Glacier Park East Site Leavenworth, WA

Supplemental Remedial Investigation Work Plan

October 26, 2020
TRC Project No. 329229
FSID No. 349
CSID No. 4234
AO No. DE 16838

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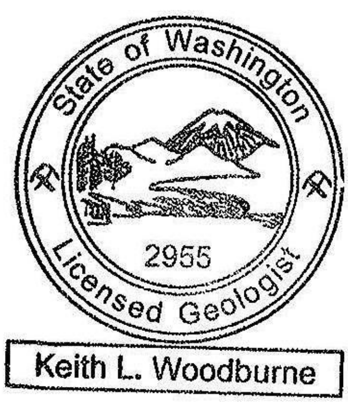

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ACRONYM LIST

’01 AO	2001 Agreed Order
AO	Agreed Order
AST	Aboveground storage tank
bgs	Below ground surface
BNSF	BNSF Railway Company
BTEX	Benzene, toluene, ethylbenzene, and total xylenes
CAP	Cleanup Action Plan
COC	Constituent of concern
CSM	Conceptual Site Model
CUL	Cleanup level
CUSA	Chevron U.S.A., Inc.
DCAP	Revised Draft Cleanup Action Plan
DRO	Diesel-range organics
Ecology	Washington State Department of Ecology
°F	Degrees Fahrenheit
GRO	Gasoline-range organics
HASP	Health & Safety Plan
LNAPL	Light non-aqueous phase liquid
MTCA	Model Toxics Cleanup Act
ORO	Oil-range organics
PID	Photoionization detector
QAPP	Quality Assurance Project Plan
RCW	Revised Code of Washington
RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SGC	Silica gel cleanup
Site	Glacier Park East Site
SOP	Standard Operating Procedure
SFS	Supplemental Feasibility Study
SRI	Supplemental Remedial Investigation
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
TRC	TRC Environmental Corporation
UECA	Uniform Environmental Covenants Act
µg/L	Micrograms per liter
WAC	Washington Administrative Code
WP	Work Plan

1.0 Introduction

On behalf of BNSF Railway Company (BNSF) and Chevron U.S.A., Inc. (CUSA), TRC Environmental Corporation (TRC) is providing this Supplemental Remedial Investigation Work Plan (SRI WP) to the Washington State Department of Ecology (Ecology) pursuant to Agreed Order (AO) No. DE 16838 Scope of Work for the Glacier Park East Site (Site).

1.1 Supplemental Remedial Investigation Purpose

Pursuant to the prior Agreed Order No. DE 01TCPCR-3168, dated September 25, 2001 ('01 AO), a 2002 Cleanup Action Plan (CAP), which presented soil isolation and groundwater monitoring as the preferred remedial alternative, was submitted and approved by Ecology. Diesel-range organics (DRO) and oil-range organics (ORO) concentrations have exceeded Model Toxics Control Act (MTCA) Method A cleanup levels (CULs) at multiple locations since post-construction groundwater monitoring has been initiated. In addition, gasoline-range organics (GRO) and benzene were detected at concentrations greater than MTCA Method A CULs in samples from MW-3. On March 15, 2018, Ecology issued a determination that the accepted remedy is insufficient to meet the MTCA cleanup standards (Ecology, 2018). The basis for the determination was that the cleanup levels are not being attained at the standard points of compliance (throughout the Site).

Based on Ecology's determination, Ecology, BNSF, and CUSA entered into a new AO dated January 22, 2020 (Ecology, 2020). Under the 2020 AO, additional soil and groundwater investigation is required to refine the Conceptual Site Model (CSM) and prepare an SRI Report, Supplemental Feasibility Study (SFS) Report, and revised Draft Cleanup Action Plan (DCAP).

1.2 SRI WP Organization

The SRI WP is organized into the following Sections:

- Section 1.0: Introduction – Purpose for the SRI and outline of the SRI WP
- Section 2.0: Background – General Site information, history, and use
- Section 3.0: Environmental Setting – Summaries of regional climate, regional and local geology, groundwater occurrence, depth, and flow directions
- Section 4.0: Summary of relevant existing information
- Section 5.0: Current Conditions – Nature and extent of soil and groundwater impacts, description of current remedy, identification of data gaps
- Section 6.0: Proposed Field Activities and Permitting
- Section 7.0: Schedule
- Section 8.0: References
- Appendix A: Quality Assurance Project Plan (QAPP) and Sampling and Analysis Plan (SAP)
- Appendix B: Health & Safety Plan (HASP).

2.0 Background

The Site is located northeast of the intersection of U.S. Highway 2 and Chumstick Highway (formerly State Route 209) in Leavenworth, Chelan County, Washington (Figure 1). The City of Leavenworth is in the upper reaches of the Wenatchee River valley at an elevation of approximately 1,170 feet above mean seal level.

The Glacier Park East property is a vacant 1-acre lot located in a small depression bordered by U.S. Highway 2 to the southeast, Chumstick Highway to the southwest, the BNSF right-of-way to the northwest, and Chelan County Public Utilities District property to the northeast. Ponderosa pine trees cover most of the eastern portion of the property. The remaining area is sparsely vegetated and generally covered with coarse gravel and an asphaltic concrete cap, as described in Section 3.0 of this report. The Wenatchee River is located approximately 800 feet to the southeast.

2.1 Site History and Use

The property was undeveloped until the mid-1920s when Standard Oil Company of California leased the property from Great Northern Railroad. A bulk fuel storage facility was constructed on the property, the exact date of construction is unknown.

Historical structures consisted of one 20,000-gallon aboveground storage tank (AST), one 13,000-gallon AST, a pump house, a warehouse/office building, a loading rack providing petroleum products to tank trucks, and an unloading rack for receiving product from rail tank cars. Two smaller ASTs (approximately 5,000 gallons each) were reportedly used to store gasoline for a short period based on 1967 and 1979 aerial photographs. The locations of historical structures are shown on Figure 2. These structures were removed in 1990.

The property was used as a staging area to store equipment and soil associated with US Highway 2 bridge construction over the Wenatchee River in 1992. Prior to cap placement, the City of Leavenworth placed snow from plowing onto the central portion of the property.

3.0 Environmental Setting

The environmental setting of the property is an important consideration for the asphaltic concrete cap isolation remedy, which is designed to prevent vertical infiltration of precipitation through impacted soil and leaching of petroleum hydrocarbons from soil to groundwater. The cap is also intended to prevent recharge to the transient perched groundwater, reducing the potential for perched groundwater to come in contact with impacted soil beneath the cap. The current monitoring well network includes a total of six monitoring wells (MW-1 through MW-6) and three transient perched groundwater piezometers (PZ-1 through PZ-3) as shown on Figure 2.

3.1 Regional Climate

Leavenworth is located within the rain shadow of the Cascade Mountains. The orographic lifting of air masses as they pass the Cascade Mountains causes much of their moisture to be deposited on the windward (western) slope and near the crest. The average annual precipitation in the Leavenworth area is approximately 24 inches. Approximately 80 percent of the precipitation falls between October 1 and March 1 in the Leavenworth area. Most of the winter precipitation occurs as snow. Snow cover is found on the ground in Leavenworth about 110 days during the year.

January is the coldest month in the region, with an average daily maximum temperature of 33 degrees Fahrenheit (°F) and an average daily minimum temperature of 16°F. July is the warmest month with an average daily maximum temperature of 89°F and an average daily minimum temperature of 51°F.

3.2 Regional Geology

The stratigraphic profile of the Wenatchee River Valley consists of a complex mixture of Quaternary alluvium and glacial deposits. The regional stratigraphic sequences generally consist of:

- Quaternary Alluvium – Surficial deposits composed of moderately sorted gravel and cobbles along rivers grading to poorly sorted gravelly sand with silt in tributaries.
- Pleistocene Glacial Drift – Surficial deposits date from the most recent glaciation. The glacial drift consists primarily of till on slopes and valley sidewalls grading to outwash gravel on the valley floors. Glacial drift exists below the Site to an unknown depth. The drift is composed of silt and sand with abundant gravel and cobbles.
- Chumstick Formation – White to gray sandstone with interbedded pebbly sandstone, shale and conglomerates of Tertiary Age.

3.3 Site-Specific Geology

The central area of the property was filled with approximately 10 to 15 feet of clean imported soil prior to capping with asphaltic concrete. Based on information from soil boring and well completion logs, the native subsurface soil is primarily composed of approximately 10 to 25 feet of silty sand overlying a 5 to 20 feet layer of sandy silt that overlies a layer of poorly graded sand with silt and gravel. Not all monitoring wells, however, screen these same soil layers (Figure 3). At well MW-5, fine to coarse gravel underlain by gravel with sand and silt was encountered at approximately 45 feet below ground surface (bgs), extending to approximately 60 feet bgs. The upper portion of the screened interval for MW-5 is completed within the gravel layer. These gravel units were not noted in any other borings, except for two separate thin gravel layers in MW-4.

3.4 Hydrogeology

Groundwater occurs in two separate zones, a shallow transient zone of perched groundwater that is sporadically observed and laterally discontinuous, and a deeper aquifer that is continuous beneath the Site. The deeper aquifer is encountered at a depth of approximately 50 to 75 feet bgs. Groundwater elevation data are provided in Table 1. A thin zone of transient perched groundwater was encountered at approximately 14 feet bgs during installation of monitoring well HC-2. The perched groundwater was later observed in piezometers PZ-1, PZ-2, and PZ-3, which were installed in 2016. Although no water was initially observed following installation of the piezometers, approximately 5 feet of water was observed in PZ-2 during the February 2017 gauging event, and perched groundwater was observed in all three shallow piezometers in April and May 2017. Since then, no perched groundwater has been observed in PZ-1 and PZ-3, but perched groundwater has been routinely observed in PZ-2, except for two events in November 2018 and November 2019.

