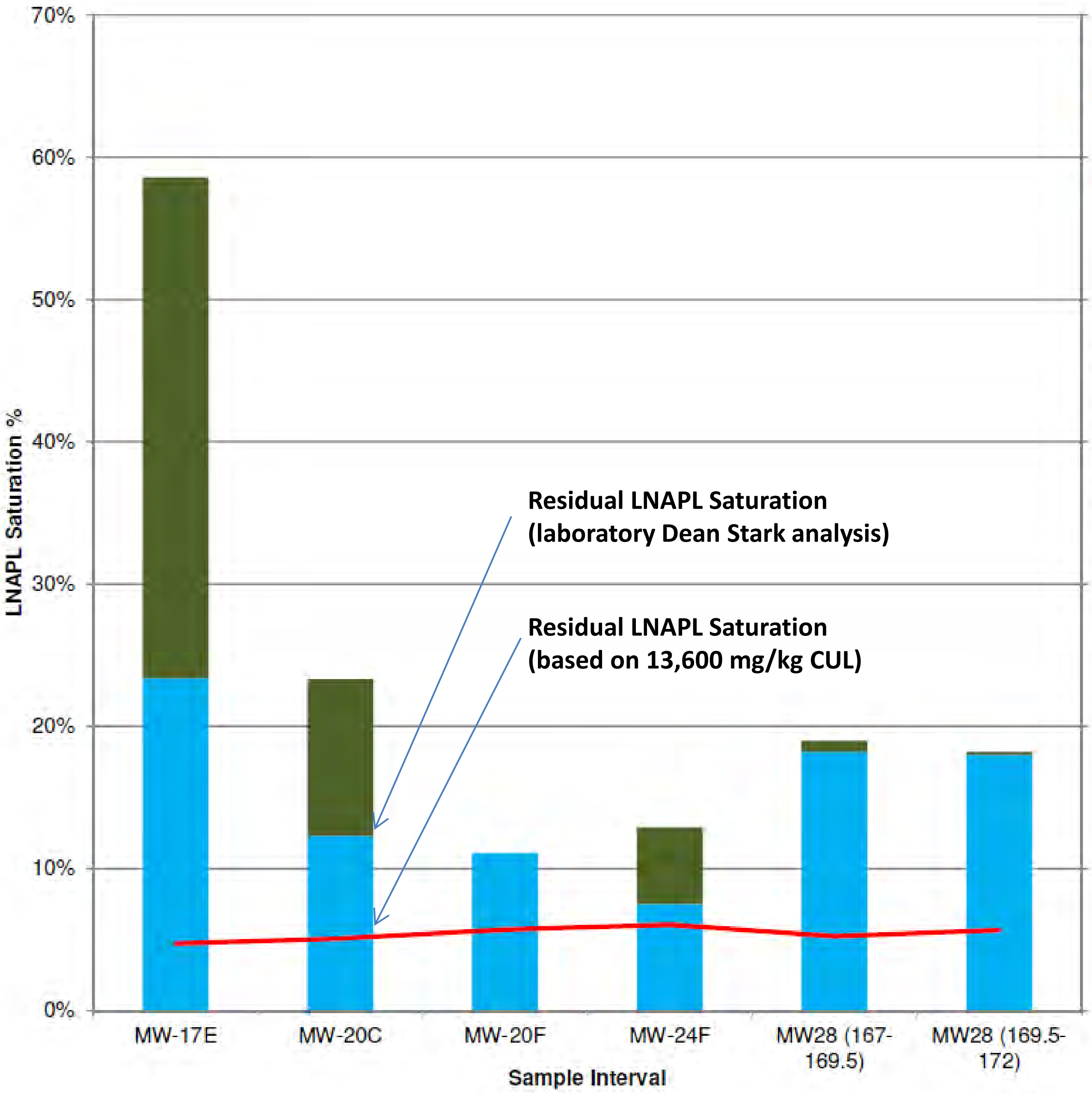
Figure 29

Geologic Profile B-B' with LNAPL Overlay
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

\\wdwalfs01\CAD\DWGS\0366860 Black Tank\21\0366860021.01.dwg
0366860.21
3/06/2017
J.Rahmani

DRAFT



Residual LNAPL Saturation (laboratory Dean Stark analysis)

Residual LNAPL Saturation (based on 13,600 mg/kg CUL)

🟩 Mobile LNAPL Saturation (%) as quantified by Dean Stark analysis in laboratory.

🟦 Residual LNAPL Saturation (%) as quantified by Dean Stark analysis in laboratory.

🟥 Residual LNAPL Saturation (%) as calculated based on CUL of 13,600 mg/kg.

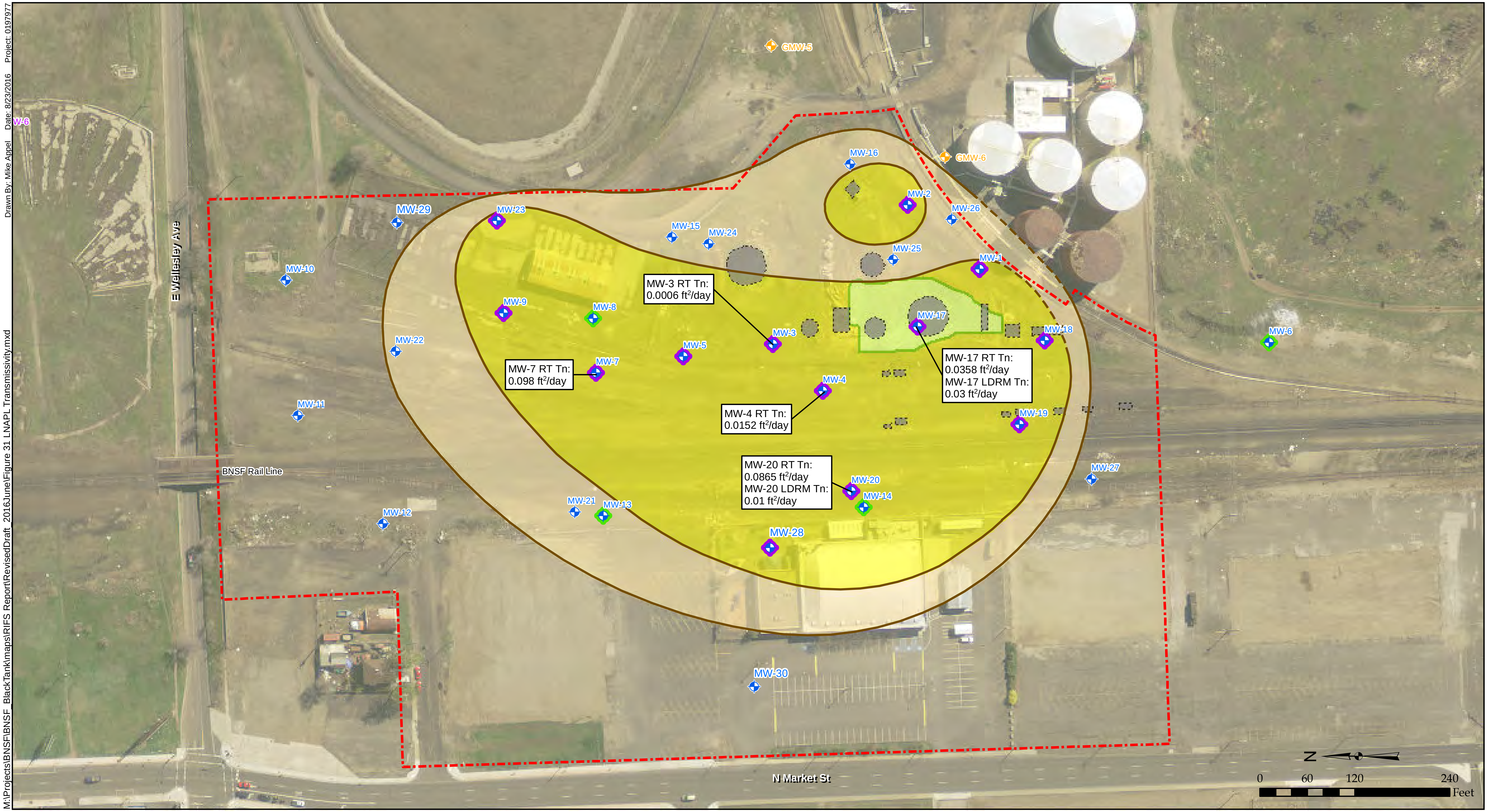
Notes:
LNAPL – Light Non-Aqueous Phase Liquid
Mobile LNAPL - LNAPL that is interconnected in pore space and has the potential to move under a hydraulic gradient.
Residual LNAPL - The portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients.
LNAPL Saturation - The percentage of the soil pore space that is filled with LNAPL.

Significant Finding: For all soil core samples collected, the residual LNAPL Saturation quantified by Dean Stark analysis exceeded the calculated residual LNAPL saturation of 13,600 mg/kg (i.e., the proposed TPH-D/HO CUL for subsurface soils).

Figure 30
Calculated Residual LNAPL Comparison to Lab-Based Residual LNAPL
BNSF Black Tank
Spokane, Washington

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 31 LNAPL Transmissivity.mxd Drawn By: Mike Appel Date: 8/23/2016 Project: 0197977



MW-3 RT Tn:
0.0006 ft^2/day

MW-7 RT Tn:
0.098 ft^2/day

MW-17 RT Tn:
0.0358 ft^2/day
MW-17 LDRM Tn:
0.03 ft^2/day

MW-4 RT Tn:
0.0152 ft^2/day

MW-20 RT Tn:
0.0865 ft^2/day
MW-20 LDRM Tn:
0.01 ft^2/day

Legend

◆ Measurable LNAPL in Well
◆ Uncertain Results (submerged screen or dry well)
◆ No Measurable LNAPL in Well
◆ SemMaterials Monitoring Well with No Measurable LNAPL in Well
▭ Proposed BNSF Black Tank Site Boundary
🟩 Former Black Tank Excavation
▨ Historical Aboveground Storage Tank
🟨 Mobile and Residual LNAPL
▨ Residual LNAPL

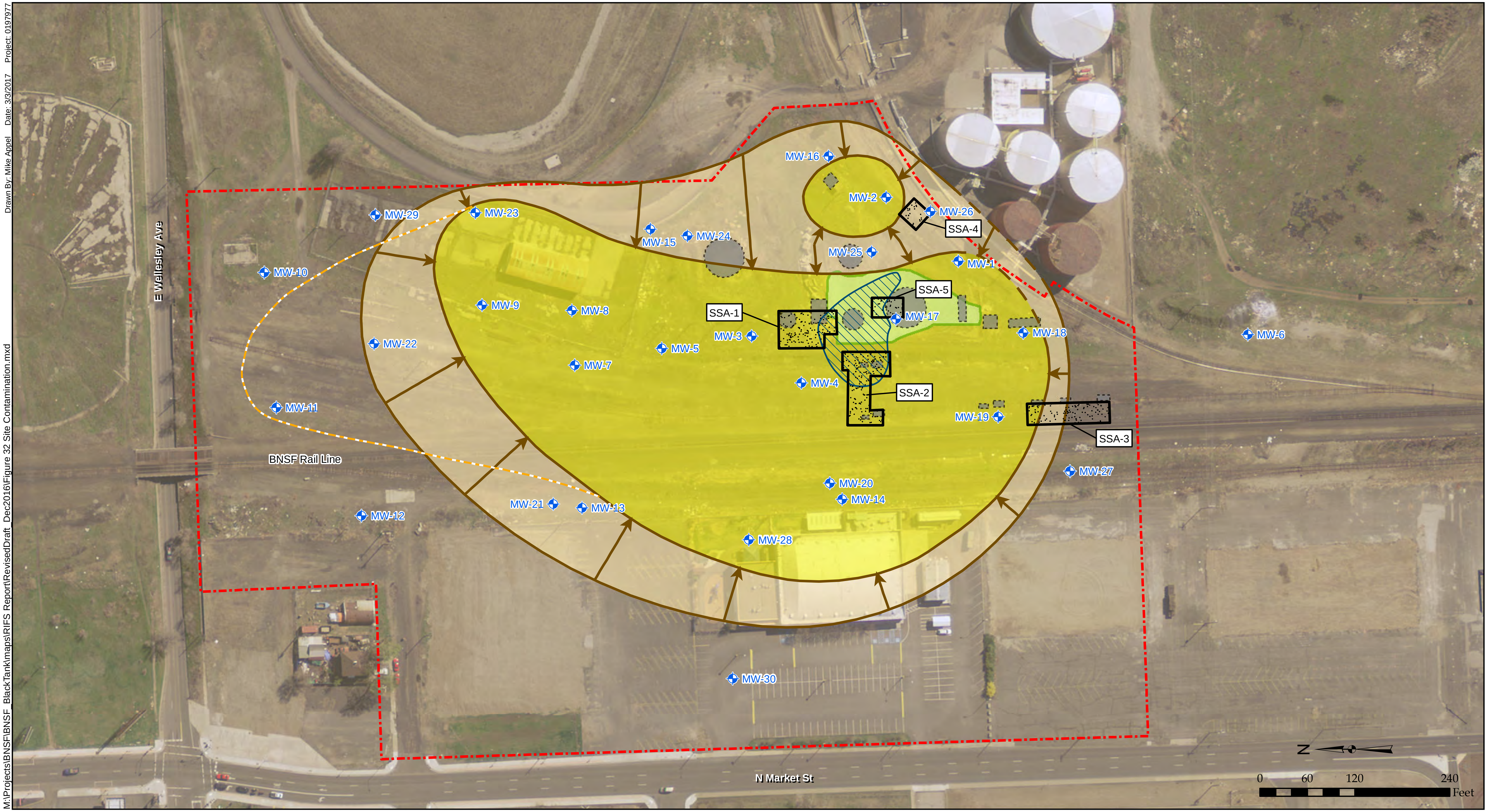
Notes:
The ITRC transmissivity range indicating that hydraulic conductivity of LNAPL by conventional means is not practical is 0.1 to 0.8 ft^2/day.
ITRC = Interstate Technology and Regulatory Council
RT Tn = Recovery Test Estimated Transmissivity
LDRM Tn = LDRM Modeled Transmissivity
ft^2/day = Square Feet per Day
LNAPL = Light Non-Aqueous Phase Liquid.
Aerial Photo: USGS, April 2012.

Figure 31
LNAPL Transmissivity Estimates
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 32 Site Contamination.mxd   Drawn By: Mike Appel   Date: 3/3/2017   Project: 0197977



Legend

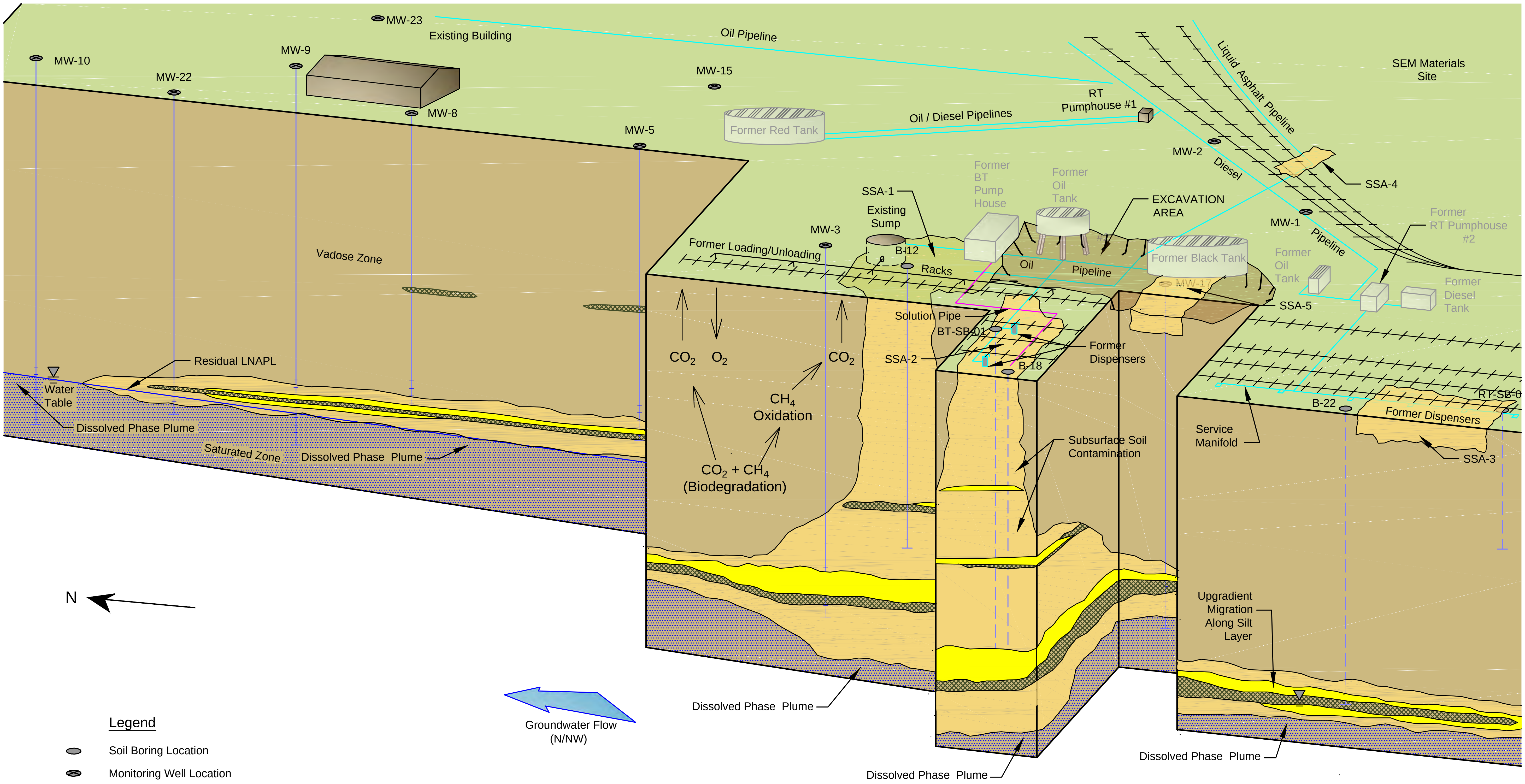
- ✛ Monitoring Well
- → Receeding Mobile LNAPL Due to Natural Source Zone Depletion
- — Most Recent Approximate Extent of LNAPL, June 2016
- – – Most Recent Inferred Extent of LNAPL, June 2016
- - - Approximate Seasonal Maximum Extent of Dissolved Phase TPH-D/HO Plume
- 🟥 Proposed BNSF Black Tank Site Boundary
- ▨ Intermediate Soil Exceeding the Preliminary CUL
- ⬛ Surface Soil Exceeding Preliminary CULs
- 🟩 Former Black Tank Excavation
- ▩ Historical Aboveground Storage Tank
- 🟨 Mobile and Residual LNAPL
- ▭ Residual LNAPL

Notes:
CUL = Cleanup Level
LNAPL = Light Non-Aqueous Phase Liquid
Mobile LNAPL = LNAPL that is interconnected in pore space and has the potential to move under a hydraulic gradient.
Residual LNAPL = The portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients. Residual LNAPL is present throughout the mobile and residual LNAPL areas shown.
Aerial Photo: USGS, April 2012.

Figure 32
Site Contamination
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT



Legend

●	Soil Boring Location
⊗	Monitoring Well Location
▨	Residual LNAPL/ Petroleum Impacted Soil
▨	Mobile LNAPL
▨	Vadose Zone
▨	Saturated Zone
▨	Excavation Area
▨	Silt and Silty Sand Facies

Notes

1. Not to scale.
2. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.
3. LNAPL - Light Non-Aqueous Phase Liquid
4. SSA - Surface Soil Area
5. CO_2 - Carbon Dioxide
6. CH_4 - Methane
7. O_2 - Oxygen
8. Residual LNAPL - The portion of LNAPL that is hydraulically discontinuous and immobile to gravity drain forces and hydraulic gradients.
9. Mobile LNAPL - LNAPL that is interconnected in pore space and has the potential to move under a hydraulic gradient.
10. Migrating LNAPL-LNAPL that is both mobile LNAPL and is subjected to a driving pressure head that forces the mobile LNAPL into adjacent soils and results in plume expansion. Note that Migrating LNAPL is not present at the Site.

Figure 33

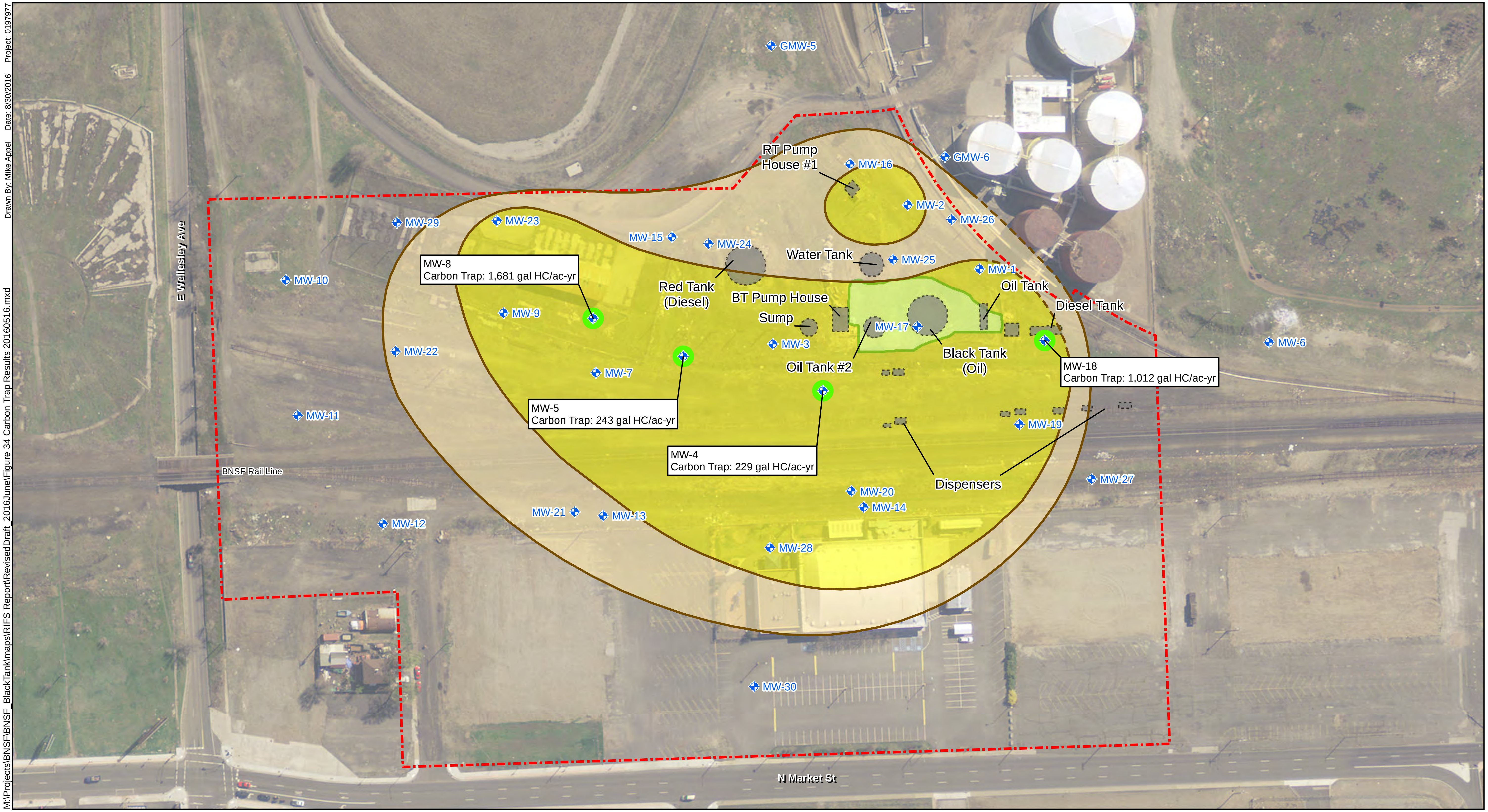
Conceptual Site Model
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

\\wdwalfs01\CAD\DWGS\0175844–BNSF Black Tanks\23\017584423–07ver2.dwg
0175844.23
3/06/2017
J. Estrada

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 34 Carbon Trap Results 20160516.mxd Drawn By: Mike Appel Date: 8/30/2016 Project: 0197977



Legend

◆	Monitoring Well	--	Most Recent Inferred Extent of LNAPL, June 2016	▨	Historical Aboveground Storage Tank
●	Carbon Trap Sample	▭	Proposed BNSF Black Tank Site Boundary	🟨	Mobile LNAPL
—	Most Recent Approximate Extent of LNAPL, June 2016	🟩	Former Black Tank Excavation	▭	Residual LNAPL

Notes:
Calculated LNAPL biodegredation rate in gallons of hydrocarbons per acres per year (gal HC-ac-yr) assumes a hydrocarbon density of 0.97 g/mL and a formula of $C_{10}H_{22}$.
LNAPL = Light Non-Aqueous Phase Liquid
g/mL = grams per milliliter
$C_{10}H_{22}$ = Decane
Aerial Photo: USGS, April 2012.

N

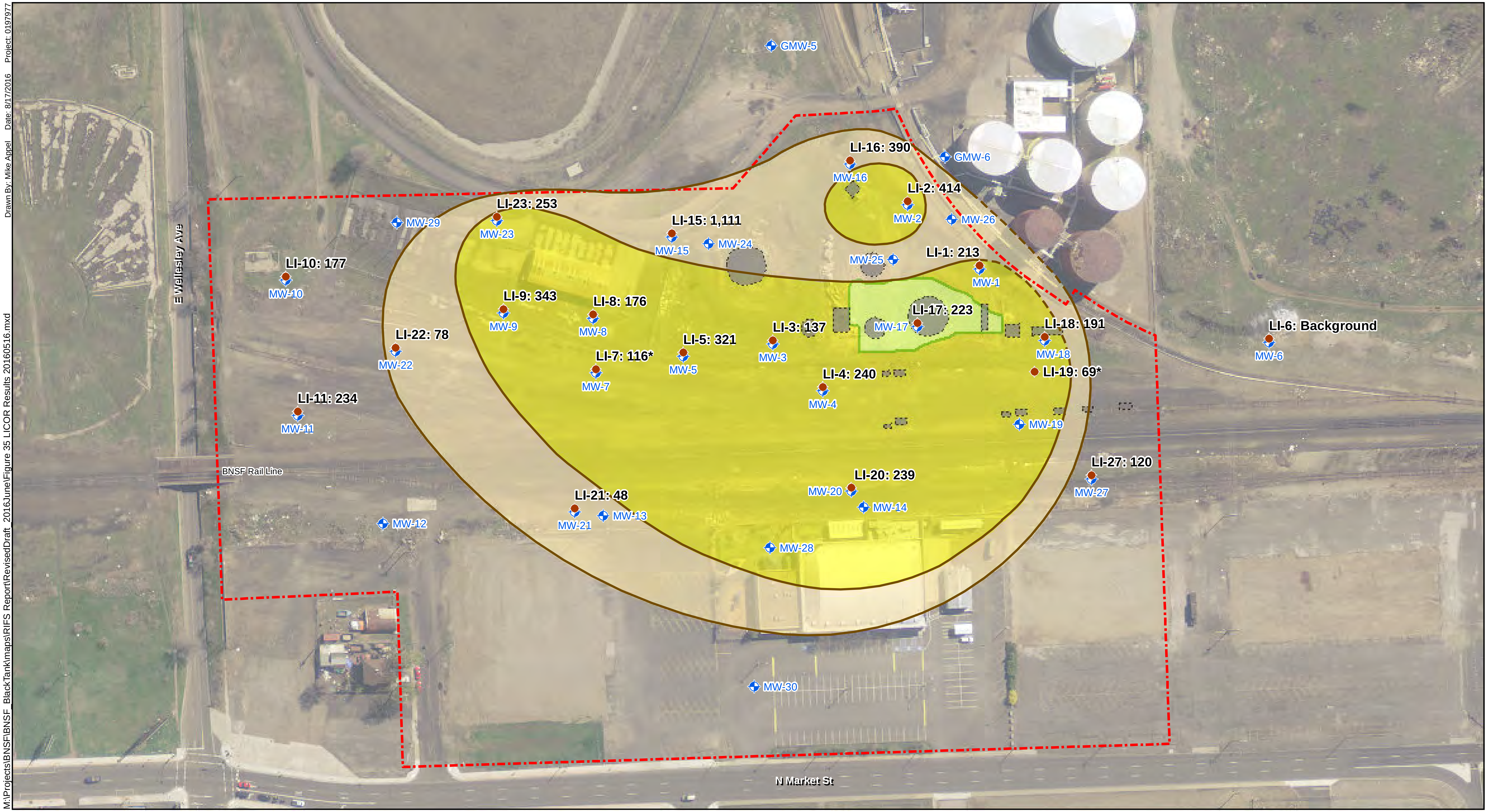
0 60 120 240
Feet

Figure 34
Carbon Trap Results - April 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_2016June\Figure 35 LICOR Results 20160516.mxd Drawn By: Mike Appel Date: 8/17/2016 Project: 0197977



Legend

- ● LICOR Samples with Average Biodegredation Rate in gal HC/ac-yr
- ⊕ Monitoring Well
- — Most Recent Approximate Extent of LNAPL, June 2016
- - - Most Recent Inferred Extent of LNAPL, June 2016
- 🟥 Proposed BNSF Black Tank Site Boundary
- 🟩 Former Black Tank Excavation
- ▨ Historical Aboveground Storage Tank
- 🟨 Mobile LNAPL
- ▨ Residual LNAPL

Notes:
Calculated LNAPL biodegredation rate in gallons of hydrocarbons per acres per year (gal HC-ac-yr) assumes a hydrocarbon density of 0.97 g/mL and a formula of $C_{10}H_{22}$.
* - Calculated average biodegredation rate for observations above background flux.
LNAPL = Light Non-Aqueous Phase Liquid
g/mL = grams per milliliter
$C_{10}H_{22}$ = Decane
Aerial Photo: USGS, April 2012.

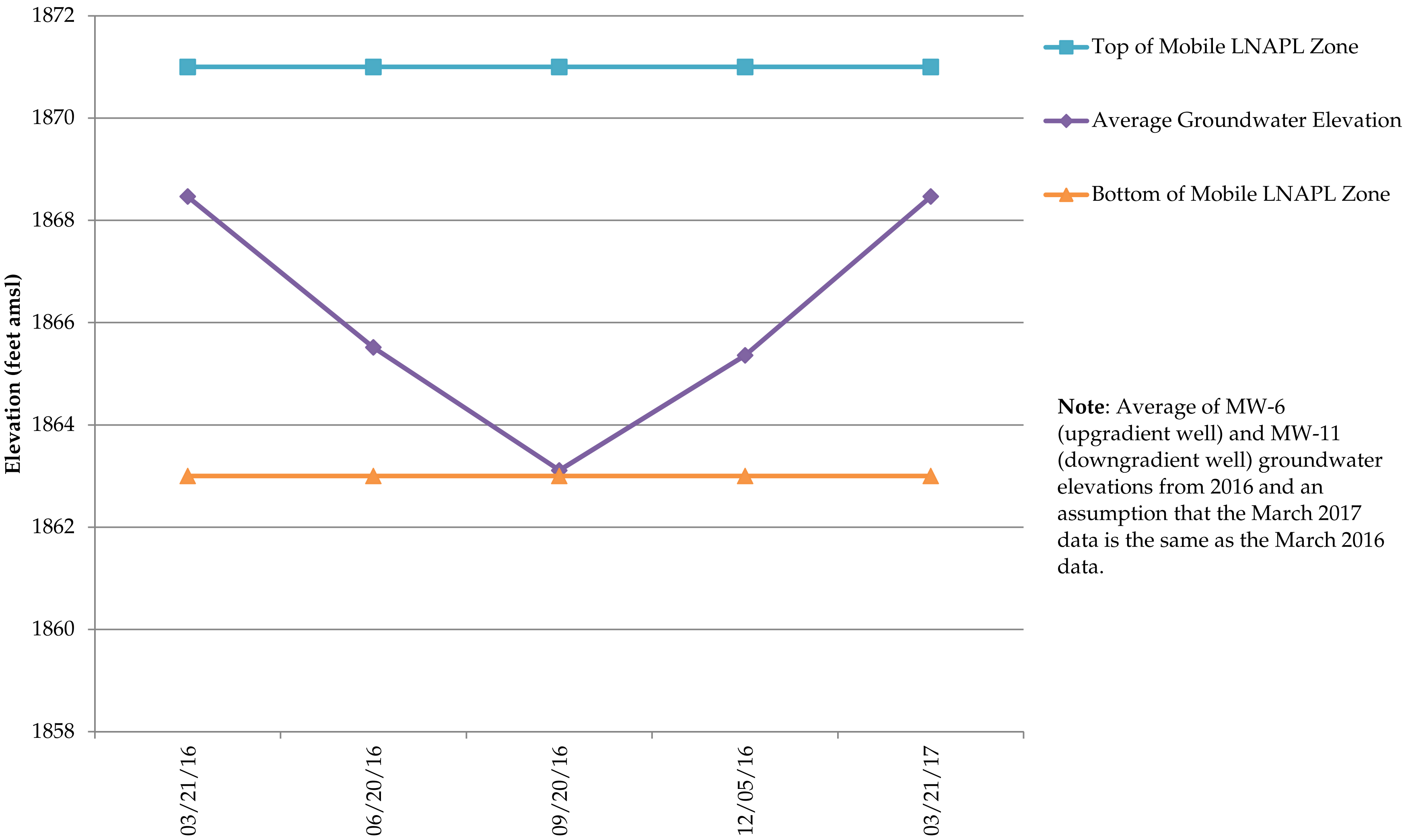
N

0 60 120 240 Feet

Figure 35

Carbon Flux Chamber Results
April 2016
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

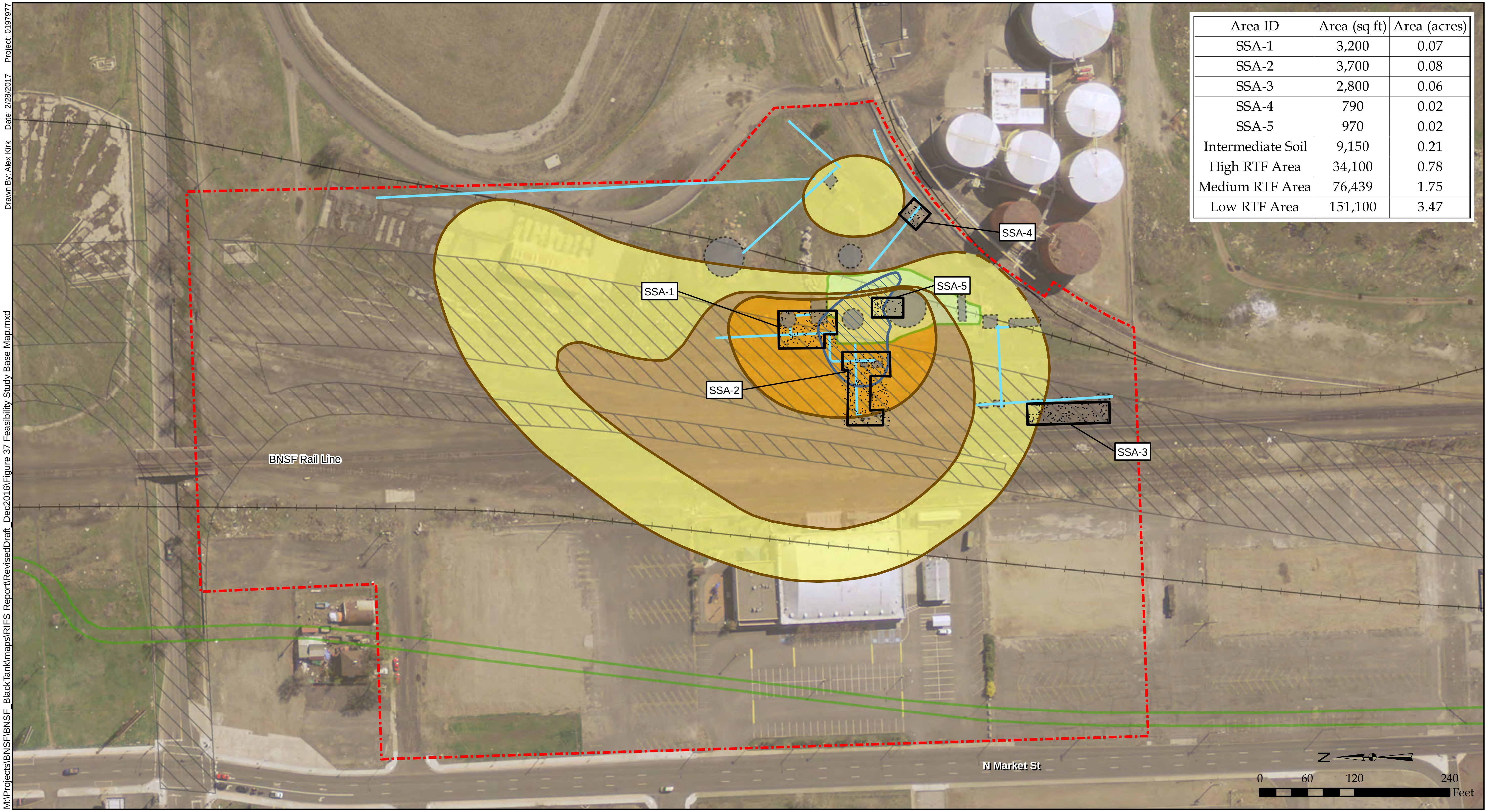


Note: Average of MW-6 (upgradient well) and MW-11 (downgradient well) groundwater elevations from 2016 and an assumption that the March 2017 data is the same as the March 2016 data.

Figure 36
Average Groundwater Elevation
Across the Mobile LNAPL Zone
BNSF Black Tank
Spokane, Washington

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 37 Feasibility Study Base Map.mxd Drawn By: Alex Kirk Date: 2/28/2017 Project: 0197977



Area ID	Area (sq ft)	Area (acres)
SSA-1	3,200	0.07
SSA-2	3,700	0.08
SSA-3	2,800	0.06
SSA-4	790	0.02
SSA-5	970	0.02
Intermediate Soil	9,150	0.21
High RTF Area	34,100	0.78
Medium RTF Area	76,439	1.75
Low RTF Area	151,100	3.47

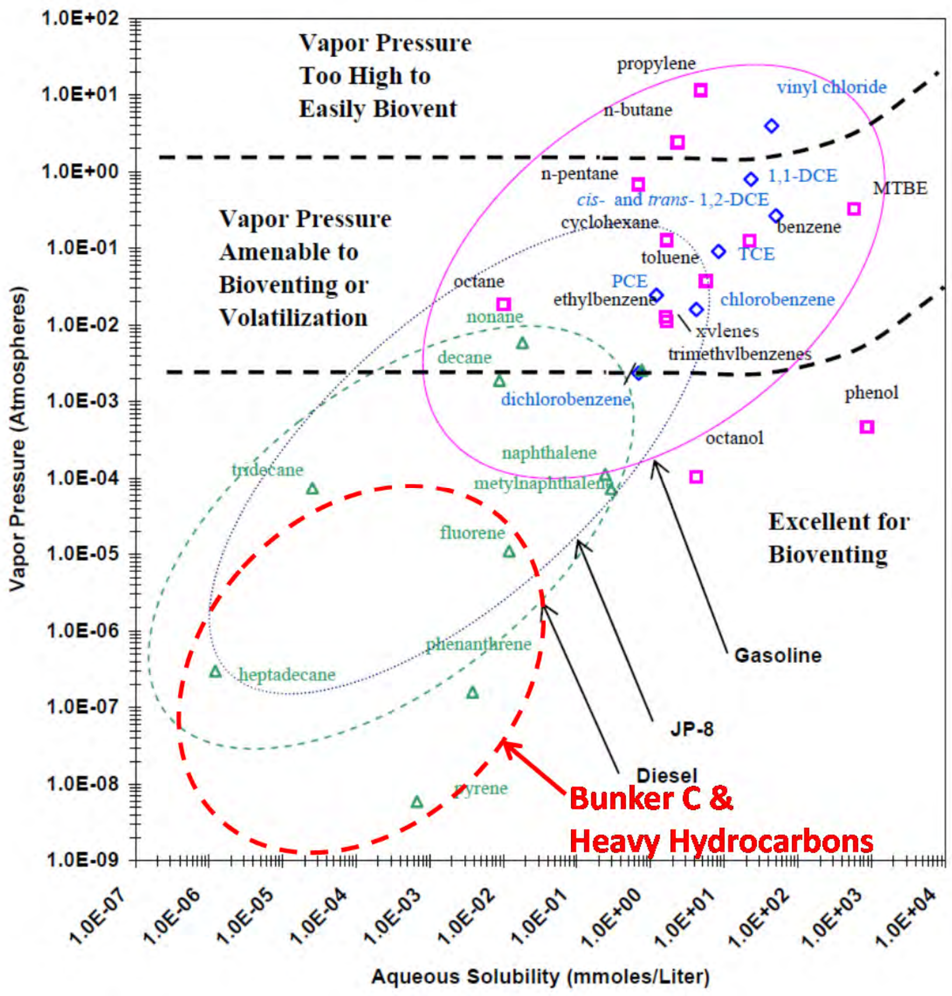
Legend

- Existing Piping (Petroleum and Chemical Solution)
- DOT Proposed Railroad Realignment Option - 2014
- Proposed BNSF Black Tank Site Boundary
- ▨ TPH-D/HO in Intermediate Soil Exceeding the Preliminary CUL
- Approximate Lateral Limits of Surface Soil Cleanup Areas
- ▨ DOT Proposed Highway Alignment Option - 2014
- 🟩 DOT Proposed Pedestrian Pathway - 2014
- 🟩 Former Black Tank Excavation
- Historical Aboveground Storage Tank, Sump or Pump House
- 🟧 High RTF Area
- 🟫 Medium RTF Area
- 🟨 Low RTF Area

Notes:
CUL = Cleanup Level
LNAPL = Light Non-Aqueous Phase Liquid
RTF: Restoration Timeframe
TPH-D/HO = Combined Diesel and Heavy Oil-Range Petroleum Hydrocarbons
Preliminary CUL = 13,600 milligrams per kilogram
Aerial Photo: USGS, April 2012.

Figure 37
Cleanup Action Areas
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com



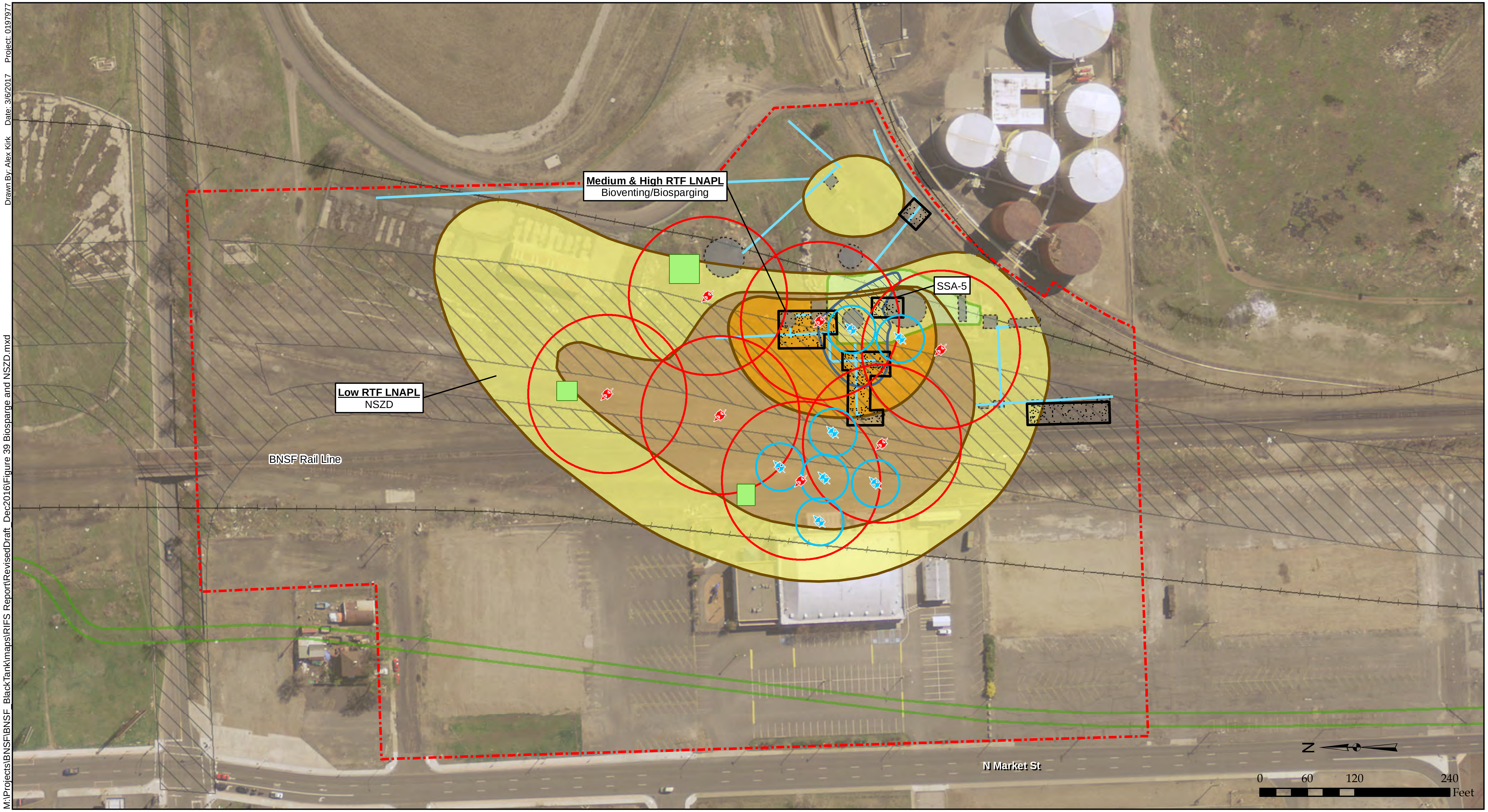
Note: Figure adapted from Bioventing Manual, EPA/540R-95/534a.

Figure 38
Hydrocarbons Amenable to Bioventing
BNSF Black Tank
Spokane, Washington

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 39 Biosparge and NSZD.mxd

Drawn By: Alex Kirk Date: 3/6/2017 Project: 0197977



Legend

- Proposed Biosparge Well
- Proposed Bioventing Injection Well
- ○ Proposed Biosparge Well 30 ft ROI
- ○ Proposed Bioventing Injection Well 100 ft ROI
- 🟩 Proposed Mechanical Equipment Facility
- 🟧 High RTF Area
- Medium RTF Area
- Low RTF Area
- Existing Piping (Petroleum and Chemical Solution)
- DOT Proposed Railroad Realignment Option - 2014
- Proposed BNSF Black Tank Site Boundary
- ▨ TPH-D/HO in Intermediate Soil Exceeding the Preliminary CUL
- Approximate Lateral Limits of Surface Soil Cleanup Areas
- ▨ DOT Proposed Highway Alignment Option - 2014
- DOT Proposed Pedestrian Pathway - 2014
- Former Black Tank Excavation
- Historical Aboveground Storage Tank, Sump or Pump House

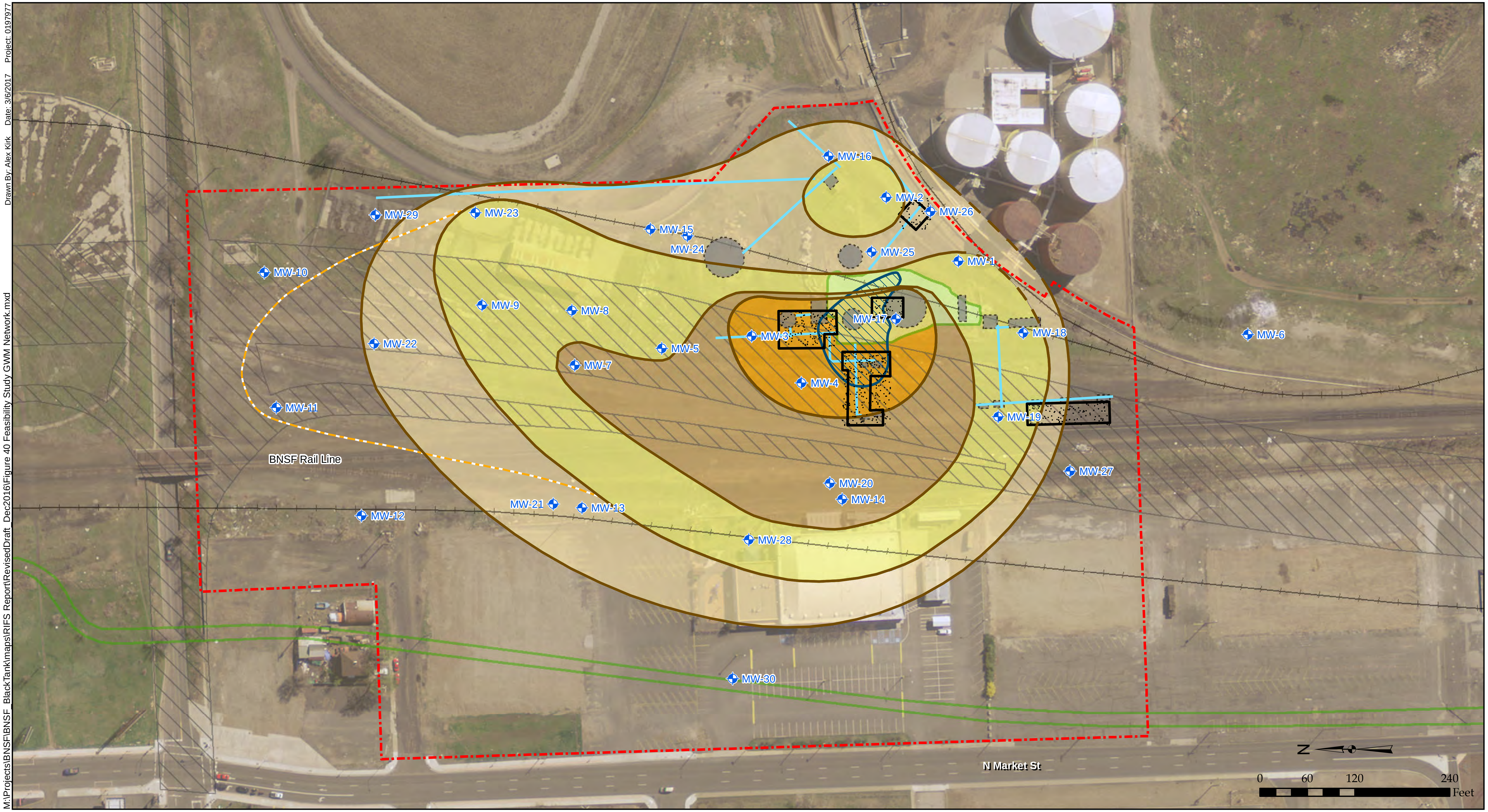
Notes:
CUL = Cleanup Level
DOT = Washington State Department of Transportation
LNAPL = Light Non-Aqueous Phase Liquid
NSZD = Natural Source Zone Depletion
ROI = Radius of Influence
RTF = Restoration Timeframe
TPH-D/HO = Combined Diesel and Heavy Oil-Range Petroleum Hydrocarbons
Preliminary CUL = 13,600 milligrams per kilogram
Aerial Photo: USGS, April 2012.

Figure 39
Conceptual Representation of Cleanup Action B
(NSZD and Biosparging/Bioventing)
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 40 Feasibility Study GWM Network.mxd Drawn By: Alex Kirk Date: 3/6/2017 Project: 0197977



Legend

- ⌖ Existing Monitoring Well
- — Existing Piping (Petroleum and Chemical Solution)
- —+— DOT Proposed Railroad Realignment Option - 2014
- - - Approximate Seasonal Maximum Extent of Dissolved Phase TPH-D/HO Plume
- ▨ TPH-D/HO in Intermediate Soil Exceeding the Preliminary CUL
- ☐ Approximate Lateral Limits of Surface Soil Cleanup Areas
- ☐ Proposed BNSF Black Tank Site Boundary
- ▨ DOT Proposed Highway Alignment Option - 2014
- ☐ DOT Proposed Pedestrian Pathway - 2014
- 🟩 Former Black Tank Excavation
- ■ Historical Aboveground Storage Tank
- 🟧 High RTF Area
- ■ Medium RTF Area
- 🟨 Low RTF Area
- ☐ Residual LNAPL

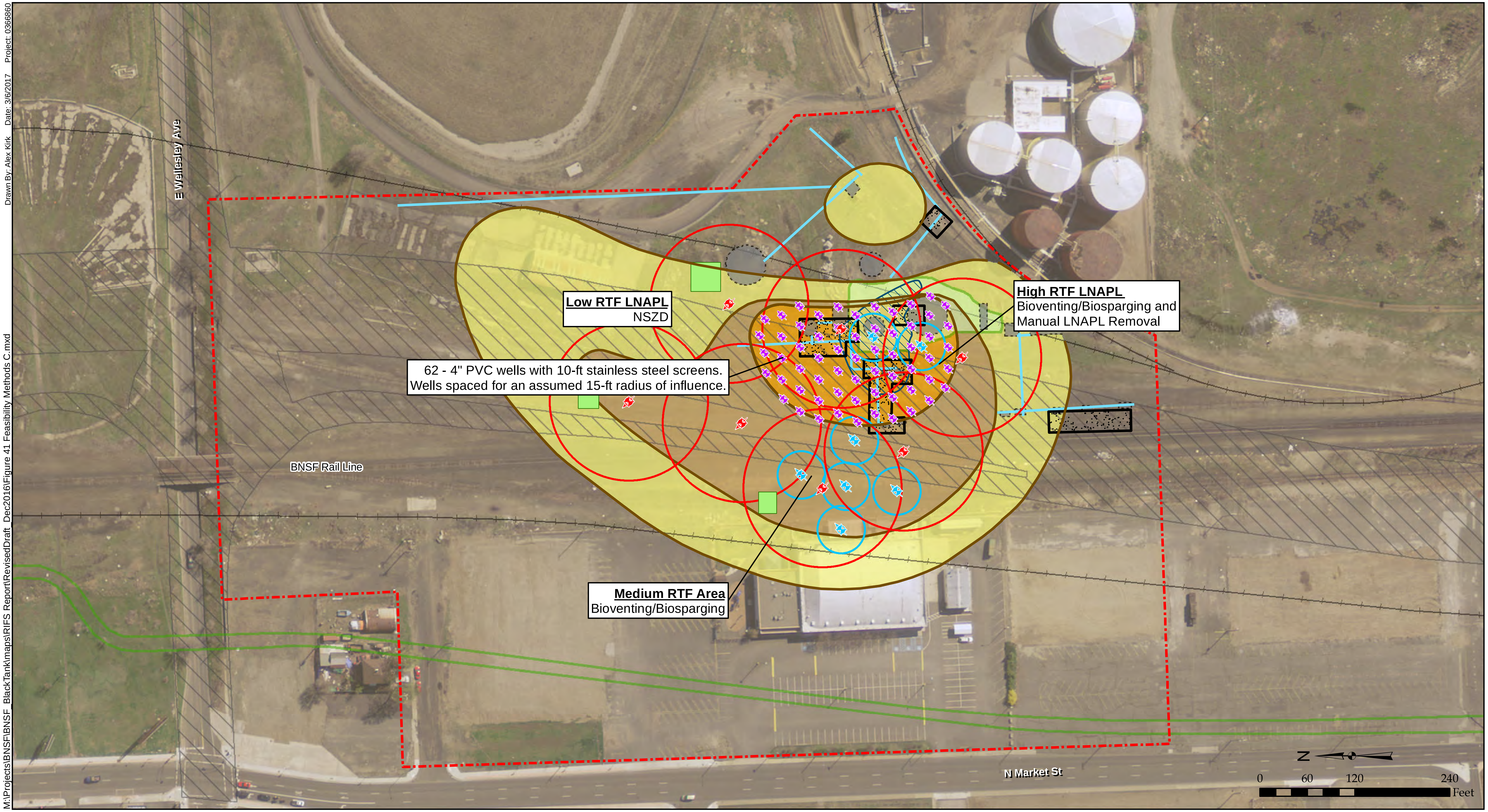
Notes:
If the proposed 2014 alignment is adopted, then up to 16 of the existing wells may need to be abandoned and 12 replacement wells constructed.
CUL = Cleanup Level
LNAPL = Light Non-Aqueous Phase Liquid
RTF = Restoration Timeframe
TPH-D/HO = Combined Diesel and Heavy Oil-Range Petroleum Hydrocarbons
Preliminary CUL = 13,600 milligrams per kilogram
Aerial Photo: USGS, April 2012.

Figure 40
Potential Groundwater Monitoring Well Network
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 41 Feasibility Methods C.mxd Drawn By: Alex Kirk Date: 3/6/2017 Project: 0366860



Legend

- ✦ LNAPL Removal Well
- ✦ Proposed Biosparge Well
- ✦ Proposed Bioventing Injection Well
- ○ Proposed Bioventing Injection Well 100 ft ROI
- ○ Proposed Biosparge Well 30 ft ROI
- 🟩 Proposed Mechanical Equipment Facility
- — Existing Piping (Petroleum and Chemical Solution)
- ┼ DOT Proposed Railroad Realignment Option - 2014
- ▭ Proposed BNSF Black Tank Site Boundary
- ▨ TPH-D/HO in Intermediate Soil Exceeding the Preliminary CUL
- ▭ Approximate Lateral Limits of Surface Soil Cleanup Areas
- ▨ DOT Proposed Highway Alignment Option - 2014
- ▭ DOT Proposed Pedestrian Pathway - 2014
- ▭ Former Black Tank Excavation
- ▭ Historical Aboveground Storage Tank
- 🟧 High RTF Area
- 🟫 Medium RTF Area
- 🟨 Low RTF Area

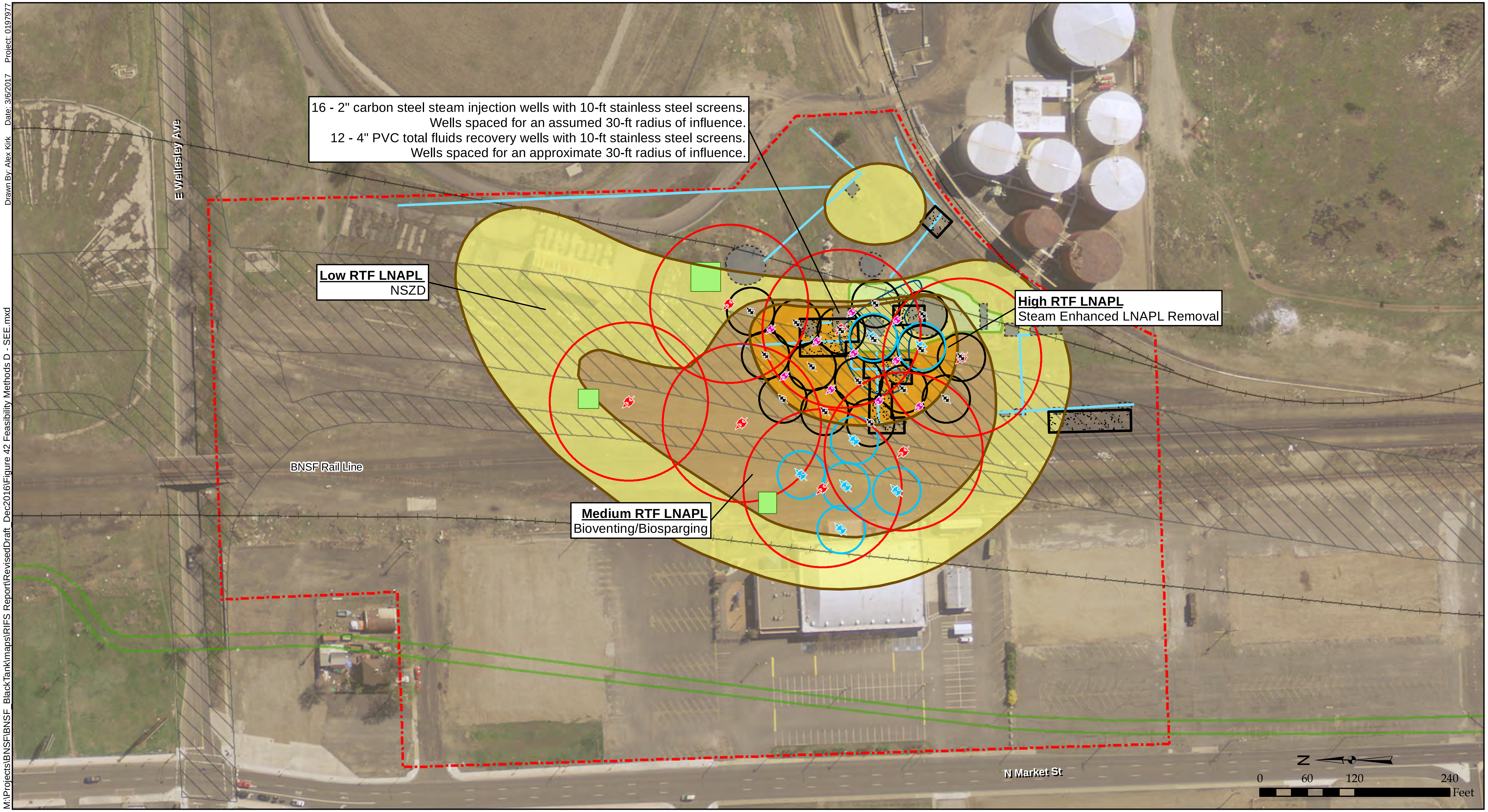
Notes:
CUL = Cleanup Level
DOT = Washington State Department of Transportation
LNAPL = Light Non-Aqueous Phase Liquid
NSZD = Natural Source Zone Depletion
ROI = Radius of Influence
RTF = Restoration Timeframe
TPH-D/HO = Combined Diesel and Heavy Oil-Range Petroleum Hydrocarbons
Preliminary CUL = 13,600 milligrams per kilogram
Aerial Photo: USGS, April 2012.

Figure 41
Conceptual Representation of Cleanup Action C (NSZD, Bioventing/Biosparging, and Manual LNAPL Removal)
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 42 Feasibility Methods D - SEE.mxd Drawn By: Alex Kirk Date: 3/6/2017 Project: 0197977



Legend

- Proposed Steam Injection Well
- Proposed Total Fluids Recovery Well
- Proposed Bioventing Injection Well
- Proposed Biosparge Well
- ○ Proposed Steam Injection Well 30 ft ROI
- ○ Proposed Bioventing Injection Well 100 ft ROI
- ○ Proposed Biosparge Well 30 ft ROI
- 🟩 Proposed Mechanical Equipment Facility
- Existing Piping (Petroleum and Chemical Solution)
- DOT Proposed Railroad Realignment Option - 2014
- Proposed BNSF Black Tank Site Boundary
- ▨ TPH-D/HO in Intermediate Soil Exceeding the Preliminary CUL
- Approximate Lateral Limits of Surface Soil Cleanup Areas
- ▨ DOT Proposed Highway Alignment Option - 2014
- DOT Proposed Pedestrian Pathway - 2014
- 🟩 Former Black Tank Tank Excavation
- Historical Aboveground Storage Tank
- 🟧 High RTF Area
- 🟫 Medium RTF Area
- 🟨 Low RTF Area

Notes:
CUL = Cleanup Level
DOT = Washington State Department of Transportation
LNAPL = Light Non-Aqueous Phase Liquid
NSZD = Natural Source Zone Depletion
ROI = Radius of Influence
RTF = Restoration Timeframe
TPH-D/HO = Combined Diesel and Heavy Oil-Range Petroleum Hydrocarbons
Preliminary CUL = 13,600 milligrams per kilogram
Aerial Photo: USGS, April 2012.

Figure 42
Conceptual Representation of Cleanup Action D
(NSZD, Bioventing/Biosparging and
Steam Enhanced LNAPL Recovery)
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

DRAFT

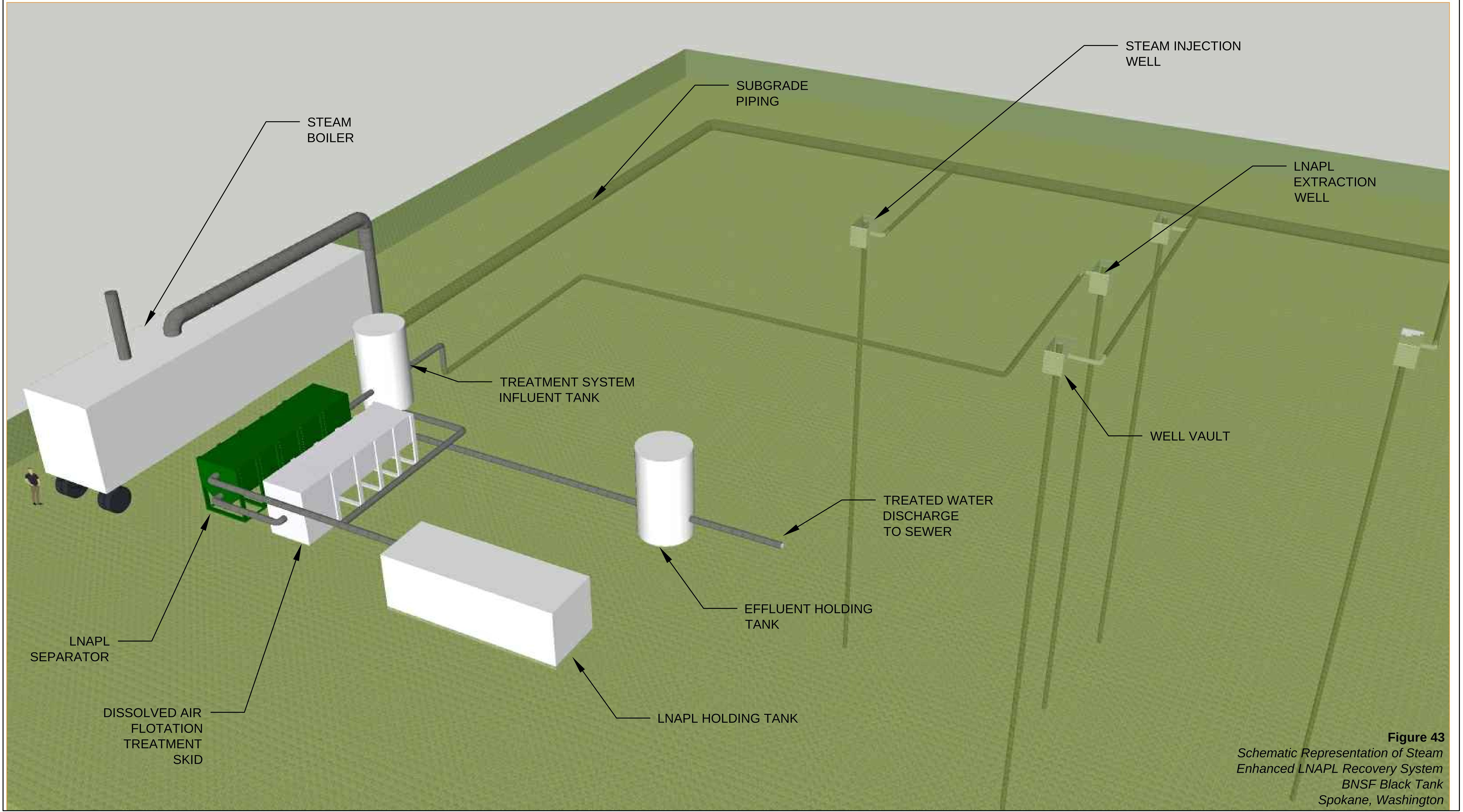
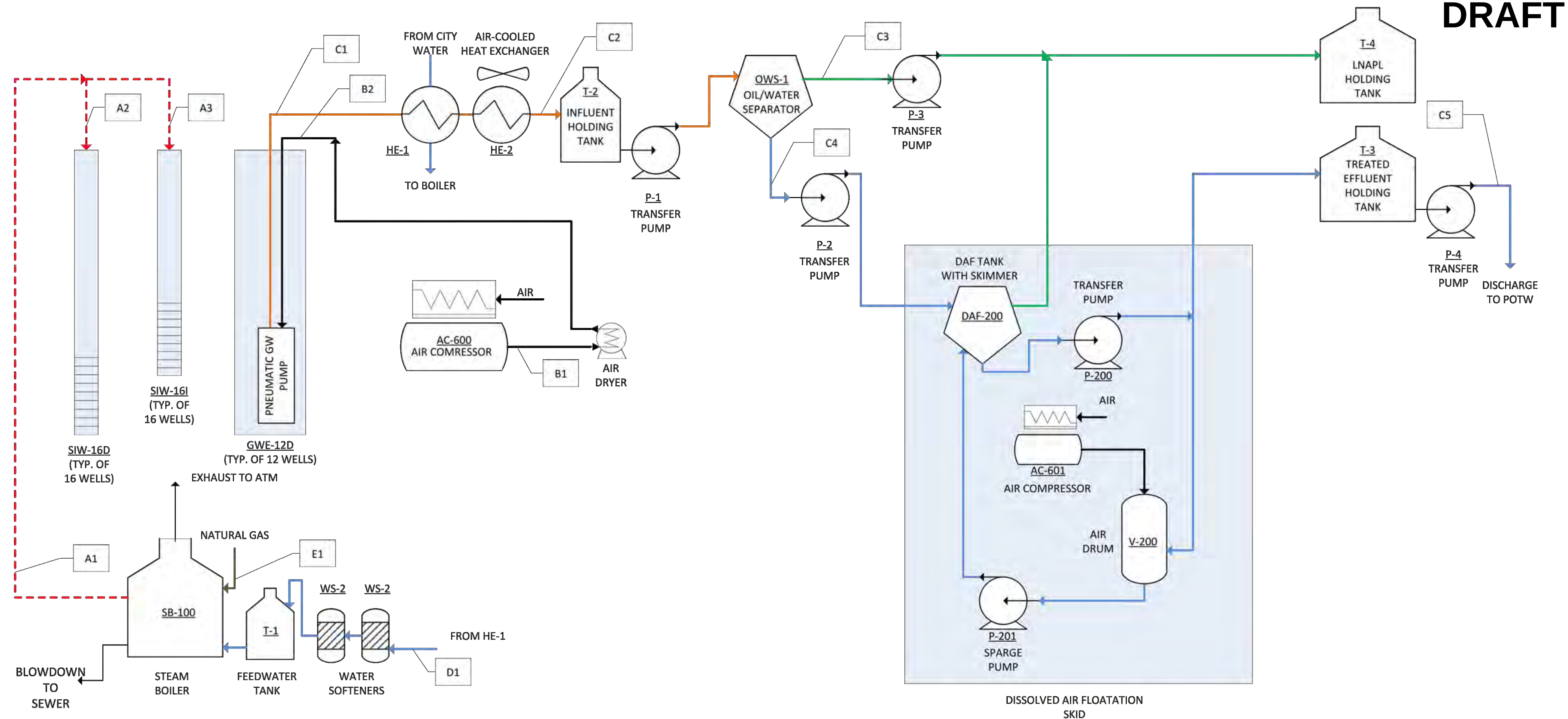


Figure 43
Schematic Representation of Steam Enhanced LNAPL Recovery System
BNSF Black Tank
Spokane, Washington

G.Mackey 3/06/2017 0197977 D:\Programs\ACAD Files\BNSF Black Tank\BNSF Figures.dwg

DRAFT



	SERVICE	FLOW & PRESSURE		SERVICE	FLOW & PRESSURE
A1	TOTAL STEAM SUPPLY	9,600 lb/hr@ 150 psig	E1	NATURAL GAS	140 cfm @ 50 psig
A2	STEAM SUPPLY TO SIW-D	300 lb/hr@ 40 psig			
A3	STEAM SUPPLY TO SIW-I	300 lb/hr @ 40 psig			
B1	TOTAL COMPRESSED AIR SUPPLY	50 SCFM @ 100 PSIG			
B2	COMPRESSED AIR PER LNAPL EXTRACTION WELL	3 SCFM @ 100 PSIG			
C1	GROUNDWATER/LNAPL EXTRACTION PER EXTRACTION WELL	3 GPM @ 30 psig			
C2	TOTAL GROUNDWATER EXTRACTION	36 GPM @ 30 psig			
C3	LNAPL TO HOLDING TANK	12 GPM			
C4	INFLUENT TO DAF UNIT	24 GPM @ 30 PSIG			
C5	DISCHARGE TO POTW	24 GPM @ 30 PSIG			
D1	BOILER FEEDWATER (CITY)	20 GPM @ 60 PSIG			

LEGEND

- - -▶	STEAM INJECTION
──▶	COMPRESSED AIR
──▶	MIXED FLUIDS
──▶	RECOVERED LNAPL
──▶	WATER
──▶	NATURAL GAS

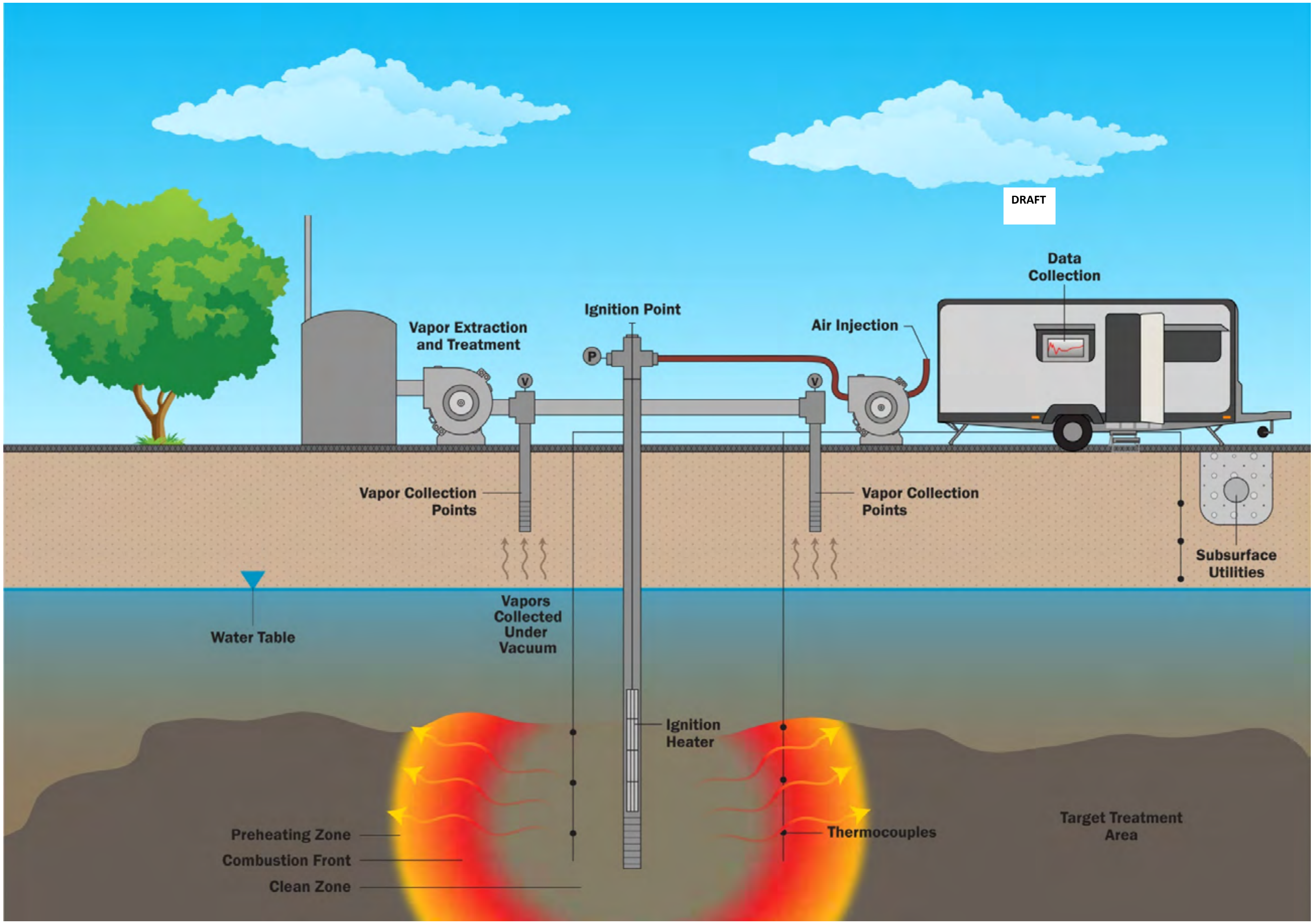
Figure 44
Conceptual Process Flow Diagram
Steam Enhanced LNAPL Recovery System
BNSF Black Tank
Spokane, Washington

Environmental Resources Management
www.erm.com
ERM

D:\Programs\ACAD Files\BNSF Black Tank\BNSF Figures.dwg
0197977
3/06/2017
G.Mackey

DRAFT

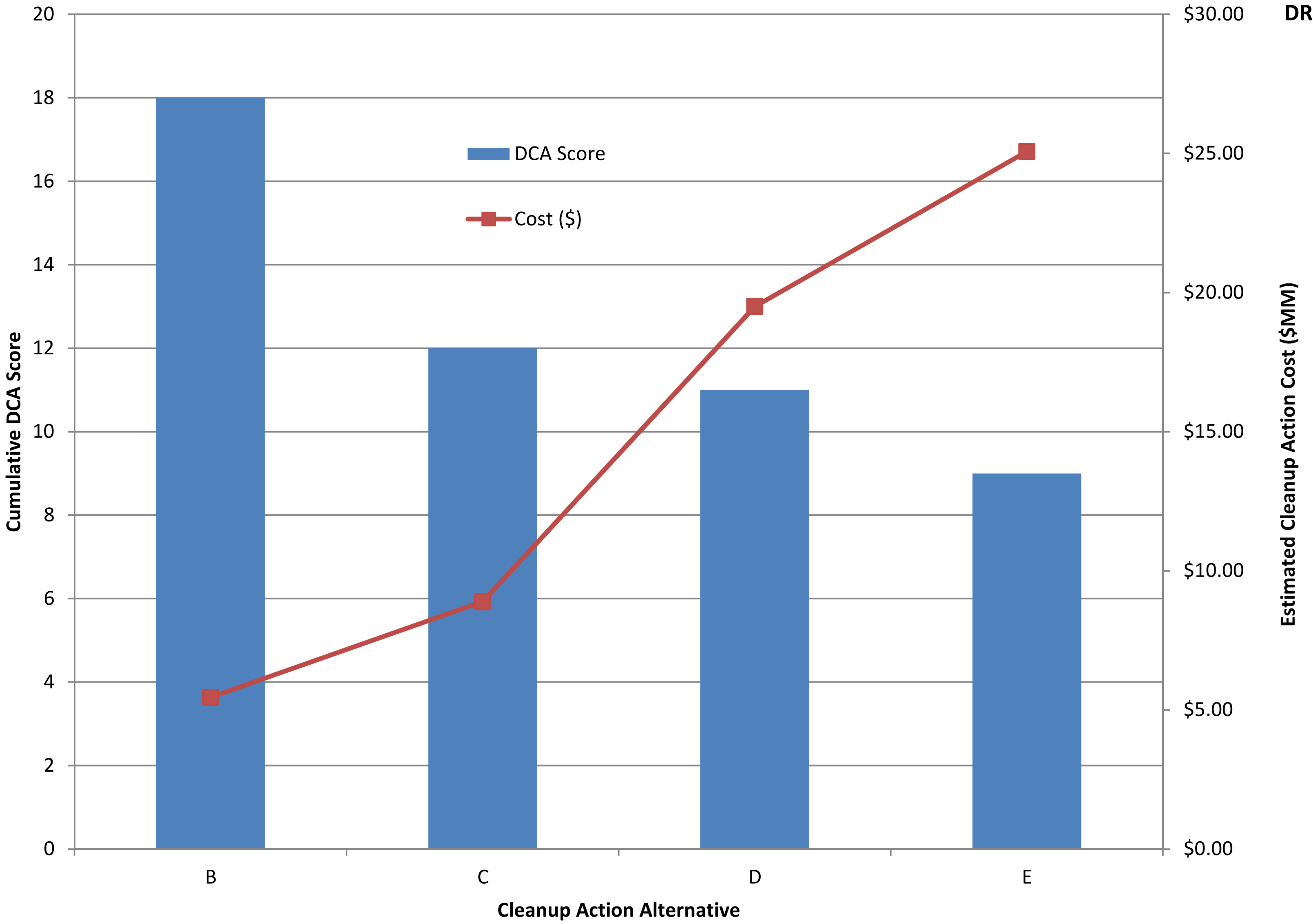
M:\Projects\BNSF\BNSF_BlackTank\maps\RIFS Report\RevisedDraft_Dec2016\Figure 45 Smoldering_Technology.mxd   Drawn By: Melody Kieneker   Date: 3/6/2017   Project: 0197977



Environmental Resources Management
www.erm.com

Notes:
Image Sourced from http://www.savronsolutions.com/products

Figure 45
Conceptual Representation of Smoldering Technology
BNSF Black Tank
Spokane, Washington



Environmental Resources Management
www.erm.com

Notes:
DCA = Disproportionate Cost Analysis
$MM = Million Dollars

Figure 46
Results of the DCA for Deep Contamination
BNSF Black Tank
Spokane, Washington

Tables

DRAFT
TABLE 1

Historical Document Summary
BNSF Black Tank Site
Spokane, Washington

Year	Document - Description of Contents
1928	Hillyard Industrial Sewer and Pump Station Map - shows Black Tank, Oil Tank #2, Black Tank (BT) pump house, sump and sewer pipelines.
Mar. 1931	Oblique aerial photograph showing Great Northern Shops at Hillyard - shows Black Tank, Oil Tank #2, BT pump house, and possibly the sump (from 2002 Inland Empire Railroad Calendar by Inland Empire Railroad Historical Society).
Dec. 1937	G.N.RY. Newport - Spokane Section, Engineering Site Plan of Spokane No. 2, 3 Hillyard - shows same infrastructure as 1928 drawing plus Red Tank, Oil Tank, Red Tank (RT) pump house #2, diesel tank, fuel dispensers, oil spur, connecting fuel pipelines, water tank, water dispensers, connecting water pipelines, solution pipeline and steam pipeline. Although the drawing is dated December 1937, it appears to have been updated to show some infrastructure constructed after 1937.
Sept. 1950	Ground-level photograph of Hillyard - shows the Black Tank, Oil Tank #2 (elevated), water tank (elevated), dispensers, Red Tank and the BT pump house (from 2000 Inland Empire Railroad Calendar by Inland Empire Railroad Historical Society).
Early 1950s	Ground-level photograph of Hillyard erecting shop - shows Oil Tank #2 (elevated), water tank (elevated), dispensers, Red Tank and the BT pump house (from 1988 Inland Empire Railroad Calendar by Inland Empire Railroad Historical Society).
Dec. 20, 1956	Lease agreement between Great Northern Railway Co. and Blackline Asphalt Sales, Inc. to allow construction and operation of 4-inch liquid asphalt pipeline. Includes drawing of pipeline alignment.
Nov. 25, 1969	Photocopy of drawing showing steam line alignment for Blackline Asphalt Sales, Inc. Abbreviation O.H. indicates overhead line.
Dec. 31, 1974	Lease transfer agreement between Backline Asphalt Co. and Husky Oil Co. Transfers interests in existing facilities: certain roadways and rail crossings; 2 storage tanks, sump, pump house; 4-inch liquid asphalt line; warehouse and tank; Asphalt and fuel oil storage tanks and mixing plant.
Feb. 5, 1975	Termination of steam contract between BN and Husky Oil Co. Letter states that Husky now has its own steam plant.

Year	Document - Description of Contents
March 1, 1977	Lease agreement between BN and Husky Oil Co. to use existing tank ("Black Tank").
Dec. 1, 1979	Lease agreement between BN and Husky Oil Co. for existing warehouse and tank together.
Dec. 3, 1982	Blanket Assignment between BN, Husky Oil Co., and Intermountain Asphalt Co.
April 1, 1983	Blanket Assignment between BN, Intermountain Asphalt Co., Tristate Oil and Asphalt Sales. Inc. and Koch Asphalt Co.
Aug. 19, 1987	Letter from Glacier Park Co. to Koch Asphalt identifying asphaltic material inside Black Tank containment berm and other environmental concerns related to the Koch Asphalt operations. Includes a copy of a photograph showing impacted area around the Black Tank.
Dec. 31, 1987	Letter from Koch Industries Inc. to Glacier Park Co. regarding soil contamination, apparently related to the Black Tank. Letter includes laboratory results of "oil sludge" sample analysis. The sample was analyzed for EP Toxicity heavy metals and PCBs, total PCBs (Arochlor 1242, 1254 and 1260) and purgeable volatile organics. No information on sample location provided.
Feb. 2, 1988	Letter from Morrison-Knudsen Engineers, Inc. to Glacier Park Co. presenting analytical results for six tar-like material samples collected from within the containment area around the Black Tank. All of the samples were analyzed for PCBs and one of the samples was analyzed for diesel.
March 3, 1988	Letter from Chemical Processors.,Inc. to A. H Koch presenting a revised estimate of contaminated soil and water at the "Koch Asphalt Site" and the volume of residuals in tank. The letter includes a hand drawn site plan showing the estimated extent of soil and surface water contamination. The drawing is clearly of the subject property and the Black Tank containment area. The letter presents a work scope for removal of the contaminated media in and around the Black Tank.
March 4, 1988	Letter from Chemical Processors Inc. to A. H Koch regarding proposed collection of soil, surface water and tank content samples. Soil to be analyzed for PCBs. Hand drawn soil sample grid provided.

Year	Document - Description of Contents
March 11, 1988	Letter from Chemical Processors Inc. to A. H Koch. This is a field sampling report for the work that was scoped in the March 4, 1988 letter. Hand-drawn figure shows approximate locations where samples were collected. No analytical data provided.
May 5, 1988	Letter from Chemical Processors Inc. to A. H Koch detailing results of interviews with former employees of the Koch facility. The letter describes different types of oils reportedly stored in the tank (i.e., MC 250 and Number 6 oil, both common asphaltic oils), dust oil (a rolling mill oil) and clarified dust oil (a viscous greenish product with high sulfur). Samples of the presumed dust oil and asphaltic oils were analyzed for PCBs, heavy metals and chlorinated solvents. Soil and water samples collected from within the containment area around the Black Tank were analyzed for PCBs. Analytical results for the product, soil and water samples are summarized.
Undated	GNRHS & NPRHA Archives and GN-NP Archives Search result for GN_AFE_Mattson: HILLYARDWA-20555 shows facility start date as 1912.

Historical Aerial Photograph Summary
BNSF Black Tank Site
Spokane, Washington

Year	Type	Source	Document - Description of Contents
1920s	Oblique aerial photograph	Husky Oil	Photo No. 1 - shows Black Tank, Oil Tank #2, Black Tank (BT) pump house, and possibly the sump.
1930	Oblique aerial photograph	Husky Oil	Photo No. 2 - shows Black Tank and possibly Oil Tank #2, but too distant and grainy to see any detail.
1930	Oblique aerial photograph	Husky Oil	Photo No. 3 - shows Oil Tank #2 , BT pump house and the sump, but the Black Tank is out of the frame of view.
1931	Oblique aerial photograph	Husky Oil	2002 Inland Empire Railroad Calendar Photograph - shows Black Tank, Oil Tank #2, BT pump house, and possibly the sump.
1940	Ground level photograph	Husky Oil	The photo shows Black Tank, Oil Tank #2 (elevated) the water tank (elevated), BT pump house and a refueling station on the rail spur immediately to the west of the BT pump house and Oil Tank #2.
1950	Oblique aerial photograph	Husky Oil	Photo No. 4 - shows Black Tank and possibly Oil Tank #2, but too distant and grainy to see any detail.
1955	Oblique aerial photograph	Husky Oil	Photo No. 5 - shows Black Tank, Oil Tank #2 (elevated), BT pump house, water tank (elevated), Red Tank, steam pipeline (elevated), RT Pump House #2, and Red Tank (RT) Pump House #1. Dark staining visible at the location of fueling dispensers and manifold to the southwest of the Black Tank. There is a grid of (2 by 5) objects or features directly south of the Black Tank, but the features are unidentifiable due to the resolution of the photograph.
1957	Vertical aerial photograph	Husky Oil	Photo No. 6 - shows same features at the 1955 photo except that Oil Tank #2 has been removed.
1962	Vertical aerial photograph	Husky Oil	Photo No. 7 - shows same features as the 1957 photo, but the photo is very grainy.
1963	Oblique aerial photograph	Husky Oil	Photo No. 8 - shows same features as the 1957 photo, but too distant and grainy to see any detail.
1967	Vertical aerial photograph	Husky Oil	Photo No. 9 - shows same features as the 1957 photo, except for the presence of a crescent of dark staining in the containment area of the Red Tank and an irregular area of dark staining around the Black Tank.

Year	Type	Source	Document - Description of Contents
1968	Vertical aerial photograph	Husky Oil	Photo No. 10 - shows same features as the 1967 photo except the dark staining around the Red Tank appears smaller and the dark staining around the Black Tank is more obvious.
1972	Vertical aerial photograph	Husky Oil	Photo No. 11 - shows the same features as the 1968 photo except the water tank has been removed and the dark staining around the Black Tank extends throughout the area of the former Oil Tank #2 and up to and east of the BT Pump House as well as down to the area east of the oil tank.
1974	Vertical aerial photograph	Ecology	The photo shows the same features as the 1972 photo except the dark staining in the Red Tank containment area extends further to the southwest and there appears to be less dark staining on the west side of the Black Tank.
1976	Vertical aerial photograph	Husky Oil	Photo No. 12 - shows the same features as the 1974 photo except that the dark staining in the Red Tank containment area is only in a small area to the northeast of the tank, the BT Pump House appears to have been removed, a containment wall has been constructed on the west side of the Blank Tank, a containment berm has been constructed around the north, east and south sides of the Black Tank and approximately 80% of the containment area around the Black Tank shows dark staining.
1977	Vertical aerial photograph	Husky Oil	Photo No. 13 - shows the same features as the 1976 photo.
1979	Vertical aerial photograph	Husky Oil	Photo No. 14 - shows the same features as the 1976 and 1977 photos.
1980	Vertical aerial photograph	Ecology	The photo shows the same features as the 1976, 1977 and 1979 photos.
1985	Vertical aerial photograph	Husky Oil	Photo No. 15 - shows the same features as the 1976, 1977, 1979 and 1980 photos.

Year	Type	Source	Document - Description of Contents
1991	Vertical aerial photograph	Husky Oil	Photo No. 16 - shows the same features as the 1976, 1977, 1979, 1980 and 1981 photos except that the SEM Materials facility has expanded their operations to include four large ASTs in the area immediately south of the subject property.
1997	Vertical aerial photograph	Husky Oil	Photo No. 17 - shows that the Red Tank and RT Pump House #2 have been removed and the SEM Materials operations south of the subject property continue to expand. The Black Tank and associated staining remain.
2000	Vertical aerial photograph	Ecology	The photo shows the same features as the 1997 photo.
2003	Vertical aerial photograph	Google	The photo shows the same features as the 1997 and 2000 photo.
2005	Vertical aerial photograph	Google	The photo shows the same features as the 1997, 2000 and 2003 photo.
2006	Vertical aerial photograph	Google	The photo shows the same features as the 1997, 2000, 2003 and 2005 photo, except that the Black Tank has been removed and the stained soil and containment berm have been excavated.
2012	Vertical aerial photograph	Google	The photo shows all structures except RT Pump House #1 and the Red Tank containment berm have been removed. Large pieces of concrete rubble exists at the former northern side of the Black Tank containment berm and an open excavation exists at the west side of the former Black Tank containment area. Remnants of the Sump and associated piping also remain.

DRAFT

Table 3

Detail Summary of the Smear Zone and Bed of Silt and Silty Sand Facies at the Groundwater Table

BNSF Black Tank Site

Spokane, Washington

Boring/Well	Ground Surface Elevation *feet amsl*	TOC Elevation *feet amsl*	Silt and Silty Sand Facies Bed at Groundwater Table					Smear Zone				
			Top Depth *feet bgs*	Bottom Depth *feet bgs*	Thickness *feet*	Top Elevation *feet amsl*	Bottom Elevation *feet amsl*	Top Depth *feet bgs*	Bottom Depth *feet bgs*	Thickness *feet*	Top Elevation *feet amsl*	Bottom Elevation *feet amsl*
BT-SB-01	2032.00	NM	165.4	168.4	3	1867	1864	149 (1)	172.6	24	1883	1859
MW-1	2033.51	2036.07	(2)	(2)	(2)	(2)	(2)	159.5	161.2	2	1874	1872
MW-2	2034.18	2037.07	173.0	174.0	1	1861	1860	171.5	176.0	5	1863	1858
MW-3	2038.56	2040.89	175.0	176.5	2	1864	1862	156.0	185.0	29	1883	1854
MW-4	2033.97	2033.59	169.5	170.0	1	1864	1864	152.0	170.0	18	1882	1864
MW-5	2038.54	2040.97	169.5	170.0	1	1869	1869	165.0	170.0	5	1874	1869
MW-6	2026.68	2029.48	161.0	165.0	4	1866	1862	NSZ	NSZ	NSZ	NSZ	NSZ
MW-7	2036.46	2036.00	167.0	168.0	1	1869	1868	163.0	175.0	12	1873	1861
MW-8	2038.29	2040.76	167.0	170.5	4	1871	1868	164.5	177.0	13	1874	1861
MW-9	2038.25	2040.60	166.0	168.0	2	1872	1870	167.5	177.0	10	1871	1861
MW-10	2038.40	2038.07	NP	NP	NP	NP	NP	NSZ	NSZ	NSZ	NSZ	NSZ
MW-11	2038.01	2037.67	168.0	170.0	2	1870	1868	NSZ	NSZ	NSZ	NSZ	NSZ
MW-12	2038.51	2038.21	NP	NP	NP	NP	NP	NSZ	NSZ	NSZ	NSZ	NSZ
MW-13	2039.54	2039.21	170.8	177.0	6	1869	1863	168.0	174.0	6	1872	1866
MW-14	2039.26	2038.84	160.0	180.0	20	1879	1859	161.5	180.0	19	1878	1859
MW-15	2037.66	2037.40	NP	NP	NP	NP	NP	169.0	178.0	9	1869	1860
MW-16	2034.15	2036.70	167.1	168.0	1	1867	1866	166.0	168.0	2	1868	1866
MW-17	2028.08	2030.78	156.0	163.5	8	1872	1865	145.2	165.0	20	1883	1863
MW-18	2034.90	2037.67	169.0	171.0	2	1866	1864	160.0	173.0	13	1875	1862
MW-19	2030.91	2030.43	164.4	169.0	5	1867	1862	157.0	166.2	9	1874	1865
MW-20	2039.48	2039.11	160.0	175.4	15	1879	1864	160.0	178.0	18	1879	1861
MW-21	2039.50	2039.04	167.0	172.0	5	1873	1868	165.0	172.0	7	1875	1868
MW-22	2038.35	2041.20	166.0	168.0	2	1872	1870	174.0	175.0	1	1864	1863
MW-23	2038.68	2041.49	167.4	168.0	1	1871	1871	168.0	175.0	7	1871	1864
MW-24	2037.77	2040.41	162.8	166.7	4	1875	1871	164.0	177.5	14	1874	1860
MW-25	2033.17	2036.14	159.0	163.0	4	1874	1870	157.0	161.2	4	1876	1872
MW-26	2032.77	2035.63	161.0	163.0	2	1872	1870	157.0	162.5	6	1876	1870
MW-27	2038.36	2038.15	167.0	168.6	2	1871	1870	NSZ	NSZ	NSZ	NSZ	NSZ
MW-28	2040.36	2042.76	168.0	174.0	6	1872	1866	165.5	173.5	8	1875	1867
MW-29	2038.54	2041.05	170.4	176.1	6	1868	1862	NSZ	NSZ	NSZ	NSZ	NSZ
MW-30	2038.61	2041.25	170.8	173.0	2	1868	1866	NSZ	NSZ	NSZ	NSZ	NSZ

Notes:

(1) Top of smear zone is assumed to be at the same elevation as at MW-17 because contamination is continuous from ground surface to the groundwater table at this location.
(2) Target interval was not sampled at this location.

Abbreviations:

amsl = above mean sea level
bgs = below ground surface
NP = Silt and silty sand facies not present in smear zone
NSZ = No smear zone
NM = Not Measured
TOC = Top of Casing

Monitoring Well	**Date**	**Collector**	**Total Depth (feet)**	**TOC Elevation** *feet amsl*	**Depth to Product** *feet*	**Depth to Groundwater** *feet*	**Approximate Product Thickness** *feet*	**Corrected Depth to Groundwater** *feet*	**Product Elevation** *feet amsl*	**Groundwater Elevation** *feet amsl*	**Corrected Groundwater Elevation** *feet amsl*	**Comments**
MW-1	01/17/08		182.5	2036.08	NM	166.00	NM	166.00	NM	1870.08	1870.08	
	02/04/08	Landau	182	2036.08	171.90	171.90	0.00	171.90	1864.18	1864.18	1864.18	Sheen observed
	07/25/08	Landau	182	2036.08	169.34	169.34	0.00	169.34	1866.74	1866.74	1866.74	Sheen observed
	12/15/08	Landau	182	2036.08	172.85	172.85	0.00	172.85	1863.23	1863.23	1863.23	Sheen observed
	01/15/09	Landau	182	2036.08	171.22	NM	NM	NM	1864.86	NM	NM	Product observed, but not measured
	03/19/09	Landau	182	2036.08	170.50	NM	NM	NM	1865.58	NM	NM	Product observed, but not measured
	12/18/09	Landau	182	2036.08	173.05	NM	NM	NM	1863.03	NM	NM	Product observed, but not measured
	08/04/10	Landau	182	2036.08	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	182	2036.08	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	182	2036.07	171.98	174.90	2.92	172.10	1864.09	1861.17	1863.97	Product is too viscous to allow accurate water level measurement
	03/03/14	ERM	182	2036.07	171.14	172.30	1.16	171.19	1864.93	1863.77	1864.88	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	182	2036.07	168.35	172.29	3.94	168.52	1867.72	1863.78	1867.55	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	182	2036.07	173.33	174.04	0.71	173.36	1862.74	1862.03	1862.71	Product and water level measured after cleaning the well
	03/10/16	ERM	182	2036.07	168.15	NM	NM	NM	1867.92	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	182	2036.07	167.02	167.05	0.03	167.02	1869.05	1869.02	1869.05	
	06/20/16	ERM	182	2036.07	170.3	170.38	0.08	170.30	1865.77	1865.69	1865.77	
	09/20/16	ERM	182	2036.07	173.95	174.06	0.11	173.95	1862.12	1862.01	1862.12	
	12/07/16	ERM	182	2036.07	170.41	170.60	0.19	170.42	1865.66	1865.47	1865.65	
MW-2	01/17/08		182	2037.10	NM	165.00	NM	165.00	NM	1872.10	1872.10	
	02/04/08	Landau	182	2037.10	ND	173.55	ND	173.55	ND	1863.55	1863.55	
	07/25/08	Landau	182	2037.10	ND	170.58	ND	170.58	ND	1866.52	1866.52	
	12/15/08	Landau	182	2037.10	173.11	NM	NM	NM	1863.99	NM	NM	Product observed, but not measured
	01/15/09	Landau	182	2037.10	172.48	172.49	0.01	172.48	1864.62	1864.61	1864.62	Product observed, but not measured
	03/19/09	Landau	182	2037.10	171.23	171.23	0.00	171.23	1865.87	1865.87	1865.87	Sheen observed
	12/18/09	Landau	182	2037.10	172.74	NM	NM	NM	1864.36	NM	NM	Product observed, but not measured
	08/04/10	Landau	182	2037.10	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	182	2037.10	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	182	2037.07	173.25	173.72	0.47	173.27	1863.82	1863.35	1863.80	Product is too viscous to allow accurate water level measurement
	03/03/14	ERM	182	2037.07	172.68	172.89	0.21	172.69	1864.39	1864.18	1864.38	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	182	2037.07	169.8	170.71	0.91	169.84	1867.27	1866.36	1867.23	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	182	2037.07	174.42	174.48	0.06	174.42	1862.65	1862.59	1862.65	Product and water level measured after cleaning the well
	03/10/16	ERM	182	2037.07	169.62	NM	NM	NM	1867.45	NM	NM	Product is too viscous to allow accurate water level measurement
	03/22/16	ERM	182	2037.07	168.55	168.65	0.10	168.55	1868.52	1868.42	1868.52	
	06/20/16	ERM	182	2037.07	170.74	171.1	0.36	170.76	1866.33	1865.97	1866.31	
	09/20/16	ERM	182	2037.07	175.38	175.82	0.44	175.40	1861.69	1861.25	1861.67	
	12/07/16	ERM	182	2037.07	171.69	NM	Trace	NM	1865.38	NM	NM	Inconclusive measurement results; trace amount of product removed.