Prior groundwater monitoring reports have estimated a northwesterly groundwater flow direction in the deeper aquifer based on inclusion of the relatively low groundwater elevations measured in well MW-5. GeoEngineers, Inc. noted in their 2001 report, *Monitoring Well Installation and Ground*

Water Analyses, Glacier Park East Site, Leavenworth, Washington, that well MW-5 appeared to be screened in a less permeable silt as compared to other wells (GeoEngineers, 2001). This may be the cause for significantly lower groundwater elevations in well MW-5 compared to other wells. Groundwater elevation in MW-6 (installed in 2017) confirms a northwesterly groundwater flow direction (Figure 4).

4.0 Summary of Relevant Existing Information

BNSF and CUSA entered into Agreed Order No 94TC-C441 with Ecology in 1995. A Remedial Investigation and Feasibility Study (RI/FS) was completed in accordance with the AO and the associated report was submitted to Ecology in 1997. Soil and groundwater data presented in the RI/FS Report supported the conclusion that shallow soil was impacted by petroleum hydrocarbons at concentrations greater than MTCA Method A CULs due to historical releases from the former ASTs and other historical operations. Further, infiltration of precipitation through the shallow impacted soil served as an ongoing source of dissolved petroleum hydrocarbon impacts to shallow transient perched groundwater and to the deeper aquifer, as shown on Figure 5.

Based on the findings and conclusions of the RI/FS, BNSF and CUSA entered into Agreed Order No. DE 01TCPCR-3168 ('01 AO) with Ecology in September 2001. The AO specified the selected cleanup action as soil isolation. The soil isolation cleanup action was implemented by placement of clean fill over the shallow impacted soil to bring the ground surface elevation higher than the elevation of surrounding roadways and installation of an asphaltic concrete cap. Additionally, the '01 AO set forth requirements for the installation of three additional monitoring wells and quarterly groundwater monitoring for a minimum of 5 years (Ecology, 2001).

Quarterly groundwater monitoring was performed from 2001 to 2006. In 2007 the groundwater sampling frequency was reduced to semi-annual monitoring with the understanding that four quarters of clean groundwater analytical results would be required to receive a No Further Action (NFA) determination (Ecology, 2007).

An Environmental Covenant for the Site that met the requirements of the Uniform Environmental Covenants Act (UECA) was filed with Chelan County and provided to Ecology on November 26, 2012. The Environmental Covenant included restrictions on property use, groundwater use, soil disturbance, and soil use.

Based on an Ecology Site evaluation during their September 2014 presentation, it was Ecology's opinion that the source of the fluctuating concentrations of constituents of concern (COCs), specifically GRO, DRO, ORO and benzene, in groundwater samples from wells MW-3 and MW-4 are from mobilization and migration of COCs in groundwater resulting from infiltration of precipitation (primarily snow melt) beneath the cap.

Three piezometers, PZ-1, PZ-2, and PZ-3 were installed at locations adjacent to the edge of the cap in 2016-2017 to characterize the potential presence and lateral extent of the suspected shallow transient perched water bearing zone. The presence of a shallow perched water-bearing zone was confirmed by the presence of water in one or more of the piezometers during water level gauging events performed between November 2016 through November 2019 (Table 1). In addition, a soil sample from PZ-2 had detections of GRO and naphthalene at concentrations greater than the MTCA Method A CULs (Table 2).

Monitoring well MW-6 was installed southeast of the capped area (within the City of Leavenworth right of way) in May 2017 as shown on Figure 2. The groundwater elevation in MW-6 was greater than the on-Site wells for all monitoring events since installation, indicating that MW-6 is hydraulically upgradient and the groundwater flow direction is from MW-6 toward the west-northwest. Additionally, there were no detections of COCs in the groundwater sample collected from well MW-6 following installation and development, and there has been only one detection of DRO and ORO without silica gel cleanup (SGC) in well MW-6 (204 micrograms per liter [µg/L] and 335 µg/L, respectively, in June 2018) in the six semi-annual monitoring events conducted between May 2017 and November 2019.

On March 15, 2018, Ecology issued a determination of insufficiency in meeting the cleanup standards following implementation of the soil isolation remedy outlined in the 2002 cleanup action plan (CAP). Ecology determined the 2002 CAP would need to be revised and that revision would require additional remedial investigation to define the extent of impacts and refine the CSM adequate to evaluate alternatives in an updated SFS.

BNSF, CUSA, and Ecology agreed on a Scope of Work and schedule for completion of the requirements under the new Agreed Order No. DE 16838 (2020 AO), which include a supplemental RI that fully further characterizes the Site and a SFS that is sufficient to prepare a revised DCAP.

4.1 Description of the Current Remedy

The current remedy approved by Ecology and implemented in 2003 is a combination of engineering and institutional controls. Engineering controls include raising the grade above impacted soil with clean fill and capping. Institutional controls are implemented through an environmental covenant. These measures were designed to isolate soil with DRO and ORO at concentrations greater than MTCA Method A CULs from exposure to potential receptors and to limit leaching to groundwater by preventing infiltration of precipitation through the impacted soil. Performance of the approved remedy is evaluated through periodic groundwater monitoring. The engineering and institutional controls comprising the current remedy are summarized below.

4.1.1 Engineering Controls

Soil isolation consists of approximately 10 to 15 feet of imported clean fill soil that raises the surface elevation to higher than that of surrounding roadways with a layer of asphaltic concrete placed over the soil. The edges of the raised cap are surrounded by a large rock barrier to prevent erosion and limit access to the surface of the cap. The location and extent of the capped soil isolation area is depicted on Figure 2.

4.1.2 Institutional Controls

An environmental covenant that met the requirements of the UECA was filed with Chelan County and provided to Ecology on November 26, 2012. The environmental covenant included restrictions on property use, groundwater use, and soil disturbance.

5.0 Current Conditions

Soil and groundwater are media of concern based on detected concentrations of one or more COCs at concentrations greater than MTCA Method A CULs in those media. COCs for soil are DRO, ORO, GRO, benzene, toluene, ethylbenzene, and total xylenes (BTEX), and naphthalene.

COCs for groundwater are DRO, ORO, GRO, and benzene. CULs for soil are the MTCA Method A Soil Cleanup Levels for Unrestricted Land Uses as defined in Table 740-1 of Washington Administrative Code (WAC) 173-340-900. CULs for groundwater are the MTCA Method A Cleanup Levels for Ground Water as defined in Table 720-1 of WAC 173-340-900 (Ecology, 2013). The nature and extent of soil and groundwater impacted by COCs at concentrations greater than MTCA Method A CULs are described in the following sections

5.1 Nature and Extent of Soil Impacts

The presence of petroleum-impacted shallow soil beneath the capped area at the former bulk fuel storage area is believed to be from releases from ASTs that were historically used to store petroleum fuels and oils. The vertical extent of petroleum-impacted soil is depicted in two cross sections on Figure 3. The historical lateral extent of petroleum-impacted soil present beneath the capped area is depicted on Figure 6. In 2016, a soil sample collected in the borehole for PZ-2 had detections of GRO and naphthalene at concentrations greater than MTCA Method A CUL (Table 2), extending the estimated lateral extent of soil impacts beyond the capped area to the northeast Additional data are needed to bound the lateral extent of petroleum hydrocarbons in soil and to assess if impacted soil outside the asphaltic concrete is a potential source to groundwater

5.2 Nature and Extent of Groundwater Impacts

Since 2001, a total of 49 groundwater monitoring events have been conducted at the Site. A summary of historical groundwater analytical results is provided in Table 3 and the most recent results, during the 2019 second semi-annual groundwater monitoring event, are presented on Figure 4. Graphs depicting groundwater elevation versus total petroleum hydrocarbons (TPH) concentrations for wells MW-2, MW-3, and MW-4 are included as Figures 7, 8, and 9, respectively.

Based on the analytical results from the most recent groundwater sampling events, DRO and ORO concentrations in samples analyzed without SGC exceed the MTCA Method A CULs in MW-3 and MW-4. However, using SGC, DRO and ORO concentrations are not detected at the laboratory reporting limits, 200 µg/L and 250 µg/L, respectively, (Figure 5).

Monitoring wells were installed with long screen intervals that were screened across multiple lithologic units, including in some cases impacted soil (Figures 2 and 3).

5.3 Additional Data Requirements

Concentrations of petroleum hydrocarbons in groundwater at the site have not decreased as originally anticipated when the cap was installed. Based on a March 2018 letter from Ecology (Ecology, 2018) and recent communications with Ecology, the following additional data requirements have been identified. The data requirements are presented with the specific proposed investigation tasks designed to provide those data in the table below:

Data Requirements	Proposed Investigation Tasks
Groundwater COCs are not vertically characterized. Potential exists for stratification of groundwater COC plume within discrete lithologic units.	Depth-discrete groundwater sampling over three intervals at the six existing monitoring wells. (see Section 6.2)

Data Requirements	Proposed Investigation Tasks
The horizontal and vertical extent of petroleum hydrocarbons in soil beneath and northeast of the cap needs to be further characterized.	Soil sampling at multiple depths in proposed shallow borings SB-1 through SB-6 and potential step out borings performed for further lateral characterization in the vicinity of SB-1 through SB-3, if warranted (see Section 6.3)
Does transient perched groundwater persist beneath the cap, and if so, is it impacted with petroleum hydrocarbons.	Install and sample transient perched groundwater piezometer PZ-4 at boring location SB-5 or SB-6 (see Section 6.4)
Further understand the nature of groundwater gradient and flow direction	Perform 1-year of water levels data logging with transducers installed in MW-1 through MW-6 (see Section 6.5)
Obtain hydraulic conductivity data to further characterize and resolve ambiguity in groundwater flow direction and potential plume migration direction.	Perform slug tests in monitoring wells MW-1 through MW-6 and conduct groundwater monitoring (see Sections 6.4, 6.6, and 6.7)
MW-5 was installed by air rotary and detailed stratigraphic information is not present.	Perform detailed stratigraphic logging at deep borehole GWB-1 (see Section 6.3)

6.0 Proposed Field Activities and Permitting

6.1 Pre-Field Activities / Utility Clearance

A Site-specific Health and Safety Plan (HASP) has been prepared for current and proposed field activities and is provided as Appendix B. Upon Ecology approval of the scope of work in this SRI WP, and following contractor selection, the HASP will be updated.