Monitoring Well	**Date**	**Collector**	**Total Depth (feet)**	**TOC Elevation** *feet amsl*	**Depth to Product** *feet*	**Depth to Groundwater** *feet*	**Approximate Product Thickness** *feet*	**Corrected Depth to Groundwater** *feet*	**Product Elevation** *feet amsl*	**Groundwater Elevation** *feet amsl*	**Corrected Groundwater Elevation** *feet amsl*	**Comments**
MW-3	01/24/08		193	2040.92	NM	173.3	NM	173.3	NM	1867.62	1867.62	
	02/04/08	Landau	193	2040.92	169.80	NM	NM	NM	1871.12	NM	NM	Product observed, but not measured
	07/25/08	Landau	193	2040.92	168.32	168.32	0.00	168.32	1872.6	1872.60	1872.60	Sheen observed
	12/15/08	Landau	193	2040.92	169.92	169.92	0.00	169.92	1871	1871.00	1871.00	Sheen observed
	01/15/09	Landau	193	2040.92	169.73	NM	NM	NM	1871.19	NM	NM	Product observed, but not measured
	03/19/09	Landau	193	2040.92	168.90	NM	NM	NM	1872.02	NM	NM	Product observed, but not measured
	12/18/09	Landau	193	2040.92	169.59	NM	NM	NM	1871.33	NM	NM	Product observed, but not measured
	08/04/10	Landau	193	2040.92	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	193	2040.92	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	193	2040.89	NM	NM	NM	NM	NM	NM	NM	Product is too viscous to allow accurate water level measurement
	03/04/14	ERM	193	2040.89	NM	NM	NM	NM	NM	NM	NM	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	193	2040.89	168.68	NM	NM	NM	1872.21	NM	NM	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	193	2040.89	NM	ND	NM	NM	NM	ND	NM	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	193	2040.89	169.7	NM	NM	NM	1871.19	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	193	2040.89	168.31	176.98	8.67	168.67	1872.58	1863.91	1872.22	
	06/20/16	ERM	193	2040.89	169.2	177.75	8.55	169.56	1871.69	1863.14	1871.33	
	09/20/16	ERM	193	2040.89	169.14	172.78	3.64	169.29	1871.75	1868.11	1871.60	
	12/07/16	ERM	193	2040.89	169.34	170.6	1.26	169.39	1871.55	1870.29	1871.50	Product is very viscous
MW-4	01/29/08		170	2033.62	NM	166.00	NM	166.00	NM	1867.62	1867.62	
	02/04/08	Landau	168	2033.62	166.80	166.80	0.00	166.80	1866.82	1866.82	1866.82	Sheen observed
	07/25/08	Landau	168	2033.62	162.21	162.21	0.00	162.21	1871.41	1871.41	1871.41	Sheen observed
	12/15/08	Landau	168	2033.62	166.01	166.01	0.00	166.01	1867.61	1867.61	1867.61	Sheen observed
	01/15/09	Landau	168	2033.62	162.13	NM	NM	NM	1871.49	NM	NM	Product observed, but not measured
	03/19/09	Landau	168	2033.62	161.75	NM	NM	NM	1871.87	NM	NM	Product observed, but not measured
	12/18/09	Landau	168	2033.62	162.52	NM	NM	NM	1871.1	NM	NM	Product observed, but not measured
	08/04/10	Landau	168	2033.62	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	168	2033.62	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	168	2033.59	NM	NM	NM	NM	NM	NM	NM	Product is too viscous to allow accurate water level measurement
	03/04/14	ERM	168	2033.59	ND	NM	NM	NM	ND	NM	NM	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	168	2033.59	163.31	NM	NM	NM	1870.28	NM	NM	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	168	2033.59	169.38	ND	NM	NM	1864.21	ND	NM	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	168	2033.59	161.6	NM	NM	NM	1871.99	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	168	2033.59	161.71	165.98	4.27	161.89	1871.88	1867.61	1871.70	
	06/23/16	ERM	168	2033.59	161.55	163.68	2.13	161.64	1872.04	1869.91	1871.95	
	09/20/16	ERM	168	2033.59	161.57	166.12	4.55	161.76	1872.02	1867.47	1871.83	
	12/07/16	ERM	168	2033.59	162.69	166.4	3.71	162.85	1870.9	1867.19	1870.74	

Monitoring Well	Date	Collector	Total Depth (feet)	TOC Elevation *feet amsl*	Depth to Product *feet*	Depth to Groundwater *feet*	Approximate Product Thickness *feet*	Corrected Depth to Groundwater *feet*	Product Elevation *feet amsl*	Groundwater Elevation *feet amsl*	Corrected Groundwater Elevation *feet amsl*	Comments
MW-5	01/30/08		169.5	2041.00	NM	167	NM	167	NM	1874.00	1874.00	
	02/04/08	Landau	169.5	2041.00	168.94	168.94	0.00	168.94	1872.06	1872.06	1872.06	Sheen observed
	07/25/08	Landau	169.5	2041.00	168.87	168.87	0.00	168.87	1872.13	1872.13	1872.13	Sheen observed
	12/15/08	Landau	169.5	2041.00	169.81	NM	NM	NM	1871.19	NM	NM	Product observed, but not measured
	01/15/09	Landau	169.5	2041.00	169.51	NM	NM	NM	1871.49	NM	NM	Product observed, but not measured
	03/19/09	Landau	169.5	2041.00	169.25	NM	NM	NM	1871.75	NM	NM	Product observed, but not measured
	12/18/09	Landau	169.5	2041.00	168.49	NM	NM	NM	1872.51	NM	NM	Product observed, but not measured
	08/04/10	Landau	169.5	2041.00	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	169.5	2041.00	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	169.5	2040.97	169.28	NM	NM	NM	1871.69	NM	NM	Product is too viscous to allow accurate water level measurement
	03/04/14	ERM	169.5	2040.97	169.38	170.62	1.24	169.43	1871.59	1870.35	1871.54	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	169.5	2040.97	169.09	170.58	1.49	169.15	1871.88	1870.39	1871.82	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	169.5	2040.97	169.29	170.9	1.61	169.36	1871.68	1870.07	1871.61	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	169.5	2040.97	165.77	NM	NM	NM	1875.2	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	169.5	2040.97	169.95	170.47	0.52	169.97	1871.02	1870.50	1871.00	
	06/23/16	ERM	169.5	2040.97	169.61	170.48	0.87	169.65	1871.36	1870.49	1871.32	
	09/20/16	ERM	169.5	2040.87	169.47	170.35	0.88	169.51	1871.4	1870.52	1871.36	
	12/07/16	ERM	169.5	2040.87	169.58	170.36	0.78	169.61	1871.29	1870.51	1871.26	
MW-6	07/21/08		185	2029.49	NM	161.80	NM	161.80	NM	1867.69	1867.69	
	07/25/08	Landau	185	2029.49	ND	162.61	ND	162.61	ND	1866.88	1866.88	Submerged Screen
	12/15/08	Landau	185	2029.49	ND	164.46	ND	164.46	ND	1865.03	1865.03	Submerged Screen
	01/15/09	Landau	185	2029.49	ND	163.79	ND	163.79	ND	1865.70	1865.70	Submerged Screen
	03/19/09	Landau	185	2029.49	ND	162.57	ND	162.57	ND	1866.92	1866.92	Submerged Screen
	10/14/09	Landau	185	2029.49	ND	ND	NM	NM	ND	ND	NM	Well is dry
	12/18/09	Landau	185	2029.49	ND	162.49	ND	162.49	ND	1867.00	1867.00	Submerged Screen
	02/01/10	Landau	185	2029.49	ND	164.61	ND	164.61	ND	1864.88	1864.88	Submerged Screen
	04/06/10	Landau	185	2029.49	ND	164.01	ND	164.01	ND	1865.48	1865.48	Submerged Screen
	08/03/10	Landau	185	2029.49	ND	164.76	ND	164.76	ND	1864.73	1864.73	Submerged Screen
	10/24/10	Landau	185	2029.49	ND	165.76	ND	165.76	ND	1863.73	1863.73	Submerged Screen
	01/24/11	Landau	185	2029.49	ND	160.82	ND	160.82	ND	1868.67	1868.67	Submerged Screen
	04/29/11	Landau	185	2029.49	ND	158.84	ND	158.84	ND	1870.65	1870.65	Submerged Screen
	07/13/11	Landau	185	2029.49	ND	158.86	ND	158.86	ND	1870.63	1870.63	Submerged Screen
	10/07/11	Landau	185	2029.49	ND	165.36	ND	165.36	ND	1864.13	1864.13	Submerged Screen
	12/03/13	ERM	185	2029.48	ND	164.68	ND	164.68	ND	1864.80	1864.80	Submerged Screen
	03/03/14	ERM	185	2029.48	ND	164.04	ND	164.04	ND	1865.44	1865.44	Submerged Screen
	06/26/14	ERM	185	2029.48	ND	161.38	ND	161.38	ND	1868.10	1868.10	Submerged Screen
	10/03/14	ERM	185	2029.48	ND	166.08	ND	166.08	ND	1863.40	1863.40	Submerged Screen
	03/10/16	ERM	185	2029.48	ND	166.08	ND	166.08	ND	1863.40	1863.40	Submerged Screen
	03/21/16	ERM	185	2029.48	ND	159.82	ND	159.82	ND	1869.66	1869.66	Submerged Screen
	06/20/16	ERM	185	2029.48	ND	163.18	ND	163.18	ND	1866.30	1866.30	Submerged Screen
	09/20/16	ERM	185	2029.48	ND	163.98	ND	163.98	ND	1865.50	1865.50	Submerged Screen
	12/05/16	ERM	185	2029.48	ND	163.08	ND	163.08	ND	1866.40	1866.40	Submerged Screen

DRAFT
Table 4

Groundwater and LNAPL Level Measurements
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Collector	Total Depth (feet)	TOC Elevation *feet amsl*	Depth to Product *feet*	Depth to Groundwater *feet*	Approximate Product Thickness *feet*	Corrected Depth to Groundwater *feet*	Product Elevation *feet amsl*	Groundwater Elevation *feet amsl*	Corrected Groundwater Elevation *feet amsl*	Comments
MW-7	07/22/08		175	2036.04	NM	165.00	NM	165.00	NM	1871.04	1871.04	
	07/25/08	Landau	169	2036.04	169.02	169.02	0.00	169.02	1867.02	1867.02	1867.02	Sheen observed
	12/15/08	Landau	169	2036.04	165.45	NM	NM	NM	1870.59	NM	NM	Product observed, but not measured
	01/15/09	Landau	169	2036.04	165.71	NM	NM	NM	1870.33	NM	NM	Product observed, but not measured
	03/19/09	Landau	169	2036.04	165.71	NM	NM	NM	1870.33	NM	NM	Product observed, but not measured
	12/18/09	Landau	169	2036.04	165.55	NM	NM	NM	1870.49	NM	NM	Product observed, but not measured
	08/04/10	Landau	169	2036.04	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	169	2036.04	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	169	2036.00	165.50	167.89	2.39	165.60	1870.5	1868.11	1870.40	Product is too viscous to allow accurate water level measurement
	03/04/14	ERM	169	2036.00	165.64	NM	NM	NM	1870.36	NM	NM	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	169	2036.00	165.28	166.83	1.55	165.35	1870.72	1869.17	1870.65	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	169	2036.00	165.5	ND	NM	NM	1870.5	ND	NM	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	169	2036.00	169.98	NM	NM	NM	1866.02	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	169	2036.00	165.69	167.91	2.22	165.78	1870.31	1868.09	1870.22	
	06/20/16	ERM	169	2036.00	165.88	167.82	1.94	165.96	1870.12	1868.18	1870.04	
	09/20/16	ERM	169	2036.00	165.4	167.74	2.34	165.50	1870.6	1868.26	1870.50	
	12/07/16	ERM	169	2036.00	165.35	165.45	0.10	165.35	1870.65	1870.55	1870.65	Potentially erroneous measurement
MW-8	07/24/08		177	2040.79	NM	165.00	NM	165.00	NM	1875.79	1875.79	
	07/25/08	Landau	166	2040.79	ND	169.95	ND	169.95	ND	1870.84	1870.84	
	12/15/08	Landau	166	2040.79	ND	169.41	ND	169.41	ND	1871.38	1871.38	
	01/15/09	Landau	166	2040.79	169.65	169.65	0.00	169.65	1871.14	1871.14	1871.14	Sheen observed
	03/19/09	Landau	166	2040.79	ND	ND	NM	NM	ND	ND	NM	Well is dry
	12/18/09	Landau	166	2040.79	169.55	169.55	0.00	169.55	1871.24	1871.24	1871.24	Sheen observed
	08/04/10	Landau	166	2040.79	ND	ND	NM	NM	ND	ND	NM	Well is dry
	10/24/10	Landau	166	2040.79	ND	ND	NM	NM	ND	ND	NM	Well is dry
	12/03/13	ERM	169.10	2040.76	ND	169.10	ND	169.10	ND	1871.66	1871.66	Well is dry
	03/03/14	ERM	169.10	2040.76	ND	ND	NM	NM	ND	ND	NM	Well is dry
	06/26/14	ERM	169.10	2040.76	ND	NM	NM	NM	ND	NM	NM	Well is dry
	10/03/14	ERM	169.10	2040.76	ND	ND	NM	NM	ND	ND	NM	Well is dry
	03/10/16	ERM	169.10	2040.76	NM	Dry	NM	NM	NM	NM	NM	Well is dry
	03/21/16	ERM	169.10	2040.76	Dry	Dry	NM	NM	NM	NM	NM	Well is dry
	06/20/16	ERM	169.10	2040.76	Dry	Dry	NM	NM	NM	NM	NM	Well is dry
	09/20/16	ERM	169.10	2040.76	NM	Dry	NM	NM	NM	NM	NM	Well is dry
	12/05/16	ERM	169.10	2040.76	NM	Dry	NM	NM	NM	NM	NM	Well is dry

Monitoring Well	**Date**	**Collector**	**Total Depth (feet)**	**TOC Elevation** *feet amsl*	**Depth to Product** *feet*	**Depth to Groundwater** *feet*	**Approximate Product Thickness** *feet*	**Corrected Depth to Groundwater** *feet*	**Product Elevation** *feet amsl*	**Groundwater Elevation** *feet amsl*	**Corrected Groundwater Elevation** *feet amsl*	**Comments**
MW-9	07/24/08		193.0	2040.63	NM	173.00	NM	173.00	NM	1867.63	1867.63	
	07/25/08	Landau	190	2040.63	175.1	175.10	0.00	175.10	1865.53	1865.53	1865.53	Sheen observed
	12/15/08	Landau	190	2040.63	177.28	177.28	0.00	177.28	1863.35	1863.35	1863.35	Sheen observed
	01/15/09	Landau	190	2040.63	176.77	176.77	0.00	176.77	1863.86	1863.86	1863.86	Sheen observed
	03/19/09	Landau	190	2040.63	175.50	NM	NM	NM	1865.13	NM	NM	Product observed, but not measured
	12/18/09	Landau	190	2040.63	175.92	175.92	0.00	175.92	1864.71	1864.71	1864.71	Sheen observed
	08/04/10	Landau	190	2040.63	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	10/24/10	Landau	190	2040.63	NM	NM	NM	NM	NM	NM	NM	Product observed, but not measured
	12/03/13	ERM	193	2040.60	177.5	177.65	0.15	177.51	1863.10	1862.95	1863.09	Product is too viscous to allow accurate water level measurement
	03/03/14	ERM	193	2040.60	176.91	177.04	0.13	176.92	1863.69	1863.56	1863.68	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	193	2040.60	173.84	173.91	0.07	173.84	1866.76	1866.69	1866.76	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	193	2040.60	178.84	178.87	0.03	178.84	1861.76	1861.73	1861.76	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	193	2040.60	173.9	NM	NM	NM	1866.7	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	193	2040.60	173.01	173.11	0.10	173.01	1867.59	1867.49	1867.59	
	06/20/16	ERM	193	2040.60	175.6	175.74	0.14	175.61	1865	1864.86	1864.99	
	09/20/16	ERM	193	2040.60	179.51	179.61	0.10	179.51	1861.09	1860.99	1861.09	
	12/07/16	ERM	193	2040.60	175.96	176.11	0.15	175.97	1864.64	1864.49	1864.63	
MW-10	05/26/09		197.1	2038.09	NM	NM	NM	NM	NM	NM	NM	
	10/14/09	Landau	198	2038.09	ND	176.49	ND	176.49	ND	1861.60	1861.60	
	12/18/09	Landau	198	2038.09	ND	175.34	ND	175.34	ND	1862.75	1862.75	
	02/01/10	Landau	198	2038.09	ND	175.03	ND	175.03	ND	1863.06	1863.06	
	04/06/10	Landau	198	2038.09	ND	174.61	ND	174.61	ND	1863.48	1863.48	
	08/03/10	Landau	198	2038.09	ND	174.90	ND	174.90	ND	1863.19	1863.19	
	10/24/10	Landau	198	2038.09	ND	176.13	ND	176.13	ND	1861.96	1861.96	
	01/24/11	Landau	198	2038.09	ND	172.05	ND	172.05	ND	1866.04	1866.04	
	04/29/11	Landau	198	2038.09	ND	169.47	ND	169.47	ND	1868.62	1868.62	
	07/13/11	Landau	198	2038.09	ND	168.98	ND	168.98	ND	1869.11	1869.11	
	10/07/11	Landau	198	2038.09	ND	175.58	ND	175.58	ND	1862.51	1862.51	
	12/03/13	ERM	198	2038.07	ND	175.11	ND	175.11	ND	1862.96	1862.96	
	03/03/14	ERM	198	2038.07	ND	174.48	ND	174.48	ND	1863.59	1863.59	
	06/26/14	ERM	198	2038.07	ND	171.53	ND	171.53	ND	1866.54	1866.54	
	10/03/14	ERM	198	2038.07	ND	176.42	ND	176.42	ND	1861.65	1861.65	
	03/10/16	ERM	198	2038.07	ND	171.73	ND	171.73	ND	1866.34	1866.34	
	03/21/16	ERM	198	2038.07	ND	170.79	ND	170.79	ND	1867.28	1867.28	
	06/20/16	ERM	198	2038.07	ND	173.28	ND	173.28	ND	1864.79	1864.79	
	09/20/16	ERM	198	2038.07	ND	177.29	ND	177.29	ND	1860.78	1860.78	
	12/05/16	ERM	198	2038.07	ND	173.70	ND	173.7	ND	1864.37	1864.37	

Monitoring Well	Date	Collector	Total Depth (feet)	TOC Elevation *feet amsl*	Depth to Product *feet*	Depth to Groundwater *feet*	Approximate Product Thickness *feet*	Corrected Depth to Groundwater *feet*	Product Elevation *feet amsl*	Groundwater Elevation *feet amsl*	Corrected Groundwater Elevation *feet amsl*	Comments
MW-11	05/29/09		197	2037.71	NM	NM	NM	NM	NM	NM	NM	
	10/14/09	Landau	197	2037.71	ND	176.14	ND	176.14	ND	1861.57	1861.57	
	12/18/09	Landau	197	2037.71	ND	174.98	ND	174.98	ND	1862.73	1862.73	
	02/01/10	Landau	197	2037.71	ND	174.69	ND	174.69	ND	1863.02	1863.02	
	04/06/10	Landau	197	2037.71	ND	174.26	ND	174.26	ND	1863.45	1863.45	
	08/03/10	Landau	197	2037.71	ND	174.53	ND	174.53	ND	1863.18	1863.18	
	10/24/10	Landau	197	2037.71	ND	175.80	ND	175.80	ND	1861.91	1861.91	
	01/24/11	Landau	197	2037.71	ND	171.72	ND	171.72	ND	1865.99	1865.99	
	04/29/11	Landau	197	2037.71	ND	169.10	ND	169.10	ND	1868.61	1868.61	
	07/13/11	Landau	197	2037.71	ND	168.63	ND	168.63	ND	1869.08	1869.08	
	10/07/11	Landau	197	2037.71	ND	175.27	ND	175.27	ND	1862.44	1862.44	
	12/03/13	ERM	197	2037.67	ND	174.72	ND	174.72	ND	1862.95	1862.95	
	03/03/14	ERM	197	2037.67	ND	174.12	ND	174.12	ND	1863.55	1863.55	
	06/26/14	ERM	197	2037.67	ND	171.20	ND	171.20	ND	1866.47	1866.47	
	10/03/14	ERM	197	2037.67	ND	176.11	ND	176.11	ND	1861.56	1861.56	
	03/10/16	ERM	197	2037.67	ND	171.38	ND	171.38	ND	1866.29	1866.29	
	03/21/16	ERM	197	2037.67	ND	170.4	ND	170.4	ND	1867.27	1867.27	
	06/20/16	ERM	197	2037.67	ND	172.94	ND	172.94	ND	1864.73	1864.73	
	09/20/16	ERM	197	2037.67	ND	176.95	ND	176.95	ND	1860.72	1860.72	
	12/05/16	ERM	197	2037.67	ND	173.35	ND	173.35	ND	1864.32	1864.32	
MW-12	06/01/09		197	2038.26	NM	NM	NM	NM	NM	NM	NM	
	10/14/09	Landau	198	2038.26	ND	176.58	ND	176.58	ND	1861.68	1861.68	
	12/18/09	Landau	198	2038.26	ND	175.43	ND	175.43	ND	1862.83	1862.83	
	02/01/10	Landau	198	2038.26	ND	175.12	ND	175.12	ND	1863.14	1863.14	
	04/06/10	Landau	198	2038.26	ND	174.71	ND	174.71	ND	1863.55	1863.55	
	08/03/10	Landau	198	2038.26	ND	175.01	ND	175.01	ND	1863.25	1863.25	
	10/24/10	Landau	198	2038.26	ND	176.23	ND	176.23	ND	1862.03	1862.03	
	01/24/11	Landau	198	2038.26	ND	172.10	ND	172.10	ND	1866.16	1866.16	
	04/29/11	Landau	198	2038.26	ND	169.54	ND	169.54	ND	1868.72	1868.72	
	07/13/11	Landau	198	2038.26	ND	169.10	ND	169.10	ND	1869.16	1869.16	
	10/07/11	Landau	198	2038.26	ND	175.69	ND	175.69	ND	1862.57	1862.57	
	12/03/13	ERM	198	2038.21	ND	175.18	ND	175.18	ND	1863.03	1863.03	
	03/03/14	ERM	198	2038.21	ND	174.72	ND	174.72	ND	1863.49	1863.49	
	06/26/14	ERM	198	2038.21	ND	171.64	ND	171.64	ND	1866.57	1866.57	
	10/03/14	ERM	198	2038.21	ND	176.55	ND	176.55	ND	1861.66	1861.66	
	03/10/16	ERM	198	2038.21	ND	171.8	ND	171.8	ND	1866.41	1866.41	
	03/21/16	ERM	198	2038.21	ND	170.85	ND	170.85	ND	1867.36	1867.36	
	06/20/16	ERM	198	2038.21	ND	172.94	ND	172.94	ND	1865.27	1865.27	
	09/20/16	ERM	198	2038.21	ND	177.4	ND	177.4	ND	1860.81	1860.81	
	12/07/16	ERM	198	2038.21	ND	173.78	ND	173.78	ND	1864.43	1864.43	

Monitoring Well	Date	Collector	Total Depth (feet)	TOC Elevation *feet amsl*	Depth to Product *feet*	Depth to Groundwater *feet*	Approximate Product Thickness *feet*	Corrected Depth to Groundwater *feet*	Product Elevation *feet amsl*	Groundwater Elevation *feet amsl*	Corrected Groundwater Elevation *feet amsl*	Comments
MW-13	06/03/09		197	2039.3	NM	NM	NM	NM	NM	NM	NM	
	10/14/09	Landau	197	2038.91	ND	177.20	ND	177.20	ND	1861.71	1861.71	Submerged Screen
	12/18/09	Landau	197	2038.91	ND	176.04	ND	176.04	ND	1862.87	1862.87	Submerged Screen
	02/01/10	Landau	197	2038.91	ND	175.74	ND	175.74	ND	1863.17	1863.17	Submerged Screen
	04/06/10	Landau	197	2038.91	ND	175.29	ND	175.29	ND	1863.62	1863.62	Submerged Screen
	08/03/10	Landau	197	2038.91	ND	175.67	ND	175.67	ND	1863.24	1863.24	Submerged Screen
	10/24/10	Landau	197	2038.91	ND	176.86	ND	176.86	ND	1862.05	1862.05	Submerged Screen
	01/24/11	Landau	197	2038.91	ND	172.57	ND	172.57	ND	1866.34	1866.34	Submerged Screen
	04/29/11	Landau	197	2038.91	ND	170.13	ND	170.13	ND	1868.78	1868.78	Submerged Screen
	07/13/11	Landau	197	2038.91	ND	169.77	ND	169.77	ND	1869.14	1869.14	Submerged Screen
	10/07/11	Landau	197	2038.91	ND	176.33	ND	176.33	ND	1862.58	1862.58	Submerged Screen
	12/03/13	ERM	197	2039.21	ND	175.82	ND	175.82	ND	1863.39	1863.39	Submerged Screen
	03/03/14	ERM	197	2039.21	ND	175.16	ND	175.16	ND	1864.05	1864.05	Submerged Screen
	06/26/14	ERM	197	2039.21	ND	172.31	ND	172.31	ND	1866.90	1866.90	Submerged Screen
	10/03/14	ERM	197	2039.21	ND	177.18	ND	177.18	ND	1862.03	1862.03	Submerged Screen
	03/10/16	ERM	197	2039.21	ND	172.35	ND	172.35	ND	1866.86	1866.86	Submerged Screen
	03/21/16	ERM	197	2039.21	ND	171.38	ND	171.38	ND	1867.83	1867.83	Submerged Screen
	06/20/16	ERM	197	2039.21	ND	174.08	ND	174.08	ND	1865.13	1865.13	Submerged Screen
	09/20/16	ERM	197	2039.21	ND	178.02	ND	178.02	ND	1861.19	1861.19	Submerged Screen
	12/05/16	ERM	197	2039.21	ND	173.49	ND	173.49	ND	1865.72	1865.72	Submerged Screen
MW-14	06/06/09		217	2038.9	NM	NM	NM	NM	NM	NM	NM	
	10/14/09	Landau	217	2038.85	ND	176.41	ND	176.41	ND	1862.44	1862.44	Submerged Screen
	12/18/09	Landau	217	2038.85	ND	175.25	ND	175.25	ND	1863.60	1863.60	Submerged Screen
	02/01/10	Landau	217	2038.85	ND	174.94	ND	174.94	ND	1863.91	1863.91	Submerged Screen
	04/06/10	Landau	217	2038.85	ND	174.47	ND	174.47	ND	1864.38	1864.38	Submerged Screen
	08/03/10	Landau	217	2038.85	ND	174.93	ND	174.93	ND	1863.92	1863.92	Submerged Screen
	10/24/10	Landau	217	2038.85	ND	176.04	ND	176.04	ND	1862.81	1862.81	Submerged Screen
	01/24/11	Landau	217	2038.85	ND	171.52	ND	171.52	ND	1867.33	1867.33	Submerged Screen
	04/29/11	Landau	217	2038.85	ND	169.25	ND	169.25	ND	1869.60	1869.60	Submerged Screen
	07/13/11	Landau	217	2038.85	ND	169.04	ND	169.04	ND	1869.81	1869.81	Submerged Screen
	10/07/11	Landau	217	2038.85	ND	175.57	ND	175.57	ND	1863.28	1863.28	Submerged Screen
	12/03/13	ERM	217	2038.84	ND	174.98	ND	174.98	ND	1863.86	1863.86	Submerged Screen
	03/03/14	ERM	217	2038.84	ND	174.34	ND	174.34	ND	1864.50	1864.50	Submerged Screen
	06/26/14	ERM	217	2038.84	ND	171.58	ND	171.58	ND	1867.26	1867.26	Submerged Screen
	10/03/14	ERM	217	2038.84	ND	176.35	ND	176.35	ND	1862.49	1862.49	Submerged Screen
	03/10/16	ERM	217	2038.84	ND	170.43	ND	170.43	ND	1868.41	1868.41	Submerged Screen
	03/21/16	ERM	217	2038.84	ND	NM	NM	NM	ND	NM	NM	Submerged Screen
	06/20/16	ERM	217	2038.84	ND	173.35	ND	173.35	ND	1865.49	1865.49	Submerged Screen
	09/20/16	ERM	217	2038.84	ND	177.26	ND	177.26	ND	1861.58	1861.58	Submerged Screen
	12/05/16	ERM	217	2038.84	ND	173.49	ND	173.49	ND	1865.35	1865.35	Submerged Screen

Monitoring Well	Date	Collector	Total Depth (feet)	TOC Elevation *feet amsl*	Depth to Product *feet*	Depth to Groundwater *feet*	Approximate Product Thickness *feet*	Corrected Depth to Groundwater *feet*	Product Elevation *feet amsl*	Groundwater Elevation *feet amsl*	Corrected Groundwater Elevation *feet amsl*	Comments
MW-15	05/28/09		196	2037.4	NM	NM	NM	NM	NM	NM	NM	
	10/14/09	Landau	196	2037.44	175.31	175.31	0.00	175.31	1862.13	1862.13	1862.13	Sheen observed
	12/18/09	Landau	196	2037.44	ND	174.39	ND	174.39	ND	1863.05	1863.05	
	02/01/10	Landau	196	2037.44	ND	173.86	ND	173.86	ND	1863.58	1863.58	
	04/06/10	Landau	196	2037.44	ND	173.4	ND	173.40	ND	1864.04	1864.04	
	08/03/10	Landau	196	2037.44	ND	173.79	ND	173.79	ND	1863.65	1863.65	
	10/24/10	Landau	196	2037.44	ND	174.97	ND	174.97	ND	1862.47	1862.47	
	01/24/11	Landau	196	2037.44	ND	170.64	ND	170.64	ND	1866.80	1866.80	
	04/29/11	Landau	196	2037.44	ND	168.21	ND	168.21	ND	1869.23	1869.23	
	07/13/11	Landau	196	2037.44	ND	167.87	ND	167.87	ND	1869.57	1869.57	
	10/07/11	Landau	196	2037.44	ND	174.46	ND	174.46	ND	1862.98	1862.98	
	12/03/13	ERM	196	2037.40	ND	173.92	ND	173.92	ND	1863.48	1863.48	
	03/03/14	ERM	196	2037.40	ND	173.26	ND	173.26	ND	1864.14	1864.14	
	06/26/14	ERM	196	2037.40	ND	170.41	ND	170.41	ND	1866.99	1866.99	
	10/03/14	ERM	196	2037.40	ND	175.36	ND	175.36	ND	1862.04	1862.04	
	03/10/16	ERM	196	2037.40	ND	170.43	ND	170.43	ND	1866.97	1866.97	
	03/21/16	ERM	196	2037.40	ND	169.44	ND	169.44	ND	1867.96	1867.96	
	06/20/16	ERM	196	2037.40	ND	172.18	ND	172.18	ND	1865.22	1865.22	
	09/20/16	ERM	196	2037.40	ND	176.15	ND	176.15	ND	1861.25	1861.25	
	12/05/16	ERM	196	2037.40	ND	172.46	ND	172.46	ND	1864.94	1864.94	
MW-16	12/03/13	ERM	178.8	2036.70	ND	172.97	ND	172.97	ND	1863.73	1863.73	
	03/03/14	ERM	178.8	2036.70	ND	172.33	ND	172.33	ND	1864.37	1864.37	
	06/26/14	ERM	178.8	2036.70	169.50	169.50	0.00	169.50	1867.20	1867.20	1867.20	Sheen observed
	10/03/14	ERM	178.8	2036.70	ND	174.36	ND	174.36	ND	1862.34	1862.34	
	03/10/16	ERM	178.8	2036.70	ND	169.41	ND	169.41	ND	1867.29	1867.29	
	03/21/16	ERM	178.8	2036.70	ND	168.4	ND	168.4	ND	1868.30	1868.30	
	06/20/16	ERM	178.8	2036.70	ND	171.3	ND	171.3	ND	1865.40	1865.40	
	09/20/16	ERM	178.8	2036.70	ND	175.25	ND	175.25	ND	1861.45	1861.45	
	12/05/16	ERM	178.8	2036.70	ND	171.48	ND	171.48	ND	1865.22	1865.22	
MW-17	12/03/13	ERM	170.8	2030.78	ND	166.79	ND	166.79	ND	1863.99	1863.99	
	03/03/14	ERM	170.8	2030.78	166.29	167.05	0.76	166.32	1864.49	1863.73	1864.46	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	170.8	2030.78	163.12	170.05	6.93	163.41	1867.66	1860.73	1867.37	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	170.8	2030.78	168.16	169.62	1.46	168.22	1862.62	1861.16	1862.56	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	170.8	2030.78	163.02	NM	NM	NM	1867.76	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	170.8	2030.78	161.97	166.09	4.12	162.14	1868.81	1864.69	1868.64	
	06/23/16	ERM	170.8	2030.78	165.23	167.49	2.26	165.32	1865.55	1863.29	1865.46	
	09/20/16	ERM	170.8	2030.78	168.71	170.28	1.57	168.78	1862.07	1860.50	1862.00	
	12/07/16	ERM	170.8	2030.78	165.23	165.4	0.17	165.24	1865.55	1865.38	1865.54	

Monitoring Well	**Date**	**Collector**	**Total Depth (feet)**	**TOC Elevation** *feet amsl*	**Depth to Product** *feet*	**Depth to Groundwater** *feet*	**Approximate Product Thickness** *feet*	**Corrected Depth to Groundwater** *feet*	**Product Elevation** *feet amsl*	**Groundwater Elevation** *feet amsl*	**Corrected Groundwater Elevation** *feet amsl*	**Comments**
MW-18	12/03/13	ERM	179.2	2037.67	NM	170.03	NM	NM	NM	1867.64	NM	
	03/03/14	ERM	179.2	2037.67	169.94	170.21	0.27	169.95	1867.73	1867.46	1867.72	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	179.2	2037.67	168.10	168.21	0.11	168.10	1869.57	1869.46	1869.57	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	179.2	2037.67	171.63	171.79	0.16	171.64	1866.04	1865.88	1866.03	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	179.2	2037.67	168.62	168.71	0.09	168.62	1869.05	1868.96	1869.05	
	03/21/16	ERM	179.2	2037.67	168	168.6	0.60	168.03	1869.67	1869.07	1869.64	
	06/20/16	ERM	179.2	2037.67	169.61	169.83	0.22	169.62	1868.06	1867.84	1868.05	
	09/20/16	ERM	179.2	2037.67	170.73	170.91	0.18	170.74	1866.94	1866.76	1866.93	
	12/07/16	ERM	179.2	2037.67	169.52	169.99	0.47	169.54	1868.15	1867.68	1868.13	
MW-19	12/03/13	ERM	174.9	2030.43	166.52	167.93	1.41	166.58	1863.91	1862.50	1863.85	Product is too viscous to allow accurate water level measurement
	03/04/14	ERM	174.9	2030.43	165.59	165.81	0.22	165.60	1864.84	1864.62	1864.83	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	174.9	2030.43	162.78	162.90	0.12	162.79	1867.65	1867.53	1867.64	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	174.9	2030.43	169.22	170.82	1.60	169.29	1861.21	1859.61	1861.14	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	176.4	2030.43	162.4	NM	NM	NM	1868.03	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	176.4	2030.43	162.33	163.6	1.27	162.38	1868.1	1866.83	1868.05	
	06/20/16	ERM	176.4	2030.43	164.6	165.43	0.83	164.63	1865.83	1865.00	1865.80	
	09/20/16	ERM	176.4	2030.43	167.77	168.56	0.79	167.80	1862.66	1861.87	1862.63	
	12/07/16	ERM	176.4	2030.43	168.77	169.39	0.62	168.80	1861.66	1861.04	1861.63	
MW-20	12/03/13	ERM	182.1	2039.11	ND	166.81	ND	166.81	ND	1872.30	1872.30	Sheen observed
	03/03/14	ERM	182.1	2039.11	167.40	167.45	0.05	167.40	1871.71	1871.66	1871.71	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	182.1	2039.11	166.30	168.67	2.37	166.40	1872.81	1870.44	1872.71	Product is too viscous to allow accurate water level measurement
	10/03/14	ERM	182.1	2039.11	167.13	168.96	1.83	167.21	1871.98	1870.15	1871.90	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	182.1	2039.11	167.9	NM	NM	NM	1871.21	NM	NM	Product is too viscous to allow accurate water level measurement
	03/21/16	ERM	182.1	2039.11	166.71	176.05	9.34	167.10	1872.4	1863.06	1872.01	
	06/23/16	ERM	182.1	2039.11	166.44	172.2	5.76	166.68	1872.67	1866.91	1872.43	
	09/20/16	ERM	182.1	2039.11	166.78	176.24	9.46	167.18	1872.33	1862.87	1871.93	
	12/07/16	ERM	182.1	2039.11	166.66	NM	NM	NM	1872.45	NM	NM	Inconclusive measurement result; 4.25 Liters of product removed equates to approximately 6.6 feet of product
MW-21	12/03/13	ERM	185.9	2039.04	ND	176.12	ND	176.12	ND	1862.92	1862.92	
	03/03/14	ERM	185.9	2039.04	ND	175.63	ND	175.63	ND	1863.41	1863.41	Submerged Screen
	06/26/14	ERM	185.9	2039.04	ND	172.58	ND	172.58	ND	1866.46	1866.46	Submerged Screen
	10/03/14	ERM	185.9	2039.04	ND	177.5	ND	177.50	ND	1861.54	1861.54	
	03/10/16	ERM	185.9	2039.04	ND	172.65	ND	172.65	ND	1866.39	1866.39	Submerged Screen
	03/21/16	ERM	185.9	2039.04	ND	171.67	ND	171.67	ND	1867.37	1867.37	Submerged Screen
	06/20/16	ERM	185.9	2039.04	ND	174.35	ND	174.35	ND	1864.69	1864.69	Submerged Screen
	09/20/16	ERM	185.9	2039.04	ND	178.39	ND	178.39	ND	1860.65	1860.65	
	12/05/16	ERM	185.9	2039.04	ND	174.66	ND	174.66	ND	1864.38	1864.38	Submerged Screen

Monitoring Well	**Date**	**Collector**	**Total Depth (feet)**	**TOC Elevation** *feet amsl*	**Depth to Product** *feet*	**Depth to Groundwater** *feet*	**Approximate Product Thickness** *feet*	**Corrected Depth to Groundwater** *feet*	**Product Elevation** *feet amsl*	**Groundwater Elevation** *feet amsl*	**Corrected Groundwater Elevation** *feet amsl*	**Comments**
MW-22	12/03/13	ERM	184	2041.2	ND	178.13	ND	178.13	ND	1863.07	1863.07	
	03/03/14	ERM	184	2041.2	ND	177.70	ND	177.70	ND	1863.50	1863.50	
	06/26/14	ERM	184	2041.2	ND	174.63	ND	174.63	ND	1866.57	1866.57	
	10/03/14	ERM	184	2041.2	ND	179.52	ND	179.52	ND	1861.68	1861.68	
	03/10/16	ERM	184	2041.2	ND	174.79	ND	174.79	ND	1866.41	1866.41	
	03/21/16	ERM	184	2041.2	ND	173.83	ND	173.83	ND	1867.37	1867.37	
	06/20/16	ERM	184	2041.2	ND	176.36	ND	176.36	ND	1864.84	1864.84	
	09/20/16	ERM	184	2041.2	ND	180.38	ND	180.38	ND	1860.82	1860.82	
	12/05/16	ERM	184	2041.2	ND	176.77	ND	176.77	ND	1864.43	1864.43	
MW-23	12/03/13	ERM	185.3	2041.49	ND	178.35	ND	178.35	ND	1863.14	1863.14	
	03/03/14	ERM	185.3	2041.49	177.81	177.89	0.08	177.81	1863.68	1863.60	1863.68	Product is too viscous to allow accurate water level measurement
	06/26/14	ERM	185.3	2041.49	ND	174.72	ND	174.72	ND	1866.77	1866.77	
	10/03/14	ERM	185.3	2041.49	179.68	179.7	0.02	179.68	1861.81	1861.79	1861.81	Product is too viscous to allow accurate water level measurement
	03/10/16	ERM	185.3	2041.49	174.8	174.89	0.09	174.80	1866.69	1866.60	1866.69	
	03/21/16	ERM	185.3	2041.49	173.86	173.94	0.08	173.86	1867.63	1867.55	1867.63	
	06/20/16	ERM	185.3	2041.49	176.51	176.54	0.03	176.51	1864.98	1864.95	1864.98	
	09/20/16	ERM	185.3	2041.49	180.31	181.69	1.38	180.37	1861.18	1859.80	1861.12	Potentially erroneous measurement
	12/07/16	ERM	185.3	2041.49	176.87	176.87	Trace	176.87	1864.62	1864.62	1864.62	Trace amount of product
MW-24	12/03/13	ERM	186.2	2040.41	ND	176.84	ND	176.84	ND	1863.57	1863.57	
	03/03/14	ERM	186.2	2040.41	ND	176.23	ND	176.23	ND	1864.18	1864.18	
	06/26/14	ERM	186.2	2040.41	ND	173.37	ND	173.37	ND	1867.04	1867.04	
	10/03/14	ERM	186.2	2040.41	ND	178.24	ND	178.24	ND	1862.17	1862.17	
	03/10/16	ERM	186.2	2040.41	ND	173.36	ND	173.36	ND	1867.05	1867.05	
	03/21/16	ERM	186.2	2040.41	ND	172.35	ND	172.35	ND	1868.06	1868.06	
	06/20/16	ERM	186.2	2040.41	ND	175.15	ND	175.15	ND	1865.26	1865.26	
	09/20/16	ERM	186.2	2040.41	ND	179.10	ND	179.10	ND	1861.31	1861.31	
	12/05/16	ERM	186.2	2040.41	ND	175.40	ND	175.40	ND	1865.01	1865.01	
MW-25	12/03/13	ERM	181.2	2036.14	ND	172.19	ND	172.19	ND	1863.95	1863.95	
	03/03/14	ERM	181.2	2036.14	ND	171.55	ND	171.55	ND	1864.59	1864.59	
	06/26/14	ERM	181.2	2036.14	ND	168.76	ND	168.76	ND	1867.38	1867.38	
	10/03/14	ERM	181.2	2036.14	ND	173.58	ND	173.58	ND	1862.56	1862.56	
	03/10/16	ERM	181.2	2036.14	ND	168.6	ND	168.60	ND	1867.54	1867.54	
	03/21/16	ERM	181.2	2036.14	ND	167.59	ND	167.59	ND	1868.55	1868.55	
	06/20/16	ERM	181.2	2036.14	ND	170.54	ND	170.54	ND	1865.60	1865.60	
	09/20/16	ERM	181.2	2036.14	ND	174.45	ND	174.45	ND	1861.69	1861.69	
	12/05/16	ERM	181.2	2036.14	ND	170.69	ND	170.69	ND	1865.45	1865.45	

Monitoring Well	Date	Collector	Total Depth (feet)	TOC Elevation *feet amsl*	Depth to Product *feet*	Depth to Groundwater *feet*	Approximate Product Thickness *feet*	Corrected Depth to Groundwater *feet*	Product Elevation *feet amsl*	Groundwater Elevation *feet amsl*	Corrected Groundwater Elevation *feet amsl*	Comments
MW-26	12/03/13	ERM	180.4	2035.63	ND	171.51	ND	171.51	ND	1864.12	1864.12	
	03/03/14	ERM	180.4	2035.63	ND	170.83	ND	170.83	ND	1864.80	1864.80	
	06/26/14	ERM	180.4	2035.63	ND	168.10	ND	168.10	ND	1867.53	1867.53	
	10/03/14	ERM	180.4	2035.63	ND	172.9	ND	172.90	ND	1862.73	1862.73	
	03/10/16	ERM	180.4	2035.63	ND	167.91	ND	167.91	ND	1867.72	1867.72	
	03/21/16	ERM	180.4	2035.63	ND	166.8	ND	166.80	ND	1868.83	1868.83	
	06/20/16	ERM	180.4	2035.63	ND	169.88	ND	169.88	ND	1865.75	1865.75	
	09/20/16	ERM	108.4	2035.63	ND	173.78	ND	173.78	ND	1861.85	1861.85	
	12/05/16	ERM	108.4	2035.63	ND	170.00	ND	170.00	ND	1865.63	1865.63	
MW-27	10/03/14	ERM	183.7	2038.15	ND	175.27	ND	175.27	ND	1862.88	1862.88	
	03/10/16	ERM	183.7	2038.15	NM	170.22	NM	170.22	NM	1867.93	1867.93	
	03/21/16	ERM	183.7	2038.15	NM	169.17	NM	169.17	NM	1868.98	1868.98	
	06/20/16	ERM	183.7	2038.15	ND	172.29	ND	172.29	ND	1865.86	1865.86	
	09/20/16	ERM	183.7	2038.15	ND	176.18	ND	176.18	ND	1861.97	1861.97	
	12/05/16	ERM	183.7	2038.15	ND	172.32	ND	172.32	ND	1865.83	1865.83	
MW-28	04/12/16	ERM	184.6	2042.76	174.08	174.09	0.01	174.08	1868.68	1868.67	1868.68	
	06/20/16	ERM	184.6	2042.76	177.46	178.8	1.34	177.52	1865.3	1863.96	1865.24	
	09/20/16	ERM	184.6	2042.76	181.16	182.21	1.05	181.20	1861.6	1860.55	1861.56	
	12/07/16	ERM	184.6	2042.76	177.51	178.39	0.88	177.55	1865.25	1864.37	1865.21	
MW-29	04/12/16	ERM	187.2	2041.05	ND	173.06	ND	173.06	ND	1867.99	1867.99	
	06/20/16	ERM	187.2	2041.05	ND	176.22	ND	176.22	ND	1864.83	1864.83	
	09/20/16	ERM	187.2	2041.05	ND	180.23	ND	180.23	ND	1860.82	1860.82	
	12/05/16	ERM	187.2	2041.05	ND	176.66	ND	176.66	ND	1864.39	1864.39	
MW-30	06/24/16	ERM	186.2	2041.25	ND	176.22	ND	176.22	ND	1865.03	1865.03	
	09/20/16	ERM	186.2	2041.25	ND	179.9	ND	179.90	ND	1861.35	1861.35	
	12/05/16	ERM	186.2	2041.25	ND	176.15	ND	176.15	ND	1865.10	1865.10	

Notes:

LNAPL gauging procedure was modified in March 2016 in accordance with the addendum to the Sampling and Analysis Plan (ERM 2016b) to allow for more accurate measurements.

Abbreviations:

amsl = above mean sea level
NA = Data not available
ND = Not Detected
NM = Not Measured
TOC = Top of Casing

DRAFT

Table 5

Aquifer Grain Size Analyses Summary
BNSF Black Tank Site
Spokane, Washington

			Particle Size Distribution, Weight Percent						
Sample Location	**Depth (feet bgs)**	**Description**	**Gravel**	**Sand Size**			**Fine-Grained Material**		
				Coarse	**Medium**	**Fine**	**Silt**	**Clay**	**Silt & Clay**
MW-17	154	Medium sand with silt and clay	0.48	8.84	67.26	14.37	NR	NR	9.05
	160	Silty fine sand with clay	0.00	0.00	27.86	52.26	15.72	4.17	19.88
	162.2	Silty fine sand with clay	0.00	0.00	13.31	47.62	30.09	8.98	39.07
MW-20	168.2	Medium sand	0.00	0.00	80.24	16.79	2.21	0.77	2.98
	171	Silty fine sand with clay	0.00	0.00	18.07	43.08	29.88	8.96	38.84
	173.3	Silty fine sand with clay	0.00	0.00	21.48	50.92	21.24	6.35	27.59
	176.3	Gravelly medium sand with silt and clay	32.96	16.05	27.39	15.95	NR	NR	7.65
MW-24	171.8	Medium sand with gravel, silt and clay	7.56	28.88	42.3	13.88	NR	NR	7.38
	175.8	Medium sand	6.85	16.73	64.19	9.25	NR	NR	2.98
MW-28	167.2	Medium sand with silt	0.00	0.00	79.21	13.84	4.91	2.05	6.95
	168.1	Silty medium sand	0.00	0.00	45.69	34.21	15.31	4.79	20.10
	169.8	Silty fine sand with clay	0.00	0.00	20.56	44.84	27.58	7.02	34.60
	172.8	Silty fine sand with clay	0.00	0.00	24.05	48.37	20.65	6.93	27.58
	176	Medium sand with silt and clay	9.12	29.11	46.45	9.99	NR	NR	5.34
MW-29	173.3	Clayey silt	0.00	0.00	0.00	15.08	61.49	23.44	84.92
	179	Coarse sand with gravel	32.32	40.28	22.62	2.70	NR	NR	2.08

Abbreviations:

bgs = below ground surface
NR = Not Reported

Soils classified using the Uniform Field Soil Classification System (MDOT 2009)

DRAFT

Table 6

Aquifer Hydraulic Conductivity Analysis Summary
BNSF Black Tank Site
Spokane, Washington

Sample ID	**Depth feet**	**Sample Orientation**	**Grain Size Soil Description**		**25 PSI Confining Stress**		
				Specific Permeability to Air[5]	**Effective Permeability to Water** [1,2]	**Hydraulic Conductivity**[2]	**Specific Permeability to NAPL**[3,4]
				mD	**mD**	**cm/sec**	**mD**
MW17C-(153-155.5)	154.2	Horizontal	Medium sand with silt and clay	NA	345	3.37E-04	470
MW20D-(170.5-173)	170.8	Horizontal	NA	NA	1,180	1.14E-03	2,460
MW20E-(173-175.5)	173.2	Horizontal	Silty fine sand with clay	494	100	9.94E-05	NA
MW20F-(175.5-178)	176	Horizontal	Gravelly medium sand with silt and clay	NA	9,440	9.23E-03	25,800
MW29 (172.5-175)	173.5	Horizontal	Clayey silt	4.24	1.91	1.99E-06	NA
MW29 (177-180)	178.5	Horizontal	Coarse sand with gravel	19,400	13,300	1.36E-02	NA

Notes:

1. Effective (Native) = With as-received pore fluids in place.
2. Permeability to water and hydraulic conductivity measured at saturated conditions.
3. Permeability to NAPL measured at saturated conditions.
4. NAPL viscosity used to calculate permeability to NAPL = 3,966 cP at 77 degrees Fahrenheit.
5. Specific = No pore fluids in place.

Abbreviations:

cm/sec = centimeters per second
cP = centipoise
mD = milliDarcy
NA = Not Analyzed
NAPL = Non-aqueous phase liquid
PSI = pounds per square inch

DRAFT
Table 7

Water Supply Wells in the Vicinity of the Site
BNSF Black Tank Site
Spokane, Washington

Well System Name	Water System ID	Map ID	Distance from Site (miles)	Direction from Site	Well Depth (feet bgs)
City of Spokane	83100	Nevada Street Well	1.8	Southwest	122
		Hoffman Well	0.8	Northwest	235
		Central Avenue	2.6	Northwest	272
Whitworth Water District	96601	WWD 3C	5.4	Northwest	355
		WWD 3B	5.4	Northwest	130
		WWD 1	3.2	Northwest	271
		WWD 1A	3.6	Northwest	210
		WWD 2	4.2	Northwest	163
		WWD 2A	3.5	Northwest	253
		WWD 2B	4.2	Northwest	180
		WWD 3	5.2	Northwest	92
North Spokane Irrigation District 8	61300	NSID 1	1.7	Northeast	232
		NSID 2	1.7	Northeast	255
		NSID 3	1.7	Northeast	232
		NSID 4	1.7	Northeast	234
Whitworth College	96580	Whitworth College 1	4.8	Northwest	157
		Whitworth College 2	4.8	Northwest	254
Spokane County Water District 3	93354	SWD Helena/Mead	5	Northwest	88
		SWD Freya/Farwell	5.1	Northwest	177
		SWD Cherry/Farwell	5.3	Northwest	135
		SWD 3A-2	3.1	Northwest	198
		SWD 3A-1	2.8	Northwest	293
Mt. St. Michaels	56557	Mt. St. Michaels Church	2.2	Northeast	150

Abbreviations:
bgs = below ground surface
WWD = Whitworth Water District
NSID = North Spokane Irrigation District
SWD = Spokane County Water District

DRAFT
Table 8

Monitoring Well Construction Summary
BNSF Black Tank Site
Spokane, Washington

Well Identification	Well Completion Date	Drilling Method	Washington State Plane Coordinates, North Zone (NAD 83, feet)		Borehole Depth (feet bgs)	Ground Surface Elevation (NAVD 88, feet)	Top of Casing Elevation (NAVD 88, feet)	Screen Interval Depth to		Screen Length (feet)	Screen Slot Size (inches)	Filter Pack Depth to	
			Easting	Northing				Top (feet bgs)	Bottom (feet bgs)			Top (feet bgs)	Bottom (feet bgs)
MW-01	21-Jan-08	Tubex	273792.6	2494855.0	182.5	2033.51	2036.07	157.0	182.0	25.0	0.020	153.5	182.5
MW-02	24-Jan-08	Sonic	273883.4	2494936.1	182.0	2034.18	2037.07	157.0	182.0	25.0	0.020	154.0	182.0
MW-03	28-Jan-08	Sonic	274053.8	2494760.3	193.0	2038.56	2040.89	162.0	187.0	25.0	0.020	160.0	193.0
MW-04	30-Jan-08	Sonic	273990.7	2494701.1	170.0	2033.97	2033.59	138.0	168.0	30.0	0.020	136.0	170.0
MW-05	01-Feb-08	Sonic	274167.2	2494744.7	169.5	2038.54	2040.97	158.5	169.0	10.5	0.020	165.5	169.5
MW-06	22-Jul-08	Sonic	273426.5	2494762.3	193.0	2026.68	2029.48	166.0	186.0	20.0	0.020	164.2	186.7
MW-07	23-Jul-08	Sonic	274277.4	2494723.7	175.0	2036.46	2036.00	158.5	168.5	10.0	0.020	156.0	169.0
MW-08	24-Jul-08	Sonic	274280.9	2494792.9	177.0	2038.29	2040.76	156.5	166.5	10.0	0.020	155.0	167.0
MW-09	25-Jul-08	Sonic	274394.3	2494799.6	193.0	2038.25	2040.60	170.0	190.0	20.0	0.020	170.0	190.0
MW-10	26-May-09	Sonic	274669.5	2494841.0	197.0	2038.35	2038.07	167.0	197.0	30.0	0.010	164.5	197.1
MW-11	29-May-09	Sonic	274654.5	2494670.0	197.0	2037.98	2037.67	167.0	197.0	30.0	0.010	164.9	197.0
MW-12	09-Jan-06	Sonic	274546.6	2494533.1	198.0	2038.21	2038.21	167.0	197.0	30.0	0.010	163.5	198.0
MW-13	09-Mar-06	Sonic	274268.2	2494543.2	197.0	2039.54	2039.21	182.0	197.0	15.0	0.010	180.0	197.0
MW-14	09-Jun-06	Sonic	273939.3	2494553.9	217.0	2039.26	2038.84	197.0	217.0	20.0	0.010	195.0	217.0
MW-15	28-May-09	Sonic	274181.6	2494895.5	197.0	2037.66	2037.40	166.0	196.0	30.0	0.010	163.0	196.0
MW-16	22-Oct-13	Sonic	273956.5	2494987.9	178.0	2034.15	2036.70	166.0	176.0	10.0	0.010	163.0	177.5
MW-17	03-Nov-13	Sonic	273871.0	2494782.1	178.0	2028.08	2030.78	152.8	167.8	15.0	0.010	149.8	169.2
MW-18	17-Oct-13	Sonic	273710.3	2494764.6	187.0	2034.90	2037.67	161.2	176.2	15.0	0.010	158.2	177.6
MW-19	11-Nov-13	Sonic	273742.2	2494658.5	178.0	2030.91	2030.43	160.3	175.3	15.0	0.010	157.2	176.6
MW-20	29-Oct-13	Sonic	273954.7	2494574.2	188.0	2039.48	2039.11	167.5	182.5	15.0	0.010	164.6	183.9
MW-21	01-Nov-13	Sonic	274304.5	2494547.9	188.0	2039.39	2039.04	176.3	186.3	10.0	0.010	173.4	187.8
MW-22	05-Nov-13	Sonic	274530.8	2494751.0	188.0	2038.32	2041.20	170.7	180.7	10.0	0.010	167.8	182.1
MW-23	28-Oct-13	Sonic	274402.7	2494916.3	188.0	2038.68	2041.49	172.0	182.0	10.0	0.010	169.1	183.3
MW-24	12-Nov-13	Sonic	274135.0	2494887.1	183.4	2037.77	2040.41	168.1	183.1	15.0	0.010	165.2	183.4
MW-25	14-Nov-13	Sonic	273902.1	2494866.9	178.2	2033.17	2036.14	162.9	177.9	15.0	0.010	160.9	178.2
MW-26	15-Oct-13	Sonic	273827.8	2494917.9	177.5	2032.77	2035.63	167.2	177.2	10.0	0.010	164.3	177.5
MW-27	27-Sep-14	Sonic	273651.14	2494589.65	187.0	2038.36	2038.15	173.5	183.5	10.0	0.010	171.8	184.0
MW-28	07-Apr-16	Sonic	274057.40	2494502.77	187.0	2040.36	2042.76	165.0	180.0	15.0	0.010	162.0	160.0
MW-29	09-Apr-16	Sonic	274529.23	2494913.79	183.0	2038.54	2041.05	168.0	183.0	15.0	0.010	183.0	165.0
MW-30	22-Jun-16	Sonic	274077.59	2494327.22	187.0	2042.00	2041.25	169.0	184.0	15.0	0.010	166.0	184.5

Notes:

NAD 83 = Coordinates in Washington State Plane, North Zone, North American Datum of 1983 (revised 1991)
NAVD 88 = North American Vertical Datum of 1988

Abbreviations:

bgs = below ground surface

DRAFT
Table 9

Groundwater Quality Parameter Summary
Groundwater Monitoring Events - 2010 to 2016
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Field Parameters				
		Temperature (°C)	pH	Electro-conductivity (μS/cm)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)
MW-6	8/3/2010	15.87	7.92	0.162	7.58	9
	10/21/2010	11.41	7.60	0.309	7.99	298
	1/26/2011	10.32	7.63	0.274	9.49	244
	4/25/2011	10.37	8.14	0.143	8.00	163
	7/13/2011	10.83	7.92	0.155	8.53	182
	10/7/2011	11.32	8.11	0.173	8.30	-246
	12/5/2013	6.85	8.00	0.172	5.39	136
	3/6/2014	10.73	6.55	0.152	4.41	178
	6/29/2014	13.97	6.97	0.215	6.81	126
	10/1/2014	12.73	6.59	0.194	7.44	163
	3/16/2016	15.02	7.48	0.006	5.63	163
	3/18/2016	10.06	5.98	0.147	6.53	144
	6/21/2016	17.95	6.35	0.239	4.70	91
	9/21/2016	12.18	7.02	0.221	7.98	201
	12/6/2016	10.77	6.97	0.187	6.11	337
MW-10	8/3/2010	16.61	7.48	0.219	4.49	59
	10/22/2010	11.57	7.54	0.291	5.56	269
	1/26/2011	10.85	7.27	0.373	9.42	235
	4/25/2011	10.71	7.73	0.168	5.83	149
	7/13/2011	11.18	7.66	0.194	8.21	102
	10/7/2011	11.82	7.74	0.205	4.57	-264
	12/5/2013	10.02	7.61	0.209	2.75	90
	3/4/2014	10.62	6.87	0.208	2.05	139
	6/30/2014	12.78	6.95	0.275	6.01	155
	10/1/2014	13.43	6.47	0.250	5.20	146
	3/16/2016	10.13	7.34	0.170	4.83	166
	6/21/2016	13.67	6.56	0.259	6.28	109
	9/23/2016	13.15	7.31	0.259	6.83	88
	12/6/2016	10.25	7.85	0.174	6.12	291

Table 9

Groundwater Quality Parameter Summary
Groundwater Monitoring Events - 2010 to 2016
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Field Parameters				
		Temperature (°C)	pH	Electro-conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)
MW-11	8/3/2010	17.40	7.58	0.214	4.03	41
	10/21/2010	12.18	7.25	0.475	0.74	254
	1/26/2011	11.07	7.05	0.588	6.24	222
	4/25/2011	10.85	7.38	0.280	1.37	157
	7/13/2011	11.18	7.77	0.179	1.82	85
	10/7/2011	11.75	7.81	0.247	0.61	-401
	12/4/2013	9.90	7.40	0.320	1.30	147
	3/4/2014	10.71	6.53	0.349	0.21	131
	6/30/2014	12.56	7.02	0.430	4.45	115
	10/1/2014	13.79	6.59	0.307	4.79	137
	3/16/2016	9.89	7.11	0.254	3.05	177
	6/21/2016	14.51	6.53	0.442	5.47	102
	9/23/2016	13.58	7.26	0.388	5.50	71
	12/6/2016	4.11	7.40	0.219	9.60	296
MW-12	8/4/2010	16.54	7.74	0.187	5.88	77
	10/22/2010	11.52	7.54	0.409	4.69	292
	1/26/2011	10.83	7.38	0.304	9.21	244
	4/25/2011	10.64	7.99	0.147	6.94	160
	7/13/2011	11.05	7.59	0.227	5.42	111
	10/7/2011	11.68	8.00	0.184	6.58	-249
	12/4/2013	9.40	7.57	0.193	5.32	139
	3/6/2014	11.15	6.01	0.168	4.29	195
	6/27/2014	13.25	6.62	0.258	5.30	185
	10/1/2014	11.90	6.56	0.217	6.17	141
	3/15/2016	10.17	7.63	0.199	4.77	154
	6/24/2016	12.23	6.78	0.220	6.71	104
	9/21/2016	13.49	7.19	0.196	6.23	174
	12/6/2016	9.30	7.92	0.188	8.06	292

DRAFT
Table 9

Groundwater Quality Parameter Summary
Groundwater Monitoring Events - 2010 to 2016
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Field Parameters				
		Temperature (°C)	pH	Electro-conductivity (μS/cm)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)
MW-13	8/4/2010	16.89	7.98	0.157	6.48	64
	10/22/2010	11.83	7.68	0.289	5.49	251
	1/26/2011	10.97	7.62	0.274	9.52	233
	4/25/2011	10.85	8.16	0.131	6.74	153
	7/13/2011	11.29	8.06	0.142	7.38	91
	10/7/2011	11.86	8.04	0.218	6.87	-233
	12/4/2013	10.57	7.53	0.206	4.11	149
	3/4/2014	10.29	4.65	0.183	6.09	151
	6/27/2014	13.20	6.31	0.193	5.60	137
	10/2/2014	13.61	6.51	0.223	5.16	131
	3/14/2016	10.95	7.49	0.124	6.00	144
	6/22/2016	15.49	6.40	0.192	7.20	99
	9/21/2016	14.15	6.99	0.194	5.63	196
	12/11/2016	10.57	7.28	0.212	5.11	156
MW-14	8/4/2010	17.39	8.11	0.154	6.50	70
	10/22/2010	12.17	7.75	0.266	5.84	246
	1/26/2011	11.50	7.75	0.273	10.09	229
	4/25/2011	11.46	8.14	0.135	7.16	185
	7/13/2011	12.00	8.17	0.138	7.14	86
	10/7/2011	12.21	8.34	0.144	6.97	-221
	12/5/2013	6.85	8.16	0.164	4.83	118
	3/4/2014	10.45	5.99	0.150	6.07	135
	6/27/2014	13.95	6.21	0.165	5.13	2.1
	10/1/2014	14.95	6.31	0.163	5.10	171
	3/14/2016	11.36	6.89	0.122	6.91	145
	6/22/2016	15.29	6.31	0.177	6.86	135
	9/21/2016	14.81	6.91	0.160	6.21	207
	12/11/2016	7.12	6.42	0.152	6.01	183

DRAFT

Table 9

Groundwater Quality Parameter Summary
Groundwater Monitoring Events - 2010 to 2016
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Field Parameters				
		Temperature *(°C)*	pH	Electro-conductivity *(μS/cm)*	Dissolved Oxygen *(mg/L)*	Oxidation Reduction Potential *(mV)*
MW-15	8/4/2010	16.85	7.68	0.230	3.83	-27
	10/21/2010	12.02	7.25	0.417	5.76	252
	1/26/2011	11.09	7.37	0.309	8.94	246
	4/25/2011	10.93	7.97	0.147	6.95	139
	7/13/2011	11.30	7.43	0.175	4.70	39
	10/7/2011	12.00	8.06	0.175	7.90	-251
	12/4/2013	9.29	7.24	0.208	4.64	168
	3/5/2014	10.15	6.08	0.177	3.84	163
	6/30/2014	13.85	6.27	0.213	6.04	152
	9/29/2014	14.50	6.32	0.201	5.60	138
	3/14/2016	11.10	7.90	0.138	6.21	186
	6/21/2016	15.05	6.00	0.210	5.89	104
	9/22/2016	14.40	6.78	0.202	4.17	212
	12/6/2016	10.47	7.96	0.218	8.00	278
MW-16	12/6/2013	7.00	5.93	0.354	1.96	195
	3/5/2014	10.86	7.68	0.226	5.49	121
	9/29/2014	14.30	7.79	0.390	6.40	52.8
	3/15/2016	12.41	6.56	0.174	4.63	172.5
	6/23/2016	13.45	6.75	0.219	6.73	210.8
	9/22/2016	13.60	7.62	0.366	6.32	180.2
	12/11/2016	8.43	6.85	0.271	5.73	187.2
MW-17	12/6/2013	8.35	6.15	0.539	0.35	86
MW-21	12/6/2013	7.08	6.94	0.224	7.95	164
	3/4/2014	9.98	7.12	0.160	4.80	120
	6/27/2014	14.34	6.97	0.227	4.30	92.1
	10/2/2014	13.40	7.64	0.419	2.25	73.6
	3/17/2016	10.70	6.78	0.138	4.59	168
	6/22/2016	17.20	7.51	0.232	6.05	103
	9/21/2016	14.91	7.52	0.382	2.85	180
	12/11/2016	8.12	7.31	0.189	5.73	130

Table 9

Groundwater Quality Parameter Summary
Groundwater Monitoring Events - 2010 to 2016
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Field Parameters				
		Temperature (°C)	pH	Electro-conductivity (μS/cm)	Dissolved Oxygen (mg/L)	Oxidation Reduction Potential (mV)
MW-22	12/5/2013	9.38	6.00	0.252	0.70	141
	3/4/2014	8.91	7.14	0.211	2.61	20
	6/25/2014	13.68	7.00	0.448	0.68	11
	9/30/2014	13.10	7.33	0.274	2.70	-40.8
	3/16/2016	9.39	5.40	0.176	3.43	187.8
	6/21/2016	14.94	6.72	0.321	2.43	124.3
	9/23/2016	13.34	7.72	0.231	1.68	15.5
	12/10/2016	9.11	6.52	0.248	3.11	89.7
MW-24	12/5/2013	4.89	5.93	0.406	2.08	116
	3/5/2014	7.53	7.77	0.262	2.91	89
	6/28/2014	13.56	7.49	0.472	1.90	108
	9/29/2014	13.38	7.17	0.457	2.65	6.9
	3/15/2016	9.69	5.24	0.172	3.43	167.1
	6/21/2016	17.70	7.31	0.222	6.53	91.1
	9/22/2016	15.32	7.41	0.247	6.38	186.0
	12/11/2016	5.12	6.12	0.312	4.12	131.8
MW-25	12/6/2013	7.65	5.71	0.180	3.31	197
	3/6/2014	10.75	8.25	0.165	5.90	130
	6/28/2014	13.85	7.62	0.248	5.53	135
	9/30/2014	12.47	7.83	0.186	7.59	59.2
	3/15/2016	10.71	6.26	0.196	4.99	164
	6/23/2016	13.76	7.55	0.194	7.38	126
	9/22/2016	14.32	8.14	0.208	6.27	196
	12/10/2016	6.48	7.24	0.191	6.42	140
MW-26	12/6/2013	9.10	5.73	0.403	0.64	170
	3/5/2014	11.85	7.13	0.415	1.13	109
	6/28/2014	14.71	7.05	0.353	3.30	112
	9/30/2014	12.72	7.81	0.318	4.88	88.1
	3/16/2016	11.17	6.12	0.210	2.93	186.1
	6/23/2016	13.80	7.22	0.285	7.28	127.9
	9/22/2016	14.34	7.32	0.406	4.49	208.9
	12/10/2016	7.12	7.33	0.380	6.12	140.7

Groundwater Quality Parameter Summary
Groundwater Monitoring Events - 2010 to 2016
BNSF Black Tank Site
Spokane, Washington

Monitoring Well	Date	Field Parameters				
		Temperature *(°C)*	pH	Electro-conductivity *(µS/cm)*	Dissolved Oxygen *(mg/L)*	Oxidation Reduction Potential *(mV)*
MW-27	10/2/2014	15.73	8.06	0.258	5.43	-94.6
	3/17/2016	14.46	7.26	0.183	5.30	160.6
	6/22/2016	14.57	7.75	0.236	6.40	149.6
	9/21/2016	17.43	7.78	0.244	6.67	202.5
	12/10/2016	6.09	7.52	0.21	5.12	119.2
MW-29	4/12/2016	16.25	6.93	0.370	1.78	35.8
	6/24/2016	12.30	7.70	0.595	6.41	105.9
	9/23/2016	12.55	7.44	0.566	4.61	56.2
	12/10/2016	6.22	7.30	0.411	4.12	73.1
MW-30	6/24/2016	14.35	7.15	0.210	6.62	59.1
	9/21/2016	15.33	7.48	0.262	1.10	186.8
	12/10/2016	7.12	7.12	0.312	4.87	80.3

Abbreviations:

BNSF = Burlington Northern Santa Fe Railway Company
°C = Degrees Celsius
mg/L = Milligrams per liter
µS/cm = Microsiemens per centimeter
mV = Millivolts
MW = Monitoring Well
NS = No Sample

Preliminary Cleanup Levels
BNSF Black Tank Site
Spokane, Washington

Media	Exposure Pathway	Proposed Cleanup Level Source	Contaminant of Concern	Proposed Cleanup Level
Groundwater	Drinking Water	MTCA Method A for Groundwater (WAC Table 720-1)	TPH-D/HO	500 µg/L
			Benzo(a)Pyrene	0.1 µg/L
			Benzo(a)Pyrene TEQ	0.1 µg/L
Surface Soil (surface to 15 feet bgs)	Direct Contact & Protection of Groundwater	MTCA Method A - Unrestricted Land Use (WAC Table 740-1)	TPH-D/HO	2,000 mg/kg
			Benzo(a)Pyrene	0.1 mg/kg
			Benzo(a)Pyrene TEQ	0.1 mg/kg
			Naphthalene	5 mg/kg
			Total Naphthalenes	5 mg/kg
Subsurface Soil (below 15 feet bgs)	Protection of Groundwater	MTCA Method B - TPH 11.1 Workbook Tool and Method B Protection of Groundwater [WAC 173-340-747(4)(b)]	TPH-D/HO	13,600 mg/kg
LNAPL (Mobile)	Protection of Groundwater	WAC 173-340-360(2)(c)(ii)	LNAPL (Mobile)	Removal using normally accepted engineering practices.

Notes:
1. Results of simplified terrestrial ecological evaluation - exposure analysis procedures (Table 749-1) shows no unacceptable exposure because there is little to no undeveloped land on or within 500 feet of the Site.
2. Per WAC 173-340-360 (2)(c)(ii)(A), this includes removal of free product consisting of petroleum and other light nonaqueous phase liquid from the groundwater using normally accepted engineering practices.

Abbreviations:
bgs = below ground surface
mg/kg = Milligrams per kilogram
MTCA = Model Toxics Control Act
TEQ = Toxic Equivalency Quotient
TPH = Total Petroleum Hydrocarbons
TPH-D/HO = Total Petroleum Hydrocarbons as Diesel/Heavy Oil
µg/L = micrograms per liter

DRAFT

Table 11

Summary of MTCATPH 11.1 Workbook Data and Calculations

BNSF Black Tank Site

Spokane, Washington

	Soil Sample									
Location	**MW-16**	**MW-16**	**MW-17**	**MW-18**	**MW-19**	**MW-20**	**MW-23**	**MW-24**	**MW-25**	**MW-26**
Date	**10/22/2013**	**10/22/2013**	**11/4/2013**	**10/18/2013**	**11/11/2013**	**10/31/2013**	**10/29/2013**	**11/13/2013**	**11/15/2013**	**10/16/2013**
Sample Depth	**166-167 feet bgs**	**166-167 feet bgs**	**158-159 feet bgs**	**170-171 feet bgs**	**162-163 feet bgs**	**164-165 feet bgs**	**174-175 feet bgs**	**175-175.5 feet bgs**	**157-158 feet bgs**	**160-161 feet bgs**
Sample ID	**MW-16 (166-167')**	**MW-16 (166-167')D**	**MW-17 (158-159')**	**MW-18 (170-171')**	**MW-19 (162-163')**	**MW-20 (164-165')**	**MW-23 (174-175')**	**MW-24 (175-176')**	**MW-25 (157-158')**	**MW-26 (160-161')**
Petroleum Equivalent Carbon Fraction										
AL EC > 5-6	1.58	1.9	2.53	5.59	12.1	0.2895	0.891	0.399	0.269	0.265
AL EC > 6-8	7.76	11.4	12.3	23.2	205	0.2895	24.7	7.98	0.269	2.32
AL EC > 8-10	108	60.9	33.3	47.7	354	29.9	216	37.1	9.93	12.3
AL EC > 10-12	753	504	215	131	1550	157	782	184	82.6	165
AL EC > 12-16	4890	3510	1430	570	7500	942	3850	1030	554	303
AL EC > 16-21	5980	4570	1810	674	8140	1100	3650	1110	755	362
AL EC > 21-34	8850	7700	2110	827	7020	1240	5540	1090	873	450
AR EC > 8-10	54	75.9	33.893	75.529	289.33	34.9	176.02	47.042	14.2	31.3
AR EC > 10-12	0	465	268	1	0	261	121	421	172	331
AR EC > 12-16	0	0	0	0	0	0	0	658	291	582
AR EC > 16-21	3630	1540	1720	327	3260	661	1670	670	324	184
AR EC > 21-34	1070	680	1166	95.3	0	738	280	50	413	0
Benzene	0.2725	0.275	0.238	0.25	0.2805	0.2895	0.255	0.2525	0.269	0.265
Toluene	0.2725	0.275	0.238	0.25	0.2805	0.2895	0.528	0.2525	0.269	0.265
Ethylbenzene	0.2725	0.275	0.238	0.25	0.2805	0.2895	0.255	0.2525	0.269	0.265
Total Xylenes	0.545	0.55	1.145	0.921	3.67	0.579	2.235	0.771	0.538	0.53
Naphthalene	0.815	0.2745	0.1475	0.213	6.18	0.1415	0.596	0.0273	0.2755	0.1345
1-Methyl Naphthalene	11.5	7.28	4.73	31	45.6	1.31	5.43	0.0273	0.2755	0.1345
2-Methyl Naphthalene	12.9	9.48	8.06	58.6	78	0.1415	0.2895	0.0273	0.2755	0.1345
n-Hexane	0	0	0	0	0	0	0	0	0	0
MTBE	0.2725	0.275	0.238	0.25	0.669	0.2895	0.255	0.2525	0.269	0.265
Ethylene Dibriomide (EDB)	0.03	0.0254	0	0.02905	0	0	0.03135	0	0	0.0271
1,2 Dichloroethane (EDC)	0.03	0.0254	0	0.02905	0	0	0.03135	0	0	0.0271
Benzo(a)anthracene	1.84	1.46	0.1475	0.0817	1.415	0.1415	0.2895	0.108	0.2755	0.1345
Benzo(b)fluoranthene	0.2755	0.2745	0.1475	0.02935	1.415	0.1415	0.2895	0.0273	0.2755	0.1345
Benzo(k)fluoranthene	0.2755	0.2745	0.1475	0.02935	1.415	0.1415	0.2895	0.0273	0.2755	0.1345
Benzo(a)pyrene	0.2755	0.2745	0.1475	0.02935	1.415	0.1415	0.2895	0.108	0.2755	0.1345
Chrysene	1.92	1.2	0.494	0.253	2.88	0.1415	1.79	0.329	0.2755	0.477
Dibenzo(a,h)anthracene	0.2755	0.2745	0.1475	0.02935	1.415	0.1415	0.2895	0.0273	0.2755	0.1345
Indeno(1,2,3-cd)pyrene	0.2755	0.2745	0.1475	0.02935	1.415	0.1415	0.2895	0.0273	0	0.1345
Total soil porosity	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Volumetric water content	0.098	0.098	0.154	0.16	0.118	0.117	0.15	0.085	0.096	0.075
Volumetric air content	0.312	0.312	0.256	0.25	0.292	0.293	0.26	0.325	0.314	0.335
Soil bulk density (kg/L)	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
Fraction Organic Carbon	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Dilution Factor	20	20	20	1	20	20	20	1	20	20
Target TPH Groundwater Concentration (µg/L)	500	500	500	500	500	500	500	500	500	500
Protection of Target TPH Concentration (mg/kg)	100% NAPL	100% NAPL	100% NAPL	16.39	100% NAPL	62,164	100% NAPL	9	13,866	1,097

Abbreviations:

AL = Aliphatic
AR = Aromatic
bgs = below ground surface
EC = Equivalent Carbon
kg/L = kilograms per liter
µg/L = micrograms per liter
mg/kg = milligrams per kilogram
MW = Monitoring Well
NAPL = non-aqueous phase liquid
TPH = Total Petroleum Hydrocarbons

Summary of Residual Saturation Calculations
BNSF Black Tank Site
Spokane, Washington

API Saturation Tool Input Parameter	**Soil Sample**			
	MW24	**MW20**	**MW20**	**MW17**
Product Type	Diesel	Mixed Diesel & Heavy Oil		
Measured Soil Type	Medium Sand	Gravel	Medium Sand	Fine Sand
LNAPL Density (g/cm^3)	0.958 g/cm^3	0.9814 g/cm^3		
Soil Bulk Density (g/cm^3)	1.66 g/cm^3	1.62 g/cm^3	1.54 g/cm^3	1.49 g/cm^3
Soil Porosity	0.392	0.405	0.434	0.452
Calculated Residual Saturation (mg/kg)	**16,970 mg/kg**	**27,240 mg/kg**	**34,030 mg/kg**	**69,670 mg/kg**
Rounded Residual Saturation (mg/kg)	17,000	27,000	34,000	70,000

Abbreviations:

g/cm^3 = grams per cubic centimeter
LNAPL = light non-aqueous phase liquid
mg/kg = milligrams per kilogram
MW = Monitoring Well

DRAFT

Table 13

Summary of Site-Specific MTCA Method B Protection of Groundwater Cleanup Level Calculation
BNSF Black Tank Site
Spokane, Washington

Analyte	**Cw (ug/L)**	**Kd (L/kg)**	**H' (unitless)**	**Site-specific MTCA Method B Cleanup Level for Protection of Groundwater (mg/kg)**
Benzo(a)Pyrene	0.1	968,774	4.63E-05	1,900
Benzo(a)Pyrene TEQ	0.1	968,774	4.63E-05	1,900
Naphthalene	160	1,191	0.0198	3,800
Total Naphthalenes	160	1,191	0.0198	3,800
Cadmium	5	6.7	0	0.7
Chromium	50	1,000	0	1,000
Lead	15	10,000	0	3,000
Benzene	5	62	2.28E-01	6,200
Toluene	1,000	140	2.72E-01	2,800
Ethylbenzene	700	204	3.23E-01	2,900
Xylene	1,000	233	0.279	4,700
MTBE	20	10.9	0.018	4
Methylene Chloride	5	10	0.0898	1
Trichloroethylene	5	94	0.422	9
PCBs	0.1	107,285	0	200

Abbreviations:

Cw = Water Concentration
H' = Henry's Law Constant
Kd = Distribution Coefficient
L/kg = Liters per kilogram
mg/kg = milligrams per kilogram
MTBE = Methyl tert butyl ether
MTCA = Model Toxics Control Act
PCBs = Poly-chlorinated biphenyls
TEQ = Toxic Equivalency Quotient
ug/L = micrograms per liter

DRAFT
Table 14

Soil Sample Chromatograph Evaluation
BNSF Black Tank Site
Spokane, Washington

Surface Soil - 0 to 15 feet bgs			
Sample Location	**Sample Number**	**Depth**	**Petroleum Identified**
Test Pits			
Black Tank Pipeline Test Pits	BT-TP-25-14	14 ft	Heavy Oil
	BT-TP-27-15	15 ft	Heavy Oil
	BT-TP-30-2.5	2.5 ft	Mixed Diesel and Heavy Oil
Chemical Solution Pipeline Test Pits	CSPL-TP-01-0.5	0.5 ft	Heavy Oil
	CSPL-TP-07-1.5	1.5 ft	Heavy Oil
	CSPL-TP-7-15	15 ft	Heavy Oil
	CSPL-TP-08-1.5	1.5 ft	Heavy Oil
Liquid Asphalt Pipeline Test Pits	LAPL-TP-05-1.5	1.5 ft	Diesel
	LAPL-TP-06-1.5	1.5 ft	Heavy Oil
	LAPL-TP-6-S10	10 ft	Heavy Oil
	LAPL-TP-6-13	13 ft	Heavy Oil
	LAPL-TP-6-15	15 ft	Heavy Oil with Diesel
	LAPL-TP-07-1.5	1.5 ft	Heavy Oil
	LAPL-TP-08-1.25	1.25 ft	Heavy Oil
Red Tank Test Pits	RT-TP-1-3.5	3.5 ft	Heavy Oil
	RT-TP-2-S3.5	3.5 ft	Heavy Oil
	RT-TP-2-5	5 ft	Diesel
	RT-TP-45-2.5	2.5 ft	Diesel with Heavy Oil
	RT-TP-50-2.9	2.9 ft	Diesel
	RT-TP-50A-3.0	3 ft	Diesel with Heavy Oil
	RT-TP-50B-3.0	3 ft	Diesel with Heavy Oil
Soil Borings			
RT-SB-01	RT-SB-01-(10-11)	10-11 ft	Diesel with Heavy Oil
MW-19	MW19-(10-11)	10-11 ft	Diesel
	MW19-(17-18)	17-18 ft	Diesel
Subsurface Soils - Deeper than 15 feet bgs			
Well Number	**Sample Number**	**Depth**	**Petroleum Identified**
BT-SB01	BT-SB-01 (16-17)	16 - 17 ft	Heavy Oil & Diesel
	BT-SB-01 (18-19)	18 - 19 ft	Heavy Oil & Diesel
	BT-SB-01 (26-27)	26 - 27 ft	Heavy Oil & Diesel
	BT-SB-01 (66-67)	66 - 67 ft	Heavy Oil & Diesel
	BT-SB-01 (86-87)	86 - 87 ft	Heavy Oil & Diesel
	BT-SB-01 (106-107)	106 - 107 ft	Heavy Oil & Diesel
	BT-SB-01 (116-117)	116 - 117 ft	Heavy Oil & Diesel
	BT-SB-01 (126-127)	126 - 127 ft	Heavy Oil & Diesel
	BT-SB-01 (146-147)	146 - 147 ft	Heavy Oil & Diesel
	BT-SB-01 (170-171)	170 - 171 ft	Heavy Oil & Diesel
	BT-SB-01 (176-177)	176 - 177 ft	Heavy Oil
RT-SB-01	RT-SB-01 (16-17)	16-17 ft	Diesel with Heavy Oil
	RT-SB-01 (26-27)	26 - 27 ft	Diesel with Heavy Oil
MW-01	MW-1-22.0	22 ft	Diesel
	MW-1-30.0	30 ft	Diesel
	MW-1-160	160 ft	Diesel & Heavy Oil
MW-02	MW-2-172	172 ft	Diesel & Heavy Oil
	MW-2-174	174 ft	Diesel & Heavy Oil
	MW-2-177	177 ft	Diesel & Heavy Oil
MW-03	MW-3 (75-76)	75 - 76 ft	Diesel & Heavy Oil
	MW-3 (159-160)	159 - 160 ft	Diesel & Heavy Oil
	MW-3 (173-174)	173 - 174 ft	Diesel & Heavy Oil

DRAFT
Table 14

Soil Sample Chromatograph Evaluation
BNSF Black Tank Site
Spokane, Washington

MW-4	MW-4 (139-140)	139 - 140 ft	Heavy Oil
	MW-4 (154-155)	154 - 155 ft	Diesel & Heavy Oil
	MW-4 (167-168)	167-168 ft	Diesel & Heavy Oil
	MW-4 (169-170)	169-170 ft	Diesel & Heavy Oil
MW-05	MW-5-(169-170)	169 - 170 ft	Diesel & Heavy Oil
MW-7	MW-7 (158-159)	158 - 159 ft	Diesel
	MW-7 (171-172)	171 - 172 ft	Diesel & Heavy Oil
MW-8	MW-8 (172-173)	172 - 173 ft	Diesel & Heavy Oil
MW-9	MW-9 (165-166)	165 - 166 ft	Diesel
	MW-9 (172-173)	172 - 173 ft	Diesel & Heavy Oil
MW-13	MW13S170.5-060309	170.5 ft	Diesel & Heavy Oil
	MW13S171-060309	171 ft	Diesel & Heavy Oil
MW-14	MW14S162.5-060509	162.5 ft	Diesel & Heavy Oil
	MW14S167-060509	167 ft	Diesel & Heavy Oil
	MW14S169-060509	169 ft	Diesel & Heavy Oil
	MW14S172.5-060509	172.5 ft	Diesel & Heavy Oil
	MW14S180.5-060509	180.5 ft	Diesel & Heavy Oil
MW-16	MW16-(166-167)	166-167 ft	Diesel & Heavy Oil
	DUPLICATE 1-102213	166-167 ft	Diesel & Heavy Oil
	MW16-(172-173)	172-173 ft	Heavy Oil & Diesel
MW-17	MW17-(158-159)	158-159 ft	Heavy Oil & Diesel
	MW17-(168-169)	168-169 ft	Diesel & Heavy Oil
	MW-17 DUPLICATE-110413	168-169 ft	Diesel & Heavy Oil
MW-18	MW18-(165-166)	165-166 ft	Diesel
	MW18-(170-171)	170-171 ft	Diesel
MW-19	MW19-(162-163)	162-163 ft	Diesel & Heavy Oil
MW-20	MW20-(164-165)	164-165 ft	Diesel & Heavy Oil
	MW20-(177-178)	177-178 ft	Diesel & Heavy Oil
MW-21	MW21-(170-171)	170-171 ft	Heavy Oil
MW-22	MW-22-(174-175)	174-175 ft	Diesel & Heavy Oil
MW-23	MW23-(169-170)	169-170 ft	Diesel & Heavy Oil
	MW23-(174-175)	174-175 ft	Diesel & Heavy Oil
	MW23-(177-178)	177-178 ft	Diesel & Heavy Oil
MW-24	MW24-(137-138)	137-138 ft	Diesel
	MW24-(147-148)	147-148 ft	Diesel
	MW24-(157-158)	157-158 ft	Diesel
	MW24-(162-163)	162-163 ft	Diesel
	MW24-(175-175.5)	175-175.5 ft	Diesel & Heavy Oil
	MW24-(182-183)	182-183 ft	Diesel
MW-25	MW25(157-158)	157-158 ft	Heavy Oil
	DUPLICATE-111513	157-158 ft	Heavy Oil
MW-26	MW26-(160-161)	160-161 ft	Diesel & Heavy Oil

Notes:
Chromatographic peaks in the nominal C12-C24 range considered Diesel, >C24 considered Heavy Oil.

Abbreviations:
bgs = below ground surface
ft = feet

DRAFT
Table 15
Surface Soil Sample Summary
BNSF Black Tank Site
Spokane, Washington

Analyte	**Screening Level - MTCA Method A Industrial**	**Number of Samples**	**Number of Detects**	**Minimum concentration**	**Maximum Concentration**	**Number of Samples Exceeding CUL**	**Sample Location of Maximum Concentration Detected**
Total Petroleum Hydrocarbon-Dx, mg/kg							
TPH-D (Diesel Range Organics)	NS	92	59	18.2	48400	NA	CSPL-TP-7B-2N
TPH-HO (Heavy Oil Range Organics)	NS	92	56	10.40	104000	NA	CSPL-TP-7B-2N
TPH-D/HO	**2,000**	92	64	10.4	152000	25	CSPL-TP-7B-2N
Metals, mg/kg							
Cadmium	**2**	37	24	0.13	3.3	1	RT-TP-50-2.9
Chromium	**2000***	37	37	2.5	137	0	RT-TP-50-2.9
Copper	NS	6	6	5	138	NA	RT-TP-50-2.9
Lead	**1,000**	6	6	5.9	188	0	RT-TP-50-2.9
Nickel	NS	6	6	4.2	15.3	NA	RT-TP-50-2.9
Zinc	NS	6	6	11.8	227	NA	RT-TP-50-2.9
Carcinogenic Polycyclic Aromatic Hydrocarbons, mg/kg							
Benzo(a)pyrene	**0.1**	61	18	0.0121	12.1	13	CSPL-TP-7B-2N
Benzo(a)anthracene	NS	61	14	0.0117	12	NA	CSPL-TP-7B-2N
Benzo(b)fluoranthene	NS	61	6	0.0276	0.387	NA	RT-TP-45B
Benzo(k)fluoranthene	NS	61	5	0.112	3.01	NA	BT-TP-27B-5
Chrysene	NS	61	28	0.0169	28.5	NA	CSPL-TP-7B-2N
Dibenzo(a,h)anthracene	NS	61	1	0.125	0.125	NA	BT-TP-27B-5
Indeno(1,2,3-cd)pyrene	NS	61	2	0.17	0.174	NA	BT-TP-27B-5
Benzo(a)Pyrene TEQ (ND=1/2 DL)	**0.1**	61	61	0.00755	13.7	27	CSPL-TP-7B-2N
Benzo(a)Pyrene TEQ (ND=0)	**0.1**	61	61	0.000169	13.6	14	CSPL-TP-7B-2N
Naphthalenes, mg/kg							
1-Methylnaphthalene	NS	61	28	0.011	68.6	NA	B-14 (5)
2-Methylnaphthalene	NS	61	30	0.0256	100	NA	RT-TP-45-2.5
Naphthalene	**5**	61	25	0.0181	36.1	5	RT-TP-45-2.5
Total Naphthalenes	**5**	61	61	0	159	13	RT-TP-45-2.5
Non-Carcinogenic Polycyclic Aromatic Hydrocarbons, mg/kg							
Acenaphthene	NS	61	12	0.228	11.7	NA	BT-TP-25A-3E
Acenaphthylene	NS	61	5	0.0249	1.33	NA	BT-TP-27A-4
Anthracene	NS	61	13	0.0104	14.4	NA	CSPL-TP-7B-2N
Benzo(g,h,i)perylene	NS	61	18	0.0181	2.71	NA	BT-TP-27B-5
Fluoranthene	NS	61	14	0.0156	18.5	NA	BT-TP-25A-3E
Fluorene	NS	61	13	0.0422	14.2	NA	BT-TP-25A-3E
Phenanthrene	NS	61	27	0.0143	50.7	NA	CSPL-TP-7B-2N
Pyrene	NS	61	23	0.0106	76.3	NA	CSPL-TP-7B-2N
Polychlorinated Biphenyls, mg/kg							
Aroclor 1016	1**	6	0				
Aroclor 1221	1**	6	0				
Aroclor 1232	1**	6	0				
Aroclor 1242	1**	6	0				
Aroclor 1248	1**	6	0				
Aroclor 1254	1**	6	0				
Aroclor 1260	**1****	6	1	0.187	0.187	0	LAPL-TP-06-1.5
Aroclor 1262	1**	6	0				
Aroclor 1268	1**	6	0				
Semi-Volatile Organic Compounds, mg/kg							
1,2,4-Trichlorobenzene	NS	8	0				
1,2-Dichlorobenzene	NS	8	0				
1,3-Dichlorobenzene	NS	8	0				
1,4-Dichlorobenzene	NS	8	0				
2,2-Oxybis(2-chloropropane)	NS	2	0				
2,4,5-Trichlorophenol	NS	2	0				
2,4,6-Trichlorophenol	NS	2	0				
2,4-Dichlorophenol	NS	2	0				
2,4-Dimethylphenol	NS	2	0				
2,4-Dinitrophenol	NS	2	0				
2,4-Dinitrotoluene	NS	2	0				
2,6-Dinitrotoluene	NS	2	0				
2-Chloronaphthalene	NS	2	0				
2-Chlorophenol	NS	2	0				
2-Nitroaniline	NS	2	0				
2-Nitrophenol	NS	2	0				
3&4-Methylphenol (m&p-Cresol)	NS	2	0				
3,3'-Dichlorobenzidine	NS	2	0				
3-Nitroaniline	NS	2	0				
4-Bromophenyl phenyl ether	NS	2	0				
4-Chloro-3-methylphenol	NS	2	0				
4-Chlorophenyl phenyl ether	NS	2	0				
4-Nitrophenol	NS	2	0				
Benzoic acid	NS	2	0				
Benzyl alcohol	NS	2	0				
Benzyl butyl phthalate	NS	2	0				
Bis(2-chloroethoxy)methane	NS	2	0				
Bis(2-ethylhexyl)phthalate	NS	2	0				
Dibenzofuran	NS	2	1	2.08	2.08	NA	B-14 (5)
Dibutyl Phthalate	NS	2	0				
Dichloroethyl ether	NS	2	0				
Diethyl Phthalate	NS	2	0				
Dimethylphthalate	NS	2	0				
Dinitro-o-cresol	NS	2	0				
Di-n-octyl phthalate	NS	2	0				
Hexachlorobenzene	NS	2	0				
Hexachlorobutadiene	NS	8	0				
Hexachlorocyclopentadiene	NS	2	0				

DRAFT
Table 15
Surface Soil Sample Summary
BNSF Black Tank Site
Spokane, Washington

Analyte	Screening Level - MTCA Method A Industrial	Number of Samples	Number of Detects	Minimum concentration	Maximum Concentration	Number of Samples Exceeding CUL	Sample Location of Maximum Concentration Detected
Semi-Volatile Organic Compounds, mg/kg							
Hexachloroethane	NS	2	0				
Isophorone	NS	2	0				
Nitrobenzene	NS	2	0				
n-Nitrosodi-n-propylamine	NS	2	0				
n-Nitrosodiphenylamine	NS	2	0				
o-Cresol	NS	2	0				
p-Chloroaniline	NS	2	0				
Pentachlorophenol	NS	2	0				
Phenol	NS	2	0				
p-Nitroaniline	NS	2	0				
Volatile Organic Compounds, mg/kg							
1,1,1,2-Tetrachloroethane	NS	6	0				
1,1,1-Trichloroethane	2	6	0				
1,1,2,2-Tetrachloroethane	NS	6	0				
1,1,2-Trichloroethane	NS	6	0				
1,1-Dichloroethane	NS	6	0				
1,1-Dichloroethene	NS	6	0				
1,1-Dichloropropene	NS	6	0				
1,2,3-Trichlorobenzene	NS	6	0				
1,2,3-Trichloropropane	NS	6	0				
1,2,4-Trichlorobenzene	NS	8	0				
1,2,4-Trimethylbenzene	NS	6	0				
1,2-Dibromo-3-chloropropane	NS	6	0				
1,2-Dichlorobenzene	NS	8	0				
1,2-Dichloroethane	NS	6	0				
1,2-Dichloropropane	NS	6	0				
1,3,5-Trimethylbenzene	NS	6	0				
1,3-Dichlorobenzene	NS	8	0				
1,3-Dichloropropane	NS	6	0				
1,4-Dichlorobenzene	NS	8	0				
2,2-Dichloropropane	NS	6	0				
2-Butanone	NS	6	0				
2-Phenylbutane	NS	6	0				
4-Chlorotoluene	NS	6	0				
4-Methyl-2-pentanone	NS	6	0				
Acetone	NS	6	5	0.0379	0.0919	NA	LAPL-TP-06-1.5
Allyl chloride	NS	6	0				
Benzene	0.03	31	0				
Bromobenzene	NS	6	0				
Bromodichloromethane	NS	6	0				
Bromoform	NS	6	0				
Carbon tetrachloride	NS	6	0				
Chlorobenzene	NS	6	0				
Chlorobromomethane	NS	6	0				
Chloroethane	NS	6	0				
Chloroform	NS	6	0				
cis-1,2-Dichloroethene	NS	6	0				
cis-1,3-Dichloropropene	NS	6	0				
Cumene	NS	6	0				
Cymene	NS	6	0				
Dibromochloromethane	NS	6	0				
Dibromomethane	NS	6	0				
Dichloromonofluoromethane	NS	6	0				
Ethyl ether	NS	6	0				
Ethylbenzene	6	31	0				
Ethylene dibromide	0.005	6	0				
Freon 11	NS	6	0				
Freon 113	NS	6	0				
Freon 12	NS	6	0				
Hexachlorobutadiene	NS	8	0				
m,p Xylenes	9***	12	3	0.102	1.56	0	RT-TP-50-2.9
Methyl bromide	NS	6	0				
Methyl chloride	NS	6	0				
Methyl tert-butyl ether	0.1	1	0				
Methylene chloride	0.02	6	0				
n-Butylbenzene	NS	6	0				
n-Propylbenzene	NS	6	0				
o-Chlorotoluene	NS	6	0				
o-Xylene	NS	12	0				
Styrene	NS	6	0				
tert-Butylbenzene	NS	6	0				
Tetrachloroethene	0.05	6	0				
Tetrahydrofuran	NS	6	0				
Toluene	7	30	0				
trans-1,2-Dichloroethene	NS	6	0				
trans-1,3-Dichloropropene	NS	6	0				
Trichloroethene	0.03	6	0				
Vinyl chloride	NS	6	0				
Xylenes	9***	37	1	0.0246	0.0246	0	B-14 (5)

Analyte	Screening Level - MTCA Method A Industrial	Number of Samples	Number of Detects	Minimum concentration	Maximum Concentration	Number of Samples Exceeding CUL	Sample Location of Maximum Concentration Detected
Extractable Petroleum Hydrocarbons, mg/kg							
C10-C12 Aromatics	NS	1	1	28	28	NA	RT-TP-50-2.9
C10-C12-Aliphatics	NS	4	4	0.594	25.3	NA	BT-TP-30-2.5
C12-C16-Aliphatics	NS	12	9	6.01	231	NA	RT-TP-50-2.9
C12-C16-Aromatics	NS	12	6	1.84	127	NA	BT-TP-30-2.5
C16-C21-Aliphatics	NS	12	10	7.27	1050	NA	BT-TP-30-2.5
C16-C21-Aromatics	NS	12	10	18.3	633	NA	BT-TP-30-2.5
C21-C34 Aromatics	NS	12	10	23.6	2600	NA	CSPL-TP-07-1.5
C21-C34-Aliphatics	NS	12	11	8.82	1240	NA	BT-TP-27-15, CSPL-TP-07-1.5
C8-C10-Aliphatics	NS	6	6	1.79	10.6	NA	RT-TP-50-2.9
C8-C10-Aromatics	NS	2	2	1.62	18.8	NA	RT-TP-50-2.9
Volatile Petroleum Hydrocarbons, mg/kg							
C10-C12 Aromatics	NS	11	5	0.437	11.6	NA	BT-TP-30-2.5
C10-C12-Aliphatics	NS	8	3	1.61	9.54	NA	RT-TP-2-5
C12-C13-Aromatics	NS	12	6	5.54	126	NA	RT-TP-2-5
C5-C6-Aliphatics	NS	12	2	0.404	0.967	NA	RT-TP-50-2.9
C6-C8-Aliphatics	NS	12	5	0.169	2.19	NA	RT-TP-50-2.9
C8-C10-Aliphatics	NS	6	0				
C8-C10-Aromatics	NS	10	5	1.13	4.12	NA	BT-TP-30-2.5
Methyl tert-butyl ether	0.1	7	0				
Toluene	**7**	1	1	0.746	0.746	0	RT-TP-50-2.9

Notes:
Units are in mg/kg = milligrams per kilogram
Results shown in **bold font** indicate the compound was detected samples above the laboratory reporting limit.
Results shown in **bold font** and shaded grey indicate the compound was detected in samples above the preliminary cleanup level.
Surface soil is soil between 0 and 15 feet below ground surface
Analysis performed by Pace Analytical Services, Inc. - Minneapolis, MN.
Empty cells = Not analyzed
* Chromium screening level = Chromium (III)
** PCB screening level is for Total PCBs
*** Xylene screening level is for Total Xylenes

Abbreviations:
CUL = Cleanup Level
MTCA = Model Toxics Control Act
NA = Not Applicable
ND=0 = Non-detect values calculation method where only positively identified compounds are included in calculating the Benzo(a)Pyrene TEQ.
ND=1/2DL = Non-detect values calculated as one-half the laboratory detection limit when calculating the Benzo(a)Pyrene TEQ.
NS = No Standard
TEQ = Toxic Equivalency Quotient
TPH-D = Diesel-Range Total Petroleum Hydrocarbons
TPH-HO = Heavy Oil-Range Total Petroleum Hydrocarbons
TPH-D/HO = Combined Diesel-and Heavy Oil-Range Total Petroleum Hydrocarbons

DRAFT
Table 16
Subsurface Soil Sample Summary
BNSF Black Tank Site
Spokane, Washington

Analyte	**Screening Level - Site-specific MTCA Method B Cleanup Level for Protection of Groundwater**	**Number of Samples**	**Number of Detects**	**Minimum Concentration**	**Maximum Concentration**	**Number of Samples Exceeding CUL**	**Sample Location of Maximum Concentration Detected**
Intermediate Soils (> 15 feet bgs and < 156 feet bgs)							
Total Petroleum Hydrocarbons-Dx, mg/kg							
TPH-D (Diesel Range Organics)	**NS**	85	47	17.6	18100	0	BT-SB-01 (116-117)
TPH-HO (Heavy Oil Range Organics)	**NS**	85	40	11.6	49400	0	BT-SB-01 (116-117)
TPH-D/HO	**13,600**	85	48	11.6	67500	3	BT-SB-01 (116-117)
Metals, mg/kg							
Cadmium	**0.7**	8	2	0.12	0.54	0	MW19-(127-128)
Chromium	**1,000**	8	8	2.4	10.7	0	MW19-(127-128)
Carcinogenic Polycyclic Aromatic Hydrocarbon, mg/kg							
Benzo(a)pyrene	**1,900**	26	5	0.293	1.2	0	BT-SB-01 (66-67)
Benzo(a)anthracene	**19,000**	26	3	0.79	1.1	0	BT-SB-01 (66-67)
Benzo(b)fluoranthene	**19,000**	26	1	0.749	0.749	0	BT-SB-01 (66-67)
Benzo(k)fluoranthene	**19,000**	26	2	0.144	0.355	0	BT-SB-01 (66-67)
Chrysene	**190,000**	26	7	0.107	3.36	0	BT-SB-01 (66-67)
Dibenzo(a,h)anthracene	**19,000**	26	0	0	0	0	BT-SB-01 (66-67)
Indeno(1,2,3-cd)pyrene	**19,000**	26	0	0	0	0	BT-SB-01 (66-67)
Benzo(a)Pyrene TEQ (ND=1/2 DL)	**1,900**	26	26	0.00778	1.5	0	BT-SB-01 (66-67)
Benzo(a)Pyrene TEQ (ND=0)	**1,900**	26	26	0.00107	1.42	0	BT-SB-01 (66-67)
Naphthalenes, mg/kg							
1-Methylnaphthalene	**NS**	23	1	1.54	1.54	0	B-22 (145)
2-Methylnaphthalene	**NS**	23	1	0.847	0.847	0	B-22 (145)
Naphthalene	**3,800**	27	0	0	0	0	
Total Naphthalenes	**3,800**	27	27	2.39	2.39	0	B-22 (145)
Non-Carcinogenic Polycyclic Aromatic Hydrocarbons, mg/kg							
Acenaphthene	**NS**	23	3	0.187	1.94	0	BT-SB-01 (66-67)
Acenaphthylene	**NS**	23	0	0	0	0	BT-SB-01 (66-67)
Anthracene	**NS**	23	3	0.183	3.16	0	BT-SB-01 (66-67)
Benzo(g,h,i)perylene	**NS**	23	2	0.396	0.554	0	BT-SB-01 (66-67)
Fluoranthene	**NS**	23	3	0.627	2.1	0	BT-SB-01 (66-67)
Fluorene	**NS**	23	4	0.793	4.46	0	BT-SB-01 (66-67)
Phenanthrene	**NS**	23	0	0	0	0	BT-SB-01 (66-67)
Pyrene	**NS**	23	6	0.115	9.96	0	BT-SB-01 (66-67)
Semi-Volatile Organic Compounds, mg/kg							
1,2,4-Trichlorobenzene	**NS**	4	0	0	0	0	
1,2-Dichlorobenzene	**NS**	4	0	0	0	0	
1,3-Dichlorobenzene	**NS**	4	0	0	0	0	
1,4-Dichlorobenzene	**NS**	4	0	0	0	0	
2,2-Oxybis(2-chloropropane)	**NS**	2	0	0	0	0	
2,4,5-Trichlorophenol	**NS**	2	0	0	0	0	
2,4,6-Trichlorophenol	**NS**	2	0	0	0	0	
2,4-Dichlorophenol	**NS**	2	0	0	0	0	
2,4-Dimethylphenol	**NS**	2	0	0	0	0	
2,4-Dinitrophenol	**NS**	2	0	0	0	0	
2,4-Dinitrotoluene	**NS**	2	0	0	0	0	
2,6-Dinitrotoluene	**NS**	2	0	0	0	0	
2-Chloronaphthalene	**NS**	2	0	0	0	0	
2-Chlorophenol	**NS**	2	0	0	0	0	
2-Nitroaniline	**NS**	2	0	0	0	0	
2-Nitrophenol	**NS**	2	0	0	0	0	
3&4-Methylphenol (m&p-Cresol)	**NS**	2	0	0	0	0	
3,3'-Dichlorobenzidine	**NS**	2	0	0	0	0	
3-Nitroaniline	**NS**	2	0	0	0	0	
4-Bromophenyl phenyl ether	**NS**	2	0	0	0	0	
4-Chloro-3-methylphenol	**NS**	2	0	0	0	0	
4-Chlorophenyl phenyl ether	**NS**	2	0	0	0	0	
4-Nitrophenol	**NS**	2	0	0	0	0	
Benzoic acid	**NS**	2	0	0	0	0	
Benzyl alcohol	**NS**	2	0	0	0	0	
Benzyl butyl phthalate	**NS**	2	0	0	0	0	
Bis(2-chloroethoxy)methane	**NS**	2	0	0	0	0	
Bis(2-ethylhexyl)phthalate	**NS**	2	0	0	0	0	
Dibenzofuran	**NS**	2	0	0	0	0	
Dibutyl Phthalate	**NS**	2	0	0	0	0	
Dichloroethyl ether	**NS**	2	0	0	0	0	
Diethyl Phthalate	**NS**	2	0	0	0	0	
Dimethylphthalate	**NS**	2	0	0	0	0	
Dinitro-o-cresol	**NS**	2	0	0	0	0	
Di-n-octyl phthalate	**NS**	2	0	0	0	0	
Hexachlorobenzene	**NS**	2	0	0	0	0	
Hexachlorobutadiene	**NS**	4	0	0	0	0	
Hexachlorocyclopentadiene	**NS**	2	0	0	0	0	
Hexachloroethane	**NS**	2	0	0	0	0	
Isophorone	**NS**	2	0	0	0	0	
Nitrobenzene	**NS**	2	0	0	0	0	
n-Nitrosodi-n-propylamine	**NS**	2	0	0	0	0	
n-Nitrosodiphenylamine	**NS**	2	0	0	0	0	
o-Cresol	**NS**	2	0	0	0	0	
p-Chloroaniline	**NS**	2	0	0	0	0	
Pentachlorophenol	**NS**	2	0	0	0	0	
Phenol	**NS**	2	0	0	0	0	
p-Nitroaniline	**NS**	2	0	0	0	0	
Volatile Organic Compounds, mg/kg							
1,1,1,2-Tetrachloroethane	**NS**	2	0	0	0	0	
1,1,1-Trichloroethane	**NS**	2	0	0	0	0	
1,1,2-Trichloroethane	**NS**	2	0	0	0	0	
1,1-Dichloroethane	**NS**	2	0	0	0	0	
1,1-Dichloroethene	**NS**	2	0	0	0	0	
1,1-Dichloropropene	**NS**	2	0	0	0	0	
1,2,3-Trichlorobenzene	**NS**	2	0	0	0	0	
1,2,3-Trichloropropane	**NS**	2	0	0	0	0	
1,2,4-Trichlorobenzene	**NS**	4	0	0	0	0	
1,2,4-Trimethylbenzene	**NS**	2	0	0	0	0	
1,2-Dibromo-3-chloropropane	**NS**	2	0	0	0	0	
1,2-Dichlorobenzene	**NS**	4	0	0	0	0	
1,2-Dichloroethane	**NS**	2	0	0	0	0	
1,2-Dichloropropane	**NS**	2	0	0	0	0	
1,3,5-Trimethylbenzene	**NS**	2	0	0	0	0	
1,3-Dichlorobenzene	**NS**	4	0	0	0	0	
1,3-Dichloropropane	**NS**	2	0	0	0	0	
1,4-Dichlorobenzene	**NS**	4	0	0	0	0	
2,2-Dichloropropane	**NS**	2	0	0	0	0	
2-Butanone	**NS**	2	0	0	0	0	
2-Hexanone	**NS**	2	0	0	0	0	
2-Phenylbutane	**NS**	2	0	0	0	0	
4-Chlorotoluene	**NS**	2	0	0	0	0	
4-Methyl-2-pentanone	**NS**	2	0	0	0	0	
Acetone	**NS**	2	0	0	0	0	
Benzene	**6200**	8	0	0	0	0	
Bromobenzene	**NS**	2	0	0	0	0	
Bromodichloromethane	**NS**	2	0	0	0	0	

Analyte	Screening Level - Site-specific MTCA Method B Cleanup Level for Protection of Groundwater	Number of Samples	Number of Detects	Minimum Concentration	Maximum Concentration	Number of Samples Exceeding CUL	Sample Location of Maximum Concentration Detected
Bromoform	**NS**	2	0	0	0	0	
Carbon disulfide	**NS**	2	1	0.0787	0.0787	0	B-12-95.0
Carbon tetrachloride	**NS**	2	0	0	0	0	
Chlorobenzene	**NS**	2	0	0	0	0	
Chlorobromomethane	**NS**	2	0	0	0	0	
Chloroethane	**NS**	2	0	0	0	0	
Chloroform	**NS**	2	0	0	0	0	
cis-1,2-Dichloroethene	**NS**	2	0	0	0	0	
cis-1,3-Dichloropropene	**NS**	2	0	0	0	0	
Cumene	**NS**	2	0	0	0	0	
Cymene	**NS**	2	0	0	0	0	
Dibromochloromethane	**NS**	2	0	0	0	0	
Dibromomethane	**NS**	2	0	0	0	0	
Ethylbenzene	**2900**	8	0	0	0	0	
Ethylene dibromide	**NS**	2	0	0	0	0	
Freon 11	**NS**	2	0	0	0	0	
Freon 12	**NS**	2	0	0	0	0	
Hexachlorobutadiene	**NS**	4	0	0	0	0	
m,p Xylenes	**4700**	2	0	0	0	0	
Methyl bromide	**NS**	2	0	0	0	0	
Methyl chloride	**NS**	2	0	0	0	0	
Methyl tert-butyl ether	**4**	4	0	0	0	0	
Methylene chloride	**1**	2	0	0	0	0	
n-Butylbenzene	**NS**	2	0	0	0	0	
n-Hexane	**NS**	2	0	0	0	0	
n-Propylbenzene	**NS**	2	0	0	0	0	
o-Chlorotoluene	**NS**	2	0	0	0	0	
o-Xylene	**4700**	2	0	0	0	0	
Styrene	**NS**	2	0	0	0	0	
tert-Butylbenzene	**NS**	2	0	0	0	0	
Tetrachloroethene	**NS**	2	0	0	0	0	
Toluene	**2800**	12	0	0	0	0	
trans-1,2-Dichloroethene	**NS**	2	0	0	0	0	
trans-1,3-Dichloropropene	**NS**	2	0	0	0	0	
Trichloroethene	**9**	2	0	0	0	0	
Vinyl chloride	**NS**	2	0	0	0	0	
Xylenes	**4700**	12	0	0	0	0	
Volatile Petroleum Hydrocarbons, mg/kg							
C10-C12 Aromatics	**NS**	2	1	133	133	0	B-12-28.0
C10-C12-Aliphatics	**NS**	2	1	166	166	0	B-12-28.0
C12-C13-Aromatics	**NS**	2	2	11.9	769	0	B-12-28.0
C5-C6-Aliphatics	**NS**	2	0	0	0	0	
C6-C8-Aliphatics	**NS**	2	0	0	0	0	
C8-C10-Aliphatics	**NS**	2	0	0	0	0	
C8-C10-Aromatics	**NS**	2	0	0	0	0	
Volatile Petroleum Hydrocarbons	**NS**	2	1	1110	1110	0	B-12-28.0
Extractable Petroleum Hydrocarbons, mg/kg							
C10-C12 Aromatics	**NS**	1	0	0	0	0	
C10-C12-Aliphatics	**NS**	1	1	82.5	82.5	0	B-12-28.0
C12-C16-Aliphatics	**NS**	1	1	672	672	0	B-12-28.0
C12-C16-Aromatics	**NS**	1	1	104	104	0	B-12-28.0
C16-C21-Aliphatics	**NS**	1	1	533	533	0	B-12-28.0
C16-C21-Aromatics	**NS**	1	1	523	523	0	B-12-28.0
C21-C34 Aromatics	**NS**	1	1	624	624	0	B-12-28.0
C21-C34-Aliphatics	**NS**	1	1	688	688	0	B-12-28.0
C8-C10-Aliphatics	**NS**	1	0	0	0	0	
C8-C10-Aromatics	**NS**	1	0	0	0	0	
Extractable Petroleum Hydrocarbons	**NS**	1	1	3230	3230	0	B-12-28.0
Smear Zone Soils (≥ 156 feet bgs)							
Total Petroleum Hydrocarbons-Dx, mg/kg							
TPH-D (Diesel Range Organics)	**NS**	86	51	3.2	31200	0	MW21-(170-171)
TPH-HO (Heavy Oil Range Organics)	**NS**	86	46	4.3	30500	0	MW21-(170-171)
TPH-D/HO	**13,600**	86	51	7.5	61700	17	MW21-(170-171)
Total Petroleum Hydrocarbons-Gx, mg/kg							
Benzene	**6,200**	2	0	0	0	0	
Ethylbenzene	**2,900**	2	2	0.415	0.731	0	MW-2-174
Toluene	**2,800**	2	1	1.22	1.22	0	MW-2-174
Xylenes	**4,700**	2	2	2.92	3.75	0	MW-2-174
Gasoline Range Organics	**NS**	4	4	362	2810	0	MW14S167-060509
Metals, mg/kg							
Cadmium	**0.7**	21	11	0.12	0.97	4	MW18-(170-171)
Chromium	**1,000**	21	21	6.1	18	0	MW16-(166-167)
Copper	**NS**	3	3	12.4	16.4	0	MW16-(166-167)
Lead	**3,000**	4	4	9	23.1	0	MW16-(166-167)
Nickel	**NS**	4	4	7.4	14.6	0	MW16-(166-167)
Zinc	**NS**	4	4	29	47.8	0	MW16-(166-167)
Carcinogenic Polycyclic Aromatic Hydrocarbon, mg/kg							
Benzo(a)pyrene	**1,900**	52	5	0.108	0.431	0	MW14S167-060509
Benzo(a)anthracene	**19,000**	52	10	0.057	2.44	0	MW-7 (165-166)
Benzo(b)fluoranthene	**19,000**	52	3	0.134	0.47	0	MW14S167-060509
Benzo(k)fluoranthene	**19,000**	52	2	0.0693	0.175	0	MW14S167-060509
Chrysene	**190,000**	52	21	0.0532	3.09	0	MW-7 (165-166)