Soil boring and monitoring well locations will be identified and cleared per the procedures outlined in the Quality Assurance Project Plan and Sampling and Analysis Plan (QAPP/SAP; Appendix A).

In addition, a private utility locator will be contracted to confirm the absence of buried utilities at each proposed soil boring and monitoring well location. Prior to drilling the soil borings and monitoring wells, a pilot hole will be advanced using a hand auger or air-knife to a depth of approximately 5 feet bgs to verify the absence of buried utilities.

A Notice of Intent for the installation of resource protection wells and associated fees will be submitted to Ecology at least 72 hours prior to mobilization in accordance with WAC Chapter 173-160 Section 151. This is the only identified permitting requirement for this SRI WP.

6.2 Depth-Discrete Groundwater Sampling

One round of depth-discrete groundwater samples will be collected from each of the six existing monitoring wells (MW-1 through MW-6). The samples will be collected at the top, middle, and bottom of the screens of each groundwater monitoring well, at depths outlined in Table 4. If the water level inside a specific well does not allow for the three specific targeted depths listed on Table 4, the sample depths will be adjusted based on the well boring log and the length of the water column inside the well to allow for at least two distinct sample depths per monitoring well while trying to target different lithological units.

Depth-discrete groundwater samples will be collected using snap samplers, hydrosleeves, or equivalent sampling devices designed for no-purge depth-discrete groundwater sampling. Snap samplers and other no-purge depth-discrete sampling devices do not provide purge water or sufficient sample volume to measure and record groundwater field parameters. Despite this limitation, they are preferred over pumps because they are less likely to mix potentially stratified groundwater during deployment and sampling. If no-purge depth-discrete sampling devices do not function in the wells or are not available, groundwater sampling pumps may be used.

If pumps are used for depth-discrete groundwater sampling, low-flow sampling protocols described in the QAPP/SAP (Appendix A) will be followed. In addition, to minimize mixing of the water within each monitoring well, the samples will be collected in a top-down manner, collecting the top sample as the first sample, then the middle sample, and then the bottom sample.

The results of the depth-discrete groundwater sampling will be evaluated to determine if COC stratification is present in the saturated zone and if higher concentrations are present in a particular lithologic unit or zone. If COC stratification is present, future sampling events will target the zone of highest COC concentrations in the well, and that information will be used during the lateral groundwater delineation effort discussed in Section 6.3 to assist with well screen interval selection.

6.3 Soil Borings

Six soil borings are proposed to be advanced to the depth of known or anticipated petroleum-impacted soil (SB-1 through SB-6, Figure 6). Four soil borings (SB-1, SB-2, SB-3, and SB-4) will be advanced near the northeast perimeter of the cap to delineate the extent of petroleum-impacted soil, which is anticipated to differ from what was delineated prior to the cap installation in 2003. Two soil borings (SB-5 and SB-6) will be advanced through the cap in areas of known impacts. SB-5 or SB-6 will serve as a pilot boring for the installation of piezometer PZ-4 completed in the transient perched groundwater as described in Section 6.4.

The soil borings located outside of the sloped edge of the cap area (SB-1, SB-2, and SB-3) will be advanced to an anticipated depth of 25 feet bgs. If petroleum-impacted soil exceeding MTCA Method A cleanup levels found at SB-1, SB-2, or SB-3, additional soil borings may be advanced to further delineate the lateral extent of impacts. The soil borings located within the footprint of the cap (SB-4, SB-5, and SB-6) will be advanced to an anticipated depth of 35 feet bgs. The proposed depths represent the maximum anticipated depth of petroleum-impacted soil based on the cross sections (Figure 3). If petroleum-impacted soil is identified via visual or field screening methods, the soil borings will be advanced to the depth where petroleum-impacted soil is no longer observed, or to the maximum anticipated depth.

One soil boring (GWB-1, Figure 6) will be advanced into the saturated zone to an anticipated depth of 80 feet bgs. GWB-1 will be located just north of the cap and near MW-5 as described in Section 6.4. GWB-1 will be continuously logged from grade to total depth of 80 feet bgs to provide a detailed stratigraphic log of lithology with focus on identification of potential transmissive zones within the saturated zone encountered at approximately 50 feet bgs. A detailed understanding of the stratigraphy and identification of highly transmissive zones will lead to a better understanding of groundwater flow and distribution of COCs in groundwater.

Continuous soil cores will be collected and logged at each location. Each core sample will be logged in accordance with the Unified Soil Classification System (USCS; ASTM D-2487) and will include:

- Soil description (color, texture, structure, moisture/wetness, odor);
- Depth to groundwater;
- Total depth; and
- Drill rig type and drilling method.

Odors and/or elevated volatile compound readings of the soil will be documented (using a photoionization detector [PID], or equivalent) at appropriate intervals or by targeting zones displaying visual or olfactory evidence of impact. PID readings will not be collected from soil samples obtained from below the water table to avoid damage to the PID. If visual evidence of impact and/or elevated volatile compound readings are present, a sheen test will be done in the field and the descriptors will be recorded on the lithologic log. Field observations, including soil lithology and PID measurements, will be used to try to determine the vertical extent of the petroleum-impacted soil, in accordance with the QAPP/SAP (Appendix A).

Up to three soil samples are anticipated to be collected from each soil boring, as summarized in Table 5. If petroleum-impacted soils observed, one soil sample will be collected at the top of the petroleum-impacted soil, one in the middle of the petroleum-impacted soil, and one just below the petroleum-impacted soil. If several discrete petroleum-impacted soil lenses are observed throughout a boring, a sample will be collected from the top layer and from the bottom layer, and at a depth below the bottom layer of impact to define the maximum depth of impact. If field observations and screening methods do not clearly identify petroleum impacts in soil, two soil samples will be collected from each boring at depths indicated in Table 5. The soil samples will be collected following the methods outlined in the QAPP/SAP (Appendix A) and will be analyzed for TPH as DRO, ORO, and GRO, and BTEX.

6.4 Monitoring Well Installation

Soil boring SB-5 or SB-6 will be converted to a transient perched groundwater piezometer designated PZ-4 (Figure 6). PZ-4 will provide groundwater data necessary to assess any potential contact of transient perched groundwater with petroleum-impacted soil beneath the cap. Based on the current understanding of the distribution of petroleum-impacted soil beneath the cap, it is anticipated that SB-5 will be the soil boring converted to PZ-4. However, if field observations and soil PID readings indicate that the soil is visually more impacted at SB-6 compared to SB-5, PZ-4 will be installed at SB-6. PZ-4 will be constructed as a 4-inch diameter, flush-threaded, Schedule 40, polyvinyl chloride (PVC) well with a screened interval appropriate to intersect the observed petroleum-impacted soil beneath the cap. The exact screen length and depth interval will be determined in the field, but the total screen length will not exceed 10 feet and will be set in a silica sand filter pack. The 4-inch diameter casing will facilitate evaluation and removal of light non-aqueous phase liquid (LNAPL), if present.

Transient perched groundwater piezometer PZ-4 will be gauged and sampled following the groundwater sampling methods outlined in the QAPP/SAP (Appendix A). If present, the transient perched groundwater will be sampled and analyzed for TPH as DRO, ORO (with and without SGC), and GRO, and BTEX, as well as total organic carbon (TOC). consistent with routine groundwater sampling and analysis. The transient perched groundwater piezometers will also be gauged during future semi-annual groundwater sampling events to better understand presence and flow direction of the transient perched groundwater beneath the cap.

Following installation, new piezometer PZ-4 will be developed to remove fines from the sand filter pack and well casing. Well development will be performed per the standard operating procedure (SOP) presented in the QAPP/SAP in Appendix A.

6.5 Transducer Study

Six pressure transducers were deployed in monitoring wells MW-1 through MW-6 on August 20, 2019. The goal of the transducer study is to observe fluctuations in groundwater elevation, hydraulic gradient, and potential changes in groundwater flow direction through four seasons. Findings from the transducer study will be used to gain a better understanding of hydrogeology and will be incorporated into an updated CSM that will guide future remedy selection.

6.6 Slug Testing

Slug tests will be performed in all monitoring wells (MW-1 through MW-6) to measure hydraulic conductivity. The slug tests will be performed in accordance with the procedures outlined in TRC SOP 029 Slug Test Procedures included in the QAPP/SAP (Appendix A).

Slug tests will be performed by near-instantaneous raising or lowering the water level in each well, then measuring the change in water level with time as it rebounds to the static water level. Slug tests will be performed after the transducer study is completed (August 2020). The pressure transducers currently deployed in the wells will be utilized for data collection during the slug tests.

6.7 Groundwater Monitoring

The six existing wells (MW-1 through MW-6) will be gauged and sampled following the groundwater sampling methods documented in the QAPP/SAP (Appendix A). Additionally, transient perched groundwater piezometers PZ-1 through PZ-4 will be sampled if sufficient water is present. Samples will be analyzed for groundwater COCs, which include DRO and ORO (with and without SGC), GRO, and benzene, as well as total organic carbon (TOC). The sample depth in each monitoring well will be based on results of the depth-discrete sampling summarized in Section 6.2, or in absence of vertical stratification in the six existing wells, from the middle of the well screen. The sample depths in transient perched groundwater piezometers PZ-1 through PZ-4 will be based on the amount of water present at the time of sampling; it is anticipated that the sample depth will be approximately 2 feet below the top of the water column.