Analyte	**Screening Level - Site-specific MTCA Method B Cleanup Level for Protection of Groundwater**	**Number of Samples**	**Number of Detects**	**Minimum Concentration**	**Maximum Concentration**	**Number of Samples Exceeding CUL**	**Sample Location of Maximum Concentration Detected**
Dibenzo(a,h)anthracene	**19,000**	52	2	0.0263	2.89	0	MW-7 (165-166)
Indeno(1,2,3-cd)pyrene	**19,000**	52	2	0.0228	2.59	0	MW-7 (165-166)
Benzo(a)Pyrene TEQ (ND=1/2 DL)	**1,900**	52	52	0.00747	2.15	0	MW19-(162-163)
Benzo(a)Pyrene TEQ (ND=0)	**1,900**	52	52	0.000532	0.823	0	MW-7 (165-166)
Naphthalenes, mg/kg							
1-Methylnaphthalene	**NS**	52	21	0.03	56.8	0	MW14S167-060509
2-Methylnaphthalene	**NS**	52	15	0.0122	84	0	MW14S167-060509
Naphthalene	**3,800**	52	11	0.0538	6.18	0	MW19-(162-163)
Total Naphthalenes	**3,800**	52	52	0.0461	142	0	MW14S167-060509
Non-Carcinogenic Polycyclic Aromatic Hydrocarbons, mg/kg							
Acenaphthene	**NS**	52	16	0.0275	4.03	0	MW19-(162-163)
Acenaphthylene	**NS**	52	7	0.109	1.5	0	MW16-(166-167)
Anthracene	**NS**	52	15	0.0273	3.01	0	MW14S167-060509
Benzo(g,h,i)perylene	**NS**	52	2	0.0321	0.131	0	MW14S167-060509
Fluoranthene	**NS**	52	11	0.0116	1.5	0	MW16-(166-167)
Fluorene	**NS**	52	26	0.106	9.46	0	MW19-(162-163)
Phenanthrene	**NS**	52	23	0.0186	17.4	0	MW19-(162-163)
Pyrene	**NS**	52	20	0.0537	3.39	0	MW-8 (165-166)
Polychlorinated Biphenyls, mg/kg							
Aroclor 1016	**200**	5	0	0	0	0	
Aroclor 1221	**200**	5	0	0	0	0	
Aroclor 1232	**200**	5	0	0	0	0	
Aroclor 1242	**200**	5	0	0	0	0	
Aroclor 1248	**200**	5	0	0	0	0	
Aroclor 1254	**200**	5	0	0	0	0	
Aroclor 1260	**200**	5	0	0	0	0	
Aroclor 1262	**200**	5	0	0	0	0	
Aroclor 1268	**200**	5	0	0	0	0	
Semi-Volatile Organic Compounds, mg/kg							
1,2,4-Trichlorobenzene	**NS**	7	0	0	0	0	
1,2-Dichlorobenzene	**NS**	7	0	0	0	0	
1,3-Dichlorobenzene	**NS**	7	0	0	0	0	
1,4-Dichlorobenzene	**NS**	7	0	0	0	0	
2,2-Oxybis(2-chloropropane)	**NS**	2	0	0	0	0	
2,4,5-Trichlorophenol	**NS**	2	0	0	0	0	
2,4,6-Trichlorophenol	**NS**	2	0	0	0	0	
2,4-Dichlorophenol	**NS**	2	0	0	0	0	
2,4-Dimethylphenol	**NS**	2	0	0	0	0	
2,4-Dinitrophenol	**NS**	2	0	0	0	0	
2,4-Dinitrotoluene	**NS**	2	0	0	0	0	
2,6-Dinitrotoluene	**NS**	2	0	0	0	0	
2-Chloronaphthalene	**NS**	2	0	0	0	0	
2-Chlorophenol	**NS**	2	0	0	0	0	
2-Nitroaniline	**NS**	2	0	0	0	0	
2-Nitrophenol	**NS**	2	0	0	0	0	
3&4-Methylphenol (m&p-Cresol)	**NS**	2	0	0	0	0	
3,3'-Dichlorobenzidine	**NS**	2	0	0	0	0	
3-Nitroaniline	**NS**	2	0	0	0	0	
4-Bromophenyl phenyl ether	**NS**	2	0	0	0	0	
4-Chloro-3-methylphenol	**NS**	2	0	0	0	0	
4-Chlorophenyl phenyl ether	**NS**	2	0	0	0	0	
4-Nitrophenol	**NS**	2	0	0	0	0	
Benzoic acid	**NS**	2	0	0	0	0	
Benzyl alcohol	**NS**	2	0	0	0	0	
Benzyl butyl phthalate	**NS**	2	0	0	0	0	
Bis(2-chloroethoxy)methane	**NS**	2	0	0	0	0	
Bis(2-ethylhexyl)phthalate	**NS**	2	0	0	0	0	
Dibenzofuran	**NS**	2	0	0	0	0	
Dibutyl Phthalate	**NS**	2	0	0	0	0	
Dichloroethyl ether	**NS**	2	0	0	0	0	
Diethyl Phthalate	**NS**	2	0	0	0	0	
Dimethylphthalate	**NS**	2	0	0	0	0	
Dinitro-o-cresol	**NS**	2	0	0	0	0	
Di-n-octyl phthalate	**NS**	2	0	0	0	0	
Hexachlorobenzene	**NS**	2	0	0	0	0	
Hexachlorobutadiene	**NS**	7	0	0	0	0	
Hexachlorocyclopentadiene	**NS**	2	0	0	0	0	
Hexachloroethane	**NS**	2	0	0	0	0	
Isophorone	**NS**	2	0	0	0	0	
Nitrobenzene	**NS**	2	0	0	0	0	
n-Nitrosodi-n-propylamine	**NS**	2	0	0	0	0	
n-Nitrosodiphenylamine	**NS**	2	0	0	0	0	
o-Cresol	**NS**	2	0	0	0	0	
p-Chloroaniline	**NS**	2	0	0	0	0	
Pentachlorophenol	**NS**	2	0	0	0	0	
Phenol	**NS**	2	0	0	0	0	
p-Nitroaniline	**NS**	2	0	0	0	0	
Volatile Organic Compounds, mg/kg							
1,1,1,2-Tetrachloroethane	**NS**	5	0	0	0	0	
1,1,1-Trichloroethane	**NS**	5	0	0	0	0	
1,1,2,2-Tetrachloroethane	**NS**	5	0	0	0	0	
1,1,2-Trichloroethane	**NS**	5	0	0	0	0	
1,1-Dichloroethane	**NS**	5	0	0	0	0	
1,1-Dichloroethene	**NS**	5	0	0	0	0	
1,1-Dichloropropene	**NS**	5	0	0	0	0	
1,2,3-Trichlorobenzene	**NS**	5	0	0	0	0	
1,2,3-Trichloropropane	**NS**	5	0	0	0	0	
1,2,4-Trichlorobenzene	**NS**	7	0	0	0	0	
1,2,4-Trimethylbenzene	**NS**	5	0	0	0	0	
1,2-Dibromo-3-chloropropane	**NS**	5	0	0	0	0	
1,2-Dichlorobenzene	**NS**	7	0	0	0	0	
1,2-Dichloroethane	**NS**	5	0	0	0	0	
1,2-Dichloropropane	**NS**	5	0	0	0	0	
1,3,5-Trimethylbenzene	**NS**	5	0	0	0	0	
1,3-Dichlorobenzene	**NS**	7	0	0	0	0	
1,3-Dichloropropane	**NS**	5	0	0	0	0	
1,4-Dichlorobenzene	**NS**	7	0	0	0	0	
2,2-Dichloropropane	**NS**	5	0	0	0	0	
2-Butanone	**NS**	5	1	3.67	3.67	0	MW23-(174-175)
2-Phenylbutane	**NS**	5	4	0.113	1.58	0	MW23-(174-175)
4-Chlorotoluene	**NS**	5	0	0	0	0	
4-Methyl-2-pentanone	**NS**	5	0	0	0	0	
Acetone	**NS**	5	0	0	0	0	
Allyl chloride	**NS**	5	0	0	0	0	
Benzene	**6,200**	46	1	0.427	0.427	0	MW-3 (173-174)
Bromobenzene	**NS**	5	0	0	0	0	
Bromodichloromethane	**NS**	5	0	0	0	0	
Bromoform	**NS**	5	0	0	0	0	
Carbon tetrachloride	**NS**	5	0	0	0	0	
Chlorobenzene	**NS**	5	0	0	0	0	

DRAFT
Table 16
Subsurface Soil Sample Summary
BNSF Black Tank Site
Spokane, Washington

Analyte	Screening Level - Site-specific MTCA Method B Cleanup Level for Protection of Groundwater	Number of Samples	Number of Detects	Minimum Concentration	Maximum Concentration	Number of Samples Exceeding CUL	Sample Location of Maximum Concentration Detected
Chlorobromomethane	**NS**	5	0	0	0	0	
Chloroethane	**NS**	5	0	0	0	0	
Chloroform	**NS**	5	0	0	0	0	
cis-1,2-Dichloroethene	**NS**	5	0	0	0	0	
cis-1,3-Dichloropropene	**NS**	5	0	0	0	0	
Cumene	**NS**	5	3	0.276	0.557	0	MW18-(170-171)
Cymene	**NS**	5	3	0.0729	0.194	0	MW18-(170-171)
Dibromochloromethane	**NS**	5	0	0	0	0	
Dibromomethane	**NS**	5	0	0	0	0	
Dichloromonofluoromethane	**NS**	5	0	0	0	0	
Ethyl ether	**NS**	5	0	0	0	0	
Ethylbenzene	**2,900**	46	7	0.125	2.7	0	MW-3 (173-174)
Ethylene dibromide	**NS**	5	0	0	0	0	
Freon 11	**NS**	5	0	0	0	0	
Freon 113	**NS**	5	0	0	0	0	
Freon 12	**NS**	5	0	0	0	0	
Hexachlorobutadiene	**NS**	7	0	0	0	0	
m,p Xylenes	**4,700**	9	2	0.226	1.27	0	MW19-(162-163)
Methyl bromide	**NS**	5	0	0	0	0	
Methyl chloride	**NS**	5	0	0	0	0	
Methyl tert-butyl ether	**4**	5	0	0	0	0	
Methylene chloride	**1**	5	0	0	0	0	
n-Butylbenzene	**NS**	5	4	0.0612	0.625	0	MW23-(174-175)
n-Propylbenzene	**NS**	5	2	0.34	0.813	0	MW18-(170-171)
o-Chlorotoluene	**NS**	5	0	0	0	0	
o-Xylene	**4,700**	9	5	0.658	2.4	0	MW19-(162-163)
Styrene	**NS**	5	0	0	0	0	
tert-Butylbenzene	**NS**	5	1	0.121	0.121	0	MW23-(174-175)
Tetrachloroethene	**NS**	5	0	0	0	0	
Tetrahydrofuran	**NS**	5	0	0	0	0	
Toluene	**2,800**	46	3	0.893	7.38	0	MW-3 (173-174)
trans-1,2-Dichloroethene	**NS**	5	0	0	0	0	
trans-1,3-Dichloropropene	**NS**	5	0	0	0	0	
Trichloroethene	**9**	5	0	0	0	0	
Vinyl chloride	**NS**	5	0	0	0	0	
Xylenes	**4,700**	51	11	0.0203	12.2	0	MW-3 (173-174)
Extractable Petroleum Hydrocarbons, mg/kg							
C10-C12 Aromatics	**NS**	9	6	8.45	94.9	0	MW19-(162-163)
C10-C12-Aliphatics	**NS**	9	9	58.2	1550	0	MW19-(162-163)
C12-C16-Aliphatics	**NS**	9	9	303	7500	0	MW19-(162-163)
C12-C16-Aromatics	**NS**	9	9	16.6	1160	0	MW19-(162-163)
C16-C21-Aliphatics	**NS**	9	9	362	8140	0	MW19-(162-163)
C16-C21-Aromatics	**NS**	9	9	184	3630	0	MW16-(166-167)
C21-C34 Aromatics	**NS**	9	9	262	4830	0	MW16-(166-167)
C21-C34-Aliphatics	**NS**	9	9	450	8850	0	MW16-(166-167)
C8-C10-Aliphatics	**NS**	9	9	9.93	354	0	MW19-(162-163)
C8-C10-Aromatics	**NS**	9	3	1.33	18.4	0	MW19-(162-163)
Volatile Petroleum Hydrocarbons, mg/kg							
Benzene	**6,200**	9	0	0	0	0	
C10-C12 Aromatics	**NS**	9	9	172	1180	0	MW19-(162-163)
C10-C12-Aliphatics	**NS**	9	9	53.9	390	0	MW19-(162-163)
C12-C13-Aromatics	**NS**	9	9	286	781	0	MW16-(166-167)
C5-C6-Aliphatics	**NS**	9	6	0.399	12.1	0	MW19-(162-163)
C6-C8-Aliphatics	**NS**	9	7	2.32	205	0	MW19-(162-163)
C8-C10-Aliphatics	**NS**	9	9	4.03	133	0	MW23-(174-175)
C8-C10-Aromatics	**NS**	9	9	14.2	293	0	MW19-(162-163)
Ethylbenzene	**2,900**	9	0	0	0	0	
m,p Xylenes	**4,700**	9	2	0.226	1.27	0	MW19-(162-163)
Methyl tert-butyl ether	**4**	9	1	0.669	0.669	0	MW19-(162-163)
o-Xylene	**4,700**	9	5	0.658	2.4	0	MW19-(162-163)
Toluene	**2,800**	9	1	0.528	0.528	0	MW23-(174-175)

Notes:
< = Compound not detected. Reportable detection limit shown.
Empty cells = Not analyzed
Units are in mg/kg = milligrams per kilogram
Duplicate samples were not included in the statistics presented
Analysis performed by Pace Analytical Services, Inc. - Minneapolis, MN, and Fremont Analytical Laboratories - Seattle, WA.

Abbreviations:
CUL = Cleanup level
ft = feet
NA = Not Applicable
ND=0 = Non-detect values calculation method where only positively identified compounds are included in calculating the Benzo(a)Pyrene TEQ.
ND=1/2DL = Non-detect values calculated as one-half the laboratory detection limit when calculating the Benzo(a)Pyrene TEQ.
NS = No Standard
TEQ = Toxic Equivalency Quotient
TPH-D = Diesel-Range Total Petroleum Hydrocarbons
TPH-HO = Heavy Oil-Range Total Petroleum Hydrocarbons
TPH-D/HO = Combined Diesel-and Heavy Oil-Range Total Petroleum Hydrocarbons

DRAFT

Table 17

Groundwater Sample Summary

BNSF Black Tank Site

Spokane, Washington

Analyte	CUL - MTCA Method A	Number of Samples**	Number of Detects	Minimum Concentration	Maximum Concentration	Number of Samples Exceeding CUL	Sample with Maximum Concentration
Total Petroleum Hydrocarbons-Dx, µg/L							
TPH-D (Diesel Range Organics)	NS	63	6	240	2000	NA	MW-11-062116
TPH-HO (Heavy Oil Range Organics)	NS	63	30	22	290	NA	MW-24-062116
TPH-D/HO by NWTPH-Dx	**500**	63	32	22	2200	3	MW-11-062116
Total Petroleum Hydrocarbons-Dx, SGC µg/L							
TPH-D (Diesel Range Organics)	NS	139	8	38	550	0	MW-24-12052013
TPH-HO (Heavy Oil Range Organics)	NS	139	6	7.8	1100	0	MW-06-03062014
TPH-D/HO by NWTPH-Dx, SGC	**500**	139	18	7.8	1150	2	MW-24-12052013
Carcinogenic Polycyclic Aromatic Hydrocarbons, µg/L							
Benzo(a)pyrene	**0.1**	109	1	0.11	0.11	1	MW-12-12042013
Benzo(a)anthracene	NS	109	2	0.046	0.13	0	MW-12-12042013
Benzo(b)fluoranthene	NS	109	2	0.05	0.14	0	MW-12-12042013
Benzo(k)fluoranthene	NS	109	1	0.052	0.052	0	MW-12-12042013
Chrysene	NS	109	1	0.11	0.11	0	MW-12-12042013
Dibenzo(a,h)anthracene	NS	109	0	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NS	109	1	0.048	0.048	0	MW-12-12042013
Benzo(a)Pyrene TEQ (ND=1/2 DL)	**0.1**	109	109	0.0119	0.15	1	MW-12-12042013
Benzo(a)Pyrene TEQ (ND=0)	**0.1**	109	109	0.0096	0.148	1	MW-12-12042013
Naphthalenes, µg/L							
1-Methylnaphthalene	NS	109	4	0.047	0.28	0	MW-22-062714
2-Methylnaphthalene	NS	109	2	0.054	0.078	0	MW-17-12062013
Naphthalene	**160**	109	39	0.023	0.1	0	MW-21-03042014
Total Naphthalenes	**160**	109	42	0.023	0.347	0	MW-22-062714
Volatile Organic Compounds, µg/L							
Benzene	**5**	61	0	NA	NA	NA	NA
Ethylbenzene	**700**	61	0	NA	NA	NA	NA
Toluene	**1000**	75	7	1.4	2.5	0	MW-16-092914
Xylenes	**1000**	89	0	NA	NA	NA	NA
Total PCBs, ug/L							
Total PCBs	**0.1**	4	0	NA	NA	NA	NA
Metals, ug/L							
Cadmium	**5**	15	7	0.026	0.73	0	MW-14-031416

Notes:

Units are in μg/L = micrograms per liter

Duplicate samples are not included in statistics presented

Results shown in **bold font** indicate the compound was detected above the laboratory reporting limit

▨ Results shown in **bold font** and shaded grey indicate the compound was detected above the cleanup level

Analysis performed by Pace Analytical Services, Inc -Minneapolis, MN

* Xylene screening level is for Total Xylenes

** Number of samples does not include Field Duplicates

Abbreviations:

CUL = Preliminary Cleanup Level
MTCA = Model Toxics Control Act
NA = Not applicable
ND=0 = Non-detect values calculation method where only positively identified compounds are included in calculating the Benzo(a)Pyrene TEQ
ND=1/2DL = Non-detect values calculated as one-half the laboratory detection limit when calculating the Benzo(a)Pyrene TEQ
NS = No Standard
PCBs = Polychlorinated Biphenyls
SGC = Silica Gel Cleanup
TEQ = Toxic Equivalency Quotient
TPH-D = Diesel-Range Total Petroleum Hydrocarbons
TPH-HO = Heavy Oil-Range Total Petroleum Hydrocarbons
TPH-D/HO = Combined Diesel-and Heavy Oil-Range Total Petroleum Hydrocarbons
ug/L = micrograms per liter

DRAFT
Table 18
Surface Soil Analytical Results
BNSF Black Tank Site
Spokane, Washington

Location Group	Location ID	Sample Date	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organics)	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
	MTCA Method A Soil Cleanup Level for Unrestricted Use						2000	0.1							0.1	0.1			5	5
Test Pits	BT-TP-25-S5	04-Nov-13	5 ft	BT-TP-25-S5	< 20.1	< 80.6	< 80.6	< 0.0100	< 0.0100	< 0.0100	< 0.0100	< 0.0100	< 0.0100	< 0.0100	0.00755	0	< 0.0100	< 0.0100	< 0.0100	< 0.0100
	BT-TP-25-S7	04-Nov-13	7 ft	BT-TP-25-S7	965	5,230	6,195	< 0.541	< 0.541	< 0.541	< 0.541	< 0.541	< 0.541	< 0.541	0.408	0	< 0.541	< 0.541	< 0.541	< 0.541
	BT-TP-25-14	04-Nov-13	14 ft	BT-TP-25-14	440	1,880	2,320	< 0.525	< 0.525	< 0.525	< 0.525	< 0.525	< 0.525	< 0.525	0.396	0	< 0.525	< 0.525	< 0.525	< 0.525
	BT-TP-25A-3E	30-Sep-14	3 ft	BT-TP-25A-3E	25,400	44,500	69,900	5.1	7.09	< 0.122	< 0.122	12.8	< 0.122	< 0.122	5.96	5.94	40.1	46.8	14.4	101
	BT-TP-25A-3E	30-Sep-14	6 ft	BT-TP-25A-6B	765	2,940	3,700	< 0.0521	< 0.0521	< 0.0521	< 0.0521	< 0.0521	< 0.0521	< 0.0521	0.0393	0	< 0.0521	< 0.0521	< 0.0521	< 0.0521
	BT-TP-25A-5.5	30-Sep-14	5.5 ft	BT-TP-25A-5.5	1,530	3,720	5,250	2.41	1.75	< 0.0534	< 0.0534	3.91	< 0.0534	< 0.0534	2.63	2.62	7.37	5.73	0.239	13.3
	BT-TP-25A-5.5	30-Sep-14	8 ft	BT-TP-25A-8B	1,430	7,020	8,450	0.185	< 0.107	< 0.107	< 0.107	0.221	< 0.107	< 0.107	0.214	0.187	0.112	< 0.107	< 0.107	0.112
	BT-TP-25A-6W	30-Sep-14	6 ft	BT-TP-25A-6W	503	2,490	2,990	< 0.276	< 0.276	< 0.276	< 0.276	0.313	< 0.276	< 0.276	0.210	0.00313	1.68	3.9	1.19	6.77
	BT-TP-26	23-Oct-13	2.5 ft	BT-TP-26-2.5	1,020 J	3,950 J	4,970	< 0.495 J	< 0.495 J	< 0.495 J	< 0.495 J	0.697 J	< 0.495 J	< 0.495 J	0.378	0.00697	1.52 J	2.8 J	0.517 J	4.84
	BT-TP-27-S5	01-Nov-13	5 ft	BT-TP-27-S5	< 20.3	< 81.3	< 81.3	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	0.00770	0	< 0.0102	< 0.0102	< 0.0102	< 0.0102
	BT-TP-27-S6	01-Nov-13	6 ft	BT-TP-27-S6	< 20.4	< 81.4	< 81.4	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	0.00763	0	0.0110	0.0256	< 0.0101	0.0366
	BT-TP-27-15	01-Nov-13	15 ft	BT-TP-27-15	1,510	5,680	7,190	0.422	< 0.266	< 0.266	< 0.266	0.504	< 0.266	< 0.266	0.494	0.427	< 0.266	< 0.266	< 0.266	< 0.266
	BT-TP-27-S15	01-Nov-13	15 ft	BT-TP-27-S15	< 20.0	< 79.9	< 79.9	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	0.00770	0	< 0.0102	< 0.0102	< 0.0102	< 0.0102
	BT-TP-27A-4	30-Sep-14	4 ft	BT-TP-27A-4	26,300	47,000	73,300	4.26	5.7	< 1.2	2.39	11.5	< 1.2	< 1.2	5.36	5.18	42.1	48.1	3.25	93.5
	BT-TP-27A-4	30-Sep-14	6 ft	BT-TP-27A-6B	580	2,440	3,020	< 0.104	< 0.104	< 0.104	< 0.104	< 0.104	< 0.104	< 0.104	0.0785	0	1.27	2.11	0.269	3.65
	BT-TP-27A-4.5S	30-Sep-14	4.5 ft	BT-TP-27A-4.5S	723	2,990	3,710	< 0.109	< 0.109	< 0.109	0.124	0.292	< 0.109	< 0.109	0.0916	0.0153	1.15	2.52	0.78	4.45
	BT-TP-27A-4N	30-Sep-14	4 ft	BT-TP-27A-4N	< 15.4	34.1	34.1	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	0.00763	0	0.0412	0.12	0.0224	0.184
	BT-TP-27B-5	30-Sep-14	5 ft	BT-TP-27B-5	15,000	27,000	42,000	5.13	5.25	< 1.09	3.01	10.6	< 1.09	< 1.09	6.23	6.06	< 1.09	< 1.09	< 1.09	< 1.09
	BT-TP-27B-7B	30-Sep-14	7 ft	BT-TP-27B-7B	1,170	4,840	6,010	0.539	< 0.106	< 0.106	< 0.106	0.439	0.125	0.174	0.589	0.573	< 0.106	< 0.106	< 0.106	< 0.106
	BT-TP-27B-5N	30-Sep-14	5 ft	BT-TP-27B-5N	19.2	130	149.2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.00755	0	0.0187	0.0439	0.0181	0.0807
	BT-TP-27B-5S	30-Sep-14	5 ft	BT-TP-27B-5S	498	2,180	2,680	0.133	< 0.108	< 0.108	0.132	0.223	< 0.108	< 0.108	0.170	0.148	0.979	2.54	0.662	4.18
	BT-TP-30	22-Oct-13	2.5 ft	BT-TP-30-2.5	763	1,160	1,923	0.288	0.354	0.233	< 0.137	0.778	< 0.137	< 0.137	0.375	0.354	5.6	2.12	0.967	8.69
	CSPL 1	28-Oct-13	0.5 ft	BT-TP-0.1-0.5	< 20.0	< 79.8	< 79.8	0.0145	0.0117	0.0276	< 0.0104	0.0305	< 0.0104	< 0.0104	0.0203	0.0187	0.0465	0.0922	0.0302	0.169
	CSPL-TP-07	23-Oct-13	1.5 ft	CSPL-TP-07-1.5	1,180	3,990	5,170	< 0.537	< 0.537	< 0.537	< 0.537	< 0.537	< 0.537	< 0.537	0.405	0	< 0.537	< 0.537	< 0.537	< 0.537
	CSPL-TP-7-15	01-Nov-13	15 ft	CSPL-TP-7-15	175 J	1,050 J	1,225	< 0.268	< 0.268	< 0.268	< 0.268	< 0.268	< 0.268	< 0.268	0.202	0	< 0.268	< 0.268	< 0.268	< 0.268
	CSPL-TP-7A-4E	29-Sep-14	4 ft	CSPL-TP-7A-4E	< 15.2	< 10.1	< 15.2	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	0.00770	0	< 0.0102	< 0.0102	< 0.0102	< 0.0102
	CSPL-TP-7A-6	29-Sep-14	6 ft	CSPL-TP-7A-6	1,490	3,650	5,140	0.614	0.506	< 0.0590	< 0.0590	1.18	< 0.0590	< 0.0590	0.688	0.676	1.41	1.47	0.557	3.44
	CSPL-TP-7A-6	29-Sep-14	13 ft	CSPL-TP-7A-13B	< 15.7	50.1	50.1	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	0.00770	0	< 0.0102	< 0.0102	< 0.0102	< 0.0102
	CSPL-TP-7A-6S	29-Sep-14	6 ft	CSPL-TP-7A-6S	135	714	849	0.0201	0.0160	< 0.0108	< 0.0108	0.0427	< 0.0108	< 0.0108	0.0243	0.0221	0.136	0.326	0.0948	0.557
	CSPL-TP-7B-6S	29-Sep-14	6 ft	CSPL-TP-7B-6S	< 15.4	91.1	91.1	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	0.00778	0	< 0.0103	< 0.0103	< 0.0103	< 0.0103
	CSPL-TP-7A-6W	29-Sep-14	6 ft	CSPL-TP-7A-6W	< 15.6	10.4	10.4	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	0.00763	0	< 0.0101	< 0.0101	< 0.0101	< 0.0101
	CSPL-TP-7B-2N	29-Sep-14	2 ft	CSPL-TP-7B-2N	48,400	104,000	152,000	12.1	12	< 0.372	< 0.372	28.5	< 0.372	< 0.372	13.7	13.6	57.8	63.6	5.61	127
	CSPL-TP-7B-2N	29-Sep-14	15 ft	CSPL-TP-7B-15N	18.5	125	143.5	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	0.00763	0	< 0.0101	< 0.0101	< 0.0101	< 0.0101
	CSPL-TP-08	23-Oct-13	1.5 ft	CSPL-TP-08-1.5	48.6 J	222 J	270.6	< 0.0492 J	< 0.0492 J	< 0.0492 J	< 0.0492 J	< 0.0492 J	< 0.0492 J	< 0.0492 J	0.0371	0	< 0.0492 J	< 0.0492 J	< 0.0492 J	< 0.0492 J
	LAPL-TP-05	14-Oct-13	1.5 ft	LAPL-TP-05-1.5	209 J	< 80.7 J	209 J	< 0.0103 J	< 0.0103 J	< 0.0103 J	< 0.0103 J	0.0169 J	< 0.0103 J	< 0.0103 J	0.00789	0.000169	0.0654 J	0.172 J	0.0545 J	0.292
	LAPL-TP-06	14-Oct-13	1.5 ft	LAPL-TP-06-1.5	1,500	4,600	6,100	< 0.536	< 0.536	< 0.536	< 0.536	0.835	< 0.536	< 0.536	0.410	0.00835	< 0.536	< 0.536	< 0.536	< 0.536
	LAPL-TP-6- S1.5	31-Oct-13	1.5 ft	LAPL-TP-6- S1.5	25.8	< 81.7	25.8	< 0.0105	< 0.0105	< 0.0105	< 0.0105	0.0179	< 0.0105	< 0.0105	0.00805	0.000179	< 0.0105	< 0.0105	< 0.0105	< 0.0105
	LAPL-TP-6-S10	31-Oct-13	10 ft	LAPL-TP-6-S10	281	1,330	1,611	< 0.537	< 0.537	< 0.537	< 0.537	< 0.537	< 0.537	< 0.537	0.405	0	< 0.537	< 0.537	< 0.537	< 0.537
	LAPL-TP-6-13	31-Oct-13	13 ft	LAPL-TP-6-13	401	1,610	2,010	< 0.261	< 0.261	< 0.261	< 0.261	0.308	< 0.261	< 0.261	0.199	0.00308	< 0.261	< 0.261	< 0.261	< 0.261
	LAPL-TP-6-15	31-Oct-13	15 ft	LAPL-TP-6-15	641	442	1,080	0.0880	0.115	< 0.0515	< 0.0515	0.227	< 0.0515	< 0.0515	0.112	0.102	< 0.0515	< 0.0515	< 0.0515	< 0.0515
	LAPL-TP-07	14-Oct-13	1.5 ft	LAPL-TP-07-1.5	961 J	3,430 J	4,390	< 0.524 J	< 0.524 J	< 0.524 J	< 0.524 J	< 0.524 J	< 0.524 J	< 0.524 J	0.396	0	< 0.524 J	< 0.524 J	< 0.524 J	< 0.524 J
	LAPL-TP-08	14-Oct-13	1.25 ft	LAPL-TP-08-1.25	171 J	711 J	882	0.0653 J	< 0.0528 J	< 0.0528 J	< 0.0528 J	0.101 J	< 0.0528 J	< 0.0528 J	0.0795	0.0663	< 0.0528 J	< 0.0528 J	< 0.0528 J	< 0.0528 J
	LAPL-TP-13	20-Oct-13	1.75 ft	LAPL-TP-13-1.75	< 20.8	< 83.3	< 83.3	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	0.00808	0	< 0.0107	< 0.0107	< 0.0107	< 0.0107
	RT-TP-01	31-Oct-13	3.5 ft	RT-TP-1-3.5	260	1,170	1,430	< 0.568	< 0.568	< 0.568	< 0.568	< 0.568	< 0.568	< 0.568	0.429	0	< 0.568	1.38	< 0.568	1.38
	RT-TP-1A-9	04-Nov-13	9 ft	RT-TP-1A-9	< 19.9	< 79.8	< 79.8	< 0.0104	< 0.0104	< 0.0104	< 0.0104	< 0.0104	< 0.0104	< 0.0104	0.00785	0	< 0.0104	< 0.0104	< 0.0104	< 0.0104
	RT-TP-02	04-Nov-13	3.5 ft	RT-TP-2-S3.5	57.2	100	157	< 0.0510	< 0.0510	0.0965	< 0.0510	0.0742	< 0.0510	< 0.0510	0.0461	0.0104	< 0.0510	0.0710	< 0.0510	0.0710
	RT-TP-02	04-Nov-13	5 ft	RT-TP-2-5	450	< 82.6	450	< 0.0514	< 0.0514	< 0.0514	< 0.0514	< 0.0514	< 0.0514	< 0.0514	0.0388	0	< 0.0514	0.0534	< 0.0514	0.0534
	RT-TP-45	22-Oct-13	2.5 ft	RT-TP-45-2.5	966 J	438 J	1,400	< 0.302 J	< 0.302 J	< 0.302 J	< 0.302 J	0.537 J	< 0.302 J	< 0.302 J	0.232	0.00537	23.2 J	100 J	36.1 J	159
	RT-TP-45A	25-Sep-14	2.5 ft	RT-TP-45A-2.5	26.6	64.8	91.4	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	0.00778	0	0.0380	0.116	0.0443	0.198
	RT-TP-45B	25-Sep-14	2.5 ft	RT-TP-45B-2.5	362	323	685	0.217	0.27	0.387	0.112	0.419	< 0.0105	0.17	0.316	0.315	5.18	12.3	8.3	25.8
	RT-TP-50	22-Oct-13	2.9 ft	RT-TP-50-2.9	970 J	< 486	970 J	< 0.124	< 0.124	< 0.124	< 0.124	< 0.124	< 0.124	< 0.124	0.0936	0	1.14	3.29	0.87	5.30
	RT-TP-50	22-Oct-13	3 ft	RT-TP-50A-3.0	286 J	141 J	427	< 0.0563 J	< 0.0563 J	< 0.0563 J	< 0.0563 J	0.0769 J	< 0.0563 J	< 0.0563 J	0.0430	0.000769	3.29 J	12.2 J	4.36 J	19.9
	RT-TP-50	22-Oct-13	3 ft	RT-TP-50B-3.0	1,140 J	492 J	1,630	< 0.0634 J	0.0858 J	0.104 J	< 0.0634 J	0.304 J	< 0.0634 J	< 0.0634 J	0.0632	0.022	13 J	34.8 J	14.9 J	62.7
	RT-TP-50A	25-Sep-14	2.5 ft	RT-TP-50A-2.5	< 15.2	23	23	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	0.00778	0	0.0384	0.132	0.0416	0.212
	RT-TP-50B	25-Sep-14	2.5 ft	RT-TP-50B-2.5	332	167	499	0.0121	0.0200	0.0345	< 0.0116	0.0679 J	< 0.0116	< 0.0116	0.0200	0.0182	2.11	9.52	3.09	14.7
	RT-TP-50C	25-Sep-14	2.5 ft	RT-TP-50C-2.5	197	256	453	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	0.00793	0	0.122	0.556	0.24	0.918

DRAFT
Table 18
Surface Soil Analytical Results
BNSF Black Tank Site
Spokane, Washington

Location Group	Location ID	Sample Date	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organics)	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
	MTCA Method A Soil Cleanup Level for Unrestricted Use						2000	0.1							0.1	0.1			5	5
Soil Borings	RT-SB-01	29-Sep-14	10 - 11 ft	RT-SB-01 (10-11)	397	111	508	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	0.00808	0	< 0.0107	< 0.0107	< 0.0107	< 0.0107
	MW-19	11-Nov-13	10 - 11 ft	MW19-(10-11)				< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	0.00793	0	< 0.0105	< 0.0105	< 0.0105	< 0.0105
	MW-22	05-Nov-13	7 - 8 ft	MW-22-(7-8)	< 21.1	< 84.6	< 84.6	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	0.00800	0	< 0.0106	< 0.0106	< 0.0106	< 0.0106
Geo-Engineers Soil Borings	B-01	15-Feb-07	13 ft	B-1-13.0	58 NJ	< 25.9	58 NJ													
	B-02	15-Feb-07	13 ft	B-2-13.0	252 NJ	431 NJ	683													
	B-03	16-Feb-07	14 ft	B-3-14.0	< 10.2	< 25.4	< 25.4													
	B-04	16-Feb-07	14 ft	B-4-14.0	< 10.2	< 25.6	< 25.6													
	B-06	19-Feb-07	15 ft	B6:15	< 10.3	< 25.7	< 25.7													
	B-09	20-Feb-07	14 ft	B-9-14.0	156	295	451													
	B-10	21-Feb-07	14 ft	B-10-14.0	< 10.2	< 25.5	< 25.5													
	B-11	21-Feb-07	14 ft	B-11-14.0	< 10.4	< 26	< 26													
	B-13	16-Oct-10	6 ft	B-13 (6)	< 19.5	< 78.2	< 78.2													
	B-14	14-Oct-10	5 ft	B-14 (5)	11,100	16,400	27,500	1.72	2.48	< 1.42	< 1.42	4.39	< 1.42	< 1.42	2.30	2.01	68.6	74.9	< 14.2	144
	B-15	16-Oct-10	7 ft	B-15 (7)	< 20.1	< 80.4	< 80.4													
	B-16	14-Oct-10	10 ft	B-16 (10)	460	2,470	2,930													
	B-17	11-Oct-10	14 ft	B-17 (17)	< 19.8	< 79.2	< 79.2													
	B-19	11-Oct-10	7 ft	B-19 (7)	134	1,120	1,250	< 0.334	< 0.334	< 0.334	< 0.334	< 0.334	< 0.334	< 0.334	0.252	0	< 0.334	< 0.334	< 0.334	< 0.334
	B-20	11-Oct-10	15 ft	B-20 (15)	< 20.2	< 80.9	< 80.9													
	B-21	11-Oct-10	7 ft	B-21 (7)	< 19.2	< 76.9	< 76.9													
	B-22	12-Oct-10	7 ft	B-22 (7)	48	< 77	48													
	B-23	11-Oct-10	7 ft	B-23 (7)	< 18.7	< 74.8	< 74.8													
	B-24	11-Oct-10	15 ft	B-24 (15)	< 20.3	< 81.2	< 81.2													
	MW-02	22-Jan-08	9 ft	MW-2-9.0	< 10.1	< 25.4	< 25.4													
	MW-03	24-Jan-08	14 - 15 ft	MW-3 (14-15)	< 10.2	< 25.4	< 25.4													
	MW-04	29-Jan-08	9 - 10 ft	MW-4 (9-10)	< 10.4	< 25.9	< 25.9													
	MW-05	30-Jan-08	2 - 3 ft	MW-5 (2-3)	21.7 NJ	< 28.1	21.7 NJ													
	MW-06	21-Jul-08	5 - 6 ft	MW-6 (5-6)	< 10.8	< 27	< 27													
	MW-07	22-Jul-08	2 - 3 ft	MW-7 (2-3)	< 10.2	< 25.6	< 25.6													
	MW-08	23-Jul-08	3 - 4 ft	MW-8 (3-4)	52.9	147	200													
	MW-09	24-Jul-08	2 - 3 ft	MW-9 (2-3)	< 11	39.1	39.1													
Black Tank Excavation Confirmation Samples	BS-1	4-May-06	8 ft	GE-BS-1	124	170	294													
	SW-SW	4-May-06	8 ft	GE-SW-SW	<10.5	<26.2	<26.2													
	B-4A	22-Sep-06	14 ft	GE-B-4A	18.2	<25.5	18.2													
	MB-2	7-Jul-06	12 ft	GE-MB-2	1,160	1,370	2,530													
	SW-3	22-Sep-06	8 ft	GE-SW-3	4,480	6,790	11,270													
	SW-4	22-Sep-06	8 ft	GE-SW-4	1,010	966	1,976													
	SW-5	28-Sep-06	10 ft	GE-SW-5	192	<25.5	192													

Notes:
< = Compound not detected. Reportable detection limit shown.
Empty cells = Not analyzed
Units are in mg/kg = milligrams per kilogram
Results shown in **bold font** indicate the compound was detected above the laboratory reporting limit.
Dark grey-shaded results shown in **bold font** indicate the compound was detected above the preliminary cleanup level.
Light grey-shaded values indicate that the method detection limit exceeds the preliminary cleanup level.
Light grey-shaded values in **bold font** indicate that Benzo(a)Pyrene TEQ calculated using ND=1/2DL exceeds the CUL but is less than the CUL when calculated using ND=0. The CUL exceedance is uncertain because it is entirely based on non-detects.
Surface soil is soil between - and 15 feet below ground surface.
Analysis performed by Pace Analytical Service, Inc., Minneapolis, MN.

Qualifiers - Organic:
J = The analyte was positively identified; associated numerical value is the approximate concentration of the analyte in the sample.
NJ = Evidence of the compound at an estimated quantity.
UJ = Analyte was analyzed for, but not detected. The detection limit is a quantitative estimate.

Qualifiers - Inorganic:
J = The analyte was positively identified; associated numerical value is the approximate concentration of the analyte in the sample.

DRAFT
Table 18
Surface Soil Analytical Results
BNSF Black Tank Site
Spokane, Washington

Location Group	Location ID	Sample Date	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organics)	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
	MTCA Method A Soil Cleanup Level for Unrestricted Use						2000	0.1							0.1	0.1			5	5

Abbreviations:
BT = Black Tank
CSPL = Chemical Solutions Pipeline
ft = feet
GE = GeoEngineers
LAPL = Liquid Asphalt Pipeline
MTCA = Model Toxics Control Act
MW = Monitoring Well
NS = No Standard
ND=0 = Non-detect values calculation method where only positively identified compounds are included in calculating the Benzo(a)Pyrene TEQ.
ND=1/2DL = Non-detect values calculated as one-half the laboratory detection limit when calculating the Benzo(a)Pyrene TEQ.
RT = Red Tank
TEQ = Toxic Equivalency Quotient
TPH-D = Diesel-Range Total Petroleum Hydrocarbons
TPH-HO = Heavy Oil-Range Total Petroleum Hydrocarbons
TPH-D/HO = Combined Diesel-and Heavy Oil-Range Total Petroleum Hydrocarbons
TP = Test Pit

DRAFT
Table 19

Subsurface Soil Analytical Summary
BNSF Black Tank Site
Spokane, Washington

Location Group	Location ID	Sample Date	Type	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organic	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes	Cadmium
Site-Specific MTCA Method B Soil Cleanup Level for Protection of Groundwater								13,600	1,900	19,000	19,000	19,000	190,000	19,000	19,000	1,900	1,900			3,800	3,800	0.7
Intermediate Soils (> 15 feet bgs and < 156 feet bgs)																						
ERM Soil Boring	BT-SB-01	01-Oct-14	N	16 - 17 ft	BT-SB-01 (16-17)	**817**	**2,850**	**3,670**	**0.293**	< 0.0534	< 0.0534	**0.144**	**0.21**	< 0.0534	< 0.0534	**0.320**	**0.310**	< 0.0534	< 0.0534	< 0.0534	< 0.0534	< 0.11
	BT-SB-01	01-Oct-14	N	18 - 19 ft	BT-SB-01 (18-19)	**3,860**	**6,120**	**9,980**	**0.726**	**0.824**	< 0.0532	**0.355**	**1.9**	< 0.0532	< 0.0532	**0.871**	**0.863**	< 0.0532	< 0.0532	< 0.0532	< 0.0532	< 0.13
	BT-SB-01	01-Oct-14		26 - 27 ft	BT-SB-01 (26-27)	**1,760 J**	**5,760 J**	**7,520**	**0.712 J**	< 0.524 UJ	< 0.524 UJ	< 0.524 UJ	**0.919 J**	< 0.524 UJ	< 0.524 UJ	**0.852**	**0.721**	< 0.524 UJ	< 0.524 UJ	< 0.524 UJ	< 0.524 UJ	
	BT-SB-01	01-Oct-14		66 - 67 ft	BT-SB-01 (66-67)	**6,450 J**	**12,700 J**	**19,200**	**1.2 J**	**1.1 J**	**0.749 J**	< 0.53 UJ	**3.36 J**	< 0.53 UJ	< 0.53 UJ	**1.50**	**1.42**	< 0.53 UJ	< 0.53 UJ	< 0.53 UJ	< 0.53 UJ	
	BT-SB-01	01-Oct-14		86 - 87 ft	BT-SB-01 (86-87)	**2,570 J**	**8,770 J**	**11,300**	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	**0.397**	**0**	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	< 0.526 UJ	
	BT-SB-01	01-Oct-14		106 - 107 ft	BT-SB-01 (106-107)	**2,360 J**	**7,960 J**	**10,300**	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	**0.395**	**0**	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	
	BT-SB-01	01-Oct-14		116 - 117 ft	BT-SB-01 (116-117)	**18,100 J**	**49,400 J**	**67,500**	**0.605 J**	< 0.537 UJ	< 0.537 UJ	< 0.537 UJ	**1.38 J**	< 0.537 UJ	< 0.537 UJ	**0.753**	**0.619**	< 0.537 UJ	< 0.537 UJ	< 0.537 UJ	< 0.537 UJ	
	BT-SB-01	01-Oct-14		126 - 127 ft	BT-SB-01 (126-127)	**2,350 J**	**8,220 J**	**10,600**	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	**0.395**	**0**	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	< 0.523 UJ	
	BT-SB-01	01-Oct-14		146 - 147 ft	BT-SB-01 (146-147)	**816 J**	**3,440 J**	**4,260**	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	**0.405**	**0**	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	< 0.536 UJ	
	RT-SB-01	29-Sep-14	N	16 - 17 ft	RT-SB-01 (16-17)	**111**	**44.2**	**155**	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	**0.00778**	**0**	< 0.0103	< 0.0103	< 0.0103	< 0.0103	**0.12**
	RT-SB-01	29-Sep-14	N	26 - 27 ft	RT-SB-01 (26-27)	**72.3**	**29.1**	**101**	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	**0.00800**	**0**	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.11
	RT-SB-01	29-Sep-14	N	46 - 47 ft	RT-SB-01 (46-47)	< 15.8	**11.6**	**11.6**	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	**0.00793**	**0**	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.13
Geo-Engineers Monitoring Well Soil Boring	MW-1	17-Jan-08	N	22 ft	MW-1-22.0	**230 NJ**	< 26	**230**														
	MW-1	17-Jan-08	N	30 ft	MW-1-30.0	**1,020 NJ**	< 25.9	**1,020**														
	MW-1	17-Jan-08	N	75 ft	MW-1-75.0	< 10	< 25.1	< 25.1														
	MW-1	18-Jan-08	N	150 ft	MW-1-150	< 10.2	< 25.5	< 25.5														
	MW-3	24-Jan-08	N	75 - 76 ft	MW-3 (75-76)	**611**	**758**	**1,370**														
	MW-4	29-Jan-08	N	139 - 140 ft	MW-4 (139-140)	**312 NJ**	**667 NJ**	**979**														
	MW-4	30-Jan-08	N	154 - 155 ft	MW-4 (154-155)	**2,700 NJ**	**1,950 NJ**	**4,650**														
	MW-5	31-Jan-08	N	155 - 156 ft	MW-5-(155-156)	< 10.7	< 26.7	< 26.7														
	MW-6	21-Jul-08	N	63 - 64 ft	MW-6 (63-64)	< 10.2	< 25.5	< 25.5														
	MW-6	21-Jul-08	N	110 - 111 ft	MW-6 (110-111)	< 13.2	< 33	< 33														
	MW-7	21-Jul-08	N	73 - 79 ft	MW-7 (73-79)	< 11.5	< 28.6	< 28.6														
	MW-8	24-Jul-08	N	98 - 99 ft	MW-8 (98-99)	< 11	< 27.5	< 27.5														
	MW-8	24-Jul-08	N	150 - 151 ft	MW-8 (150-151)	< 10.1	< 25.2	< 25.2														
	MW-9	25-Jul-08	N	102 - 103 ft	MW-9 (102-103)	< 10.4	< 26.1	< 26.1														
	MW-9	25-Jul-08	N	154 - 155 ft	MW-9 (154-155)	< 10.8	< 26.9	< 26.9														
	MW-11	29-May-09	N	123 ft	MW11S123-052909	< 10.6	< 26.5	< 26.5	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	**0.00800**	**0**	< 0.0106	< 0.0106	< 0.0106	< 0.0106	
ERM Monitoring Well Soil Boring	MW-17	04-Nov-13	N	138 - 139 ft	MW17-(138-139)	< 21.1	< 84.3	< 84.3	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	**0.00808**	**0**	< 0.0107	< 0.0107	< 0.0107	< 0.0107	
	MW-17	04-Nov-13	N	148 - 149 ft	MW17-(148-149)	< 21.3	< 85.1	< 85.1	< 0.0111	< 0.0111	< 0.0111	< 0.0111	< 0.0111	< 0.0111	< 0.0111	**0.00838**	**0**	< 0.0111	< 0.0111	< 0.0111	< 0.0111	
	MW-19	11-Nov-13	N	17 - 18 ft	MW19-(17-18)	**47.8**	< 81.8	**47.8**	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.0103	**0.00778**	**0**	< 0.0103	< 0.0103	< 0.0103	< 0.0103	< 0.14
	MW-19	11-Nov-13	N	127 - 128 ft	MW19-(127-128)	< 21.1	< 84.3	< 84.3	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	**0.00800**	**0**	< 0.0106	< 0.0106	< 0.0106	< 0.0106	**0.54**
	MW-19	11-Nov-13	N	135 - 136 ft	MW19-(135-136)	**5,080 J**	**181 J**	**5,261**	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	< 0.115	**0.0868**	**0**	< 0.115	< 0.115	< 0.115	< 0.115	
	MW-22	05-Nov-13	N	16 - 17 ft	MW-22-(16-17)	< 20.9	< 83.5	< 83.5	< 0.0104	< 0.0104	< 0.0104	< 0.0104	< 0.0104	< 0.0104	< 0.0104	**0.00785**	**0**	< 0.0104	< 0.0104	< 0.0104	< 0.0104	
	MW-22	05-Nov-13	N	26 - 27 ft	MW-22-(26-27)	< 20.9	< 83.8	< 83.8	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	**0.00793**	**0**	< 0.0105	< 0.0105	< 0.0105	< 0.0105	
	MW-24	13-Nov-13	N	125 - 126 ft	MW24-(125-126)	< 19.4	< 77.7	< 77.7														
	MW-24	13-Nov-13	N	137 - 138 ft	MW24-(137-138)	**21.9**	< 86.2	**21.9**														
	MW-24	13-Nov-13	N	147 - 148 ft	MW24-(147-148)	**102**	< 84.5	**102**														
	MW-25	15-Nov-13	N	147 - 148 ft	MW25(147-148)	< 20.5	< 82.0	< 82.0	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	**0.00793**	**0**	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.14