Additionally, to better understand the lateral extent of the current groundwater plume to the north, monitoring well MW-5 will be added to the semi-annual groundwater sampling schedule. Groundwater sampling at MW-5 was discontinued in 2007 as concentrations at MW-5 were less than the MTCA Method A CULs for GRO, DRO, ORO, and BTEX. However, with the addition of groundwater elevation data from MW-6, the groundwater flow direction appears to be toward the northwest. Based on the northwest groundwater flow direction, MW-5 is downgradient of impacted soil in the capped area and should be added to the semi-annual groundwater sampling schedule. If MW-5 is not a downgradient well, based on transducer data or contour maps with groundwater elevation data, then MW-5 should be not be added to the semi-annual groundwater sampling schedule.

7.0 Schedule

Contingent on Ecology approval of this SRI WP, activities will be performed per the estimated schedule below:

- Ecology approval of this SRI WP is anticipated within 90 days of submittal, including one round of revisions.
- The schedule is contingent on (1) receiving approval from Ecology, (2) acceptable weather conditions (i.e., no cover of snow), and (3) conditions are safe to proceed with the work based on the current COVID-19 restrictions.
- Depth-discrete groundwater sampling from the existing wells will be performed when conditions allow in 2020. ***The depth-discrete sampling is anticipated to be conducted in summer of 2020.***
- Following receipt of analytical results from the depth-discrete groundwater sampling, the data will be evaluated, and results of that evaluation will be used to finalize the target depths for future groundwater sampling in individual wells.
- Boring location marking and utility notifications will be performed, and subcontractors will be scheduled to complete the soil borings and well installations.
- Mobilization to the Site to complete the soil borings and piezometer PZ-4 installation. ***The anticipated start date for the soil boring/piezometer installation mobilization is late summer of 2020.***
- Following installation and development, the existing wells and piezometers, and the new piezometer PZ-4, will be gauged and sampled. ***The well sampling is anticipated to be conducted in September or October 2020.***
- Following completion of all above-listed field activities, and upon receipt of analytical results from all sampling conducted, the Draft SRI Report will be prepared. The report will present a summary of field work activities, including soil boring installation and monitoring well installation and development, along with a detailed discussion and presentation of soil and groundwater analytical results. The report will include an updated CSM and outline recommendations for any additional actions. The review of the analytical data and the preparation of the Draft SRI report are expected to take 90 calendar days to complete, following receipt of the validated analytical data.

8.0 References

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Tables

Table 1
Summary of Groundwater Elevation Data
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Well Elevation (feet)[a]	Date	Depth to Water (feet btoc)	Water Elevation (feet)	Change in Water Elevation (feet)
MW-1	1,149.84	10/5/2001	59.12	1,090.72	--
		12/20/2001	59.41	1,090.43	-0.29
		3/21/2002	59.12	1,090.72	0.29
		6/26/2002	57.29	1,092.55	1.83
		9/24/2002	57.70	1,092.14	-0.41
		12/18/2002	62.26	1,087.58	-4.56
	1,153.50	3/14/2003	65.22	1,088.28	--
		5/30/2003	60.30	1,093.20	4.92
	1,153.24	3/26/2004	60.44	1,092.80	--
		6/29/2004	56.45	1,096.79	3.99
		9/27/2004	60.50	1,092.74	-4.05
		12/1/2004	60.69	1,092.55	-0.19
		3/9/2005	61.10	1,092.14	-0.41
		6/29/2005	61.11	1,092.13	-0.01
		9/23/2005	61.82	1,091.42	-0.71
		12/30/2005	61.69	1,091.55	0.13
		3/28/2006	61.76	1,091.48	-0.07
		6/29/2006	58.89	1,094.35	2.87
		9/5/2006	59.23	1,094.01	-0.34
		12/11/2006	59.14	1,094.10	0.09
		3/30/2007	57.85	1,095.39	1.29
		9/6/2007	--	--	--
		4/29/2008	59.30	1,093.94	-1.45
		10/1/2008	59.22	1,094.02	0.08
		4/30/2009	59.36	1,093.88	-0.14
		10/12/2009	58.94	1,094.30	0.42
		4/29/2010	59.85	1,093.39	-0.91
	1,153.21	8/17/2010	59.10	1,094.11	--
		10/12/2010	59.90	1,093.31	-0.80
		4/28/2011	60.02	1,093.19	-0.12
		10/13/2011	58.29	1,094.92	1.73
		3/9/2012	59.34	1,093.87	-1.05
		6/20/2012	57.74	1,095.47	1.60
		9/20/2012	56.95	1,096.26	0.79
		12/11/2012	58.39	1,094.82	-1.44
		3/18/2013	59.31	1,093.90	-0.92
		12/4/2013	59.35	1,093.86	-0.04
		03/18/2014	60.08	1,093.13	-0.73
		06/19/2014	59.11	1,094.10	0.97
		11/19/2014	59.78	1,093.43	-0.67
		4/14/2015	59.80	1,093.41	-0.02
		11/3/2015	59.80	1,093.41	0.00
		6/1/2016	56.09	1,097.12	3.71
		11/9/2016	56.82	1,096.39	-0.73
		4/11/2017	57.97	1,095.24	-1.15
	1,157.11	5/30/2017	56.01	1,101.10	--
		11/8/2017	60.35	1,096.76	-4.34
		5/15/2018	56.38	1,100.73	3.97
		6/13/2018	56.29	1,100.82	0.09
		11/6/2018	57.89	1,099.22	-1.51
		6/19/2019	58.45	1,098.66	-2.16
		11/20/2019	59.87	1,097.24	-1.98

Table 1
Summary of Groundwater Elevation Data
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Well Elevation (feet)[a]	Date	Depth to Water (feet btoc)	Water Elevation (feet)	Change in Water Elevation (feet)
MW-2	1,150.95	10/5/2001	64.02	1,086.93	--
		12/20/2001	63.24	1,087.71	0.78
		3/21/2002	64.02	1,086.93	-0.78
		6/26/2002	58.14	1,092.81	5.88
		9/24/2002	59.53	1,091.42	-1.39
		12/18/2002	--	--	--
		3/14/2003	--	--	--
		5/30/2003	60.35	1,090.60	--
	1,161.19	3/26/2004	69.57	1,091.62	--
		6/29/2004	63.98	1,097.21	5.59
		9/27/2004	69.40	1,091.79	-5.42
		12/1/2004	69.98	1,091.21	-0.58
		3/9/2005	70.55	1,090.64	-0.57
		6/29/2005	70.20	1,090.99	0.35
		9/23/2005	72.34	1,088.85	-2.14
		12/30/2005	71.82	1,089.37	0.52
		3/28/2006	72.06	1,089.13	-0.24
		6/29/2006	66.46	1,094.73	5.60
		9/5/2006	68.72	1,092.47	-2.26
		12/11/2006	68.81	1,092.38	-0.09
		3/30/2007	66.48	1,094.71	2.33
		9/6/2007	67.05	1,094.14	-0.57
		4/29/2008	69.11	1,092.08	-2.06
		10/1/2008	68.96	1,092.23	0.15
		4/30/2009	68.23	1,092.96	0.73
		10/12/2009	68.60	1,092.59	-0.37
		4/29/2010	68.96	1,092.23	-0.36
	1,161.12	8/17/2010	68.02	1,093.10	--
		10/12/2010	68.91	1,092.21	-0.89
		4/28/2011	68.65	1,092.47	0.26
		10/13/2011	67.05	1,094.07	1.60
		3/9/2012	68.69	1,092.43	-1.64
		6/20/2012	66.03	1,095.09	2.66
		9/20/2012	66.40	1,094.72	-0.37
		12/11/2012	67.81	1,093.31	-1.41
		3/18/2013	68.02	1,093.10	-0.21
		12/4/2013	68.25	1,092.87	-0.23
		03/18/2014	68.99	1,092.13	-0.74
		06/19/2014	67.35	1,093.77	1.64
		11/19/2014	68.56	1,092.56	-1.21
		4/14/2015	67.92	1,093.20	0.64
		11/3/2015	68.42	1,092.70	-0.50
		6/1/2016	63.59	1,097.53	4.83
		11/9/2016	65.23	1,095.89	-1.64
		4/11/2017	66.58	1,094.54	-1.35
	1,165.01	5/30/2017	64.09	1,100.92	--
		11/8/2017	66.13	1,098.88	-2.04
		5/15/2018	64.59	1,100.42	1.54
		6/13/2018	64.23	1,100.78	0.36
		11/6/2018	66.70	1,098.31	-2.47
		6/19/2019	66.8	1,098.21	-0.10
		11/20/2019	68.61	1,096.40	-1.81

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Table 1
Summary of Groundwater Elevation Data
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Well Elevation (feet)[a]	Date	Depth to Water (feet btoc)	Water Elevation (feet)	Change in Water Elevation (feet)
MW-3	1,151.20	10/5/2001	60.38	1,090.82	--
		12/20/2001	61.06	1,090.14	-0.68
		3/21/2002	60.38	1,090.82	0.68
		6/26/2002	57.72	1,093.48	2.66
		9/24/2002	58.01	1,093.19	-0.29
		12/18/2002	64.56	1,086.64	-6.55
	1,156.35	3/14/2003	66.72	1,089.63	--
		5/30/2003	61.95	1,094.40	4.77
	1,156.34	3/26/2004	63.10	1,093.24	--
		6/29/2004	59.22	1,097.12	3.88
		9/27/2004	62.88	1,093.46	-3.66
		12/1/2004	63.99	1,092.35	-1.11
		3/9/2005	63.95	1,092.39	0.04
		6/29/2005	63.90	1,092.44	0.05
		9/23/2005	64.98	1,091.36	-1.08
		12/30/2005	67.80	1,088.54	-2.82
		3/28/2006	65.01	1,091.33	2.79
		6/29/2006	61.27	1,095.07	3.74
		9/5/2006	60.89	1,095.45	0.38
		12/11/2006	61.81	1,094.53	-0.92
		3/30/2007	60.60	1,095.74	1.21
		9/6/2007	58.71	1,097.63	1.89
		4/29/2008	62.10	1,094.24	-3.39
		10/1/2008	61.35	1,094.99	0.75
		4/30/2009	62.12	1,094.22	-0.77
		10/12/2009	61.46	1,094.88	0.66
		4/29/2010	63.01	1,093.33	-1.55
	1,156.29	8/17/2010	61.49	1,094.80	--
		10/12/2010	62.66	1,093.63	-1.17
		4/28/2011	62.58	1,093.71	0.08
		10/13/2011	59.96	1,096.33	2.62
		3/9/2012	62.12	1,094.17	-2.16
		6/20/2012	60.43	1,095.86	1.69
		9/20/2012	59.64	1,096.65	0.79
		12/11/2012	61.33	1,094.96	-1.69
		3/18/2013	62.30	1,093.99	-0.97
		12/4/2013	62.80	1,093.49	-0.50
		03/18/2014	63.95	1,092.34	-1.15
		06/19/2014	62.21	1,094.08	1.74
		11/19/2014	63.26	1,093.03	-1.05
		4/14/2015	62.22	1,094.07	1.04
		11/3/2015	63.58	1,092.71	-1.36
		6/1/2016	57.81	1,098.48	5.77
		11/9/2016	58.49	1,097.80	-0.68
		4/11/2017	60.35	1,095.94	-1.86
	1,160.19	5/30/2017	58.53	1,101.66	--
		11/8/2017	59.45	1,100.74	-0.92
		5/15/2018	59.00	1,101.19	0.45
		6/13/2018	59.00	1,101.19	0.00
		11/6/2018	60.39	1,099.80	-1.39
		6/19/2019	60.95	1,099.24	-0.56
		11/20/2019	62.90	1,097.29	-1.95