Location Group	Location ID	Sample Date	Type	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organic	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes	Cadmium
	Site-Specific MTCA Method B Soil Cleanup Level for Protection of Groundwater							**13,600**	**1,900**	**19,000**	**19,000**	**19,000**	**190,000**	**19,000**	**19,000**	**1,900**	**1,900**			**3,800**	**3,800**	**0.7**
Geo-Engineers Soil Boring	B-01	15-Feb-07	N	22 ft	B-1-22.0	**724 NJ**	*< 26.1*	**724**														
	B-01	15-Feb-07	N	26 ft	B-1-26.0	**3,180 NJ**	*< 266*	**3,180**														
	B-01	15-Feb-07	N	36 ft	B-1-36.0	**369 NJ**	*< 26.3*	**369**														
	B-01	15-Feb-07	N	48 ft	B-1-48.0	*< 10.6*	*< 26.6*	*< 26.6*														
	B-02	15-Feb-07	N	26 ft	B-2-26.0	**443 NJ**	**531 NJ**	**974**														
	B-02	15-Feb-07	N	36 ft	B-2-36.0	**832 NJ**	**836 NJ**	**1,670**														
	B-02	15-Feb-07	N	48 ft	B-2-48.0	**1,820 NJ**	**1,810 NJ**	**3,630**												*< 0.0463*	*< 0.0463*	
	B-02	15-Feb-07	N	78 ft	B-2-78.0	*< 10.0*	*< 25.1*	*< 25.1*														
	B-03	16-Feb-07	N	36 ft	B-3-36.0	*< 10.2*	*< 25.6*	*< 25.6*														
	B-04	16-Feb-07	N	26 ft	B-4-26.0	*< 10.2*	*< 25.5*	*< 25.5*														
	B-05	19-Feb-07	N	20 ft	B5:20	*< 10.2*	*< 25.4*	*< 25.4*														
	B-05	19-Feb-07	N	48 ft	B5:48	*< 10.2*	*< 25.6*	*< 25.6*														
	B-06	19-Feb-07	N	23 ft	B6:23	*< 10.3*	*< 25.7*	*< 25.7*														
	B-06	19-Feb-07	N	48 ft	B6:48	*< 10.4*	*< 25.9*	*< 25.9*														
	B-07	19-Feb-07	N	17 ft	B7:17	*< 10.3*	*< 25.7*	*< 25.7*														
	B-07	19-Feb-07	N	27 ft	B7:27	*< 10.1*	*< 25.2*	*< 25.2*														
	B-08	20-Feb-07	N	28 ft	B-8-28.0	*< 10.2*	*< 25.4*	*< 25.4*														
	B-08	20-Feb-07	N	37 ft	B-8-37.0	*< 10.5*	*< 25.4*	*< 25.4*														
	B-08	20-Feb-07	N	57 ft	B-8-57.0	*< 10.5*	*< 26.1*	*< 26.1*														
	B-08	20-Feb-07	N	67 ft	B-8-67.0	**5,500**	**11,000**	**16,500**														
	B-08	20-Feb-07	N	88 ft	B-8-88.0	*< 10.4*	*< 25.9*	*< 25.9*														
	B-09	20-Feb-07	N	18 ft	B-9-18.0	**137**	**259**	**396**														
	B-09	20-Feb-07	N	38 ft	B-9-38.0	*< 10.4*	*< 26.1*	*< 26.1*														
	B-10	21-Feb-07	N	38 ft	B-10-38.0	*< 10.8*	*< 26.9*	*< 26.9*														
	B-11	21-Feb-07	N	48 ft	B-11-48.0	**17.6 NJ**	**84.5 NJ**	**102**														
	B-12	21-Feb-07	N	28 ft	B-12-28.0	**6,070 NJ**	**3,070 NJ**	**9,140**	*< 0.539*	**0.790**	*< 0.539*	*< 0.539*	**1.40**	*< 0.539*	*< 0.539*	**0.470**	**0.0930**			*< 0.0886*	*< 0.0886*	
	B-12	22-Feb-07	N	68 ft	B-12-68.0	**3,170 NJ**	**4,960 NJ**	**8,130**														
	B-12	22-Feb-07	N	95 ft	B-12-95.0	**666 NJ**	**685 NJ**	**1,350**	*< 0.0534*	*< 0.0534*	*< 0.0534*	*< 0.0534*	**0.107**	*< 0.0534*	*< 0.0534*	**0.0411**	**0.00107**			*< 0.252*	*< 0.252*	
	B-12	22-Feb-07	N	108 ft	B-12-108.0	**1,660 NJ**	**1,530 NJ**	**3,190**	*< 0.0518*	*< 0.0518*	*< 0.0518*	*< 0.0518*	*< 0.0518*	*< 0.0518*	*< 0.0518*	**0.0391**	**0**			*< 0.200*	*< 0.200*	
	B-12	23-Feb-07	N	118 ft	B-12-118	**1,780 NJ**	**1,880 NJ**	**3,660**														
	B-12	23-Feb-07	N	128 ft	B-12-128	**1,750 NJ**	**2,060 NJ**	**3,810**														
	B-12	23-Feb-07	N	138 ft	B-12-138	**3,510 NJ**	**3,940 NJ**	**7,450**														
	B-12	23-Feb-07	N	148 ft	B-12-148	**4,750 NJ**	**4,790 NJ**	**9,540**														
	B-18	15-Oct-10	N	78 ft	B-18 (78)	**5,500**	**7,660**	**13,200**	*< 1.51*	*< 1.51*	*< 1.51*	*< 1.51*	*< 1.51*	*< 1.51*	*< 1.51*	**1.14**	**0**	*< 1.51*	*< 1.51*	*< 1.51*	*< 1.51*	
	B-22	13-Oct-10	N	145 ft	B-22 (145)	**2,290**	**98.8**	**2,390**	*< 0.351*	*< 0.351*	*< 0.351*	*< 0.351*	*< 0.351*	*< 0.351*	*< 0.351*	**0.265**	**0**	**1.54**	**0.847**	*< 0.351*	**2.39**	
Black Tank Excavation Confirmation Samples	B-2A	22-Sep-06		15	GE-B-2A	*<10.3*	*<25.8*	*<25.8*														
	B-3A	22-Sep-06		16	GE-B-3A	*<10.4*	*<25.9*	*<25.9*														
	MB-3	24-Aug-06		18	GE-MB-3	**4770**	**7240**	**12010**														
	B5-5@20	28-Aug-06		20	GE-B5-5@20	**2480**	**6070**	**8550**														
	B-6	22-Sep-06		15	GE-B-6	**537**	**1380**	**1917**														
	B-7	22-Sep-06		16	GE-B-7	**6040**	**4480**	**10520**														
	B-8	22-Sep-06		15	GE-B-8	**237**	**64.7**	**301.7**														
	B-9	22-Sep-06		15	GE-B-9	*<10.2*	*<25.6*	*<25.6*														
	B-10	28-Sep-06		15	GE-B-10	*<10.0*	*<25.1*	*<25.1*														
	B-11	28-Sep-06		15	GE-B-11	**2960**	**4880**	**7840**														
	B-12	28-Sep-06		15	GE-B-12	**1540**	**1690**	**3230**														

Location Group	Location ID	Sample Date	Type	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organic	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes	Cadmium
Site-Specific MTCA Method B Soil Cleanup Level for Protection of Groundwater								**13,600**	**1,900**	**19,000**	**19,000**	**19,000**	**190,000**	**19,000**	**19,000**	**1,900**	**1,900**			**3,800**	**3,800**	**0.7**
Smear Zone Soils (≥ 156 feet bgs)																						
ERM Soil Boring	BT-SB-01	02-Oct-14	N	170 - 171 ft	BT-SB-01 (170-171)	**9,570**	**9,360**	**18,900**	*< 0.287*	*< 0.287*	*< 0.287*	*< 0.287*	**0.786**	*< 0.287*	*< 0.287*	**0.223**	**0.00786**	**19.6**	**25.8**	**4.38**	**49.8**	*< 0.13*
	BT-SB-01	02-Oct-14	N	176 - 177 ft	BT-SB-01 (176-177)	*< 16.1*	**12.7**	**12.7**	*< 0.0106*	*< 0.0106*	*< 0.0106*	*< 0.0106*	*< 0.0106*	*< 0.0106*	*< 0.0106*	**0.00800**	**0**	*< 0.0106*	*< 0.0106*	*< 0.0106*	*< 0.0106*	*< 0.13*
Geo-Engineers Monitoring Well Soil Boring	MW-1	18-Jan-08	N	160 ft	MW-1-160	**4,780 NJ**	**3,400 NJ**	**8,180**	*< 1.33*	*< 1.33*	*< 1.33*	*< 1.33*	**1.42**	*< 1.33*	*< 1.33*	**1.01**	**0.0142**	**16.5**	**16.5**	*< 1.33*	**33.0**	
	MW-2	24-Jan-08	N	167 ft	MW-2-167	*< 10.9*	*< 27.3*	*< 27.3*														
	MW-2	24-Jan-08	N	172 ft	MW-2-172	**4,640 NJ**	**3,670**	**8,310**														
	MW-2	24-Jan-08	N	174 ft	MW-2-174	**4,850 NJ**	**3,460 NJ**	**8,310**														
	MW-2	24-Jan-08	N	177 ft	MW-2-177	**6,630 NJ**	*< 666*	**6,630**														
	MW-3	25-Jan-08	N	159 - 160 ft	MW-3 (159-160)	**3,300 NJ**	**2,460 NJ**	**5,760**														
	MW-3	25-Jan-08	N	173 - 174 ft	MW-3 (173-174)	**7,030 NJ**	**6,550 NJ**	**13,600**														
	MW-3	25-Jan-08	N	181 - 182 ft	MW-3 (181-182)	*< 10.6*	*< 26.4*	*< 26.4*														
	MW-4	30-Jan-08	N	167 - 168 ft	MW-4 (167-168)	**11,700 NJ**	**17,100 NJ**	**28,800**														
	MW-4	30-Jan-08	N	169 - 170 ft	MW-4 (169-170)	**13,300 NJ**	**13,900 NJ**	**27,200**														
	MW-5	31-Jan-08	N	169 - 170 ft	MW-5-(169-170)	**6,570 NJ**	**4,610 NJ**	**11,200**	*< 0.505*	*< 0.505*	*< 0.505*	*< 0.505*	**1.48**	*< 0.505*	*< 0.505*	**0.394**	**0.0148**	**22.9**	**40.5**	**1.04**	**64.4**	
	MW-6	21-Jul-08	N	160 - 161 ft	MW-6 (160-161)	*< 15.3*	*< 38.2*	*< 38.2*														
	MW-6	21-Jul-08	N	165 - 166 ft	MW-6 (165-166)	*< 12.8*	*< 32.1*	*< 32.1*														
	MW-7	23-Jul-08	N	158 - 159 ft	MW-7 (158-159)	**14 NJ**	*< 27.6*	**14**														
	MW-7	23-Jul-08	N	165 - 166 ft	MW-7 (165-166)	**17,700 NJ**	**15,400 NJ**	**33,100**	*< 2.2*	**2.44**	*< 2.2*	*< 2.2*	**3.09**	**2.89**	**2.59**	**2.14**	**0.823**	**23.8**	**15.5**	*< 2.2*	**39.3**	
	MW-7	23-Jul-08	N	171 - 172 ft	MW-7 (171-172)	**2,570 NJ**	**2,050 NJ**	**4,620**														
	MW-8	24-Jul-08	N	165 - 166 ft	MW-8 (165-166)	**15,300 NJ**	**13,400**	**28,700**	*< 2.16*	*< 2.16*	*< 2.16*	*< 2.16*	**2.49**	*< 2.16*	*< 2.16*	**1.64**	**0.0249**	*< 2.16*	*< 2.16*	*< 2.16*	*< 2.16*	
	MW-8	24-Jul-08	N	172 - 173 ft	MW-8 (172-173)	**5,990 NJ**	**4,640 NJ**	**10,600**														
	MW-9	25-Jul-08	N	165 - 166 ft	MW-9 (165-166)	**11.6 NJ**	*< 26.7*	*< 26.7*														
	MW-9	25-Jul-08	N	172 - 173 ft	MW-9 (172-173)	**3,430 NJ**	**2,760 NJ**	**6,190**														
	MW-9	25-Jul-08	N	184 - 185 ft	MW-9 (184-185)	*< 10.7*	*< 26.8*	*< 26.8*														
	MW-10	26-May-09	N	179 ft	MW10S179-52609	*< 10.3*	*< 25.8*	*< 25.8*														
	MW-11	29-May-09	N	179 ft	MW11S179-052909	*< 10.6*	*< 26.4*	*< 26.4*														
	MW-12	01-Jun-09	N	188 ft	MW12S188-060109	*< 10.2*	*< 25.6*	*< 25.6*														
	MW-13	03-Jun-09	N	170.5 ft	MW13S170.5-060309	**4,350 NJ**	**3,340 NJ**	**7,690**														
	MW-13	03-Jun-09	N	171 ft	MW13S171-060309	**935 NJ**	**645 NJ**	**1,580**	*< 0.0111*	*< 0.0111*	*< 0.0111*	*< 0.0111*	**0.0532**	*< 0.0111*	*< 0.0111*	**0.00886**	**0.000532**	**0.0339**	**0.0122**	*< 0.0111*	**0.0461**	
	MW-14	05-Jun-09	N	162.5 ft	MW14S162.5-060509	**3,940 NJ**	**3,100 NJ**	**7,040**														
	MW-14	05-Jun-09	N	167 ft	MW14S167-060509	**9,430 NJ**	**6,300 NJ**	**15,700**	**0.431**	**0.485**	**0.470**	**0.175**	**1.95**	*< 0.111*	*< 0.111*	**0.575**	**0.564**	**56.8**	**84**	**1.45**	**142**	
	MW-14	05-Jun-09	N	169 ft	MW14S169-060509	**35.5 NJ**	**41.4 NJ**	**76.9**														
	MW-14	05-Jun-09	N	172.5 ft	MW14S172.5-060509	**6,390 NJ**	**4,340 NJ**	**10,700**	**0.322**	**0.367**	**0.209**	*< 0.206*	**1.31**	*< 0.206*	*< 0.206*	**0.424**	**0.393**	**33.2**	**44.2**	**1.01**	**78.4**	
	MW-14	05-Jun-09	N	180.5 ft	MW14S180.5-060509	**46.3 NJ**	**48.8 NJ**	**95.1**														
	MW-14	05-Jun-09	N	206 ft	MW14S206-060509	*< 10.6*	*< 26.4*	*< 26.4*														
	MW-15	27-May-09	N	174 ft	MW15S174-052709	**3,440 NJ**	**2,500 NJ**	**5,940**	**0.139**	**0.114**	**0.134**	**0.0693**	**0.523**	**0.0263**	**0.0228**	**0.181**	**0.181**	*< 0.0210*		**0.0538**	**0.0538**	

Location Group	Location ID	Sample Date	Type	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organic	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes	Cadmium
Site-Specific MTCA Method B Soil Cleanup Level for Protection of Groundwater								**13,600**	**1,900**	**19,000**	**19,000**	**19,000**	**190,000**	**19,000**	**19,000**	**1,900**	**1,900**			**3,800**	**3,800**	**0.7**
ERM Monitoring Well Soil Boring	MW-16	22-Oct-13	N	160 - 161 ft	MW16-(160-161)	< 19.2 J	< 76.9 J	< 76.9	< 0.0099	< 0.0099	< 0.0099	< 0.0099	< 0.0099	< 0.0099	< 0.0099	**0.00747**	**0**	< 0.0099	< 0.0099	< 0.0099	< 0.0099	
	MW-16	22-Oct-13	N	166 - 167 ft	MW16-(166-167)	**18,700 J**	**21,500 J**	**40,200**	< 0.551	**1.84 J**	< 0.551	< 0.551	**1.92 J**	< 0.551	< 0.551	**0.589**	**0.203**	**11.5 J**	**12.9 J**	**0.815 J**	**25.2**	< 0.69
	MW-16	22-Oct-13	FD	166 - 167 ft	DUPLICATE 1-102213	**6,430 J**	**8,060 J**	**14,500**	< 0.549 J	**1.46 J**	< 0.549 J	< 0.549 J	**1.2 J**	< 0.549 J	< 0.549 J	**0.542**	**0.158**	**7.28 J**	**9.48 J**	< 0.549 J	**16.8**	< 0.16
	MW-16	22-Oct-13	N	172 - 173 ft	MW16-(172-173)	**25.1 J**	< 77.7 J	**25.1**	< 0.0099	< 0.0099	< 0.0099	< 0.0099	< 0.0099	< 0.0099	< 0.0099	**0.00747**	**0**	< 0.0099	< 0.0099	< 0.0099	< 0.0099	
	MW-17	04-Nov-13	N	158 - 159 ft	MW17-(158-159)	**3,950**	**4,970**	**8,920**	< 0.295	< 0.295	< 0.295	< 0.295	**0.494**	< 0.295	< 0.295	**0.226**	**0.00494**	**4.73**	**8.06**	< 0.295	**12.8**	< 0.17
	MW-17	04-Nov-13	N	168 - 169 ft	MW17-(168-169)	**23.6 J**	< 93.1	**23.6**	< 0.0118	< 0.0118	< 0.0118	< 0.0118	< 0.0118	< 0.0118	< 0.0118	**0.00891**	**0**	**0.0300**	**0.0507**	< 0.0118	**0.0807**	
	MW-17	04-Nov-13	FD	168 - 169 ft	DUPLICATE-110413	**95.9 J**	**111**	**207**	< 0.0117	< 0.0117	< 0.0117	< 0.0117	< 0.0117	< 0.0117	< 0.0117	**0.00883**	**0**	**0.0243**	**0.0412**	< 0.0117	**0.0655**	
	MW-17	04-Nov-13	N	177 - 178 ft	MW17-(177-178)	< 22.5	< 90.1	< 90.1	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	**0.00846**	**0**	< 0.0112	< 0.0112	< 0.0112	< 0.0112	
	MW-18	18-Oct-13	N	156 - 157 ft	MW18-(156-157)	< 21.3	< 85.1	< 85.1														
	MW-18	18-Oct-13	N	160 - 161 ft	MW18-(160-161)	**1,290 J**	**2,890 J**	**4,180**	< 0.0544	< 0.0544	< 0.0544	< 0.0544	**0.11**	< 0.0544	< 0.0544	**0.0419**	**0.00110**	< 0.0544	< 0.0544	< 0.0544	< 0.0544	
	MW-18	18-Oct-13	N	165 - 166 ft	MW18-(165-166)				< 0.5	**0.533**	< 0.5	< 0.5	**1.72**	< 0.5	< 0.5	**0.421**	**0.0705**	**32.4**	**29.6**	**0.66**	**62.7**	
	MW-18	18-Oct-13	N	170 - 171 ft	MW18-(170-171)	**8,610 J**	**9,520 J**	**18,100**	< 0.0587	**0.0817**	< 0.0587	< 0.0587	**0.253**	< 0.0587	< 0.0587	**0.0518**	**0.0107**	**31**	**58.6**	**0.213**	**89.8**	**0.97**
	MW-18	18-Oct-13	N	176 - 177 ft	MW18-(176-177)	< 20.7 J	< 82.9 J	< 82.9	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	**0.00793**	**0**	< 0.0105	< 0.0105	< 0.0105	< 0.0105	
	MW-19	11-Nov-13	N	162 - 163 ft	MW19-(162-163)	**25,300**	**25,400**	**50,700**	< 2.83	< 2.83	< 2.83	< 2.83	**2.88**	< 2.83	< 2.83	**2.15**	**0.0288**	**45.6**	**78**	**6.18**	**130**	**0.95**
	MW-19	11-Nov-13	N	167 - 168 ft	MW19-(167-168)	< 22.7	< 90.8	< 90.8	< 0.0113	< 0.0113	< 0.0113	< 0.0113	< 0.0113	< 0.0113	< 0.0113	**0.00853**	**0**	< 0.0113	< 0.0113	< 0.0113	< 0.0113	**0.87**
	MW-19	11-Nov-13	N	172 - 173 ft	MW19-(172-173)	< 21.3	< 85.1	< 85.1	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	**0.00808**	**0**	< 0.0107	< 0.0107	< 0.0107	< 0.0107	**0.66**
	MW-20	31-Oct-13	N	156 - 158 ft	MW20-(156-158)	< 22.2	< 88.6	< 88.6	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	**0.00846**	**0**	< 0.0112	< 0.0112	< 0.0112	< 0.0112	
	MW-20	31-Oct-13	N	164 - 165 ft	MW20-(164-165)	**2,020 J**	**1,910**	**3,930**	< 0.283	< 0.283	< 0.283	< 0.283	< 0.283	< 0.283	< 0.283	**0.214**	**0**	**1.31**	< 0.283	< 0.283	**1.31**	
	MW-20	31-Oct-13	N	177 - 178 ft	MW20-(177-178)	**8,620**	**8,120**	**16,740**	< 1.32	< 1.32	< 1.32	< 1.32	< 1.32	< 1.32	< 1.32	**0.997**	**0**	**21.7**	**43**	< 1.32	**64.7**	
	MW-20	31-Oct-13	N	183 - 184 ft	MW20-(183-184)	< 20.8	< 83.3	< 83.3	< 0.0109	< 0.0109	< 0.0109	< 0.0109	< 0.0109	< 0.0109	< 0.0109	**0.00823**	**0**	< 0.0109	< 0.0109	< 0.0109	< 0.0109	
	MW-21	02-Nov-13	N	159 - 160 ft	MW21-(159-160)	< 22.6	< 90.4	< 90.4	< 0.0113	< 0.0113	< 0.0113	< 0.0113	< 0.0113	< 0.0113	< 0.0113	**0.00853**	**0**	< 0.0113	< 0.0113	< 0.0113	< 0.0113	
	MW-21	02-Nov-13	N	166 - 167 ft	MW21-(166-167)	< 20.7	< 82.8	< 82.8	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	**0.00770**	**0**	< 0.0102	< 0.0102	< 0.0102	< 0.0102	
	MW-21	02-Nov-13	N	170 - 171 ft	MW21-(170-171)	**31,200**	**30,500**	**61,700**	**0.114 J**	**0.314 J**	< 0.113 J	< 0.113 J	**0.288 J**	< 0.113 J	< 0.113 J	**0.171**	**0.148**	**0.371 J**	< 0.113 J	**0.151 J**	**0.522**	**0.20**
	MW-21	02-Nov-13	N	175 - 176 ft	MW21-(175-176)	< 20.6	< 82.4	< 82.4	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	< 0.0101	**0.00763**	**0**	< 0.0101	< 0.0101	< 0.0101	< 0.0101	
	MW-22	06-Nov-13	N	164 - 165 ft	MW-22-(164-165)	< 20.8	< 83.4	< 83.4														
	MW-22	06-Nov-13	N	169 - 170 ft	MW-22-(169-170)	< 21.6	< 86.5	< 86.5	< 0.0108	< 0.0108	< 0.0108	< 0.0108	< 0.0108	< 0.0108	< 0.0108	**0.00815**	**0**	< 0.0108	< 0.0108	< 0.0108	< 0.0108	
	MW-22	06-Nov-13	N	174 - 175 ft	MW-22-(174-175)	**1,180**	**1,140**	**2,320**	< 0.0540	< 0.0540	< 0.0540	< 0.0540	**0.16**	< 0.0540	< 0.0540	**0.0421**	**0.00160**	< 0.0540	< 0.0540	< 0.0540	< 0.0540	**0.20**
	MW-22	06-Nov-13	N	180 - 181 ft	MW-22-(180-181)	< 23.1	< 92.3	< 92.3	< 0.0117	< 0.0117	< 0.0117	< 0.0117	< 0.0117	< 0.0117	< 0.0117	**0.00883**	**0**	< 0.0117	< 0.0117	< 0.0117	< 0.0117	
	MW-23	29-Oct-13	N	164 - 165 ft	MW23-(164-165)	< 19.6	< 78.4	< 78.4	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	**0.00755**	**0**	< 0.01	< 0.01	< 0.01	< 0.01	
	MW-23	29-Oct-13	N	169 - 170 ft	MW23-(169-170)	**2,590**	**2,310**	**4,900**	< 0.255	< 0.255	< 0.255	< 0.255	< 0.255	< 0.255	< 0.255	**0.193**	**0**	**0.619**	< 0.255	< 0.255	**0.619**	
	MW-23	29-Oct-13	N	174 - 175 ft	MW23-(174-175)	**20,300**	**18,500**	**38,800**	< 0.579 J	< 0.579 J	< 0.579 J	< 0.579 J	**1.79**	< 0.579 J	< 0.579 J	**0.452**	**0.0179**	**5.43 J**	< 0.579 J	**0.596 J**	**6.03**	< 0.16
	MW-23	29-Oct-13	N	177 - 178 ft	MW23-(177-178)	**1,100**	**1,110**	**2,210**	< 0.0560	**0.0570**	< 0.0560	< 0.0560	< 0.0560	< 0.0560	< 0.0560	**0.0452**	**0.00570**	**0.0869**	< 0.0560	< 0.0560	**0.0869**	
	MW-24	13-Nov-13	N	157 - 158 ft	MW24-(157-158)	**11,300 J**	**282 J**	**11,600**	< 0.107	< 0.107	< 0.107	< 0.107	< 0.107	< 0.107	< 0.107	**0.0808**	**0**	**0.13**	< 0.107	< 0.107	**0.130**	< 0.15
	MW-24	13-Nov-13	N	162 - 163 ft	MW24-(162-163)	< 22.0	< 88.0	< 88.0	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.0110	**0.00831**	**0**	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.14
	MW-24	13-Nov-13	N	175 - 175.5 ft	MW24-(175-175.5)	**3,480**	**3,780**	**7,260**	**0.108**	**0.108**	< 0.0546	< 0.0546	**0.329**	< 0.0546	< 0.0546	**0.133**	**0.122**	< 0.0546	< 0.0546	< 0.0546	< 0.0546	**0.69**
	MW-24	13-Nov-13	N	182 - 183 ft	MW24-(182-183)	**30.2**	< 90.1	**30.2**	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.0112	**0.00846**	**0**	< 0.0112	< 0.0112	< 0.0112	< 0.0112	< 0.11
	MW-25	15-Nov-13	N	157 - 158 ft	MW25(157-158)	**5,100**	**6,780**	**11,900**	< 0.551	< 0.551	< 0.551	< 0.551	< 0.551	< 0.551	< 0.551	**0.416**	**0**	< 0.551	< 0.551	< 0.551	< 0.551	**0.16**
	MW-25	15-Nov-13	FD	157 - 158 ft	DUPLICATE-111513	**2,670 J**	**4,360**	**7,030**	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	< 0.55	**0.415**	**0**	< 0.55	< 0.55	< 0.55	< 0.55	**0.15**
	MW-25	15-Nov-13	N	172 - 173 ft	MW25(172-173)	< 21.3	< 85.0	< 85.0	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.0106	**0.00800**	**0**	< 0.0106	< 0.0106	< 0.0106	< 0.0106	< 0.13
	MW-26	16-Oct-13	N	156 - 157 ft	MW26-(156-157)	< 21.3 J	< 85.3 J	< 85.3	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	**0.00808**	**0**	< 0.0107	< 0.0107	< 0.0107	< 0.0107	
	MW-26	16-Oct-13	N	160 - 161 ft	MW26-(160-161)	**6,620 J**	**7,350 J**	**13,970**	< 0.269 J	< 0.269 J	< 0.269 J	< 0.269 J	**0.477 J**	< 0.269 J	< 0.269 J	**0.207**	**0.00477**	< 0.269 J	< 0.269 J	< 0.269 J	< 0.269 J	**0.79**
	MW-26	16-Oct-13	N	168 - 169 ft	MW26-(168-169)	< 21.3 J	< 85.1 J	< 85.1	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	< 0.0105	**0.00793**	**0**	< 0.0105	< 0.0105	< 0.0105	< 0.0105	
	MW-27	28-Sep-14	N	166 - 167 ft	MW27 (166-167)	< 16.5	< 11.0	< 16.5	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.0110	< 0.0110	**0.00831**	**0**	< 0.0110	< 0.0110	< 0.0110	< 0.0110	**0.22**
	MW-27	28-Sep-14	N	174 - 175 ft	MW27 (174-175)	< 15.4	< 10.2	< 15.4	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	< 0.0102	**0.00770**	**0**	< 0.0102	< 0.0102	< 0.0102	< 0.0102	**0.12**
	MW-27	28-Sep-14	N	178 - 179 ft	MW27 (178-179)	< 16.4	< 10.9	< 16.4	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.0107	**0.00808**	**0**	< 0.0107	< 0.0107	< 0.0107	< 0.0107	< 0.12
	MW-28	17-May-16	N	165.4-165.6ft	MW28-(165.4-165.6)	**213**	**496**	**709**														
	MW-28	17-May-16	N	167.6-167.8ft	MW28-(167.6-167.8)	**7,240**	**8,050**	**15,290**														
	MW-28	17-May-16	N	170.4-170.6ft	MW28-(170.4-170.6)	**8,840**	**9,400**	**18,240**														
	MW-28	17-May-16	N	173.6-173.8ft	MW28-(173.6-173.8)	**252**	**295**	**547**														
	MW-28	17-May-16	N	174.9-175.1ft	MW28-(174.9-175.1)	**11.6**	**26.3**	**37.9**														
	MW-29	17-May-16	N	170.9-171.1ft	MW29-(170.9-171.1)	< 3.5	< 3.9 U	< 3.9														
	MW-30	6-Jul-16	N	170-172 ft	MW30(170-172) AT 170.5	**3.2 J**	**4.3 J**	**7.5 J**														

Location Group	Location ID	Sample Date	Type	Depth	Sample ID	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organic	TPH-D/HO	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes	Cadmium
Site-Specific MTCA Method B Soil Cleanup Level for Protection of Groundwater								13,600	1,900	19,000	19,000	19,000	190,000	19,000	19,000	1,900	1,900			3,800	3,800	0.7
Geo-Engineers Soil Boring	B-15	16-Oct-10	N	167 ft	B-15 (167)	**5,120**	**5,830**	**11,000**	*< 0.34*	*< 0.34*	*< 0.34*	*< 0.34*	**0.614**	*< 0.34*	*< 0.34*	**0.261**	**0.00614**	**1.74**	**0.637**	*< 0.34*	**2.38**	
	B-18	15-Oct-10	N	156 ft	B-18 (156)	**7,400**	**7,710**	**15,100**	*< 1.4*	*< 1.4*	*< 1.4*	*< 1.4*	*< 1.4*	*< 1.4*	*< 1.4*	**1.06**	**0**	*< 1.4*	*< 1.4*	*< 1.4*	*< 1.4*	
	B-25	14-Oct-10	N	167 ft	B-25 (167)	*< 20.6*	*< 82.6*	*< 82.6*														

Notes:
< = Compound not detected. Reportable detection limit shown.
Empty cells = Not analyzed
Units are in mg/kg = milligrams per kilogram
Results shown in **bold font** indicate the compound was detected above the laboratory reporting limit.
Results shown in **bold font** and shaded grey indicate the compound was detected above the preliminary cleanup level.
Analysis performed by Pace Analytical Service, Inc., Minneapolis, MN.

Qualifiers - Organic:
J = The analyte was positively identified; associated numerical value is the approximate concentration of the analyte in the sample.
NJ = Evidence of the compound at an estimated quantity.
UJ = Analyte was analyzed for, but not detected. The detection limit is a quantitative estimate.

Abbreviations:
FD = Field Duplicate
ft = feet
GE = GeoEngineers
MTCA = Model Toxics Control Act
MW = Monitoring Well
N = Normal Environmental Sample
ND = Not Detected
ND=0 = Non-detect values calculation method where only positively identified compounds are included in calculating the Benzo(a)Pyrene TEQ.
ND=1/2DL = Non-detect values calculated as one-half the laboratory detection limit when calculating the Benzo(a)Pyrene TEQ.
NS = No Standard
TEQ = Toxic Equivalency Quotient
TPH-D = Diesel-Range Total Petroleum Hydrocarbons
TPH-HO = Heavy Oil-Range Total Petroleum Hydrocarbons
TPH-D/HO = Combined Diesel-and Heavy Oil-Range Total Petroleum Hydrocarbons

DRAFT
Table 20

Groundwater Analytical Summary
BNSF Black Tank Site
Spokane, Washington

Location ID	Sample Date	Type	Sample ID	TPH-D (Diesel Range Organics) by NWTPH-Dx	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx	TPH-D/HO by NWTPH-Dx	TPH-D (Diesel Range Organics) by NWTPH-Dx, SGT	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx, SGT	TPH-D/HO by NWTPH-Dx, SGT	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
MTCA Method A for Groundwater						500			500	0.1							0.1	0.1				160
MW-02	2/6/2008	N	MW-2-020608				< 236	< 472	< 472													
MW-06	1/28/2010	N	MW6-012810				< 120	< 240	< 240	< 0.019	< 0.0096	< 0.0096	< 0.0096	< 0.0096	< 0.0096	< 0.0096	**0.0119**	**0**	< 0.0096	< 0.012	**0.038**	**0.0380**
MW-06	1/28/2010	FD	DUPLICATE-012810				< 120	< 250	< 250	< 0.019	< 0.0095	< 0.0095	< 0.0095	< 0.0095	< 0.0095	< 0.0095	**0.0119**	**0**	< 0.0095	< 0.012	**0.037**	**0.0370**
MW-06	4/8/2010	N	MW06-040810				< 120	< 240	< 240	< 0.019	< 0.0095	< 0.0095	< 0.0095	< 0.0095	< 0.0095	< 0.0095	**0.0119**	**0**	< 0.0095	< 0.012	**0.045**	**0.0450**
MW-06	8/3/2010	N	MW06-080310				< 120	< 240	< 240	< 0.020	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	**0.0126**	**0**	< 0.010	< 0.013	**0.039**	**0.0390**
MW-06	10/21/2010	N	MW-6-102110				< 120	< 240	< 240	< 0.019	< 0.0094	< 0.0094	< 0.0094	< 0.0094	< 0.0094	< 0.0094	**0.012**	**0**	< 0.0094	< 0.012	**0.026**	**0.026**
MW-06	1/26/2011	N	MW-6-012611				< 86	< 430	< 430	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	**0.0755**	**0**	< 0.11	< 0.11	< 0.11	< 0.11
MW-06	4/25/2011	N	MW-6-042511				< 77	< 380	< 380	< 0.097	< 0.097	< 0.097	< 0.097	< 0.097	< 0.097	< 0.097	**0.0717**	**0**	< 0.097	< 0.097	< 0.097	< 0.097
MW-06	7/13/2011	N	MW-6-071311				< 78	< 390	< 390	< 0.096	< 0.096	< 0.096	< 0.096	< 0.096	< 0.096	< 0.096	**0.0725**	**0**	< 0.096	< 0.096	< 0.096	< 0.096
MW-06	10/7/2011	N	MW-6-100711				< 77	< 380	< 380	< 0.095	< 0.095	< 0.095	< 0.095	< 0.095	< 0.095	< 0.095	**0.0725**	**0**	< 0.095	< 0.095	< 0.095	< 0.095
MW-06	12/5/2013	N	MW-06-12052013				< 400	< 400	< 400	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	**0.0310**	**0**	< 0.041	< 0.041	< 0.041	< 0.041
MW-06	3/6/2014	N	MW-06-03062014				< 400	**1,100**	**1,100**	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	**0.0317**	**0**	< 0.042	< 0.042	< 0.042	< 0.042
MW-06	6/29/2014	N	MW-06-062914				< 400	< 400	< 400	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	**0.0310**	**0**	< 0.041	< 0.041	< 0.041	< 0.041
MW-06	10/1/2014	N	MW-06-10012014				< 400	< 400	< 400	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	< 0.042	**0.0317**	**0**	< 0.042 UJ	< 0.042 UJ	< 0.042 UJ	< 0.042 UJ
MW-06	3/16/2016	N	MW-06-031616	< 39 U	< 7.6	< 39 U	< 25 U	< 7.6	< 25 U													
MW-06	6/21/2016	N	MW-06-062116	< 180 U	< 120	< 180 U																
MW-06	9/21/2016	N	MW-06-09212016	< 180 U	< 81	< 180 U																
MW-06	12/6/2016	N	MW-06-120616	< 40	< 77	< 77	< 40	< 77	< 77													
MW-10	8/3/2010	N	MW10-080310				< 120	< 240	< 240	< 0.020	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	**0.0126**	**0**	< 0.010	< 0.013	**0.043**	**0.0430**
MW-10	10/22/2010	N	MW-10-102210				< 120	< 250	< 250	< 0.019	< 0.0097	< 0.0097	< 0.0097	< 0.0097	< 0.0097	< 0.0097	**0.012**	**0**	< 0.0097	< 0.013	**0.03**	**0.03**
MW-10	1/26/2011	N	MW-10-012611				< 75	< 380	< 380	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	**0.0831**	**0**	< 0.10	< 0.10	< 0.10	< 0.10
MW-10	4/25/2011	N	MW-10-042511				< 80	< 400	< 400	< 0.096	< 0.096	< 0.096	< 0.096	< 0.096	< 0.096	< 0.096	**0.0732**	**0**	< 0.096	< 0.096	< 0.096	< 0.096
MW-10	7/13/2011	N	MW-10-071311				< 78	< 390	< 390	< 0.095	< 0.095	< 0.095	< 0.095	< 0.095	< 0.095	< 0.095	**0.0725**	**0**	< 0.095	< 0.095	< 0.095	< 0.095
MW-10	10/7/2011	N	MW-10-100711				**43**	< 380	**43**	< 0.098	< 0.098	< 0.098	< 0.098	< 0.098	< 0.098	< 0.098	**0.0717**	**0**	< 0.098	< 0.098	< 0.098	< 0.098
MW-10	12/5/2013	N	MW-10-12052013				< 400	< 400	< 400	< 0.043	< 0.043	< 0.043	< 0.043	< 0.043	< 0.043	< 0.043	**0.0325**	**0**	< 0.043	< 0.043	< 0.043	< 0.043
MW-10	3/4/2014	N	MW-10-03042014				< 430	< 430	< 430	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	**0.0310**	**0**	< 0.041	< 0.041	< 0.041	< 0.041
MW-10	6/30/2014	N	MW-10-063014				< 400	< 400	< 400	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	**0.0310**	**0**	< 0.041	< 0.041	< 0.041	< 0.041
MW-10	10/1/2014	N	MW-10-10012014				< 400	< 400	< 400	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	**0.0310**	**0**	< 0.041 UJ	< 0.041 UJ	< 0.041 UJ	< 0.041 UJ
MW-10	3/16/2016	N	MW-10-031616	< 81 U	**88 j**	**88 j**	< 64 U	**34 j**	**34 j**													
MW-10	6/21/2016	N	MW-10-062116	< 290 U	< 120	< 290 U																
MW-10	9/23/2016	N	MW-10-09232016	< 210 U	**230 j**	**230 j**																
MW-10	12/6/2016	N	MW-10-120616	< 38	< 72	< 72	< 38	< 72	< 72													

Location ID	Sample Date	Type	Sample ID	TPH-D (Diesel Range Organics) by NWTPH-Dx	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx	TPH-D/HO by NWTPH-Dx	TPH-D (Diesel Range Organics) by NWTPH-Dx, SGT	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx, SGT	TPH-D/HO by NWTPH-Dx, SGT	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
MTCA Method A for Groundwater						500			500	0.1							0.1	0.1				160
MW-11	1/28/2010	N	MW11-012810				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.0119**	**0**	*< 0.0094*	*< 0.012*	**0.061**	**0.0610**
MW-11	4/7/2010	N	MW11-040710				**130 NJ**	*< 240*	**130**	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.0119**	**0**	*< 0.0094*	*< 0.012*	**0.043**	**0.0430**
MW-11	8/3/2010	N	MW11-080310				*< 120*	*< 240*	*< 240*	*< 0.020*	*< 0.010*	*< 0.010*	*< 0.010*	*< 0.010*	*< 0.010*	*< 0.010*	**0.0126**	**0**	*< 0.010*	*< 0.013*	**0.051**	**0.0510**
MW-11	10/21/2010	N	MW-11-102110				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.012**	**0**	*< 0.0094*	*< 0.012*	**0.034**	**0.034**
MW-11	1/26/2011	N	MW-11-012611				*< 77*	*< 380*	*< 380*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	**0.0755**	**0**	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*
MW-11	4/25/2011	N	MW-11-042511				*< 76*	*< 380*	*< 380*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	**0.0725**	**0**	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*
MW-11	7/13/2011	N	MW-11-071311				*< 76*	*< 380*	*< 380*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	**0.0717**	**0**	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*
MW-11	10/7/2011	N	MW-11-100711				**56**	*< 380*	**56**	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	**0.0740**	**0**	*< 0.095*	*< 0.095*	**0.023**	**0.023**
MW-11	12/4/2013	N	MW-11-12042013				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-11	3/4/2014	N	MW-11-03042014				*< 410*	*< 410*	*< 410*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-11	6/30/2014	N	MW-11-063014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-11	10/1/2014	N	MW-11-10012014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*
MW-11	3/16/2016	N	MW-11-031616	**280**	**46 j**	**326 j**	*< 47 U*	*< 6.4*	*< 47 U*													
MW-11	6/21/2016	N	MW-11-062116	**2000**	**200 j**	**2200 j**																
MW-11	9/23/2016	N	MW-11-09232016	**510**	**140 j**	**650 j**																
MW-11	12/6/2016	N	MW-11-120616	**240 j**	*< 72*	**240 j**	**120 j**	*< 72*	**120 j**													
MW-12	1/28/2010	N	MW12-012810				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.0119**	**0**	*< 0.0094*	*< 0.012*	**0.049**	**0.0490**
MW-12	4/7/2010	N	MW12-040710				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.0119**	**0**	*< 0.0094*	*< 0.012*	**0.053**	**0.0530**
MW-12	8/4/2010	N	MW12-080310				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0097*	*< 0.0097*	*< 0.0097*	*< 0.0097*	*< 0.0097*	*< 0.0097*	**0.0120**	**0**	*< 0.0097*	*< 0.013*	**0.044**	**0.0440**
MW-12	10/22/2010	N	MW-12-102210				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.012**	**0**	*< 0.0094*	*< 0.012*	**0.032**	**0.032**
MW-12	1/26/2011	N	MW-12-012611				*< 77*	*< 380*	*< 380*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	**0.0755**	**0**	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*
MW-12	4/25/2011	N	MW-12-042511				*< 76*	*< 380*	*< 380*	*< 0.098*	*< 0.098*	*< 0.098*	*< 0.098*	*< 0.098*	*< 0.098*	*< 0.098*	**0.0732**	**0**	*< 0.098*	*< 0.098*	*< 0.098*	*< 0.098*
MW-12	7/13/2011	N	MW-12-071311				*< 75*	*< 380*	*< 380*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	**0.0710**	**0**	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*
MW-12	10/7/2011	N	MW-12-100711				**73**	*< 380*	**73**	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	**0.0717**	**0**	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*
MW-12	12/4/2013	N	MW-12-12042013				*< 400*	*< 400*	*< 400*	**0.11**	**0.13**	**0.14**	**0.052**	**0.11**	*< 0.041*	**0.048**	**0.150**	**0.148**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-12	3/6/2014	N	MW-12-03062014				*< 400*	**450**	**450**	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	**0.0325**	**0**	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*
MW-12	3/6/2014	FD	MW-12-03062014-D				*< 420*	*< 420*	*< 420*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-12	6/27/2014	N	MW-12-062714				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-12	6/27/2014	FD	MW-12-062714-D				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-12	10/1/2014	N	MW-12-10012014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*
MW-12	10/1/2014	FD	MW-12-10012014-D				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*
MW-12	3/15/2016	N	MW-12-031516	*< 49 U*	*< 6.8*	*< 49 U*	*< 21*	*< 6.8*	*< 21*													
MW-12	3/15/2016	FD	MW-12-DUP-031516	*< 48 U*	*< 6.8*	*< 48 U*	*< 29*	*< 6.8*	*< 29*													
MW-12	6/24/2016	FD	MW-12-062416-D	*< 180 U*	*< 120*	*< 180 U*																
MW-12	6/24/2016	N	MW-12-062416	*< 180 U*	*< 120*	*< 180 U*																
MW-12	9/21/2016	FD	MW-12-09212016-D	*< 180 U*	*< 82*	*< 180 U*																
MW-12	9/21/2016	N	MW-12-09212016	*< 180 U*	*< 80*	*< 180 U*																
MW-12	12/6/2016	FD	DUP-120616-01	*< 37*	*< 71*	*< 71*	*< 37*	*< 71*	*< 71*													
MW-12	12/6/2016	N	MW-12-120616	*< 37*	*< 71*	*< 71*	*< 37*	*< 71*	*< 71*													

Location ID	Sample Date	Type	Sample ID	TPH-D (Diesel Range Organics) by NWTPH-Dx	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx	TPH-D/HO by NWTPH-Dx	TPH-D (Diesel Range Organics) by NWTPH-Dx, SGT	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx, SGT	TPH-D/HO by NWTPH-Dx, SGT	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
MTCA Method A for Groundwater						500			500	0.1							0.1	0.1				160
MW-13	1/28/2010	N	MW13-012810				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	**0.0119**	**0**	*< 0.0095*	*< 0.012*	**0.049**	**0.0490**
MW-13	4/7/2010	N	MW13-040710				*< 120*	*< 240*	*< 240*													
MW-13	4/14/2010	N	MW13-041410							*< 0.019*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	**0.0119**	**0**	*< 0.0095*	*< 0.012*	**0.033**	**0.0330**
MW-13	8/4/2010	N	MW13-080310				*< 120*	*< 250*	*< 250*	*< 0.019*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	**0.0119**	**0**	*< 0.0095*	*< 0.012*	**0.031**	**0.0310**
MW-13	10/22/2010	N	MW-13-102210				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.012**	**0**	*< 0.0094*	*< 0.012*	**0.028**	**0.028**
MW-13	1/26/2011	N	MW-13-012611				*< 75*	*< 380*	*< 380*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	**0.0755**	**0**	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*
MW-13	4/25/2011	N	MW-13-042511				*< 78*	*< 390*	*< 390*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	**0.0740**	**0**	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*
MW-13	7/13/2011	N	MW-13-071311				*< 77*	*< 380*	*< 380*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*	**0.0725**	**0**	*< 0.094*	*< 0.094*	*< 0.094*	*< 0.094*
MW-13	10/7/2011	N	MW-13-100711				*< 76*	*< 380*	*< 380*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	**0.0717**	**0**	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*
MW-13	12/4/2013	N	MW-13-12042013				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-13	3/4/2014	N	MW-13-03042014				*< 450*	*< 450*	*< 450*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	**0.0317**	**0**	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*
MW-13	6/27/2014	N	MW-13-062714				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-13	10/2/2014	N	MW-13-10022014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-13	3/14/2016	N	MW-13-031416	*< 26 U*	*< 6.8*	*< 26 U*	*< 21*	*< 6.8*	*< 21*													
MW-13	6/22/2016	N	MW-13-062216	*< 180 U*	**130 j**	**130 j**																
MW-13	9/21/2016	N	MW-13-09212016	*< 180 U*	**110 j**	**110 j**																
MW-13	12/11/2016	N	MW-13-121116	*< 39*	*< 74*	*< 74*	*< 39*	*< 74*	*< 74*													
MW-14	1/28/2010	N	MW14-012810				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0096*	*< 0.0096*	*< 0.0096*	*< 0.0096*	*< 0.0096*	*< 0.0096*	**0.0119**	**0**	*< 0.0096*	*< 0.012*	**0.071**	**0.0710**
MW-14	4/7/2010	N	MW14-040710				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	**0.0119**	**0**	*< 0.0095*	*< 0.012*	**0.041**	**0.0410**
MW-14	4/7/2010	FD	DUPLICATE-040710																			
MW-14	8/4/2010	N	MW14-080310				*< 120*	*< 250*	*< 250*	*< 0.020*	*< 0.010*	*< 0.010*	*< 0.010*	*< 0.010*	*< 0.010*	*< 0.010*	**0.0126**	**0**	*< 0.010*	*< 0.013*	**0.043**	**0.0430**
MW-14	10/22/2010	N	MW-14-102210				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.012**	**0**	*< 0.0094*	*< 0.012*	**0.038**	**0.038**
MW-14	1/26/2011	N	MW-14-012611				*< 79*	*< 400*	*< 400*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*	**0.0831**	**0**	*< 0.11*	*< 0.11*	*< 0.11*	*< 0.11*
MW-14	4/25/2011	N	MW-14-042511				*< 78*	*< 390*	*< 390*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	**0.0732**	**0**	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*
MW-14	7/13/2011	N	MW-14-071311				*< 75*	*< 380*	*< 380*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	**0.0710**	**0**	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*
MW-14	10/7/2011	N	MW-14-100711				**38**	*< 380*	**38**	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*	**0.0725**	**0**	*< 0.097*	*< 0.097*	*< 0.097*	*< 0.097*
MW-14	12/6/2013	N	MW-14-12062013				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-14	3/4/2014	N	MW-14-03042014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-14	6/27/2014	N	MW-14-062714				*< 420*	*< 420*	*< 420*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-14	10/1/2014	N	MW-14-10012014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*	*< 0.041 UJ*
MW-14	3/14/2016	N	MW-14-031416	*< 95 U*	**56 j**	**56 j**	*< 49*	**7.8 j**	**7.8 j**													
MW-14	6/22/2016	N	MW-14-062216	*< 180 U*	**250 j**	**250 j**																
MW-14	9/21/2016	N	MW-14-09212016	*< 180 U*	*< 83*	*< 180 U*																
MW-14	12/11/2016	N	MW-14-121116	*< 38*	*< 72*	*< 72*	*< 38*	*< 72*	*< 72*													

DRAFT
Table 20

Groundwater Analytical Summary
BNSF Black Tank Site
Spokane, Washington

Location ID	Sample Date	Type	Sample ID	TPH-D (Diesel Range Organics) by NWTPH-Dx	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx	TPH-D/HO by NWTPH-Dx	TPH-D (Diesel Range Organics) by NWTPH-Dx, SGT	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx, SGT	TPH-D/HO by NWTPH-Dx, SGT	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
MTCA Method A for Groundwater						500			500	0.1							0.1	0.1				160
MW-15	1/28/2010	N	MW15-012810				*< 120*	**260 NJ**	**260**	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.0119**	**0**	*< 0.0094*	*< 0.012*	**0.051**	**0.0510**
MW-15	4/8/2010	N	MW15-040810				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	*< 0.0095*	**0.0119**	**0**	*< 0.0095*	*< 0.012*	**0.045**	**0.0450**
MW-15	8/4/2010	N	MW15-080310				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.0119**	**0**	*< 0.0094*	*< 0.012*	**0.040**	**0.0400**
MW-15	10/21/2010	N	MW-15-102110				*< 120*	*< 240*	*< 240*	*< 0.019*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	*< 0.0094*	**0.012**	**0**	*< 0.0094*	*< 0.012*	*< 0.0094*	*< 0.012*
MW-15	1/26/2011	N	MW-15-012611				*< 78*	*< 390*	*< 390*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*	**0.0831**	**0**	*< 0.10*	*< 0.10*	*< 0.10*	*< 0.10*
MW-15	4/25/2011	N	MW-15-042511				*< 78*	*< 390*	*< 390*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*	**0.0717**	**0**	*< 0.095*	*< 0.095*	*< 0.095*	*< 0.095*
MW-15	7/13/2011	N	MW-15-071311				*< 76*	*< 380*	*< 380*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	**0.0725**	**0**	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*
MW-15	10/7/2011	N	MW-15-100711				**41**	*< 380*	**41**	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*	**0.0732**	**0**	*< 0.096*	*< 0.096*	*< 0.096*	*< 0.096*
MW-15	12/4/2013	N	MW-15-12042013				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-15	3/5/2014	N	MW-15-03052014				*< 430*	*< 430*	*< 430*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-15	6/30/2014	N	MW-15-063014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-15	9/29/2014	N	MW-15-092914				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-15	3/14/2016	N	MW-15-031416	*< 25 U*	*< 7.1*	*< 25 U*	*< 21*	*< 7.1*	*< 21*													
MW-15	6/21/2016	N	MW-15-062116	*< 180 U*	**130 j**	**130 j**																
MW-15	9/22/2016	N	MW-15-09222016	*< 370 U*	**210 j**	**210 j**																
MW-15	12/6/2016	N	MW-15-120616	*< 37*	*< 71*	*< 71*	*< 37*	*< 71*	*< 71*													
MW-16	12/6/2013	N	MW-16-12062013				*< 420*	*< 420*	*< 420*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-16	3/5/2014	N	MW-16-03052014				*< 430*	*< 430*	*< 430*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-16	9/29/2014	N	MW-16-092914				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-16	3/15/2016	N	MW-16-031516	*< 88 U*	**52 j**	**52 j**	*< 46*	**9.0 j**	**9.0 j**													
MW-16	6/23/2016	N	MW-16-062316	*< 180 U*	**160 j**	**160 j**																
MW-16	9/22/2016	N	MW-16-09222016	*< 180 U*	**87 j**	**87 j**																
MW-16	12/11/2016	N	MW-16-121116	*< 390 U*	**170 j**	**170 j**	*< 36*	**93 j**	**93 j**													
MW-17	12/6/2013	N	MW-17-12062013				**470**	*< 400*	**470**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	**0.16**	**0.078**	*< 0.041*	**0.238**
MW-21	12/6/2013	N	MW-21-12062013				*< 400*	*< 400*	*< 400*	*< 0.042*	**0.046**	**0.050**	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	**0.0371**	**0.0096**	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*
MW-21	12/6/2013	FD	MW-21-12062013-D				*< 420*	*< 420*	*< 420*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-21	3/4/2014	N	MW-21-03042014				*< 430*	*< 430*	*< 430*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	**0.0325**	**0**	*< 0.043*	*< 0.043*	**0.10**	**0.100**
MW-21	6/27/2014	N	MW-21-062714				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-21	10/2/2014	N	MW-21-10022014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-21	3/17/2016	N	MW-21-031716	*< 31 U*	*< 7.2*	*< 31 U*	*< 18 U*	*< 7.2*	*< 18 U*													
MW-21	6/22/2016	N	MW-21-062216	*< 210 U*	**250 j**	**250 j**																
MW-21	9/21/2016	N	MW-21-09212016	*< 180 U*	*< 82*	*< 180 U*																
MW-21	12/11/2016	N	MW-21-121116	*< 35*	*< 67*	*< 67*	*< 35*	*< 67*	*< 67*													

DRAFT
Table 20

Groundwater Analytical Summary
BNSF Black Tank Site
Spokane, Washington

Location ID	Sample Date	Type	Sample ID	TPH-D (Diesel Range Organics) by NWTPH-Dx	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx	TPH-D/HO by NWTPH-Dx	TPH-D (Diesel Range Organics) by NWTPH-Dx, SGT	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx, SGT	TPH-D/HO by NWTPH-Dx, SGT	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
			MTCA Method A for Groundwater			500			500	0.1							0.1	0.1				160
MW-22	12/5/2013	N	MW-22-12052013				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	**0.088**	**0.0880**
MW-22	3/4/2014	N	MW-22-03042014				*< 430*	*< 430*	*< 430*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	**0.047**	*< 0.041*	*< 0.041*	**0.0470**
MW-22	6/27/2014	N	MW-22-062714				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	**0.28**	*< 0.041*	**0.067**	**0.347**
MW-22	9/30/2014	N	MW-22-093014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	**0.060**	*< 0.041*	*< 0.041*	**0.0600**
MW-22	3/16/2016	N	MW-22-031616	*< 41 U*	*< 7.4*	*< 41 U*	*< 18 U*	*< 7.4*	*< 18 U*													
MW-22	6/21/2016	N	MW-22-062116	**710 J-**	**200 j**	**910 J-**																
MW-22	9/23/2016	N	MW-22-09232016	*< 180 U*	**150 j**	**150 j**																
MW-22	12/10/2016	N	MW-22-121016	*< 39*	*< 74*	*< 74*	*< 39*	*< 74*	*< 74*													
MW-24	12/5/2013	N	MW-24-12052013				**550**	**600**	**1,150**	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	**0.0317**	**0**	*< 0.042*	*< 0.042*	**0.085**	**0.0850**
MW-24	3/5/2014	N	MW-24-03052014				*< 430*	*< 430*	*< 430*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	**0.089**	**0.0890**
MW-24	6/28/2014	N	MW-24-062814				*< 400*	*< 400*	*< 400*	*< 0.040*	*< 0.040*	*< 0.040*	*< 0.040*	*< 0.040*	*< 0.040*	*< 0.040*	**0.0302**	**0**	*< 0.040*	*< 0.040*	**0.064**	**0.0640**
MW-24	9/29/2014	N	MW-24-092914				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	**0.073**	**0.0730**
MW-24	3/15/2016	N	MW-24-031516	*< 69 U*	**22 j**	**22 j**	*< 42*	*< 7.7*	*< 42*													
MW-24	6/21/2016	N	MW-24-062116	*< 240 U*	**290**	**290**																
MW-24	9/22/2016	N	MW-24-09222016	*< 180 U*	*< 81*	*< 180 U*																
MW-24	12/11/2016	N	MW-24-121116	*< 36*	**81 j**	**81 j**	*< 36*	*< 69*	*< 69*													
MW-25	12/6/2013	N	MW-25-12062013				*< 400*	*< 400*	*< 400*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	**0.0325**	**0**	*< 0.043*	*< 0.043*	**0.045**	**0.0450**
MW-25	3/6/2014	N	MW-25-03062014				*< 400*	**480**	**480**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-25	6/28/2014	N	MW-25-062814				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	**0.071**	**0.0710**
MW-25	9/30/2014	N	MW-25-093014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-25	3/15/2016	N	MW-25-031516	*< 35 U*	*< 7.1*	*< 35 U*	*< 21*	*< 7.1*	*< 21*													
MW-25	6/23/2016	N	MW-25-062316	*< 180 U*	**190 j**	**190 j**																
MW-25	9/22/2016	N	MW-25-09222016	*< 180 U*	*< 80*	*< 180 U*																
MW-25	12/10/2016	N	MW-25-121016	*< 49 U*	**100 j**	**100 j**	*< 36*	*< 68*	*< 68*													
MW-26	12/6/2013	N	MW-26-12062013				*< 410*	*< 410*	*< 410*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	*< 0.043*	**0.0325**	**0**	*< 0.043*	**0.054**	**0.050**	**0.104**
MW-26	3/5/2014	N	MW-26-03052014				*< 410*	*< 410*	*< 410*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	*< 0.042*	**0.0317**	**0**	*< 0.042*	*< 0.042*	**0.063**	**0.0630**
MW-26	6/28/2014	N	MW-26-062814				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-26	9/30/2014	N	MW-26-093014				*< 400*	*< 400*	*< 400*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*	**0.0310**	**0**	*< 0.041*	*< 0.041*	*< 0.041*	*< 0.041*
MW-26	3/16/2016	N	MW-26-031616	*< 39 U*	*< 7.5*	*< 39 U*	*< 19 U*	*< 7.5*	*< 19 U*													
MW-26	6/23/2016	N	MW-26-062316	*< 180 U*	**130 j**	**130 j**																
MW-26	9/22/2016	N	MW-26-09222016	*< 230 U*	**180 j**	**180 j**																
MW-26	12/10/2016	N	MW-26-121016	*< 41*	*< 79*	*< 79*	*< 41*	*< 79*	*< 79*													

Location ID	Sample Date	Type	Sample ID	TPH-D (Diesel Range Organics) by NWTPH-Dx	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx	TPH-D/HO by NWTPH-Dx	TPH-D (Diesel Range Organics) by NWTPH-Dx, SGT	TPH-HO (Heavy Oil Range Organics) by NWTPH-Dx, SGT	TPH-D/HO by NWTPH-Dx, SGT	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene TEQ (ND=1/2DL)	Benzo(a)Pyrene TEQ (ND=0)	1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes
MTCA Method A for Groundwater						500			500	0.1							0.1	0.1				160
MW-27	10/2/2014	N	MW-27-10022014				< 400	< 400	< 400	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	**0.0310**	**0**	< 0.041	< 0.041	< 0.041	< 0.041
MW-27	3/17/2016	N	MW-27-031716	< 31 U	< 8.0	< 31 U	< 17 U	< 8.0	< 17 U													
MW-27	6/22/2016	N	MW-27-062216	< 180 U	< 110	< 180 U																
MW-27	9/21/2016	N	MW-27-09212016	< 340 U	**150 j**	**150 j**																
MW-27	12/10/2016	N	MW-27-121016	< 40	< 75	< 75	< 40	< 75	< 75													
MW-29	4/12/2016	N	MW-29-041216	**430**	< 160 U	**430**	< 130 U	< 59 U	< 130 U													
MW-29	6/24/2016	N	MW-29-062416	< 500 U	**130 j**	**130 j**																
MW-29	9/23/2016	N	MW-29-09232016	< 180 U	< 81	< 180 U																
MW-29	12/10/2016	N	MW-29-121016	< 390 U	**72 j**	**72 j**	< 36	< 69	< 69													
MW-30	6/24/2016	N	MW-30-062416	< 190 U	**130 j**	**130 j**																
MW-30	9/21/2016	N	MW-30-09212016	< 180 U	< 80	< 180 U																
MW-30	12/10/2016	N	MW-30-121016	< 39	**140 j**	**140 j**	< 39	**81 j**	**81 j**													

Notes:
< = Compound not detected. Reportable detection limit shown.
Empty cells = Not analyzed
NS = No Standard
Units are in µg/L = micrograms per liter
Results shown in **bold font** indicate the compound was detectedabove the laboratory reporting limit.
Results shown in **bold font** and shaded grey indicate the compound was detected above the cleanup level.
Analysis performed by Pace Analytical Service, Inc., Minneapolis, MN.
Groundwater sample results for samples only collected from wells not containing LNAPL at the time of collection.