Table 1
Summary of Groundwater Elevation Data
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Well Elevation (feet)[a]	Date	Depth to Water (feet btoc)	Water Elevation (feet)	Change in Water Elevation (feet)
MW-4	1,155.29	10/5/2001	64.03	1,091.26	--
		12/20/2001	64.42	1,090.87	-0.39
		3/21/2002	64.03	1,091.26	0.39
		6/26/2002	61.72	1,093.57	2.31
		9/24/2002	61.26	1,094.03	0.46
		12/18/2002	65.92	1,089.37	-4.66
	1,158.42	3/14/2003	73.22	1,085.20	--
		5/30/2003	63.90	1,094.52	9.32
	1,156.92	3/26/2004	63.70	1,093.22	--
		6/29/2004	60.50	1,096.42	3.20
		9/27/2004	63.79	1,093.13	-3.29
		12/1/2004	64.29	1,092.63	-0.50
		3/9/2005	64.66	1,092.26	-0.37
		6/29/2005	64.72	1,092.20	-0.06
		9/23/2005	65.67	1,091.25	-0.95
		12/30/2005	66.11	1,090.81	-0.44
		3/28/2006	65.86	1,091.06	0.25
		6/29/2006	62.21	1,094.71	3.65
		9/5/2006	61.85	1,095.07	0.36
		12/11/2006	62.50	1,094.42	-0.65
		3/30/2007	61.38	1,095.54	1.12
		9/6/2007	59.75	1,097.17	1.63
		4/29/2008	62.90	1,094.02	-3.15
		10/1/2008	62.24	1,094.68	0.66
		4/30/2009	63.07	1,093.85	-0.83
		10/12/2009	62.33	1,094.59	0.74
		4/29/2010	63.89	1,093.03	-1.56
	1,156.90	8/17/2010	62.43	1,094.47	--
		10/12/2010	63.48	1,093.42	-1.05
		4/28/2011	63.63	1,093.27	-0.15
		10/13/2011	60.73	1,096.17	2.90
		3/9/2012	62.92	1,093.98	-2.19
		6/20/2012	61.32	1,095.58	1.60
		9/20/2012	60.48	1,096.42	0.84
		12/11/2012	62.11	1,094.79	-1.63
		3/19/2013	63.15	1,093.75	-1.04
		12/4/2013	63.49	1,093.41	-0.34
		03/18/2014	64.57	1,092.33	-1.08
		06/19/2014	63.11	1,093.79	1.46
		11/19/2014	63.91	1,092.99	-0.80
		4/14/2015	63.18	1,093.72	0.73
		11/3/2015	64.09	1,092.81	-0.91
		6/1/2016	58.66	1,098.24	5.43
		11/9/2016	59.25	1,097.65	-0.59
		4/11/2017	61.26	1,095.64	-2.01
	1,160.80	5/30/2017	59.38	1,101.42	--
		11/8/2017	60.21	1,100.59	-0.83
		5/15/2018	59.82	1,100.98	0.39
		6/13/2018	58.89	1,101.91	0.93
		11/6/2018	61.15	1,099.65	-2.26
		6/19/2019	61.84	1,098.96	-0.69
		11/20/2019	63.65	1,097.15	-1.81

Table 1
Summary of Groundwater Elevation Data
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Well Elevation (feet)[a]	Date	Depth to Water (feet btoc)	Water Elevation (feet)	Change in Water Elevation (feet)
MW-5	1,158.11	10/5/2001	75.57	1,082.54	--
		12/20/2001	74.23	1,083.88	1.34
		3/21/2002	75.57	1,082.54	-1.34
		6/26/2002	67.96	1,090.15	7.61
		9/24/2002	73.87	1,084.24	-5.91
		12/18/2002	74.60	1,083.51	-0.73
	1,158.11	3/14/2003	73.09	1,085.02	--
		5/30/2003	68.95	1,089.16	4.14
		3/26/2004	72.15	1,085.96	-3.20
		6/29/2004	65.78	1,092.33	6.37
		9/27/2004	73.40	1,084.71	-7.62
		12/1/2004	72.99	1,085.12	0.41
		3/9/2005	73.25	1,084.86	-0.26
		6/29/2005	73.06	1,085.05	0.19
		9/23/2005	75.51	1,082.60	-2.45
		12/30/2005	73.86	1,084.25	1.65
		3/28/2006	73.65	1,084.46	0.21
		6/29/2006	68.18	1,089.93	5.47
		9/5/2006	73.52	1,084.59	-5.34
		12/11/2006	72.48	1,085.63	1.04
		3/30/2007	69.10	1,089.01	3.38
		9/6/2007	--	--	--
		4/29/2008	72.40	1,085.71	-3.30
		10/1/2008	73.66	1,084.45	-1.26
		4/30/2009	71.29	1,086.82	2.37
		10/12/2009	73.97	1,084.14	-2.68
		4/29/2010	71.60	1,086.51	2.37
	1,158.09	8/17/2010	72.17	1,085.92	--
		10/12/2010	73.07	1,085.02	-0.90
		4/28/2011	71.56	1,086.53	1.51
		10/13/2011	72.23	1,085.86	-0.67
		3/9/2012	73.08	1,085.01	-0.85
		6/20/2012	67.64	1,090.45	5.44
		9/20/2012	71.23	1,086.86	-3.59
		12/11/2012	73.23	1,084.86	-2.00
		3/18/2013	72.09	1,086.00	1.14
		12/4/2013	72.81	1,085.28	-0.72
		03/18/2014	72.28	1,085.81	0.53
		06/19/2014	69.41	1,088.68	2.87
		11/19/2014	72.44	1,085.65	-3.03
		4/14/2015	71.30	1,086.79	1.14
		11/3/2015	72.62	1,085.47	-1.32
		6/1/2016	68.90	1,089.19	3.72
		11/9/2016	70.73	1,087.36	-1.83
		4/11/2017	70.34	1,087.75	0.39
	1,161.99	5/30/2017	65.86	1,096.13	--
		11/8/2017	72.15	1,089.84	-6.29
		5/15/2018	66.69	1,095.30	5.46
		6/13/2018	68.28	1,093.71	-1.59
		11/6/2018	72.11	1,089.88	-3.83
		6/19/2019	69.81	1,092.18	2.30
		11/20/2019	73.34	1,088.65	-3.53

Table 1
Summary of Groundwater Elevation Data
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Well Elevation (feet)[a]	Date	Depth to Water (feet btoc)	Water Elevation (feet)	Change in Water Elevation (feet)
MW-6	1,159.11	5/30/2017	56.58	1,102.53	--
		11/8/2017	57.26	1,101.85	-0.68
		5/15/2018	56.94	1,102.17	0.32
		6/13/2018	56.36	1,102.75	0.58
		11/6/2018	57.91	1,101.20	-1.55
		6/19/2019	58.22	1,100.89	-0.31
		11/20/2019	59.45	1,099.66	-1.23
PZ-1	1,159.50	11/9/2016	Dry	Dry	--
		2/17/2017	--	--	--
		4/11/2017	13.59	1,145.91	--
		4/21/2017	13.69	1,145.81	-0.10
	1,163.04	5/30/2017	16.90	1,146.14	--
		11/8/2017	Dry	Dry	--
		5/15/2018	Dry	Dry	--
		6/13/2018	Dry	Dry	--
		11/6/2018	Dry	Dry	--
		6/19/2019	Dry	Dry	--
		11/20/2019	Dry	Dry	
PZ-2	1,146.87	11/9/2016	14.07	1,132.80	--
		2/17/2017	9.23	1,137.64	--
		4/11/2017	0.13	1,146.74	9.10
		4/21/2017	0.43	1,146.44	-0.30
	1,150.45	5/30/2017	4.33	1,146.12	--
		11/8/2017	14.46	1,135.99	-10.13
		5/15/2018	4.79	1,145.66	9.67
		6/13/2018	6.33	1,144.12	-1.54
		11/6/2018	Dry	Dry	--
		6/19/2019	13.77	1,136.68	--
		11/20/2019	Dry	Dry	--
PZ-3	1,154.66	11/9/2016	Dry	Dry	--
		2/17/2017	Dry	Dry	--
		4/11/2017	21.1	1,133.56	--
		4/21/2017	20.83	1,133.83	0.27
	1,158.24	5/30/2017	22.67	1,135.57	--
		11/8/2017	Dry	Dry	--
		5/15/2018	Dry	Dry	--
		6/13/2018	Dry	Dry	--
		11/6/2018	Dry	Dry	--
		6/19/2019	Dry	Dry	--
		11/20/2019	Dry	Dry	--