Qualifiers - Organic:
NJ = Evidence of the compound at an estimated quantity.
UJ = Analyte was analyzed for, but not detected. The detection limit is a quantitative estimate.

Abbreviations:
FD = Field Duplicate
MTCA = Model Toxics Control Act
N = Normal Environmental Sample
ND=0 = Non-detect values calculation method where only positively identified compounds are included in calculating the Benzo(a)Pyrene TEQ.
ND=1/2DL = Non-detect values calculated as one-half the laboratory detection limit when calculating the Benzo(a)Pyrene TEQ.
TPH = Total Petroleum Hydrocarbons

DRAFT
Table 21
LNAPL Analytical Summary
BNSF Black Tank Site
Spokane, Washington

						Total Petroleum Hydrocarbons-Dx				Metals								Carcinogenic Polycyclic Aromatic Hydrocarbon							
Location ID	Sample Date	Sample Type	Sample ID	Units	Product Type	TPH-D (Diesel Range Organics)	TPH-HO (Heavy Oil Range Organics)	TPH-D/HO	TPH-G (Gasoline Range Organics)	Cadmium	Total Chromium	Dissolved Chromium	Copper	Total Lead	Dissolved Lead	Nickel	Zinc	Benzo(a)pyrene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Chrysene	Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(a)Pyrene Equivalent (Calculated)
MW-01	07-Oct-14	P	MW1-100714P	µg/kg	Mixed Diesel & Bunker C	323,000,000	338,000,000	661,000,000	6,790,000	< 160	< 520		15,200	510 J		15,800	1,300	< 7,380	10,100	< 7,380	6,820 j	35,200	< 7,380	< 7,380	6,840
MW-01	21-Jan-08	M	GRAB-MW-1	µg/L		10,100 NJ	10,300 NJ	20,400																	
MW-01	06-Feb-08	M	MW-1-020608	µg/L		18,000	16,000	34,000																	
MW-01	04-Dec-13	M	MW1-120413	µg/L		42,900	46,800	89,700	< 100		< 10.0			< 10.0				< 1.0	1.7	< 1.0	< 1.0	3.7	< 1.0	< 1.0	0.907
MW-01	27-Jun-14	M	MW-1-062714	µg/L																					
MW-01	26-Sep-14	M	MW-01-09262014	µg/L		4,700	5,300	10,000	228									< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	0.159
MW-02	23-Sep-14	P	MW-2-092314P	µg/kg	Mixed Diesel & Bunker C	266,000,000	286,000,000	552,000,000	4,880,000	< 130	< 430		13,900	< 870		11,800	2,200	< 30,000	< 30,000			41,700	< 30,000	< 30,000	19,900
MW-02	06-Dec-13	M	MW2-120613	µg/L		761,000	818,000	1,579,000	< 100		74.7			32.9				< 42.1	55.1	< 42.1	< 42.1	145	< 42.1	< 42.1	36.4
MW-02	27-Jun-14	M	MW-2-062714	µg/L							35.6	0.3 J		15.0	< 0.10										
MW-02	26-Sep-14	M	MW-02-09262014	µg/L		8,000	8,700	16,700	< 100									< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	0.159
MW-03	05-Dec-13	P	MW3-120513	µg/kg	Mixed Bunker C & Diesel	249,000,000	412,000,000	661,000,000	1,620,000	< 140	< 480		1,300	< 960		7,200	< 960	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	56,600
MW-03	24-Sep-14	P	MW-3-09242014P	µg/kg																					
MW-03	06-Feb-08	M	MW-3-020608	µg/L		147,000	210,000	357,000																	
MW-03	24-Sep-14	M	MW-3-09242014	µg/L		28,900 J	5,000	33,900	< 100									< 0.21	< 0.21			< 0.21	< 0.21	< 0.21	0.138
MW-04	06-Dec-13	P	MW4-120613	µg/kg	Mixed Bunker C & Diesel	252,000,000	441,000,000	693,000,000	3,010,000	< 140	< 480		700	< 960		2,800	< 960	< 75,000	< 75,000	< 75,000	< 75,000	107,000	< 75,000	< 75,000	57,300
MW-04	24-Sep-14	P	MW-4-092414P	µg/kg																					
MW-04	06-Feb-08	M	MW-4-020608	µg/L		1,190,000	1,780,000	2,970,000																	
MW-05	06-Dec-13	P	MW5-120613	µg/kg	Mixed Diesel & Bunker C	442,000,000	472,000,000	914,000,000	8,110,000	< 140	< 480		2,100	< 950		11,800	< 950	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	56,600
MW-05	06-Feb-08	M	MW-5-020608	µg/L		8,250	6,960	15,210																	
MW-07	05-Dec-13	P	MW7-120513	µg/kg	Mixed Diesel & Bunker C	483,000,000	492,000,000	975,000,000	11,200,000	< 150	< 490		7,900	< 980		30,600	< 980	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	< 75,000	56,600
MW-09	05-Dec-13	M	MW9-120513	µg/L	Mixed Diesel & Bunker C	77,000	76,400	153,400	612		< 10.0			< 10.0				0.90	1.2	< 0.21	< 0.21	4.9	< 0.21	< 0.21	1.11
MW-09	25-Sep-14	M	MW-09-09252014	µg/L		2,100	2,300	4,400	< 100									< 0.041	< 0.041	< 0.041	< 0.041	0.089	< 0.041	< 0.041	0.0316
MW-16	29-Jun-14	M	MW-16-062914	µg/L	Diesel	2,400	< 2,500	2,400										< 0.040	< 0.040	< 0.040	< 0.040	0.058	< 0.040	< 0.040	0.0306
MW-17	26-Sep-14	M	MW-17-09262014	µg/L	Diesel	1,300	< 400	1,300	374									< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	0.0310
MW-18	23-Sep-14	P	MW-18-09232014P	µg/kg	Mixed Diesel & Bunker C	237,000,000	257,000,000	494,000,000	4,480,000 J	< 130	< 440		3,400	< 880		11,800	< 880	< 30,000	< 30,000			< 30,000	< 30,000	< 30,000	19,700
MW-18	03-Dec-13	M	MW18-120313	µg/L		4,000,000	3,970,000	7,970,000	543		< 10.0			< 10.0				< 1.2	4.8	< 1.2	< 1.2	13.3	< 1.2	< 1.2	1.45
MW-18	27-Jun-14	M	MW-18-062714	µg/L				0																	
MW-18	23-Sep-14	M	MW-18-09232014	µg/L		2,600 J	620	3,220	221									< 0.21	< 0.21			< 0.21	< 0.21	< 0.21	0.138
MW-19	24-Sep-14	P	MW-19-09242014P	µg/kg	Mixed Diesel & Bunker C	160,000,000	182,000,000	342,000,000	4,650,000	< 130	< 440		7,400	< 880		11,100	< 880	< 30,000	< 30,000			37,000	< 30,000	< 30,000	19,900
MW-19	04-Dec-13	M	MW19-120413	µg/L		34,100	32,700	66,800	527		23.0			32.2				< 2.2	26.6	10.4	10.5	60.3	< 2.2	< 2.2	6.67
MW-19	26-Jun-14	M	MW-19-062614	µg/L				0			1.2	0.24 J		0.92	< 0.10										
MW-19	24-Sep-14	M	MW-19-09242014	µg/L		4,200 J	440	4,640	379									< 0.21	< 0.21			< 0.21	< 0.21	< 0.21	0.138
MW-20	04-Mar-14	P	MW-20-030514P	µg/kg	Bunker C				4,790,000																
MW-20	27-Jun-14	P	MW-20-062714 PROD	µg/kg			253,000,000 J	253,000,000		28 J	97 J		2,700	770 J		11,600	800 J	< 30,000	< 30,000	< 30,000	< 30,000	27,500 J	< 30,000	< 30,000	22,800
MW-20	04-Dec-13	M	MW20-120413	µg/L		5,900	5,100	11,000	327		107			37.7				< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	0.159
MW-20	27-Jun-14	M	MW-20-062714	µg/L				0			6.3	0.42 J		2.7	< 0.10										
MW-20	26-Sep-14	M	MW-20-09262014	µg/L		3,600	2,000 J	5,600	300									< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	0.159
MW-23	04-Dec-13	M	MW23-120413	µg/L	Mixed Diesel & Bunker C	1,700	1,100	2,800	315		315			169				< 0.041	0.075	< 0.041	< 0.041	0.052	< 0.041	< 0.041	0.0367
MW-23	28-Jun-14	M	MW-23-062814	µg/L		1,200	< 950	1,200			1.6	< 0.50		1.0	< 0.10			< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	0.0310
MW-23	25-Sep-14	M	MW-23-09252014	µg/L		2,600	1,100	3,700	218									< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	< 0.041	0.0310

Notes:
< = Compound not detected. Reportable detection limit shown.
Empty cells = Not analyzed
Units of LNAPL samples are in µg/kg = micrograms per kilogram
Units of mixed LNAPL and water samples are in µg/L = micrograms per liter
Results shown in bold font indicate the compound was detectedabove the laboratory reporting limit.
Analysis performed by Pace Analytical Services, Inc.

Qualifiers:
J = The analyte was positively identified; associated numerical value is the approximate concentration of the analyte in the sample.
UJ = Analyte was analyzed for, but not detected. The detection limit is a quantitative estimate.

Abbreviations:
LNAPL = Light Nonaqueous Phase Liquid
M = Mixed LNAPL and Groundwater Sample
P = Product (LNAPL) Sample
µg/kg = micrograms per kilogram
µg/L = micrograms per liter
TPH = Total Petroleum Hydrocarbons

Location ID	Sample Date	Sample Type	Sample ID	Units	Product Type	Naphthalenes				Polychlorinated Biphenyls									Volatile Organic Compounds			
						1-Methylnaphthalene	2-Methylnaphthalene	Naphthalene	Total Naphthalenes	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242	Aroclor 1248	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268	Benzene	Ethylbenzene	Toluene	Xylenes
MW-01	07-Oct-14	P	MW1-100714P	µg/kg	Mixed Diesel & Bunker C	**101,00**	**42,100**	8,620	**151720**	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 413	< 413	< 413	< 1,240
MW-01	21-Jan-08	M	GRAB-MW-1	µg/L																		
MW-01	06-Feb-08	M	MW-1-020608	µg/L															< 0.5	< 0.5	< 0.5	< 1
MW-01	04-Dec-13	M	MW1-120413	µg/L		**5.6**	**2.6**	**1.2**	**9.40**	< 30.8	< 30.8	< 30.8	< 30.8	< 30.8	< 30.8	< 30.8	< 30.8	< 30.8	< 1.0	< 1.0	< 1.0	< 3.0
MW-01	27-Jun-14	M	MW-1-062714	µg/L						< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1				
MW-01	26-Sep-14	M	MW-01-09262014	µg/L		**2.4**	**0.96**	**0.86**	**4.22**										< 1.0	< 1.0	< 1.0	< 3.0
MW-02	23-Sep-14	P	MW-2-092314P	µg/kg	Mixed Diesel & Bunker C	**38,100**	**42,000**	< 30,000	**80,100**	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	<427	<427	<427	< 1,280
MW-02	06-Dec-13	M	MW2-120613	µg/L		**240**	**319**	**73.6**	**633**	< 30.9	< 30.9	< 30.9	< 30.9	< 30.9	< 30.9	< 30.9	< 30.9	< 30.9	< 1.0	< 1.0	< 1.0	< 3.0
MW-02	27-Jun-14	M	MW-2-062714	µg/L						< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0				
MW-02	26-Sep-14	M	MW-02-09262014	µg/L		< 0.21	< 0.21	< 0.21	< 0.21										< 1.0	< 1.0	< 1.0	< 3.0
MW-03	05-Dec-13	P	MW3-120513	µg/kg	Mixed Bunker C & Diesel	< 75,000	< 75,000	< 75,000	< 75,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 396	< 990	< 990	< 2,970
MW-03	24-Sep-14	P	MW-3-09242014P	µg/kg						< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	**6,190**	< 5,000	< 5,000	< 5,000				
MW-03	06-Feb-08	M	MW-3-020608	µg/L															< 0.5	**0.939**	**1.26**	**5.1**
MW-03	24-Sep-14	M	MW-3-09242014	µg/L		**0.67**	< 0.21	< 0.21	**0.670**										< 2.0	< 2.0	< 2.0	< 6.0
MW-04	06-Dec-13	P	MW4-120613	µg/kg	Mixed Bunker C & Diesel	**470,000**	**443,000**	< 75,000	**913,000**	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 806	< 2,020	< 2,020	< 6,050
MW-04	24-Sep-14	P	MW-4-092414P	µg/kg						< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000				
MW-04	06-Feb-08	M	MW-4-020608	µg/L															**0.837**	**3.47**	< 0.5	**2.1**
MW-05	06-Dec-13	P	MW5-120613	µg/kg	Mixed Diesel & Bunker C	**340,00**	**112,000**	< 75,000	**452,000**	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 787	< 1,970	< 1,970	< 5,910
MW-05	06-Feb-08	M	MW-5-020608	µg/L															< 0.5	< 0.5	< 0.5	< 1
MW-07	05-Dec-13	P	MW7-120513	µg/kg	Mixed Diesel & Bunker C	**213,000**	**154,000**	< 75,000	**367,000**	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 25,000	< 893	< 2,230	< 2,230	< 6,700
MW-09	05-Dec-13	M	MW9-120513	µg/L	Mixed Diesel & Bunker C	**1.3**	**2.0**	**0.95**	**4.25**	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 2.0	< 2.0	< 2.0	< 6.0
MW-09	25-Sep-14	M	MW-09-09252014	µg/L		**0.15**	**0.067**	< 0.041	**0.217**										< 1.0	< 1.0	< 1.0	< 3.0
MW-16	29-Jun-14	M	MW-16-062914	µg/L	Diesel	< 0.040	< 0.040	< 0.040	< 0.040										< 1.0	< 1.0	< 1.0	< 3.0
MW-17	26-Sep-14	M	MW-17-09262014	µg/L	Diesel	**3.5**	**2.9**	**3.8**	**10.2**										**9.9**	**9.6**	**2.5**	**10.6**
MW-18	23-Sep-14	P	MW-18-09232014P	µg/kg	Mixed Diesel & Bunker C	**399,000**	**637,000**	< 30,000	**1,040,000**	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 0.427	< 0.427	< 0.427	< 1.28
MW-18	03-Dec-13	M	MW18-120313	µg/L		**262**	**570**	**7.1**	**839**	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 1.0	< 1.0	< 1.0	< 3.0
MW-18	27-Jun-14	M	MW-18-062714	µg/L						< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1	< 2.1				
MW-18	23-Sep-14	M	MW-18-09232014	µg/L		**12.7**	**16.7**	**0.31**	**29.7**										< 1.0	< 1.0	< 1.0	< 3.0
MW-19	24-Sep-14	P	MW-19-09242014P	µg/kg	Mixed Diesel & Bunker C	**542,000**	**700,000**	< 30,000	**1,240,000**	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 431	< 431	< 431	< 1,290
MW-19	04-Dec-13	M	MW19-120413	µg/L		**1,300**	**1,850**	**27.2**	**3,180**	< 3.1	< 3.1	< 3.1	< 3.1	< 3.1	< 3.1	< 3.1	< 3.1	< 3.1	< 1.0	< 1.0	< 1.0	< 3.0
MW-19	26-Jun-14	M	MW-19-062614	µg/L						< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0				
MW-19	24-Sep-14	M	MW-19-09242014	µg/L		**17.4**	**19.0**	**0.59**	**37.0**										< 1.0	< 1.0	< 1.0	< 3.0
MW-20	04-Mar-14	P	MW-20-030514P	µg/kg	Bunker C			< 1,390	< 1,390										< 139	< 347	< 347	< 1,040
MW-20	27-Jun-14	P	MW-20-062714 PROD	µg/kg		**265,000**	**219,000**	< 30,000	**484,000**	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000	< 5,000				
MW-20	04-Dec-13	M	MW20-120413	µg/L		**19.3**	**27.7**	**0.33**	**47.3**	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 0.11	< 1.0	< 1.0	< 1.0	< 3.0
MW-20	27-Jun-14	M	MW-20-062714	µg/L																		
MW-20	26-Sep-14	M	MW-20-09262014	µg/L		**8.5**	**5.8**	< 0.21	**14.3**										< 1.0	< 1.0	< 1.0	< 3.0
MW-23	04-Dec-13	M	MW23-120413	µg/L	Mixed Diesel & Bunker C	**2.8**	**0.11**	**0.19**	**3.10**	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 1.0	< 1.0	< 1.0	< 3.0
MW-23	28-Jun-14	M	MW-23-062814	µg/L		**1.5**	< 0.041	< 0.041	**1.50**										< 1.0	< 1.0	< 1.0	< 3.0
MW-23	25-Sep-14	M	MW-23-09252014	µg/L		**1.1**	< 0.041	**0.073**	**1.17**										< 1.0	< 1.0	< 1.0	< 3.0

Notes:
< = Compound not detected. Reportable detection limit shown.
Empty cells = Not analyzed
Units of LNAPL samples are in µg/kg = micrograms per kilogram
Units of mixed LNAPL and water samples are in µg/L = micrograms per liter
Results shown in bold font indicate the compound was detectedabove the laboratory reporting limit.
Analysis performed by Pace Analytical Services, Inc.

Qualifiers:
J = The analyte was positively identified; associated numerical value is the approximate concentration of the analyte
UJ = Analyte was analyzed for, but not detected. The detection limit is a quantitative estimate.

Abbreviations:
LNAPL = Light Nonaqueous Phase Liquid
M = Mixed LNAPL and Groundwater Sample
P = Product (LNAPL) Sample
µg/kg = micrograms per kilogram
µg/L = micrograms per liter
TPH = Total Petroleum Hydrocarbons

DRAFT

Table 22

Summary of LNAPL Fluid Properties

BNSF Black Tank Site

Spokane, Washington

Location/Sample ID	Temperature	Density (g/cc)	Viscosity (centistokes)	Interfacial Tension Testing		
				Temperature	Surface Tension [oil-air] (dynes/cm)	Interfacial Tension [oil-water] (dynes/cm)
MW-1	70F	0.955	2070	70F	30.1	19.1
MW-3	70F	0.9814	5570	71F	31.2	11.2
MW-18	70F	0.9575	1660	71F	30.3	15.4

Abbreviations:

F = degrees Fahrenheit

g/cc = grams per cubic centimeter

cm = centimeter

DRAFT
Table 23

MW-17 LNAPL Core Photography Log Summary
BNSF Black Tank Site
Spokane, Washington

Core Location	Sample Interval (ft bgs)	% Recovery	Description
MW-17	148-149.9	100	No fluorescence observed in what appears to be a mixed grain soil fine sand, silts, clay and some medium sand. An area of low fluorescence LNAPL observed from 148.4-148.7 ft bgs.
MW-17	149.9-150.5	0	No Recovery.
MW-17	150.5-151.1	100	Very low fluorescence observed in what appears to be a mixed grain soil of fine sand, medium sand, silt, and clay.
MW-17	151.1-152.3	100	Low fluorescence LNAPL observed in what appears to be a mixed grain soil of fine sand, silts, medium sand, and some clay.
MW-17	152.3-154.0	100	Moderate fluorescence LNAPL observed from 152.3-154.0 ft bgs, with fluorescence gradually increasing with depth. No recovery from 152.8-153.0. Soil appears to be a mixture of fine to medium sand and silt, with silt content decreasing with depth and medium sand content increasing with depth.
MW-17	154.0-157.7	100	High fluorescence LNAPL observed in what appears to be a predominantly medium grained sand soil, with some fine grained sand and silt. Concentration of fine grained particles increases with depth; medium grained sand content decreases with depth. No recovery from 155.3-155.5 ft bgs.
MW-17	157.7-158.0	0	No recovery.
MW-17	158.0-162.4	100	High fluorescence LNAPL observed in what appears to be a fine grained soil. From 161.5-162.4 ft bgs observe inclusions distributed unevenly within core that display no fluorescence; possibly clay inclusions.
MW-17	162.4-163.0	0	No recovery.
MW-17	163.0-163.4	100	No fluorescence observed in what appears to be a soil mixture of fine to medium grained sand; sand coarsens with depth.
MW-17	163.4-164.8	100	No fluorescence observed in what appears to be a mixed grain soil of gravel and coarse sand with some medium and fine sand.
MW-17	164.8-165.5	0	No recovery.
MW-17	165.5-167.5	100	No fluorescence observed in what appears to be a mixed grain soil of gravel and coarse sand, with some fine grained sand.
MW-17	167.5-170.4	0	No recovery.
MW-17	170.4-172.3	100	No fluorescence observed in what appears to be a mixed grain soil of gravel and coarse to fine grained sands.
MW-17	172.3-173.0	0	No recovery.
MW-17	173.0-174.9	100	No fluorescence observed in what appears to be a mixed grain soil of gravel and coarse to fine grained sands.

Abbreviations:

ft = feet

bgs = below ground surface

LNAPL = Light non-aqueous phase liquid

DRAFT
Table 24

MW-20 LNAPL Core Photography Log Summary
BNSF Black Tank Site
Spokane, Washington

Core Location	Sample Interval (ft bgs)	% Recovery	Description
MW-20	161.0-163.6	100	Very low to no fluorescence, distributed unevenly, observed in what appears to be a mixed grain soil of silt through medium sand with a small amount of coarse sand.
MW-20	163.6-165.5	0	No recovery.
MW-20	165.5-167.0	100	Moderate to high fluorescence LNAPL observed in what appears to be a mixed grain soil of predominantly medium sand, with fine sand and silt, and some coarse sand included.
MW-20	167.0-170.0	100	High fluorescence LNAPL observed in what appears to be a fairly uniform soil of medium to fine grained sand.
MW-20	170.0-170.5	0	No recovery.
MW-20	170.5-171.7	100	High fluorescence LNAPL observed in what appears to be a fairly uniform soil of fine to medium grained sand.
MW-20	171.7-172.1	100	Moderate fluorescence LNAPL, distributed unevenly, observed in what appears to be a mixed grain soil of fine sand, medium sand, silt, and possibly some clay.
MW-20	172.1-172.6	100	Very low fluorescence LNAPL observed in what appears to be a mixed grain soil of medium sand through silt.
MW-20	172.6-173.0	0	No recovery.
MW-20	173.0-174.2	100	No fluorescence observed in what appears to be a mixed grain soil of fine to medium sand.
MW-20	174.2-174.6	100	Very low fluorescence observed in what appears to be a mixed grain soil of fine to coarse sand with some gravel.
MW-20	174.6-175.3	100	Moderate to high fluorescence LNAPL observed in what appears to be a mixed grain soil of sands and gravel.
MW-20	175.3-175.5	0	No recovery.
MW-20	175.5-177.6	100	Moderately high fluorescence LNAPL oversexed in a mixed grain soil of gravel and sands.
MW-20	177.6-178.0	0	No recovery.
MW-20	178.0-184.4	100	No fluorescence observed in a mixed grain soil of gravel with sand, varying in concentrations with depth.

Abbreviations:
ft = feet
bgs = below ground surface
LNAPL = Light non-aqueous phase liquid

DRAFT

Table 25

MW-24 LNAPL Core Photography Log Summary

BNSF Black Tank Site

Spokane, Washington

Core Location	Sample Interval (ft bgs)	% Recovery	Description
MW-24	163.0-164.0	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-24	164.0-164.6	100	Moderately low fluorescence LNAPL observed in what appears to be a mixed grain soil of silt, fine sand and clay.
MW-24	164.6-165.0	100	Low fluorescence LNAPL, distributed unevenly, observed in a predominantly fine grained soil mixture; silt, fine grained sand and clay.
MW-24	165.0-165.5	0	No recovery.
MW-24	165.5-166.7	100	No fluorescence observed in what appears as a mixed grain soil of silt and fine to medium sand. From 165.5-165.8 ft bgs see some small areas of very low fluorescence distributed unevenly.
MW-24	166.7-167.4	100	No fluorescence observed in what appears to be a mixed grain soil of medium sand with coarse sand, some gravel and some fine sand.
MW-24	167.4-168.0	0	No recovery.
MW-24	168.0-170.0	100	Low fluorescence LNAPL observed in a mixed grain soil of coarse to medium sand with gravel. Gravel content increases in size and concentration at 169.1 ft bgs. LNAPL fluorescence also increases slightly at 169.1 ft bgs, but is still low.
MW-24	170.0-170.5	0	No recovery.
MW-24	170.5-172.5	100	Moderate fluorescence LNAPL observed in a mixed grain soil of gravel and medium to coarse sand.
MW-24	172.5-173.0	0	No recovery.
MW-24	173.0-174.0	100	Moderate fluorescence LNAPL observed in what appears to be a mixed grain soil of medium to coarse sand with a small concentration of gravel.
MW-24	174.0-174.8	100	Moderately high fluorescence LNAPL observed in what appears to be a mixed grain soil of coarse to medium sand and some gravel.
MW-24	174.8-175.5	0	No recovery.
MW-24	175.5-176.6	100	High fluorescence LNAPL observed in a mixed grain soil of medium sand with gravel, some coarse sand and some fine sand.
MW-24	176.6-177.5	100	Moderate to low fluorescence observed in a mixed grain soil of gravel and medium to coarse sand.
MW-24	177.5-178.0	0	No recovery.
MW-24	178.0-179.8	100	No fluorescence observed in what a appears to be a mixed grain soil of medium sand with coarse sand.
MW-24	179.8-180.4	0	No recovery.
MW-24	180.4-182.2	100	No fluorescence observed in what appears to be a mixed grain soil of medium sand with coarse sand and traces of gravel.
MW-24	182.2-183.0	0	No recovery.

Abbreviations:

ft = feet

bgs = below ground surface

LNAPL = Light non-aqueous phase liquid

DRAFT

Table 26

MW-28 LNAPL Core Photography Log Summary

BNSF Black Tank Site

Spokane, Washington

Core Location	Sample Interval (ft bgs)	% Recovery	Description
MW-28	161.0-163.3	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-28	163.3-164.0	0	No Recovery.
MW-28	164.0-165.6	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-28	165.6-166.6	100	Very low fluorescence LNAPL, increasing fluorescence with depth, observed in mixed grain soil of medium to fine sand.
MW-28	166.6-167	0	No Recovery.
MW-28	167.0-168.0	100	Moderate fluorescence LNAPL, unevenly distributed fluorescence increasing with depth, observed in mixed grain soil of medium to fine sand with staining.
MW-28	168.0-168.7	100	High fluorescence LNAPL observed in mixed grain soil of silt and fine to medium sand with heavy staining.
MW-28	168.7-169.5	0	No Recovery
MW-28	169.5-171.7	100	High fluorescence LNAPL, unevenly distributed fluorescence decreasing with depth, observed in mixed grain soil of silt and fine to medium sand with heavy staining.
MW-28	171.7-172.0	0	No Recovery.
MW-28	172.0-172.5	100	Moderate fluorescence LNAPL, unevenly distributed fluorescence with no fluorescence in center of core, observed in mixed grain soil of silt and fine to medium sand.
MW-28	172.5-173	100	Low fluorescence LNAPL, unevenly distributed fluorescence, observed in mixed grain soil of silt and fine to medium sand.
MW-28	173-174	100	No fluorescence observed in mixed grain soil of silt and fine to medium sand.
MW-28	174-174.3	100	No fluorescence observed in mixed grain soil of fine to medium sand.
MW-28	174.3-174.5	0	No Recovery.
MW-28	174.5-176.8	100	No fluorescence observed in mixed grain soil of fine to coarse sand.
MW-28	176.8-177.0	0	No Recovery.
MW-28	177.0-179.1	100	No fluorescence observed in mixed grain soil of fine to coarse sand.

Abbreviations:

ft = feet

bgs = below ground surface

LNAPL = Light non-aqueous phase liquid

MW-29 LNAPL Core Photography Log Summary
BNSF Black Tank Site
Spokane, Washington

Core Location	Sample Interval (ft bgs)	% Recovery	Description
MW-29	165.5-167.5	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-29	167.5-169.5	0	No Recovery.
MW-29	169.5-170.4	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-29	170.4-170.8	100	No fluorescence observed in mixed grain soil of silt and fine sand.
MW-29	170.8-171	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-29	171-172	100	No fluorescence observed in mixed grain soil of silt and fine sand.
MW-29	172-172.5	0	No Recovery.
MW-29	172.5-174.1	100	No fluorescence observed in mixed grain soil of silt and fine sand.
MW-29	174.1-174.9	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-29	174.9-175	0	No Recovery.
MW-29	175-175.7	100	No fluorescence observed in mixed grain soil of silt and fine sand.
MW-29	175.7-176.1	100	No fluorescence observed in what appears to be a mixed grain soil of medium to fine sand.
MW-29	176.1-177	100	No fluorescence observed in what appears to be a mixed grain soil of medium to coarse sand with gravel.
MW-29	177-179.2	100	No fluorescence observed in what appears to be a mixed grain soil of medium to coarse sand with gravel.

Abbreviations:

ft = feet

bgs = below ground surface

LNAPL = Light non-aqueous phase liquid

Table 28

Summary of Core Sample Intervals, Testing Parameters and Rationale
BNSF Black Tank Site
Spokane, Washington

Core Location	Sample Interval (ft bgs)	Core Fluorescence	Parameter	Rationale
MW-17	154	Medium	Grain Size	Zone of high fluorescence LNAPL in vadose zone soils logged as silt (ML). Grain size to quantify soil type.
MW-17	154.2	Medium	Drainage Capillary Pressure Data	Zone of high fluorescence LNAPL in vadose zone soils logged as silt (ML). Analysis to quantify soil characteristics and LNAPL saturation.
MW-17	157	Medium	Pore Fluid Saturation	Beginning of "v. heavy product" on log. LNAPL in vadose zone soils logged as silt (ML). Analysis to quantify LNAPL saturation.
MW-17	160	High	LNAPL Mobility	"v. heavy product" noted on log. LNAPL in vadose zone soils logged as silt (ML). High fluorescence. Analysis to quantify LNAPL saturation and mobility.
MW-17	160	High	Grain Size	Zone of high fluorescence LNAPL. Analysis to quantify soil characteristics
MW-17	162.2	None	Grain Size	Zone of no fluorescence under LNAPL in vadose zone soils logged as silt (ML). Grain size to qualify soil type.
MW-20	166	Medium	Pore Fluid Saturation	Beginning of "heavy product" on log. LNAPL in vadose zone soils logged as silty sand (SM). Analysis to quantify LNAPL saturation.
MW-20	168.2	High	Grain Size	Zone of highest fluorescence LNAPL in vadose zone soils logged as sand (SP). Grain size to quantify soil type.
MW-20	168.4	High	LNAPL Mobility	"Heavy product" noted on log. LNAPL in vadose zone soils logged as sand (SP). High fluorescence. Analysis to quantify LNAPL saturation and mobility.
MW-20	170.8	High	Drainage Capillary Pressure Data	Zone of high fluorescence LNAPL in vadose zone soils logged as sand (SP). Analysis to quantify soil characteristics and LNAPL saturation.
MW-20	171	High	Grain Size; Pore Fluid Saturations	Zone of high fluorescence LNAPL in vadose zone soils logged as sand (SP). Analysis to quantify soil characteristics and LNAPL saturation.
MW-20	173.1	None	Capillarity Package	Zone of no fluorescence in vadose zone soils lagged as sandy silt (SP/SM). Analysis to quantify soil characteristics to understand absence of LNAPL.
MW-20	173.3	None	Grain Size	Zone of no fluorescence in vadose zone soils logged as sandy silt (SP/SM). Grain size to qualify soil type.
MW-20	176	High	Drainage Capillary Pressure Data	Zone of high fluorescence LNAPL in saturated zone soils logged as sand / silty sand (SP/SM). Grain size to quantify soil type.
MW-20	176.3	High	Grain Size	Zone of high fluorescence LNAPL in saturated zone soils logged as sand / silty sand (SP/SM). Grain size to quantify soil type.
MW-20	177	High	LNAPL Mobility	Zone of high fluorescence LNAPL in saturated zone soils logged as sand / silty sand (SP/SM). Analysis to quantify LNAPL saturation and mobility at lower end of LNAPL zone.
MW-24	171.8	Low	Grain Size	Beginning of "free product" on log. Zone of low fluorescence LNAPL in vadose zone soils logged as sand (SP). Grain size to quantify soil type.
MW-24	172	Low	Pore Fluid Saturation	Beginning of 'free product" on log. Zone of low fluorescence LNAPL in vadose zone soils logged as sand (SP). Pore fluid saturation will be used to estimate residual saturation in vadose zone.
MW-24	175.8	High	Grain Size	"free product" on log near water table. Zone of high fluorescence LNAPL in saturated zone soils logged as sand (SP). Grain size to quantify soil type.

Table 28

Summary of Core Sample Intervals, Testing Parameters and Rationale

BNSF Black Tank Site
Spokane, Washington

Core Location	Sample Interval (ft bgs)	Core Fluorescence	Parameter	Rationale
MW-24	176	High	LNAPL Mobility	"free product" on log near water table. Zone of high fluorescence LNAPL in saturated zone soils logged as sand (SP). Analysis to quantify LNAPL saturation and mobility. Soil characteristics likely similar to MW-
MW-24	177	Low	Pore Fluid Saturation	End of "free product" on log. Zone of low fluorescence LNAPL in saturated soils logged as sand (SP). Pore fluid saturation will be used to estimate residual saturation in saturated zone.
MW-28	167.2	Medium	Grain Size	Zone of medium fluorescence LNAPL on core photograph. LNAPL in vadose zone soils logged as sand (SW) above finer grained soils. Grain size to quantify soil type.
MW-28	167.5	Medium	Pore Fluid Saturations	Zone of medium fluorescence LNAPL on core photograph. LNAPL in vadose zone soils logged as sand (SW) above finer grained soils. Analysis to quantify LNAPL saturation.
MW-28	168.1	High	Grain Size	Zone of high fluorescence LNAPL on core photograph. LNAPL in upper smear zone finer grained soils logged as silty fine sand (SM). Grain size to quantify soil type.
MW-28	168.5	High	LNAPL Mobility	Zone of high fluorescence LNAPL in upper smear zone finer grained soils logged as silty fine sand (SM). Analysis to quantify LNAPL saturation and mobility.
MW-28	169.8	High	Grain Size	Zone of high fluorescence LNAPL on core photograph. LNAPL in lower smear zone finer grained soils logged as silty fine sand (SM). Grain size to quantify soil type.
MW-28	170	High	LNAPL Mobility	Zone of high fluorescence LNAPL in lower smear zone finer grained soils logged as silty fine sand (SM). Analysis to quantify LNAPL saturation and mobility.
MW-28	172.8	None	Grain Size	Zone of no fluorescence below smear zone in finer grained soils logged as silty fine sand (SM). Grain size to quantify soil type.
MW-28	173.2	High	Pore Fluid Saturations	Zone of no fluorescence below smear zone in finer grained soils logged as silty fine sand (SM). Analysis to quantify LNAPL saturation.
MW-28	176	High	Grain Size	Zone of no fluorescence in coarser grained soils logged as sand (SW). Grain size to quantify soil type.
MW-29	173.3	None	Grain Size	Zone of no fluorescence in finer grained soils logged as silty fine sand (SM). Grain size to quantify soil type.
MW-29	173.5	None	Drainage Capillary Pressure Data	Zone of no fluorescence in finer grained soils logged as silty fine sand (SM). Analysis to quantify soil characteristics.
MW-29	178.5	None	Grain Size	Zone of no fluorescence in coarser grained soils logged as sand and fine gravel (GP). Grain size to quantify soil type.
MW-29	179	None	Drainage Capillary Pressure Data	Zone of no fluorescence in coarser grained soils logged as sand and fine gravel (GP). Analysis to quantify soil characteristics.

Abbreviations:
ft = feet
bgs = below ground surface
LNAPL = Light non-aqueous phase liquid

DRAFT

Table 29

Summary of Pore Fluid Saturations and LNAPL Mobility Testing

BNSF Black Tank Site

Spokane, Washington

Core Location	Sample Interval (feet bgs)	In-Place Conditions			Residual Conditions				% of Total LNAPL Saturation that is Residual LNAPL
		Water Saturation (%)	LNAPL Saturation (%)	Total (Water + LNAPL) Pore Fluid Saturation (%)	Residual Water Saturation (%)	LNAPL Residual Saturation (%)	Mobile LNAPL Saturation (%)	LNAPL Produced	
MW-17D	157	18.9	46	65					
MW-17E	160	27.2	58.6	86	8.5	23.4	35.2	Dark Brown	40%
MW-20B	166	49.2	21.6	71					
MW-20C	168.4	42.6	23.3	66	6.1	12.3	11	Dark Brown	53%
MW-20D	171	48.8	29.9	79					
MW-20F	177	15.3	11.1	26	14.7	11.1	0	None Visible	100%
MW-24D	172	22	4.7	27					
MW-24F	176	51.3	12.9	64	7.1	7.5	5.4	Dark Brown	58%
MW-24F	177	44.1	2.8	47					
MW28 (167-169.5)	167.5	65.3	6.1	71					
MW28 (167-169.5)	168.5	52.5	19	72	8.3	18.2	0.8	Dark Brown	96%
MW28 (169.5-172)	170.0	50.7	18.2	69	16.1	18	0.2	Dark Brown	99%
MW28 (172-174.5)	173.2	53.9	2.9	57					

Abbreviations:

bgs = below ground surface

LNAPL = Light non-aqueous phase liquid

DRAFT
Table 30

Comparison of TPH-Based Residual LNAPL Saturations to Lab-Based Residual LNAPL Saturations
BNSF Black Tank Site
Spokane, Washington

Core Location	Calculated TPH-D/HO Residual Saturation (mg/kg)	Measured Soil Bulk Density	Measured Soil Porosity	LNAPL Density	Calculated TPH-D/HO Residual LNAPL Saturation (%)	LNAPL Residual Saturation (%)	Mobile LNAPL Saturation (%)
MW-17E	13,600	1.49	0.451	0.95	4.7%	23%	35%
MW-20C	13,600	1.54	0.434	0.95	5.1%	12%	11%
MW-20F	13,600	1.62	0.405	0.95	5.7%	11%	0%
MW-24F	13,600	1.66	0.392	0.95	6.1%	8%	5%
MW28 (167-169.5)	13,600	1.56	43%	0.95	5.2%	18%	1%
MW28 (169.5-172)	13,600	1.61	41%	0.95	5.7%	18%	0%

Abbreviations:
bgs = below ground surface
CUL = cleanup level
LNAPL = Light non-aqueous phase liquid
TPH-D/HO = Combined Diesel-and Heavy Oil-Range Total Petroleum Hydrocarbons

Significant Finding: For all soil core samples collected, the residual LNAPL Saturation quantified by Dean Stark analysis exceeded the calculated residual LNAPL saturation of 13,600 mg/kg (i.e., the proposed TPH-D/HO CUL for subsurface soils).

$$S_n = \mathrm{TPH} \cdot \frac{\text{Bulk Density} \cdot 10^{-6}}{\phi\rho} \quad \text{where } \phi = \text{porosity, and } \rho = \text{LNAPL density}$$

Sn = LNAPL Saturation
Calculated TPH-D/HO nits in mg/kg.
Source: LCSM Tools: Conversion of TPH in Soil to NAPL Saturation, ANSR Volume 2, Issue 1, January 2012

DRAFT
Table 31

CO_2 Soil Flux Trap and Biodegradation Rate Summary
BNSF Black Tank
Spokane, Washington

		Deployment Dates			Blank Corrected Results[1]	^{14}C Analysis (Fossil Fuel)		
					CO_2 Flux[2]	Modern Carbon	Fossil Fuel CO_2 Flux	Biodegradation Rate[3]
Sample Name	**Sample Location**	**deployed**	**retrieved**	**days**	**µmol/m^2-s**	**µmol/m^2-s**	**µmol/m^2-s**	**gal/acre-yr**
BTWA-R1-CO2-TB	Travel Blank	NA	NA	0.0	0.00	-	-	-
BTWA-R1-CO2-01	MW-18	3/23/16 14:30	4/5/16 17:05	13.1	3.00	0.95	2.05	1,012
BTWA-R1-CO2-02	MW-4	3/23/16 15:18	4/5/16 17:45	13.1	0.62	0.16	0.46	229
BTWA-R1-CO2-03	MW-5	3/23/16 16:00	4/5/16 15:55	13.0	1.32	0.83	0.49	243
BTWA-R1-CO2-04	MW-8	3/23/16 17:05	4/5/16 15:35	12.9	5.32	1.93	3.40	1,681

Notes:

[1] = Results are travel blank-corrected but not background location corrected. Blank Corrected Results = Raw Results - Travel Blank

[2] = Trap cross sectional area is 8.11 e-03 m^2

[3] = The flux equivalence is 1 microMole/(m^2·sec) equals 495 gallons/(acre.year). This assumes a hydrocarbon density of 0.97 g/mL and a formula of $C_{10}H_{22}$.

Abbreviations:

µmol/m^2·s = micromoles per square meter per second
^{14}C = Carbon 14
CO_2 = Carbon Dioxide
gal/acre·yr = gallons per acre per year
NA = not applicable

DRAFT

Table 32

CO_2 Soil Flux Chamber and Biodegradation Rate Summary

BNSF Black Tank

Spokane, Washington

Location	Date	Time	Average Experimental CO_2 Flux[1,2] (µmol/m^2·s)	Standard Deviation Experimental CO_2 Flux[1,2] (µmol/m^2·s)	Background Corrected Experimental CO_2 Flux[1,3] (µmol/m^2·s)	Biodegradation Rate[4] (gal/acre·year)	Average Biodegradation Rate[4] (gal/acre·year)
LI-01	3/17/2016	12:37	0.41	0.12	0.04	20	213
	3/23/2016	18:19	0.59	0.09	0.33	161	
	4/5/2016	16:51	1.27	0.44	0.82	404	
	4/11/2016	14:15	1.04	0.33	0.54	267	
LI-02	3/17/2016	12:27	0.53	0.18	0.16	79	414
	3/23/2016	17:57	1.49	0.34	1.22	605	
	4/5/2016	16:30	1.34	0.22	0.88	435	
	4/11/2016	13:50	1.58	0.19	1.08	536	
LI-03	3/17/2016	14:21	0.58	0.04	0.20	100	137
	3/23/2016	15:33	0.53	0.04	0.27	133	
	4/5/2016	16:08	0.72	0.07	0.26	128	
	4/11/2016	13:18	0.88	0.06	0.38	188	
LI-04	3/17/2016	14:02	0.31	0.16	-	-	240
	3/23/2016	15:17	0.21	0.06	-	-	
	4/5/2016	17:41	0.78	0.59	0.32	158	
	4/11/2016	11:12	1.15	0.10	0.65	323	
LI-05	3/17/2016	14:47	0.70	0.08	0.32	160	321
	3/23/2016	15:51	0.80	0.24	0.53	263	
	4/5/2016	15:57	0.62	0.08	0.17	82	
	4/11/2016	13:09	2.07	0.78	1.57	779	
LI-06 (Background)	3/17/2016	11:26	0.38	0.05	-	-	-
	3/17/2016	17:45	0.37	0.11	-	-	
	3/18/2016	11:15	0.58	0.52	-	-	
	3/18/2016	13:30	0.54	0.07	-	-	
	3/23/2016	14:15	0.36	0.01	-	-	
	3/23/2016	19:21	0.17	0.03	-	-	
	4/5/2016	14:15	0.71	0.51	-	-	
	4/5/2016	19:16	0.20	0.01	-	-	
	4/11/2016	10:41	0.68	0.09	-	-	
	4/11/2016	15:10	0.32	0.01	-	-	
LI-07	3/17/2016	15:43	0.36	0.03	-	-	116
	3/23/2016	16:13	0.37	0.11	0.11	54	
	4/5/2016	18:06	0.49	0.15	-	-	
	4/11/2016	11:21	0.86	0.08	0.36	178	
LI-08	3/18/2015	12:02	0.81	0.26	0.25	125	176
	3/23/2016	17:01	0.41	0.08	0.15	73	
	4/5/2016	15:30	0.50	0.03	0.04	22	
	4/11/2016	12:32	1.48	0.30	0.98	484	
LI-09	3/18/2016	12:14	0.86	0.27	0.30	149	343
	3/23/2016	17:15	1.44	0.48	1.18	584	
	4/5/2016	15:17	1.05	0.11	0.59	291	
	4/11/2016	12:04	1.20	0.17	0.71	350	
LI-10	3/18/2016	12:31	0.64	0.10	0.08	39	177
	3/23/2016	16:38	0.46	0.13	0.20	98	
	4/5/2016	17:17	0.98	0.68	0.53	260	
	4/11/2016	11:41	1.13	0.15	0.63	312	
LI-11	3/23/2016	16:49	0.44	0.06	0.17	85	234
	4/5/2016	17:27	0.94	0.11	0.48	237	
	4/11/2016	11:32	1.26	0.18	0.77	379	
LI-15	3/17/2016	12:02	1.36	0.18	0.99	488	1,111
	3/23/2016	17:44	2.74	0.65	2.48	1,226	
	4/5/2016	15:45	3.27	2.37	2.82	1,394	
	4/11/2016	13:29	3.19	0.26	2.70	1,335	
LI-16	3/17/2016	12:15	0.96	0.08	0.59	292	390
	3/23/2016	18:07	1.38	0.44	1.12	554	
	4/5/2016	16:20	1.06	0.24	0.60	298	
	4/11/2016	13:39	1.34	0.14	0.84	416	
LI-17	3/18/2016	11:29	1.19	0.18	0.63	313	223
	3/23/2016	18:32	0.38	0.16	0.11	55	
	4/5/2016	16:41	0.66	0.17	0.20	100	
	4/11/2016	14:04	1.36	0.42	0.86	426	
LI-18	3/17/2016	12:56	0.69	0.13	0.31	155	191
	3/23/2016	14:34	0.58	0.16	0.28	158	
	4/5/2016	17:02	0.48	0.21	0.02	11	
	4/11/2016	10:53	1.39	0.32	0.89	442	

DRAFT

Table 32

CO_2 Soil Flux Chamber and Biodegradation Rate Summary
BNSF Black Tank
Spokane, Washington

Location	Date	Time	Average Experimental CO_2 Flux[1,2] (µmol/m^2·s)	Standard Deviation Experimental CO_2 Flux[1,2] (µmol/m^2·s)	Background Corrected Experimental CO_2 Flux[1,3] (µmol/m^2·s)	Biodegradation Rate[4] (gal/acre·year)	Average Biodegradation Rate[4] (gal/acre·year)
LI-19	3/17/2016	13:43	0.31	0.13	-	-	69
	3/23/2016	15:03	0.10	0.12	-	-	
	4/5/2016	17:52	0.27	0.20	-	-	
	4/11/2016	11:02	0.64	0.12	0.14	69	
LI-20	3/18/2016	13:06	0.84	0.11	0.28	138	239
	3/23/2016	18:55	0.29	0.01	0.02	11	
	4/5/2016	18:39	0.78	0.14	0.33	161	
	4/11/2016	14:44	1.81	0.07	1.31	648	
LI-21	3/18/2016	12:56	0.66	0.49	0.10	49	48
	3/23/2016	18:46	0.29	0.04	0.02	11	
	4/5/2016	18:27	0.70	0.54	0.24	118	
	4/11/2016	14:32	0.53	0.07	0.03	16	
LI-22	3/23/2016	16:26	0.42	0.09	0.16	78	78
LI-23	3/17/2016	17:12	0.37	0.06	-	-	253
	3/23/2016	17:27	0.39	0.05	0.13	62	
	4/5/2016	15:03	0.35	0.15	-	-	
	4/11/2016	11:54	1.39	0.21	0.90	444	
LI-27	3/18/2016	13:16	0.95	0.15	0.39	194	120
	3/23/2016	19:06	0.32	0.15	0.06	29	
	4/5/2016	18:49	0.47	0.24	0.02	7	
	4/11/2016	14:54	1.00	0.21	0.51	251	
Total Site Average							**255**

Notes:

[1] = Chamber cross sectional area is 8.11 e-03 m^2

[2] = Experimental flux measurements were collected in minimum replicates of three.

[3] = Background considered the average of LI-06 monitoring location observations at the beginning and end of day on date of measurement.

[4] = C10H22 with a density of 0.97 mg/L is assumed to be representative of site contaminants for calculation of biodegradation rate.

\- = Background flux corrections resulting in negative flux values considered to show zero flux contributed from petroleum degradation

Abbreviations:

µmol/m^2·s = micromoles per square meter per second
gal/acre·year = gallons per acre per year
CO_2 = carbon dioxide

LNAPL Degradation Rate (gal/acre/year) calculated by assuming C10H22 alkane with density of 0.97 g/ml

$C_{10}H_{22} + 15.5O_2$ -> $10CO_2 + 11H_2O$

CO2 Flux	1	umol/m2/s
	1.4	gal/acre/day
	495	gal/acre/year
LNAPL Degradation Rate	1.2	g/m2/day
Unit Conversion	1000000	umol/mol
mol C10H22 / mol CO2	0.10	mol/mol
MW C10H22	142	g/mol
LNAPL Density	0.97	g/mL
Unit Conversion	1000	mL/L
Unit Conversion	3.8	L/gal
Unit Conversion	4047	m2/Ac
Unit Conversion	86400	s/day
Unit Conversion	365	days/year

DRAFT

Table 33

In-Situ Respirometry Summary - March 2016

BNSF Black Tank

Spokane, Washington

Location	Date	DTW ft btoc	DTP ft btoc	Top of Screen ft btoc	Bottom of Screen ft btoc	Casing Volume Liters	Vapor Purge Rate LPM	Vapor Purge Time minutes	Vapor Purge Volume Liters	O_2 %	CO_2 %	CO_2 ppm	CH_4 %	PID ppm	Notes
MW-04	3/17/2016	-	161.60	138.0	168.0	100	20	26	520	0.6	15.6	-	0.0	1.9	Moderate vacuum during purging.
MW-05	3/17/2016	-	165.77	158.5	169.0	102	20	25	500	12.1	6.7	-	0.0	2.1	
MW-06	3/17/2016	160.09	ND	166.0	186.0	99	20	46	920	20.7	0.1	360	0.0	0.0	Screen submerged.
MW-07	3/17/2016	-	169.98	158.5	168.5	105	20	26	520	15.2	3.9	-	0.0	3.9	
MW-08	3/18/2016	-	ND	156.5	166.5	103	20	25	500	13.9	4.5	-	0.0	17.0	Well is dry.
MW-11	3/21/2016	171.38	ND	167.0	197.0	106	20	26	520	19.2	0.4	-	0.0	20.3	
MW-17	3/18/2016	-	163.02	163.0	167.8	101	20	16	320	5.0	11.9	-	0.2	11.7	
MW-18	3/17/2016	168.71	168.62	168.0	171.0	104	20	31	620	10.9	7.1	-	0.3	24.8	
MW-18	3/21/2016	168.71	168.62	168.0	171.0	104	20	30	600	7.5	9.9	-	0.2	13.9	Methane odor during purge.
MW-20	3/18/2016	-	167.9	167.5	182.5	104	20	27	540	1.9	13.2	-	2.8	10.7	
MW-22	3/17/2016	174.79	ND	170.7	180.7	108	20	18	360	20.4	0.3	-	0.0	0.6	Pump failed. High vacuum. Measurements may be compromised.
MW-22	3/17/2016	174.79	ND	170.7	180.7	108	20	32	640	20.0	0.4	-	0.0	20.3	High vacuum. Measurements may be compromised.
MW-23	3/17/2016	-	174.89	172.0	182.0	108	10 - 20	17	255	-	-	-	-	-	High vacuum. Cannot collect measurement.

Abbreviations:

- = not available
% = percent
CO_2 = carbon dioxide
CH_4 = methane
DTP = depth to product
DTW = depth to water
ft btoc = feet below top of casing
LPM = liters per minute
ND = not detected
O_2 = oxygen
ppm = parts per million

DRAFT
Table 34

Natural Source Zone Depletion Groundwater Parameter Data - March 2016
BNSF Black Tank
Spokane, Washington

Monitoring Well	Location	Date Sampled	Diesel-Range Hydrocarbons[1,2] mg/l	Heavy Oil-Range Hydrocarbons [1,2] mg/l	Dissolved Oxygen[3] µg/l	Nitrate µg/l	Methane µg/l	Ferrous Iron µg/l	Sulfate µg/l	Manganese µg/l
MW-06	Upgradient of LNAPL Plume	3/16/2016	0.039 U	0.0076	6.53	**1,100**	2.2 U	29.1 U	**10,100**	0.24 U
MW-10	Downgradient of LNAPL Plume	3/16/2016	0.081 U	**0.088**	4.83	**580**	1.8 U	29.1 UJ	**7,100**	0.24 U
MW-11			**0.28**	**0.046** j	3.05	**280**	**10.6**	29.1 UJ	**5,100**	**0.80**
MW-22			0.041 U	0.0074	3.43	**540**	5.6 U	29.1 U	**6,800**	**3.6**

Notes:

[1] = Hydrocarbons analyzed by Washington State Department of Ecology Method NWTPH-Dx without Silica Gel Cleanup.

[2] = MTCA Method A Groundwater Cleanup Level (Chapter 173-340-900 Washington Administrative Code) is 0.5 mg/l

[3] = Dissolved oxygen measured during well purging with a Horiba U-52 water quality meter

Bold cells indicate detections above the analytical method detection limit

Analysis performed by Pace Analytical Services, Inc. - Minneapolis, MN, and Fremont Analytical Laboratories - Seattle, WA.

Abbreviations:

mg/l = milligrams per liter
µg/l = micrograms per liter
U = Not detected at laboratory detection limits
UJ = Analyte was analyzed for, but not detected. The detection limit is a quantitative estimate.
j = Result detected between the method detection limit and reporting limit.

Table 35

Natural Source Zone Depletion Summary - Saturated Zone - March 2016
BNSF Black Tank
Spokane, Washington

Well Pair	**Saturated Zone NSZD Rates [1, 2] (gal HC/acre-yr)**		
	Biodegradation	**Dissolution**	**Total**
MW-6 to MW-10	5.1	1.2	6.4
MW-6 to MW-11	64	8.5	73
MW-6 to MW-22	50	0.61	50
Average Rates	40	3.4	43

Notes:

[1] = ITRC 2009. Evaluating Natural Source Zone Depletion at Sites with LNAPL, LNAPL-1, Technology Overview, Interstate Technology & Regulatory Council, Washington D.C., 76 pp.

[2] = Biodegradation rate assumes a hydrocarbon density of 0.97 g/mL and a formula of $C_{10}H_{22}$.

Abbreviations:

gal HC/acre-yr = gallons of hydrocarbons per acre per year

Table 36

Vadose Zone NSZD Rates for LNAPL Hydrocarbons
BNSF Black Tank Site
Spokane, Washington

Vadose NSZD Rate (gal/acre-yr)	Details	Reference
655	Heavily weathered crude oil, Guadalupe Oil Field (average).	Lundegard and Johnson, 2006.
1,800	Weathered crude oil from Bemidji, Minnesota, crude oil spill.	Sihota et al., 2011.
2,100–7,700	Former refinery site, including heavy oils.	McCoy et al., 2014.
100s–1000s	Review of vadose zone NSZD rates for petroleum LNAPLs.	Lyverse, 2014.
510 - 630	Three separate crude oil release sites in Canada.	Palaia et al., 2014.
850	Waste oil release site in Canada.	Palaia et al., 2014.
540	Diesel fuel release site in Canada.	Palaia et al., 2014.

Abbreviations:
gal HC/acre-yr = gallons of hydrocarbons per acre per year
NSZD = Natural Source Zone Depletion
LNAPL = Light Non-Aqueous Phase Liquid

Table 37

Cleanup Technologies for Surface Soil
BNSF Black Tank Site
Spokane, Washington

Technology	Description	Effectiveness	Implementability	Retained
Institutional Controls	Erect a fence around the Site (cannot cross rail lines), post signs warning of contamination, and install security equipment. File an environmental covenant on the property deed acknowledging the presence of surface soil contamination and requirements for managing risks from contact with contaminated soil in the event that the Site is redeveloped.	Surface soil is a direct contact risk only. Institutional controls restrict access to surface soil.	There are no administrative or technical impediments to implementation. Not affected by highway construction.	Yes
Excavation	Mechanically remove contaminated soil to 15 ft bgs (MTCA standard point of compliance). Dispose soil at permitted landfill. Backfill and compact excavations with clean imported fill soil.	Effective and commonly employed technology for eliminating risks associated with contaminated surface soil.	There are no administrative impediments to implementation. Excavation of would need to occur before highway construction if the 2014 WSDOT highway alignment is adopted.	Yes
Capping	Construct physical barrier over contaminated soil areas to prevent direct contact and reduce leaching potential. Multiple cap materials and design approaches possible.	Effective and commonly employed technology for reducing risks associated with contaminated surface soil.	There are no administrative impediments to implementation. Capping would need to occur before highway construction if the 2014 WSDOT highway alignment is adopted. Environmental covenant required because contamination remains at Site above cleanup levels.	Yes
Natural Source Zone Depletion	Natural degradation processes reduce TPH concentration over time without active intervention.	Data from field testing demonstrates that NSZD is effectively reducing contaminant mass at the Site. However, unlikely to achieve surface soil cleanup levels.	Natural ongoing process. Requires no infrastructure to implement. Environmental covenant required until cleanup levels achieved.	No
Soil Vapor Extraction	Extract air from the subsurface via wells screened in the vadose zone to volatilize and recover hydrocarbons at the ground surface. Treat extracted air as needed to meet local air regulations.	Soil vapor extraction would not be effective because of the low vapor pressure of the heavy oil and diesel contamination present in surface soil.	There are no administrative or technical impediments to implementing soil vapor extraction technology at the Site. Infrastructure would need to be installed before highway construction if the 2014 WSDOT alignment is adopted.	No
Bioventing	Inject air into the subsurface or extract air from the subsurface via wells at a rate that oxygenates the vadose zone and accelerates aerobic biodegradation of hydrocarbons. Treat extracted air as needed to meet local air regulations.	Bioventing can effectively enhance the rate of NSZD observed to be occurring at the Site. However, unlikely to achieve surface soil cleanup levels.	There are no administrative impediments to implementing bioventing technology at the Site. Infrastructure would need to be installed before highway construction if the 2014 WSDOT alignment is adopted.	No

Notes:
Gray shaded rows identify technologies retained for developing cleanup actions.

Abbreviations:
ft bgs = feet below ground surface
MTCA = Model Toxics Control Act
NSZD = Natural Source Zone Depletion
TPH = Total Petroleum Hydrocarbons
WSDOT = Washington State Department of Transportation

Table 38

Cleanup Technologies for Cleanup of Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

Technology	Description	Effectiveness	Implementability	Retained
Deep Soil Excavation	Mechanically remove contaminated soil deeper than 15 ft bgs and extending to the smear zone (~170 ft bgs) using non-standard shoring methods. Dispose soil at permitted landfill. Backfill and compact excavations with a combination of clean excavated soil and clean imported fill soil.	Can be effective but is not commonly employed for deep contamination. Site data show that only two intervals of intermediate soil (one at 66 to 67 feet bgs and the other at 116 to 117 feet bgs) covering an area of approximately 9,150 square feet exhibit petroleum hydrocarbon concentrations exceeding the preliminary CULs. Because the volume of shallow and intermediate contamination requiring cleanup is low, deep soil excavation would be highly inefficient for this Site.	Impractical to implement at extreme depths (e.g., to the smear zone) because of the extraordinary shoring efforts, non-standard construction equipment and logistics, requirement for vast area for staging clean soil, and need to shutdown active rail corridor and neighboring businesses during implementation. This technology also carries with it high risks to worker health and safety and geotechnical risks associated with long-term settling.	No
Hydraulic Containment[1]	Construct and operate extraction wells equipped with total fluids pumps to prevent LNAPL and dissolved-phase contaminant migration. Treat extracted groundwater and recycle oil.	Not effective as a standalone cleanup technology because the LNAPL and dissolved-phase plume are stable under current conditions and there are no closely proximate downgradient resources or receptors to protect. Effective as a containment component for cleanup action that mobilizes LNAPL and the dissolved-phase plume.	Extraction wells can be installed at the Site and standard technologies exist for extracting and treating the extracted groundwater and possibly LNAPL. Not influenced by highway alignment.	Yes - in conjunction with other technologies that require groundwater extraction
Physical Containment	Construct slurry or sheet pile walls to prevent off-Site LNAPL migration.	Not effective as a standalone cleanup technology because the LNAPL and dissolved-phase plume are stable within under current conditions and there are no closely proximate downgradient resources or receptors to protect.	Extreme depths to which physical barriers would need to be constructed present significant technical challenges and would require non-standard construction equipment and shutdown of the active rail corridor during implementation.	No
Manual LNAPL Removal	Manually bail LNAPL from wells screened in the smear zone of the mobile LNAPL area. Recycle recovered oil.	Site LNAPL transmissivity data and skimming test data indicate that manual bailing will result in low LNAPL mass removal relative to total mass of mobile LNAPL present in the subsurface.	Recovery wells can be installed, but will require high density well spacing and significant manual labor for the technology to be effectively implemented. This technology carries with it high risks to worker health and safety because of the constant and repetitive manual labor. Cannot be implemented within the 2014 WSDOT highway alignment.	Yes
Total Fluids Recovery[1]	Construct and operate extraction wells equipped with total fluids pumps to remove LNAPL and groundwater from within the mobile LNAPL area. Treat extracted groundwater and recycle oil.	LNAPL transmissivity analysis concludes that recovery by extraction-based technologies is not practicable under ambient conditions. However, the technology is effective as a component of an enhanced recovery application (see below).	Extraction wells can be installed at the Site and technologies exist for removing and treating the extracted LNAPL and groundwater, but installation of a high-density recovery well network and specialty pumps capable of recovering the high-viscosity LNAPL would be necessary for effective implementation. Cannot be implemented within the 2014 WSDOT highway alignment.	Yes - in conjunction with other technologies that require groundwater extraction

Technology	Description	Effectiveness	Implementability	Retained
Dual-Phase Extraction	Depress groundwater table by recovering fluids from extraction wells constructed in the smear zone to expose LNAPL in normally saturated soil then place vacuum on extraction wells to recover LNAPL. Treat extracted groundwater[1] and soil gas and recycle oil.	LNAPL transmissivity analysis concludes that recovery by extraction-based technologies is not practicable under ambient conditions. Additionally cleanup of heavy oil via vapor extraction is not effective due to the minimal volatility of the LNAPL present at the Site.	Extraction wells can be installed at the Site and technologies exist for removing and treating the extracted LNAPL, groundwater and soil gas; however, vapor extraction is not effective for the Site conditions. Without vapor extraction, this technology becomes total fluids recovery, which has been retained for further analysis.	No
Natural Source Zone Depletion	Natural degradation processes reduce LNAPL mass.	Data from field testing demonstrates that NSZD is effectively reducing contaminant mass at the Site.	Natural ongoing process. Requires no infrastructure to implement. Not influenced by highway alignment.	Yes
Bioventing	Inject air into the subsurface via an injection well network to oxygenate vadose zone contamination and accelerate aerobic biodegradation of hydrocarbons.	Bioventing can effectively enhance the rate of NSZD observed to be occurring at the Site. Seasonal fluctuation in water table aids in overcoming LNAPL to water/air mass transfer limitations.	There are no administrative impediments to implementing bioventing technology at the Site. Infrastructure would need to be installed before highway construction if the 2014 WSDOT highway alignment is adopted. Pilot testing is required to obtain design parameters.	Yes
Heated Bioventing	Construct same as bioventing (see above). Preheat injected air to increase formation temperatures (up to 30 degrees C) to increase aerobic biological activity.	See above for bioventing. Higher operating temperature can increase bio-kinetics and reduce restoration timeframe.	Technology has not been implemented at sites with similar conditions, but there is an increasing body of literature supporting its implementability. Infrastructure would need to be installed before highway construction if the 2014 WSDOT highway alignment is adopted. Requires pilot testing before full-scale operation. Could be implemented as an add-on to bioventing.	Yes
Biosparging	Inject air into the aquifer via an injection well network to oxygenate saturated zone contamination and accelerate aerobic biodegradation of hydrocarbons.	Biosparging, coupled with bioventing, can effectively enhance the rate of NSZD observed at the Site, in the vadose and saturated zones.	Infrastructure installed for bioventing can also be used for biosparging, and would require installation before highway construction if the 2014 WSDOT highway alignment is adopted. Pilot testing is required to obtain design parameters.	Yes
Biostimulation – Sulfate Injection	Inject a sulfate solution (an anaerobic electron acceptor) into the subsurface via an injection well network to accelerate anaerobic biodegradation of hydrocarbons.	Injection of electron acceptor can enhance the rate of NSZD observed to be occurring at the Site and reduce restoration timeframe. Technology has not been proven for conditions at this Site. Requires injection of significant volumes of chemical to be effective.	Injection of chemicals to sole-source aquifer requires significant administrative approvals, carries risk, and is likely an impediment to public acceptance. Technology has not been implemented at sites with similar conditions or contaminants.	No
Solidification	Using large-diameter augers, drill to smear zone and perform deep soil mixing and inject solidifying additives (e.g., cement) to reduce LNAPL mobility.	Solidification can reduce mobility of LNAPL; however, LNAPL and dissolved-phase plume are stable within the Site boundary under current conditions and there are no closely proximate downgradient resources or receptors to protect. Technology also does not destroy or reduce the volume of LNAPL.	Impractical to implement at extreme depths. Typical depth limits for deep soil mixing is about 130 ft bgs[3]; whereas Site contamination is at 170 ft bgs. Can result in significant variability of treated soil strength.	No

Table 38

Cleanup Technologies for Cleanup of Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

Technology	Description	Effectiveness	Implementability	Retained
Smoldering Combustion	Install air injection wells and ignition sources into the smear zone then initiate combustion of LNAPL. Sustain/propagate combustion by injecting oxygen into the subsurface to achieve *in-situ* thermal destruction of LNAPL.	Test data from other sites suggests the technology may be effective; however, technology is in development; not proven at full-scale for Site conditions.	Pilot testing required for proof-of-concept and to generate design information. Potential to cause soil instability. Soil heterogeneity may limit propagation of combustion front. Would need to be implemented before highway construction if the 2014 WSDOT highway alignment is adopted.	Yes
Steam-Enhanced LNAPL Removal[1,2]	Inject steam below the groundwater table and the smear zone via an injection well network to elevate soil and groundwater temperatures. Recover mobilized LNAPL and groundwater by total fluids extraction. Treat extracted groundwater and recycle oil.	Steam injection and total fluids recovery have been demonstrated effective for removing hydrocarbon mass from coarse-grained, permeable lithology but not from silty sand.	Additional modelling or pilot testing required confirming proof-of-concept and providing design information. Resource intensive (low sustainability) technology. Would need to be implemented before highway construction if the 2014 WSDOT highway alignment is adopted.	Yes
Enhanced Recovery[1] (Surfactants)	Inject surfactant solution into the smear zone via an injection well network to increase LNAPL mobility. Recover mobilized materials and prevent plume expansion by total fluids recovery. Treat extracted groundwater and recycle oil.	Largely an experimental technology that has failed to gain traction and wide use in the industry. No full-scale projects in the literature for conditions similar to the Site. Chemical delivery to silty sand difficult.	Injection of chemicals to sole-source aquifer carries risk and is likely an impediment to public acceptance. High rate of groundwater extraction and treatment required to achieve containment and recovery. Some surfactants are toxic, but non-toxic and biodegradable surfactants exist. Pilot testing required for confirming surfactant type and proof-of-concept and for providing design information.	No
ISCO and Enhanced Extraction[1]	Inject oxidant(s) into the smear zone via an injection well network to chemically oxidize LNAPL residues, increase mobility, and stimulate biodegradation. Use total fluids recovery, as needed, to recover mobilized materials and prevent plume expansion. Treat extracted groundwater and recycle oil.	ISCO technologies are not considered applicable to LNAPL sites with low volatility and low solubility hydrocarbons. Volume of oxidant required to oxidize LNAPL many times greater than volume of contamination. Chemical delivery to silty sand difficult.	Injection of chemicals to sole-source aquifer carries risk (from injectate and potential mobilization of metals) and is likely an impediment to public acceptance. Volume of oxidant required to treat LNAPL is unreasonably high. This technology carries with it a high risk to worker health and safety because of potential exposure to strong oxidants. Pilot testing required confirming proof-of-concept and providing design information.	No

Notes:
An environmental covenant is an assumed component of the selected cleanup actions. Also, groundwater monitoring is an assumed component of the selected cleanup action.
Gray shaded rows identify technologies retained for developing cleanup actions.

[1] Extracted fluids are treated at the surface, as needed and using any of several standard wastewater treatment technologies depending on the composition of the fluids produced. Treated water is discharged to the sanitary sewer.

[2] Electrical resistive heating is another thermal technology. Steam was selected as the representative thermal process option.

[3] Source: U.S. Department of Transportation. 2013. *Federal Highway Administration Design Manual: Deep Mixing for Embankment and Foundation Support*. Publication No. FHWA-HRT-13-046. October.

Abbreviations:
ft bgs = feet below ground surface
ISCO = In-Situ Chemical Oxidation
LNAPL = Light non-aqueous phase liquid
MTCA = Model Toxics Control Act
NSZD = Natural Source Zone Depletion
SVE = Soil vapor extraction
TPH = Total Petroleum Hydrocarbon
WSDOT = Washington State Department of Transportation

DRAFT

Table 39

Cleanup Actions for Deep Contamination
(LNAPL, Intermediate Soil, Groundwater)
BNSF Black Tank Site
Spokane, Washington

Cleanup Action	Low RTF LNAPL Area[1]	Medium RTF LNAPL Area[1]	High RTF LNAPL Area[1] and Intermediate Soil[2]	Groundwater
A[3]	NSZD	NSZD	NSZD	Monitoring and Institutional Controls
B		Bioventing/Biosparging	Bioventing/Biosparging	
C		Bioventing/Biosparging	Bioventing/Biosparging and Manual LNAPL Removal	
D		Bioventing/Biosparging	Bioventing/Biosparging and Steam Enhanced Extraction	
E		Smoldering Combustion	Smoldering Combustion	

Notes:
Groundwater monitoring and institutional controls will apply to all cleanup actions.

[1] The LNAPL area is divided into low, medium, and high RTF areas based on the remediation level analysis (see Section 8.5).

[2] Intermediate Soil refers to soil that exceeds cleanup levels between the LNAPL smear zone at the water table and the standard point of compliance for surface soils (15 feet bgs). The footprint of the Intermediate Soil generally coincides with the High RTF LNAPL area.

[3] Cleanup Action A is included for informational purposes only; it does not meet the MTCA threshold requirement that prohibits reliance on natural processes alone to cleanup LNAPL sites (see Section 8.1.2.4).

Abbreviations:
ft bgs = feet below ground surface
LNAPL = Light non-aqueous phase liquid
NSZD = Natural Source Zone Depletion
RTF = Restoration timeframe

Table 40

Case Studies of LNAPL Removal Using Bioventing
BNSF Black Tank Site
Spokane, Washington

Case Study	Citation
Bioventing for Heavy Hydrocarbons: Cold Regions Lab pilot study gave bioventing rate of **3.2 mg/kg-day** for heavy fuel oils, **Bunker C,** and crude oil.	Reynolds et al., 1997.
Bioventing for Bunker C: At Washington Water Power Central Steam Plant, Spokane, Washington, obtained biodegradation of ~**3,700 gal/year** for **Bunker C fuel oil** (based on reported flow rates and oxygen concentrations).	Ecology, 2014.
Bioventing for Coal Tar: At the Reilly Tar site, bioventing rates obtained in **0.6 to 2.2 mg/kg-day** range.	Alleman et al., 1995.
Bioventing for LNAPL Removal: Site in South Korea with release of mixed fuels including **Bunker C** gave bioventing rates of **2.7 to 4.8** mg/kg-d.	Lee, J. et al., 2001.
Bioventing for Heavy Hydrocarbons: Laboratory studies found greater than **5 mg/kg-day** at 4 sites containing various heavy oils.	Lee and Swindoll, 1993.
Bioventing for LNAPL Removal: In describing how bioslurping works (slide 150) to reduce LNAPL that bioventing occurs as well as increased aerobic biodegradation due to the venting aspect of bioslurping.	ITRC, 2016.
Bioventing for LNAPL Removal: At Eielson AFB, bioventing was used successfully at seven jet fuel sites with significant free product.	Biestel, 2003 & 2004
Bioventing for LNAPL Removal: "Bioventing is one of the most cost effective and efficient technologies for fuel hydrocarbon contaminated sites." Including jet fuel free product sites.	AFCEE. 1996.
Bioventing for Crude Oil: At sites in Alaska, obtained bioventing rates of 0.9 to 15 mg/kg-day. At Tecate, Italy crude oil blow-out site, obtained bioventing rates of **5 to 10 mg/kg-day**.	Hinchee Personal Experience.
Bioventing for Railroad Diesel: At Great Falls, Montana BNSF site, obtained bioventing rates of **1.2 to 1.6 mg/kg-day**.	BNSF Experience.
SVE & Bioventing for LNAPL Removal: Review of SVE states that SVE can remove free product. Also states that for lower vapor pressure compounds that bioventing (biodegradation) is the removal mechanism.	Fam et. al., 1995.
SVE & Bioventing for LNAPL Removal: In field example of gasoline and oil spill, SVE and bioventing removed significant free product.	Dasch et al., 1997.
SVE for LNAPL Removal: Describes the process by which mass was removed from a "free-liquid gasoline" during SVE.	Johnson et al., 1990.
SVE for LNAPL Removal: States that SVE is an effective technique for the removal of free product.	Trowbridge, B.E., and Malot, J.J., 1990.

Abbreviations:
gal/year = gallons per year
LNAPL = Light Non-Aqueous Phase Liquid
mg/kg-day = milligram per kilogram per day
SVE = Soil Vapor Extraction

DRAFT

Table 41

Estimated Remedial Timeframes for the Black Tank Site
BNSF Black Tank Site
Spokane, Washington

Area (acre)	Technology	Residual[1] LNAPL (above smear zone)		Mobile LNAPL		Total LNAPL	Removal Rate	Time[2] to Remediate
		gallons	gal/acre	gallons	gal/acre	gal/acre	gal/yr	
Low RTF (3.5)	NSZD	21,000	6,100	9,000	2,600	8,700	800	7 years
Medium RTF (1.7)	Bioventing	N/A	N/A	84,000	49,000	49,000	5,900	8 years
High RTF (0.8)	Bioventing	N/A	N/A	66,000	83,000	83,000	5,900	14 years

Notes:

[1] Half of this mass was used in the NSZD calculations, it does not enter the bioventing calculations. See text for details.

[2] Using 800 gal/acre-yr for NSZD, if the lower 250 gal/acre-yr based on flux chamber measurements the estimated cleanup time for the passive area would be 22 years; 5,870 gal/acre-yr for bioventing.

Abbreviations:
gal/acre = gallons per acre
gal/year = gallons per year
LNAPL = Light Non-Aqueous Phase Liquid
NSZD = Natural Source Zone Depletion
RTF = Restoration Time Frame

DRAFT
Table 42

Bioventing Enhancements for Heavy Hydrocarbons
BNSF Black Tank Site
Spokane, Washington

Bioventing Enhancement	**Mode of Action**
Increased air flow (existing wells)	Increases oxygen input rate and expands radii of influence of injection wells to promote biodegradation.
Combining air injection with extraction in a push-pull configuration	Can improve air and oxygen distribution at depth.
Increased density of injection wells	Increases overlap of radii of influence of injection wells, thus increasing oxygen concentrations to promote biodegradation. Minimizes stagnant zones of low oxygen levels.
Biosparging	Increases oxygen levels in saturated zone, increase biodegradation rates in saturated zone.
Heated bioventing[1]	Biodegradation rates increase with increased temperature.

[1] Heated bioventing can increase biodegradation rates over unheated bioventing. Leeson et al. (1995) found that biodegradation rates more than doubled with a 10˚C temperature rise (see also Beyke and Fleming 2005; and Zeman 2013). Injection of heated ambient air is not an efficient means of increasing soil temperature because of heat transfer limitations (air has a low heat capacity relative to soil). However, injection of heated air that is conditioned to near 100% relative humidity overcomes this heat transfer limitation (i.e., higher heat capacity) and is considered an effective means of elevating in situ soil temperature. A temperature increase of about 20˚C can be achieved in approximately 1 year of injecting fully humidified 40˚C air.

DRAFT
Table 43

Summary of Example SEE Sites
BNSF Black Tank Site
Spokane, Washington

Site	COCs	Contaminant Zone and Depth	Soil Type	Year of SEE Implementation	Steam Goal (Volatilization or Mobilization/Recovery)	Follow-up Technology Required	Success in Achieving Site RAOs	Would Meet Equivalent MTCA LNAPL standards?	Costs	Concerns
		(feet bgs)								(Known Failures)
Black Tank Site	LNAPL: bunker C, asphaltic compounds, diesel	Vadose zone: 0-160 Smear zone: 145-170	Fine-Med Sands; interbedded silty sand layers							High viscosity, even after heating. Incomplete heating and recovery because of heterogeneous geology.
Arnold AFB	DNAPL: chlorinated solvents	Saturated zone: 60 to 90	Coarse gravel over weathered bedrock	2010 -2011	Volatilization	Technologies under consideration: Pump and Treat; Dual Phase Extraction	Did not achieve drinking water standards; did not achieve performance goal of 150 ug/L PCE; changed performance goal to 1500 ug/L. Site average gw conc after treatment was 1000 ug/L.	N/A	$12.5M/ 0.25 acre	High heat loss; Permeable unit, too much cold water flowing into treatment area precluded achieving target temperatures.
Beede Waste Oil Site	LNAPL: waste oils	Vadose zone:0-28 Saturated Zone: 16- 28	Gravelly and fine sands	Pilot: 2013	Mobilization/ recovery and some volatilization	Additional SEE planned for Phase 2 Treatment	Declared success, but not quantified. Sheen still visible in wells.	No. Product still present in wells.	~ $7.5M/acre	
Loring AFB	LNAPL: gasoline DNAPL: chlorinated solvents	Saturated zone: 30-65 on eastern side 45-95 on western side	Fractured bedrock	Pilot: 2002	Volatilization	Technical Impractibility Waiver issued as part of final groundwater remedy. Ongoing testing of remedial technologies at this site. Natural attenuation.	ARARs not achieved.	No. Product still present in wells.	$250K/16 lbs removed	Highly complex; low interconnectivity; low permeability (lower steam injection rates than anticipated); excessive heat loss; potential mobilization of DNAPL.
Pacific Wood Treating Corp	DNAPL: Creosote & PCP; metals	Saturated zone: 40	Silts and sands	2004-2011	Mobilization/ recovery and volatilization	Groundwater extraction	Clean Closure Certificate received 10/2012.	N/A		
Visalia Pole Yard	LNAPL: Diesel oil w/PCP DNAPL: Creosote & PCP	Smear and saturated zone: 80 to ~100	Fine to coarse sands	Pilot: 1997-2000	Mobilization/ recovery and volatilization	Air sparging/bioventing to enhance biodegradation	Achieved groundwater cleanup standards.	No. Product still present in wells.	$22.5M	

DRAFT
Table 43

Summary of Example SEE Sites
BNSF Black Tank Site
Spokane, Washington

Site	COCs	Contaminant Zone and Depth (feet bgs)	Soil Type	Year of SEE Implementation	Steam Goal (Volatilization or Mobilization/Recovery)	Follow-up Technology Required	Success in Achieving Site RAOs	Would Meet Equivalent MTCA LNAPL standards?	Costs	Concerns (Known Failures)
Williams AFB	LNAPL: JP-4 Jet Fuel	Saturated zone (due to 80'+ rise in water table)	Mostly sand with silty layers	Pilot: 2008-2010;	Mobilization/ recovery and volatilization	Enhanced bioremediation	Not expected to achieve cleanup standards; LNAPL remains.	No. Product still present in wells.	~$12 M for pilot	
		145-195 and 210-240		Full scale: Oct/2014-					~$20M full scale	
Wyckoff/Eagle Harbor	DNAPL: Creosote, PCBs	LNAPL Impacts: 8-35	Sand and gravel	Pilot: 6-month study in 2003	Mobilization/ recovery and volatilization	In-Situ Solidification, pump and treat	Not successful – little LNAPL recovered; implemented in-situ solidification.	No. Product still present in wells.	$10M for pilot	
		Vadose Zone: 0-15								
		Saturated zone: > 15								

DRAFT

Table 44

Evaluation of Threshold Requirements for Deep Contamination Cleanup Actions
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

MTCA Requirements and Evaluation Factors		Cleanup Actions for Deep Contamination[1]					Notes
		A[2]	B	C	D	E	
		NSZD	Bioventing/ Biosparging	Bioventing/ Biosparging and Manual LNAPL Recovery	Bioventing/ Biosparging and Steam Enhanced Extraction	Smoldering Combustion	
Threshold Requirements	Protect human health and the environment	Protective	Protective	Protective	Protective	Protective	All cleanup actions will meet the preliminary CULs over varying periods of time. Until CULs are met, human health would be protected by: 1) controlling access to the Site; 2) prohibiting development of groundwater at the Site through an environmental covenant; and 3) monitoring groundwater to ensure that the LNAPL and dissolved-phase contaminant plumes decline in response to the cleanup actions.
	Comply with cleanup standards	Complies	Complies	Complies	Complies	Complies	All cleanup actions are expected to remove mobile LNAPL and reduce contaminant concentrations in the intermediate soil, smear zone soil, and groundwater to levels that meet the preliminary CULs.
	Comply with applicable state and federal laws	Does not Comply	Complies	Complies	Complies	Complies	Cleanup Actions B through E can be designed and implemented to comply with applicable state and federal laws. Cleanup Action A does not meet the MTCA threshold requirement that prohibits reliance on natural processes alone to address LNAPL (see Section 8.1.2.4).
	Provide for compliance monitoring	Complies	Complies	Complies	Complies	Complies	Contamination is confined to the Site and standard monitoring techniques (e.g., groundwater monitoring) can be used to evaluate cleanup actions and changes in conditions that could increase risk to human health and the environment.

Notes:

Groundwater monitoring and institutional controls apply to all cleanup actions.

[1] See Table 39 for detailed accounting of how technologies are applied to the Low, Medium and High RTF LNAPL areas.

Abbreviations:

CUL = Cleanup level
LNAPL = Light non-aqueous phase liquid
MTCA = Model Toxics Control Act
NSZD = Natural Source Zone Depletion

DRAFT
Table 45

Evaluation of Permanency to the Maximum Extent Practicable for Deep Contamination (Intermediate Soil, LNAPL, and Groundwater)

BNSF Black Tank Site
Spokane, Washington

	Evaluation Factor	A - NSZD[1]	B - Bioventing/Biosparging[2]	C - Bioventing/Biosparging and Manual LNAPL Recovery[2]	D - Bioventing/Biosparging and SEE[2]	E - Smoldering Combustion[2]	Notes
OVERALL PROTECTIVENESS	Risk Reduction		5	5	5	5	Site poses moderate risk that is readily managed during cleanup by monitoring and institutional controls. All cleanup actions achieve the cleanup standards.
	Restoration Timeframe		4	5	7	7	The order of estimated restoration timeframes is ~14 years for Cleanup Action B, ~13 years for Cleanup Action C, and ~10 years for Cleanup Action D and ~7 years for Cleanup Action E.
	Active Remediation Time		3	4	7	8	The order of estimated periods of active remediation is as follows: Cleanup Action E (~3 years), Cleanup Action D (~10 years), Cleanup Action C (~ 13 years), and Cleanup Action B (~14 years). Active remediation time includes construction, operation, closeout, and Site restoration.
	Implementation Risks		10	5	4	1	Cleanup Action E has the highest implementation risk because it exposes workers to complex and risky process equipment, and the smoldering front could potentially spread to off-Site properties, reduce the structural integrity of the soil, generate emissions that migrate off Site, and mobilize dissolved phase contamination. Cleanup Action D also has a high implementation risk because it exposes workers to complex and risky process equipment, generates air emissions, and may mobilize petroleum hydrocarbon contamination in groundwater beyond the designed extraction system. Cleanup Action C has the third highest implementation risks because it has the highest drilling and manpower requirements (manually bailing LNAPL from wells), which results in high potential for worker injury and exposure to contaminants. Cleanup Action B has the fewest implementation risks.
	Overall Environmental Quality Improvement		5	5	5	5	Same for all cleanup actions because all meet the cleanup standards. Magnitude of scoring assumed moderate based on risk reduction (see above).
	DCA Score[3]		27	24	28	26	
	Rank[4]		3	1	4	2	
PERMANENCE	Degree of reduction in Toxicity, Mobility, and Volume of Hazardous Substances		4	5	6	8	Cleanup Action E uses combustion to reduce the toxicity, mobility, and volume of hazardous substances in the mobile and residual LNAPL; this process works well for all petroleum hydrocarbon types. Cleanup Actions B, C, and D use enhanced biodegradation and NSZD processes to reduce the toxicity, mobility, and volume of hazardous substances in the mobile and residual LNAPL. These processes work well for petroleum hydrocarbons. Cleanup Action C and D further reduce the volume of hazardous substances in the subsurface by removing mobile LNAPL, but they do not reduce the toxicity or mobility of the substances or destroy them.
	Adequacy of Hazardous Substance Destruction		5	4	3	8	Cleanup Action E uses in situ combustion to destroy petroleum hydrocarbons associated with mobile and residual LNAPL. Cleanup Actions B, C, and D use enhanced biodegradation or NSZD processes to destroy hazardous substances associated with mobile and residual LNAPL. Biodegradation works well to destroy short- and medium-chain hydrocarbons and is least effective at destroying long-chain petroleum hydrocarbons. Cleanup Actions C and D remove mobile LNAPL that can be recycled as opposed to destroyed.
	Reduction or Elimination of Releases and Sources of Releases		NA	NA	NA	NA	Not applicable. Primary release sources no longer exist at the Site. Surface soil cleanup actions will remove remaining subsurface infrastructure.
	Degree of Irreversibility of Waste Treatment Process		10	10	10	10	To the extent that treatment occurs within each cleanup action whether by biodegradation or combustion, the treatment reactions are irreversible. Therefore, all cleanup actions score the same.
	Characteristics and Quantity of Treatment Residuals Generated		10	8	3	7	The in situ LNAPL biodegradation components of Cleanup Actions B, C, and D generate no residuals that need to be managed. Cleanup Actions C and D generate LNAPL and contaminated groundwater at the ground surface that need to be managed. Cleanup Action D generates a much larger volume of contaminated groundwater than Cleanup Action C. The vapor phase combustion product from Cleanup Action E is, for FS purposes, assumed to require no treatment.
	DCA Score		29	27	22	33	
	Rank		3	2	1	4	

DRAFT
Table 45

Evaluation of Permanency to the Maximum Extent Practicable for Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

	Evaluation Factor	A - NSZD[1]	B - Bioventing/Biosparging[2]	C - Bioventing/Biosparging and Manual LNAPL Recovery[2]	D - Bioventing/Biosparging and SEE[2]	E - Smoldering Combustion[2]	Notes
LONG-TERM EFFECTIVENESS	Certainty of Success		8	4	4	2	Cleanup Action E has the lowest certainty of success because it is a developing technology not previously implemented on a full-scale basis at sites with similar conditions. Cleanup Actions C and D have medium-low certainty because they utilize technologies that have not successfully met remediation criteria at similar sites. Moreover, they require LNAPL extraction and the low transmissivity of the LNAPL at the Site indicates hydraulic recovery is poor. Cleanup Action B has the highest certainty of success because it utilizes technologies (bioventing and biosparging) that have been successfully implemented on a full-scale basis at multiple sites having similar conditions and contaminants.
	Long-term reliability		6	7	8	2	Assumed to be equivalent to scoring for certainty of success because all cleanup actions are predicted to achieve the cleanup levels.
	Magnitude of Residual Risk		8	8	8	9	Cleanup Action E leaves the smallest residual risk because it employs a technology (combustion) that destroys the most petroleum hydrocarbons. Cleanup actions B, C, and D will have similar residual risk because they all remove or destroy the same volume of petroleum hydrocarbons (i.e., enough to address the mobile LNAPL).
	Effectiveness of Controls Required to Manage Treatment Residues and Remaining Waste		9	6	3	6	Cleanup Actions B, C, and D generate small quantities of investigation-derived waste (IDW) from drilling and monitoring activities that can be effectively managed on Site pending transport off Site for disposal. Cleanup Action C also generates moderate quantities of LNAPL and contaminated water that do not require treatment. Cleanup Action D generates relatively large quantities of LNAPL and contaminated water that require treatment. If additional hydraulic control is needed to contain the petroleum hydrocarbon plume, then even more contaminated groundwater will require treatment. The wastes and/or the treatment residuals from Cleanup Action D can be effectively managed on Site pending transport off Site for recycling or disposal, but the required effort is significant. Cleanup Action E generates moderate quantities of IDW.
	DCA Score		31	25	23	19	
	Rank		4	3	2	1	

DRAFT
Table 45

Evaluation of Permanency to the Maximum Extent Practicable for Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

	Evaluation Factor	A - NSZD[1]	B - Bioventing/Biosparging[2]	C - Bioventing/Biosparging and Manual LNAPL Recovery[2]	D - Bioventing/Biosparging and SEE[2]	E - Smoldering Combustion[2]	Notes
MANAGEMENT OF SHORT-TERM RISKS	Protection of Human Health During Construction		8	2	2	2	Risk to worker health and safety during construction is directly related to the quantity of drilling and construction activities required by each cleanup action. Worker protection is highest for Cleanup Action B because it has the lowest drilling requirements. Worker protection is significantly lower for Cleanup Actions C, D, and E because of higher drilling and construction requirements.
	Protection of Human Health During Implementation		8	2	3	2	Cleanup Action B has the least implementation risks because it is a commonly employed, straightforward technology that can be monitored remotely with a good safety record. Cleanup Action E has higher implementation risks because it has moderate manpower requirements for operation of moderately complex process equipment and it has the potential to negatively impact adjacent parcels is the combustion front is not adequately managed. Cleanup Action D has high implementation risks resulting from operation of complex, high-temperature process and total fluids recovery equipment. Cleanup Action C has high implementation risks because of the high manpower requirements to bail deep wells and the potential for worker exposure to LNAPL.
	Protection of the Environment During Construction and Implementation		9	6	3	3	Cleanup actions that can potentially mobilize contamination in groundwater and/or generate residuals that could impact the groundwater could have a negative impact on the environment. Additionally, cleanup actions that generate untreated waste and/or air emissions also have a negative impact on the environment. The scoring for this subfactor is based on the information described above for "Effectiveness of Controls Required to Manage Treatment Residues and Remaining Waste" and "Characteristics and Quantity of Treatment Residuals Generated."
	DCA Score		25	10	8	7	
	Rank		4	3	2	1	

DRAFT
Table 45

Evaluation of Permanency to the Maximum Extent Practicable for Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

	Evaluation Factor	**A - NSZD[1]**	**B - Bioventing/Biosparging[2]**	**C - Bioventing/Biosparging and Manual LNAPL Recovery [2]**	**D - Bioventing/Biosparging and SEE[2]**	**E - Smoldering Combustion[2]**	**Notes**
IMPLEMENTABILITY	Technically Possible		8	8	5	1	Based on their full-scale implementation at many sites having similar contaminants and conditions, Cleanup Actions B and C have the highest technical possibility score because both have been implemented elsewhere successfully. Cleanup Action D has been implemented on a full-scale basis at other sites but not with similar conditions and not with much success. Cleanup Action E has been implemented at a pilot scale at a few sites and full-scale on one site, but at no sites having similar conditions.
	Availability of Necessary Facilities, Services, and Materials		10	10	8	5	All of the necessary facilities, services, and materials to implement Cleanup Actions B and C are readily available in the Site vicinity; therefore, those cleanup actions receive high scores. The expertise, equipment, and materials needed to implement Cleanup Action D are all available in the western U.S., but not all are available in the Site vicinity; therefore, this cleanup action receives a moderately high score. The expertise, facilities, services, and materials needed for Cleanup Action E are only available from Savron in Toronto, Canada and thus, this cleanup action gets a moderate score.
	Administrative and Regulatory Requirements		9	8	4	7	The primary administrative and regulatory requirements for implementation include construction and operation permitting, institutional controls to manage Site access, and compliance with environmental regulations for waste management and air emissions. The institutional controls requirements are similar for all of the cleanup actions. Cleanup Action B has the least requirements because all it will require is a building permit, followed by Cleanup Action C, which will require a building permit and ongoing compliance with waste management regulations for LNAPL storage and disposal/recycling. Cleanup Action E will likely require building permits and possibly air emissions permits. Cleanup Action D has the highest regulatory burden because it will require a building permit, air emissions permit, wastewater discharge permit as well as ongoing monitoring and compliance with air emissions, wastewater, and waste management regulations.
	Project Scheduling, Size, and Complexity		8	6	2	3	Cleanup Actions D and E are the most complex and thus, receive the lowest scores. They require specialized expertise, relatively high design review, complex infrastructure, and pilot testing to evaluate performance and develop design criteria. Cleanup Action C is more complex to implement than Cleanup Action B; therefore, Cleanup Actions B and C receive progressively higher scores.
	Monitoring Requirements		8	8	3	3	Moderately low levels of groundwater and NSZD monitoring are required for Cleanup Actions B and C. Cleanup Actions D and E require moderate groundwater monitoring to ensure that the induced heat is not mobilizing contamination and thermal monitoring to evaluate system performance. Cleanup Action E also requires air emissions and wastewater effluent monitoring, giving it a high total monitoring requirement and the lowest score.
	Access for Construction, Operation, and Monitoring		8	2	6	6	The majority of the Site is currently owned and operated by one of the PLPs. Therefore, access can be easily arranged for all cleanup actions. If the NSC is constructed across the treatment area, then access for construction, operation, and monitoring would be more difficult, particularly for cleanup actions that have infrastructure within the NSC footprint (i.e., Cleanup Actions C, D, and E). Cleanup Action B receives the highest score because 1) the infrastructure can be configured to exist outside of NSC pavement limits and 2) the wells do not require downhole equipment so can be angled beneath the NSC if necessary. Cleanup Action C receives the lowest score because of greater risk of being impacted by the NSC project. Also, LNAPL extraction wells cannot be angled beneath the NSC. Cleanup Actions D and E score moderately well because of the short implementation periods for SEE and smoldering combustion.
	Integration with Existing (*and anticipated future*) Facility Operations		9	5	6	6	All of the cleanup actions can be integrated with current facility operations. However, the degree of integration difficulty increases with increases in permanent infrastructure installed in or around existing rail lines. Cleanup Actions D and E involve the most complex in ground and above ground infrastructure. Cleanup Action B has the greatest flexibility to be integrated with the NSC project regardless of the NSC project schedule and alignment. Cleanup Actions D and E have less flexibility but short implementation timeframes that may be compatible with the NSC project schedule. Cleanup Action C has a fairly long implementation timeframe and the greatest potential to conflict with the NSC project.
	Integration with Other Current or Potential Remedial Actions		9	9	9	9	The cleanup action for surface soil (capping and/or excavation) is the only other cleanup action currently known for the Site, and all of the deep contamination cleanup actions can be easily integrated with that cleanup action.
	DCA Score		69	56	43	40	
	Rank		4	3	2	1	

DRAFT
Table 45
Evaluation of Permanency to the Maximum Extent Practicable for Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

	Evaluation Factor	A - NSZD[1]	B - Bioventing/Biosparging[2]	C - Bioventing/Biosparging and Manual LNAPL Recovery[2]	D - Bioventing/Biosparging and SEE[2]	E - Smoldering Combustion[2]	Notes
CONSIDERATION OF PUBLIC	Public Concerns						
	DCA Score		0	0	0	0	
	Rank						
Cumulative DCA Rank			18	12	11	9	

Notes:

[1] Cleanup Action A is shaded gray to show that it is included in the table for informational purposes only. This cleanup action does not meet the MTCA threshold criterion of WAC 173-340-360 (c)(ii)(A) that requires "*Treatment or removal of the source of the release …. for liquid wastes, areas contaminated with high concentrations of hazardous substances, highly mobile hazardous substances, or hazardous substances that cannot be reliably contained. This includes removal [of] free product consisting of petroleum and other light nonaqueous phase liquid (LNAPL) from the ground water using normally accepted engineering practices.*"

[3] The DCA Score is obtained by summing the subfactor score for each permanency factor evaluated. Each subfactor is scored between 1 and 10, with 1 being the least favorable score and 10 the most favorable score based on the cleanup action's ability to meet the permanency factor evaluated (e.g., not effective, not permanent, carries high short-term risks, difficult to implement).

[4] Rank is determined by ordering the DCA scores for each of the five cleanup actions from 1 to 4.

Abbreviations:

DCA = Disproportionate cost analysis
LNAPL = Light non-aqueous phase liquid
NA = Not applicable
NSZD = Natural Source Zone Depletion
PLP = Potentially liable person
RTF = Restoration timeframe

Table 46

Estimated Restoration Timeframes for Cleanup Actions
BNSF Black Tank Site
Spokane, Washington

LNAPL Area	**Estimated Restoration Timeframes for Cleanup Actions**			
	B	**C**	**D**	**E**
	Bioventing/ Biosparging	**Bioventing/ Biosparging and Manual LNAPL Recovery**	**Bioventing/ Biosparging and Steam Enhanced Extraction**	**Smoldering Combustion**
Low RTF	7 years	7 years	7 years	7 years
Medium RTF	8 years	8 years	8 years	3 years
High RTF	14 years	13 years	10 years[1]	3 years
Site-wide RTF	~14 years	~13 years	~ 10 years	~ 7 years

Notes:

[1] Assumes 3 years of SEE treatment and an additional 7 years of treatment for residual mobile LNAPL with bioventing/biosparging

Abbreviations:

LNAPL = Light non-aqueous phase liquid

RTF = Restoration Timeframes

DRAFT

Table 47

Summary Estimates of Total Cleanup Action Costs

(Intermediate Soil, LNAPL, and Groundwater)

BNSF Black Tank Site

Spokane, Washington

Deep Contamination Cleanup Actions				Estimated Site-Wide Cleanup Action Costs				
Cleanup Action	Low RTF LNAPL Area	Medium RTF LNAPL Area	High RTF LNAPL Area and Intermediate Soil	Surface Soil[1]	Low RTF LNAPL Area	Medium and High RTF LNAPL Areas	Groundwater	Grand Total
B	NSZD	Bioventing/ Biosparging	Bioventing/Biosparging	$1,455,000	$344,000	$3,156,000	$496,000	$5,451,000
C	NSZD	Bioventing/ Biosparging	Bioventing/Biosparging and Manual LNAPL Recovery	$1,455,000	$344,000	$6,593,000	$496,000	$8,888,000
D	NSZD	Bioventing/ Biosparging	Bioventing/Biosparging and Steam Enhanced Extraction	$1,455,000	$344,000	$16,319,000	$686,000	$19,500,000
E	NSZD	Smoldering Combustion	Smoldering Combustion	$1,455,000	$344,000	$22,588,000	$686,000	$25,073,000

[1] Excavation is the recommended cleanup action for surface soil (see Section 10.3)

Note: See Appendix V for detailed cleanup action cost estimates.

DRAFT
Table 48

Cleanup Action Ranking Summary for Deep Contamination
(Intermediate Soil, LNAPL, and Groundwater)
BNSF Black Tank Site
Spokane, Washington

MTCA Requirements and Evaluation Factors		A: NSZD	B: Bioventing/ Biosparging	C: Bioventing/ Biosparging and Manual LNAPL Recovery	D: Bioventing/ Biosparging and Steam Enhanced Extraction	E: Smoldering Combustion
Threshold Requirements	Protect human health and the environment	Protective	Protective	Protective	Protective	Protective
	Comply with cleanup standards	Complies	Complies	Complies	Complies	Complies
	Comply with applicable state and federal laws	Does not Comply	Complies	Complies	Complies	Complies
	Provide for compliance monitoring	Complies	Complies	Complies	Complies	Complies
Use Permanent Solution to the Maximum Extent Practicable	Overall protectiveness	NA	3 ◕	1 ◔	4 ●	2 ◑
	Permanence	NA	3 ◕	2 ◑	1 ◔	4 ●
	Long-term effectiveness	NA	4 ●	3 ◕	2 ◑	1 ◔
	Management of short-term risks	NA	4 ●	3 ◕	2 ◑	1 ◔
	Implementability	NA	4 ●	3 ◕	2 ◑	1 ◔
	Consideration of public concerns	NA	0	0	0	0
	Cumulative Rank	NA	18 ●	12 ◕	11 ◑	9 ◔
Costs	**Deep Contamination Cleanup Costs**	NA	$3,996,000	$7,433,000	$18,045,000	$23,618,000
	Total Estimated Cleanup Costs[1]	NA	$5,451,000	$8,888,000	$19,500,000	$25,073,000

Notes:

[1] Total estimated cleanup costs include cost of surface soil cleanup (estimated at $1,455,000).

Abbreviations:

LNAPL = Light non-aqueous phase liquid
MTCA = Model Toxics Control Act
NA = Not applicable
NSZD = Natural Source Zone Depletion

Rank:

1 ◔ = Low
2 ◑ = Medium
3 ◕ = Medium-High
4 ● = High

Appendix A
Key Historical Records

Appendix B
Representative Aerial Photographs

Appendix C
Vertical Hydraulic Gradient Evaluation

Appendix D
Soil Core Photographs and LNAPL Mobility Characterization Data Reports

Appendix E
Test Pit Logs

Appendix F
Soil Boring & Monitoring Well Construction Logs

Appendix G
LNAPL Fluid Properties Characterization Data Reports

Appendix H
Well Development Logs

Appendix I
Groundwater Purge and Sample Logs

Appendix J
Data Validation Memoranda and Laboratory Analytical Reports

Appendix K
Survey Data

Appendix L
Terrestrial Ecological Evaluation

Appendix M
MTCATPH 11.1 Calculations

Appendix N
Residual Soil Saturation Calculations

Appendix O
Representative Chromatograms

Appendix P
Tabulated Laboratory Analytical Data

Appendix Q
LNAPL Vertical Profiles and Modeling Inputs and Outputs

Appendix R
LNAPL Transmissivity Evaluation

Appendix S
Saturated Zone NSZD Calculations

Appendix U
Groundwater Modeling Report

Appendix V
Thermal Model

Appendix W
Detailed Remedial Cost Estimates