NOTES
-- = not measured
btoc = below top of casing
[a] Elevation datum: NGVD29 (prior to 2017) and NAVD88 (from 2017)

Table 2
Summary of Soil Analytical Results
October 2016
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Boring ID	Sample Depth (feet bgs)	Sample Date	Total Petroleum Hydrocarbons			Volatile Organic Compounds[c]							
			Diesel-Range[a]	Oil-Range[a]	Gasoline-Range[b]	Benzene	Toluene	Ethyl-benzene	Total Xylenes	MTBE	Naph-thalene	EDC	EDB
MTCA Method A Cleanup Levels (mg/kg)[d]			**2,000**	**2,000**	**100**	**0.03**	**7**	**6**	**9**	**0.1**	**5**	**11**	**0.005**
PZ-1	24-25	10/18/16	<4.36	<10.9	<0.109	<0.00109	<0.00545	<0.00109	<0.00327	<0.00109	<0.00545	<0.00109	<0.00109
PZ-2	5-7.5	10/17/16	302	<12.2	**1,180**	*<0.0316* [e]	<0.585	4.28	8.22	<0.0249	**6.12**	<0.117	*<0.0401* [e]
PZ-2	8-9	10/17/16	<4.29	<10.7	<0.107	<0.00107	<0.00536	<0.00107	<0.00322	<0.00107	<0.00536	<0.00107	<0.00107
PZ-3	20-21.25	10/18/16	<5	<12.5	0.194	<0.00125	<0.00624	0.00133	<0.00375	<0.00125	<0.00624	<0.00125	<0.00125
PZ-3	21.5-22	10/18/16	<5.15	<12.9	<0.129	<0.00129	<0.00644	0.0237	<0.00386	<0.00129	<0.00644	<0.00129	<0.00129

NOTES:
Analytical results presented in milligrams per kilogram (mg/kg)
Results in **bold** denote concentrations greater than applicable cleanup levels and laboratory detection limits.
Results in *italic* denote concentrations greater than applicable cleanup levels but less than laboratory detection limits.

ABBREVIATIONS:
< = not detected at concentration greater than or equal to laboratory reporting limit
mg/kg = milligram per kilogram
bgs = below ground surface
MTCA = Model Toxics Control Act
MTBE = Methyl tert-butyl ether
EDC = 1,2-Dichloroethane
EDB = 1,2-Dibromoethane

FOOTNOTES:
[a] Analyzed by Northwest Method NWTPH-Dx (no silica gel cleanup).
[b] Analyzed by Northwest Method NWTPH-Gx.
[c] Analyzed by United States Environmental Protection Agency Method 8260.
[d] Washington State Department of Ecology, Model Toxics Control Act (MTCA) Cleanup Level and Risk Calculations (CLARC) Tables Method A values for Soil, Chapter 173-340 WAC, MTCA Chapter 70.105D RCW, Uniform Environmental Covenants Act Chapter 64.70 TCW. Publication No. 94-06. Revised May 2019.
[e] Reported to method detection limit due to dilution of sample.

Table 3
Summary of Groundwater Analytical Results
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Sample Date	Total Petroleum Hydrocarbons					Volatile Organic Compounds[d]			
		Gasoline-Range[a]	Diesel-Range (w/ SGC)[b]	Diesel-Range (w/o SGC)[c]	Oil-Range (w/ SGC)[b]	Oil-Range (w/o SGC)[c]	Benzene	Toluene	Ethyl - benzene	Total Xylenes
MTCA Method A Cleanup Levels[e] (µg/L)		**800**	**500**	**500**	**500**	**500**	**5**	**1,000**	**700**	**1,000**
MW-1	10/4/2001	<50	<281 I	--	<562	--	<0.5	1.79	<0.5	<1.0
	12/20/2001	<50	<250 J	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/21/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/26/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/24/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/18/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/14/2003	<50	**543**	--	<500	--	<0.5	<0.5	<0.5	1.24
	5/30/2003	<50	**710**	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/26/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/27/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/1/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/9/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2005	<50	**1,710**	--	**1,130**	--	<0.5	<0.5	<0.5	<1.0
	6/29/2005 - Dup	<50	**1,040**	--	**722**	--	<0.5	<0.5	<0.5	<1.0
	9/23/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/30/2005	<50	<282	--	<562	--	<0.5	<0.5	<0.5	<1.0
	3/28/2006	<50	<253	--	<505	--	<0.5	<0.5	<0.5	<1.0
	6/29/2006	<50	<253	--	<505	--	<0.5	<0.5	<0.5	<1.0
	9/5/2006	<80	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	12/11/2006	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/30/2007	<50	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	6/13/2018	<100	<200	488	<250	**517**	<1.00	<1.00	<1.00	<3.00
	11/6/2018	<100	<200	412	<250	<250	<1.00	<1.00	<1.00	<3.00
	6/20/2019	<100	<200	337	<250	377	<1.00	<1.00	<1.00	<3.00
	11/22/2019	<100	<200	289	<250	<250	<1.00	<1.00	<1.00	<3.00
MW-2	10/4/2001	<50	--	--	--	--	<0.5	<0.5	<0.5	<1.0
	12/20/2001	102	<250 J	--	<500	--	0.52	<0.5	<0.5	<1.0
	3/21/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/26/2002	82	<250	--	<500	--	<0.5	<0.5	<0.5	1.73
	9/24/2002	125	<250	--	<500	--	<0.5	<0.5	0.815	1.06
	12/18/2002	--	--	--	--	--	--	--	--	--
	3/14/2003	--	--	--	--	--	--	--	--	--
	5/30/2003	165	499	--	<500	--	1.18	<0.5	<0.5	<1.0
	3/26/2004	99.1	<250	--	<500	--	<0.5	<0.6	<0.5	1.30
	6/29/2004	71.2	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/27/2004	96.9	264	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/1/2004	67.8	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/9/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2005	55.6	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/23/2005	54.6	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/30/2005	84.6	<248	--	<495	--	<0.5	<0.5	0.763	2.74
	3/28/2006	180	<253	--	<505	--	0.558	<0.5	0.993	1.38
	6/29/2006	154	<250	--	<500	--	0.801	<0.5	<0.5	<1.0
	9/5/2006	98.2	<278	--	<556	--	0.932	<0.5	0.79	<1.0
	12/11/2006	71	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/30/2007	258	<245	--	<490	--	2.66	<0.5	1.11	2.12
	9/6/2007	341	<253	--	<505	--	**5.28**	<0.5	3.67	3.23

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Monitoring Well	Sample Date	Total Petroleum Hydrocarbons					Volatile Organic Compounds[d]			
		Gasoline-Range[a]	Diesel-Range (w/ SGC)[b]	Diesel-Range (w/o SGC)[c]	Oil-Range (w/ SGC)[b]	Oil-Range (w/o SGC)[c]	Benzene	Toluene	Ethyl - benzene	Total Xylenes
MTCA Method A Cleanup Levels[e] (µg/L)		800	500	500	500	500	5	1,000	700	1,000
MW-2 Cont'd	4/29/2008	318	<250	--	<500	--	3.22	<0.5	0.968	1.28
	10/1/2008	563	<250	--	<500	--	2.97	0.608	3.93	2.88
	4/30/2009	154	<245	--	<490	--	0.604	<0.5	<0.5	1.10
	10/12/2009	300	180	--	<470	--	1.0 H	<1.0	<1.0	<1.0
	4/29/2010	160	<120	--	300	--	<0.5	<0.5	<0.5	1.8
	10/12/2010	190	220	--	<250	--	0.76	<0.5	<0.5	<1.0
	4/28/2011	97	<120	--	<240	--	<1.0	<1.0	<1.0	<1.0
	10/13/2011	590	140	--	<260	--	4.6	<1.0	6.4	2.7
	3/9/2012	580	75.2	--	<450	--	<1.0	<1.0	<1.0	<3.0
	6/20/2012	118	<76	--	<380	--	1.1	<1.0	<1.0	<3.0
	9/20/2012	74.7	<76	--	<380	--	<1.0	<1.0	<1.0	<3.0
	12/11/2012	<100	200	--	290	--	<1.0	<1.0	<1.0	<3.0
	3/18/2013	<100	240	--	<250	--	<0.5	<5.0	<0.5	<1.5
	12/4/2013	<100	240	--	<250	--	<0.5	<5.0	<0.5	<1.5
	3/18/2014	<100	240	--	<250	--	<0.5	<5.0	<0.5	<1.5
	6/19/2014	<100	260	--	<250	--	<0.5	<5.0	<0.5	<1.5
	11/20/2014	<100	**700**	--	**610**	--	<0.5	<5.0	<0.5	<1.5
	4/15/2015	<100	350	--	<250	--	<0.5	<5.0	<0.5	<1.5
	11/3/2015	<100	436	--	**537**	--	<0.5	<5.0	<0.5	<1.5
	6/1/2016	370	**554**	--	357	--	**5.54**	<5.0	2.39	<1.50 B
	11/9/2016	<100	284	487	<500	<500	<1.0	<5.0	<1.0	<3.0
	5/30/2017	211	314	391	<250	365	<1.00	<1.00	<1.00	<3.00
	11/8/2017	107	<200	392	<250	<250	<1.00	<1.00	<1.00	<3.00
	6/13/2018	<100	<200	389	<250	358	<1.00	<1.00	<1.00	<3.00
	11/6/2018	104 B	<200	411	<250	319	<1.00	<1.00	<1.00	<3.00
	6/20/2019	141 B	<200	327	<250	309	<1.00	<1.00	<1.00	<3.00
	11/21/2019	<100	<200	247	<250	<250	<1.00	<1.00	<1.00	<3.00
MW-3	10/5/2001	**1,280 I**	**1,730**	--	<500	--	**28.1 I**	11.2 I	51.6 I	4.52 I
	12/20/2001	**977 I**	<250 J	--	<500 J	--	**19.2 I**	2.40 I	7.62 I	3.55 I
	12/20/2001 - Dup	**950 I**	<250 J	--	<500 J	--	**19.3 I**	2.42 I	7.60 I	3.55 I
	3/21/2002	**993 I**	255	--	<500	--	**14.9 I**	2.95 I	4.58 I	7.35 I
	3/21/2002 - Dup	**963 I**	428	--	<500	--	**16.7 I**	1.23 I	2.66 I	1.84 I
	6/26/2002	**823**	<250	--	<500	--	**16.6**	1.02 I	2.46 I	3.6
	6/26/2002 - Dup	762	<250	--	<500	--	**15.4**	1.03 I	2.48 I	3.56 I
	9/24/2002	**1,020 I**	<250 J	--	<500 J	--	**16.2 I**	4.77 I	29.4 I	8.74 I
	9/24/2002 - Dup	**1,030 I**	<250 J	--	<500 J	--	**16.3 I**	4.73 I	29.6 I	8.69 I
	12/18/2002	**1,300**	<250	--	<500	--	**20.7**	7.42	78.9	10.4
	12/18/2002 - Dup	**1,250**	<250	--	<500	--	**21.1**	7.43	79.4	10.2
	3/14/2003	**919 I**	**2,330**	--	<500	--	**12 I**	2.58 I	27.7 I	2.5 I
	3/14/2003 - Dup	**849 I**	**2,200**	--	<500	--	**11.4 I**	2.21 I	25.5 I	2.32 I
	5/30/2003	**959**	**2,820**	--	<500	--	**22.7**	6.01	42.8	7.12
	5/30/2003 - Dup	**845**	**3,610**	--	**580**	--	**14.4**	3.88	27	3.46
	3/26/2004	**1,060**	443	--	<500	--	**19.7**	7.44	24	4.32
	3/26/2004 - Dup	**1,090**	**528**	--	<500	--	**19.1**	7.14	23	3.62
	6/29/2004	**1,260**	305	--	<500	--	**25.6**	8.11	20.7	2.99
	6/29/2004 - Dup	**1,050**	<250	--	<500	--	**21.7**	6.82	17.4	2.61
	9/27/2004	**1,340**	**535**	--	<500	--	**19.4**	9.41	31.8	7.29

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		Gasoline-Range[a]	Diesel-Range (w/ SGC)[b]	Diesel-Range (w/o SGC)[c]	Oil-Range (w/ SGC)[b]	Oil-Range (w/o SGC)[c]	Benzene	Toluene	Ethyl - benzene	Total Xylenes
MTCA Method A Cleanup Levels[e] (µg/L)		**800**	**500**	**500**	**500**	**500**	**5**	**1,000**	**700**	**1,000**
MW-3 Cont'd	12/1/2004	**1,450**	259	--	<500	--	**20.9**	8.06	27	4.82
	3/9/2005	698	**602**	--	<500	--	**11.7**	2.52	4.84	1.28
	3/9/2005 - Dup	639	334	--	<500	--	**9.33**	1.98	3.84	<1.0
	6/29/2005	**909**	324	--	<500	--	**11**	1.67	4.72	2.27
	6/29/2005 - Dup	--	--	--	<501	--	--	--	--	--
	9/23/2005	718	<250	--	<500	--	**7.38**	0.994	1.96	2.25
	12/30/2005	377	<248	--	<495	--	**5.01**	0.799	0.89	1.04
	3/28/2006	603	<250	--	<500	--	4.28	<0.5	0.918	1.99
	6/29/2006	**998**	<278	--	<500	--	**12.7**	1.61	10.5	3.03
	9/5/2006	655	366	--	<556	--	**20.1**	8.83	74.5	33.5
	12/11/2006	**959**	369	--	<490	--	4.66	<0.5	<0.5	2.06
	3/30/2007	**2,510**	341	--	<485	--	**32.3**	17.7	89.9	56.8
	9/6/2007	**2,080**	<250	--	<500	--	**30.7**	38.8	137	106
	4/29/2008	**1,550 J**	419 I	--	<476	--	**12.8**	16.2	48.4	29.9
	4/29/2008 - Dup	**2,000 J**	<250	--	<500	--	**16.7**	19.9	54.6	31.7
	10/1/2008	**2,250 J**	<248	--	<495	--	**17.4**	24.2	117	84.2
	10/1/2008 - Dup	**2,390 J**	<240	--	<481	--	**18.3**	25.4	118	88.9
	4/30/2009	**1,050**	<248	--	**532**	--	**9.39**	7.33	26.5	25
	4/30/2009 - Dup	**1,040**	<238	--	<476	--	**9.36**	7.3	26.2	24.6
	10/12/2009	**4,600**	**980**	--	**720**	--	**27**	41	180	40
	10/12/2009 - Dup	**4,700**	**910**	--	**570**	--	**27**	43	190	42
	4/29/2010	**1,100**	**690**	--	<250	--	**9.9**	7.5	16	13
	4/29/2010 - Dup	**890**	480	--	<250	--	**9**	6.4	14	12
	10/12/2010	**1,300**	**1,600**	--	<240	--	**11**	18	69	68
	10/12/2010 - Dup	**1,300**	**2,700**	--	370	--	**10**	18	70	69
	4/28/2011	65	120	--	<250	--	1	<1.0	<1.0	<1.0
	4/28/2011 - Dup	74	150	--	<250	--	1	<1.0	<1.0	<1.0
	10/13/2011	<50	<130	--	<260	--	<1.0	<1.0	<1.0	<1.0
	10/13/2011 - Dup	57	<120	--	<250	--	<1.0	<1.0	<1.0	<1.0
	3/9/2012	**1,080**	**3,800**	--	**1,400**	--	**10**	9.6	9.7	18.6
	3/9/2012 - Dup	**985**	**4,100**	--	**1,500**	--	**9.1**	8.7	8.9	17
	6/20/2012	50.6	120	--	<380	--	1.4	<1.0	<1.0	<3.0
	6/20/2012 - Dup	62.1	<82	--	<410	--	1.6	<1.0	<1.0	<3.0
	9/20/2012	<50	93	--	<420	--	<1.0	<1.0	<1.0	<3.0
	9/20/2012 - Dup	<50	<79	--	<400	--	<1.0	<1.0	<1.0	<3.0
	12/11/2012	**1,460**	**1,800**	--	**1,300**	--	**7.3**	39.9	14.9	71.5
	12/11/2012 - Dup	708	**1,600**	--	**1,300**	--	3.7	22.9	7.2	35.1
	3/18/2013	600	**1,800**	--	**1,300**	--	**5.2**	7.8	2.7	24
	3/18/2013 - Dup	610	**1,100**	--	**250**	--	**5.4**	8.1	2.8	25
	12/4/2013	**1,000**	**2,300**	--	**630**	--	**14**	21	19	110
	12/4/2013 - Dup	**1,000**	**2,900**	--	**1,000**	--	**14**	20	19	110
	3/18/2014	<100	**1,900**	--	**860**	--	1.7	<5.0	<0.5	1.6
	3/18/2014 - Dup	<100	**1,900**	--	**870**	--	1.6	<5.0	<0.5	1.6
	6/19/2014	<100	**800**	--	250	--	0.95	<5.0	<0.5	<1.5
	6/19/2014 - Dup	<100	**1,000**	--	380	--	<0.5	<5.0	<0.5	<1.5
	11/20/2014	150	**2,700**	--	**1,400**	--	1.7	<5.0	0.74	<1.5
	11/20/2014 - Dup	120	**2,800**	--	**1,500**	--	1.8	<5.0	0.64	<1.5
	4/15/2015	<100	**1,400**	--	**510**	--	0.77	<5.0	<0.5	<1.5
	11/3/2015	471	**3,080**	--	**1,820**	--	4.65	<5.0	1.95	5.68
	6/1/2016	<100	**1,700**	--	**1,100**	--	1.21	<5.0	<0.5	<1.5 B
	11/10/2016	230	**1,210**	**3,010**	<500	**1,640**	2.87	<5.0	<1.0	<3.0
	5/30/2017	212	**1,340**	**1,500**	**785**	**1,110**	1.83	<1.00	<1.00	<3.00
	11/9/2017	749	**547**	**2,200**	<250	**1,130**	4.16	14.7	26.7	79.3
	6/13/2018	<100	<200	**1,110**	<250	**970**	<1.00	<1.00	<1.00	<3.00
	11/6/2018	**1,230**	<200	**2,670**	<250	**1,210**	4.74	16.5	27.5	102
	6/20/2019	219 B	<200	**1,540**	<250	**924**	1.02	<1.00	<1.00	<3.00
	11/22/2019	**1,080**	<200	**2,070**	<250	**907**	2.68	6.47	<1.00	43.4

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		Gasoline-Range[a]	Diesel-Range (w/ SGC)[b]	Diesel-Range (w/o SGC)[c]	Oil-Range (w/ SGC)[b]	Oil-Range (w/o SGC)[c]	Benzene	Toluene	Ethyl - benzene	Total Xylenes
MTCA Method A Cleanup Levels[e] (µg/L)		**800**	**500**	**500**	**500**	**500**	**5**	**1,000**	**700**	**1,000**
MW-4	10/5/2001	149	**1,940**	--	<561	--	<0.5	2.17	<0.5	<1.0
	10/5/2001 - Dup	140	**2,180**	--	<561	--	<0.5	2.08	<0.5	<1.0
	12/20/2001	50.7	<250 J	--	<500 J	--	<0.5	<0.5	<0.5	<1.0
	3/21/2002	63.4	393	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/26/2002	244	<250	--	<500	--	2.73	<0.5	<0.5	1.06
	9/24/2002	253	<250	--	<500	--	3.31	<0.5	<0.5	1.01
	12/18/2002	236	<250	--	<500	--	1.73	<0.5	<0.5	<1.0
	3/14/2003	254	**2,830**	--	<500	--	0.847	<0.5	<0.5	<1.0
	5/30/2003	199	**2,980**	--	<500	--	0.602	<0.5	<0.5	<1.0
	3/26/2004	204	314	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2004	204	469	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/27/2004	192	408	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/1/2004	196	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/9/2005	153	378	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2005	183	477	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/23/2005	180	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/30/2005	137	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	3/28/2006	170	<243	--	<485	--	<0.5	<0.5	<0.5	<1.0
	6/29/2006	132	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/5/2006	<80	<263	--	<526	--	<0.5	<0.5	<0.5	<1.0
	12/11/2006	<50	<245	--	<490	--	<0.5	<0.5	<0.5	<1.0
	3/30/2007	<50	<253	--	<505	--	<0.5	<0.5	<0.5	<1.0
	9/6/2007	267	<250	--	<500	--	0.65	<0.5	<0.5	<3.0
	4/29/2008	98.7	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	10/1/2008	52.2	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	4/30/2009	76.4	<245	--	<490	--	--	<0.5	<0.5	<1.0
	10/12/2009	68	<120	--	<250	--	<1.0	<1.0	<1.0	<1.0
	4/29/2010	75	<120	--	<240	--	<0.5	<0.5	<0.5	<1.0
	10/12/2010	65	**580**	--	<240	--	<0.5	<0.5	<0.5	<1.0
	4/28/2011	<50	<120	--	<240	--	<1.0	<1.0	<1.0	<1.0
	10/13/2011	140	350	--	<250	--	<1.0	<1.0	<1.0	<1.0
	3/9/2012	<50	**2,800**	--	**1,400**	--	<1.0	<1.0	<1.0	<3.0
	6/20/2012	<50	<79	--	<400	--	<1.0	<1.0	<1.0	<3.0
	9/20/2012	<50	<79	--	<400	--	<1.0	<1.0	<1.0	<3.0
	12/11/2012	<100	**2,100**	--	**1,800**	--	<1.0	<1.0	<1.0	<3.0
	3/18/2013	<100	**1,400**	--	400	--	<0.5	<5.0	<0.5	<1.5
	12/4/2013	<100	**1,300**	--	440	--	<0.5	<5.0	<0.5	<1.5
	3/18/2014	<100	**2,200**	--	**1,100**	--	<0.5	<5.0	<0.5	<1.5
	6/19/2014	<100	**1,600**	--	**710**	--	<0.5	<5.0	<0.5	<1.5
	11/20/2014	<100	**2,900**	--	**1,900**	--	<0.5	<5.0	<0.5	<1.5
	4/15/2015	<100	**1,900**	--	**940**	--	0.56	<5.0	<0.5	<1.5
	4/15/2015 - Dup	<100	**1,800**	--	**790**	--	<0.5	<5.0	<0.5	<1.5
	11/3/2015	<100	**1,980**	--	**1,310**	--	<0.5	<5.0	<0.5	<1.5
	6/1/2016	<100	**878**	--	**575**	--	<0.5	<5.0	<0.5	<1.5 B
	6/1/16 - Dup	<100	**1,160**	--	**937**	--	<0.5	<5.0	<0.5	<1.5 B
	11/10/2016	<100	**1,200**	**2,930**	<500	**1,490**	<1.0	<5.0	<1.0	<3.0
	11/10/2016- Dup	<100	**1,070**	**2,930**	<500	**1,500**	<1.0	<5.0	<1.0	<3.0
	5/30/2017	<100	**1,040**	**1,090**	**880**	**1,120**	<1.00	<1.00	<1.00	<3.00
	5/30/2017- Dup	<100	**1,010**	**1,120**	**833**	**1,150**	<1.00	<1.00	<1.00	<3.00
	11/8/2017	<100	324	**2,680**	<250	**1,710**	<1.00	<1.00	<1.00	<3.00
	11/8/2017- Dup	<100	356	**2,670**	<250	**1,640**	<1.00	<1.00	<1.00	<3.00
	6/13/2018	<100	<200	**1,150**	<250	**1,060**	<1.00	<1.00	<1.00	<3.00
	6/13/2018 - Dup	<100	<200	**1,160**	<250	**1,170**	<1.00	<1.00	<1.00	<3.00
	11/7/2018	<100	<200	**1,830**	<250	**1,220**	<1.00	<1.00	<1.00	<3.00
	6/20/2019	<100	<200	**620**	<250	**685**	<1.00	<1.00	<1.00	<3.00
	11/22/2019	<100	<200	**1,120**	<250	**551**	<1.00	<1.00	<1.00	<3.00
	11/22/2019 - Dup	<100	<200	**1,100**	<250	**553**	<1.00	<1.00	<1.00	<3.00

Table 3
Summary of Groundwater Analytical Results
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Monitoring Well	Sample Date	Total Petroleum Hydrocarbons					Volatile Organic Compounds[d]			
		Gasoline-Range[a]	Diesel-Range (w/ SGC)[b]	Diesel-Range (w/o SGC)[c]	Oil-Range (w/ SGC)[b]	Oil-Range (w/o SGC)[c]	Benzene	Toluene	Ethyl - benzene	Total Xylenes
MTCA Method A Cleanup Levels[e] (µg/L)		**800**	**500**	**500**	**500**	**500**	**5**	**1,000**	**700**	**1,000**
MW-5	10/5/2001	<50	--	--	--	--	<0.5	<0.5	<0.5	<1.0
	12/20/2001	<50	<250 J	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/21/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/26/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/24/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/18/2002	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/14/2003	<50	<250	--	<500	--	<0.5	<0.5	<0.5	1.24
	5/30/2003	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/26/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/27/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/27/2004 - Dup	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/1/2004	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/1/2004 - Dup	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	3/9/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/23/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	9/23/2005 - Dup	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/30/2005	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/30/2005 - Dup	<50	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	3/28/2006	<50	<243	--	<485	--	<0.5	<0.5	<0.5	<1.0
	3/28/2006 - Dup	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2006	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	6/29/2006 - Dup	<50	<263	--	<526	--	<0.5	<0.5	<0.5	<1.0
	9/5/2006	<80	<278	--	<556	--	<0.5	<0.5	<0.5	<1.0
	9/5/2006 - Dup	<80	<253	--	<505	--	<0.5	<0.5	<0.5	<1.0
	12/11/2006	<50	<250	--	<500	--	<0.5	<0.5	<0.5	<1.0
	12/11/2006 - Dup	<50	<248	--	<495	--	<0.5	<0.5	<0.5	<1.0
	3/30/2007	<50	<245	--	<490	--	<0.5	<0.5	<0.5	<1.0
	3/30/2007 - Dup	<50	<245	--	<490	--	<0.5	<0.5	<0.5	<1.0
MW-6	5/31/2017	<100	<200	<400	<250	<500	<1.00	<1.00	<1.00	<3.00
	11/9/2017	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00
	6/13/2018	<100	<200	204	<250	335	<1.00	<1.00	<1.00	<3.00
	11/5/2018	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00
	6/19/2019	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00
	11/21/2019	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00
PZ-1	4/21/2017	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00
PZ-2	4/21/2017	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00
PZ-3	4/21/2017	<100	<200	<200	<250	<250	<1.00	<1.00	<1.00	<3.00

NOTES:
Analytical results presented in micrograms per liter (µg/L).
Results in **bold** denote concentrations greater than or equal to the applicable cleanup level.
< denotes analyte not detected at concentration greater than or equal to the given reporting limit.
-- sample was not analyzed for this constituent.
B = analyte was detected in the blank and the value presented here may be biased high.
H = samples were analyzed outside of the analytical holding time due to an analyst oversight.
I = analyte concentration may be artifically elevated because of co-eluting compounds or components.
J = analyte was detected in the sample at an estimated concentration between the method detection limit and the reporting limit.

ABBREVIATIONS:
Dup = duplicate sample
MTCA = Model Toxics Control Act
SGC = Silica Gel Cleanup
MW = Monitoring well
PZ = Piezometer

FOOTNOTES:
[a] Analyzed by Northwest Method NWTPH-Gx.
[b] Analyzed by Northwest Method NWTPH-Dx.
[c] Analyzed by Northwest Method NWTPH-Dx. Samples collected in November 2017 were analyzed outside of the analytical holding time and should be considered minimum values.
[d] Analyzed by USEPA Method 8021B (prior to November 2016) and USEPA Method 8260C or 8260D (November 2016 to 2019).
[e] Washington State Department of Ecology, Model Toxics Control Act Regulation and Statute, MTCA Cleanup Regulation Chapter 173-340 WAC, Model Toxics Control Act Chapter 70.105D RCW, Uniform Environmental Covenants Act Chapter 64.70 RCW. Publication No. 94-06. Revised May 2019.

Table 4
Proposed Groundwater Depth-Discrete Sampling
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Well ID	Date Installed	Well Diameter (in)	Total Depth (ft bgs)	Screen Interval (ft bgs)	Sample Interval #1 (ft bgs)	Sample Interval #2 (ft bgs)	Sample Interval #3 (ft bgs)	Comments
MW-1	11/8/1995	2	77	62-77	64	70	75	All intervals in SP-SM unit
MW-2	NA	2	83	63-83	65	72	78	All intervals in SM unit, to depth logged
MW-3	9/18/2001	2	78	58-78	60	67	75	All intervals in SP-SM unit
MW-4	9/19/2001	2	74	54-74	57	64	72	Intervals target GP, SM, and GP units
MW-5	9/20/2001	2	80.5	60.5-80.5	63	70	78	Intervals target GP-GM, SP-SM, and GP-GM units
MW-6	5/23/2017	2	76.0	53-73	55	63	71	All intervals in SW unit

NOTES:
in = inches
ft bgs = feet below ground surface
NA = Not available
SP-SM = fine to coarse sand with silt and gravel
SM = silty fine to coarse sand with gravel
GP = fine to coarse gravel with sand and trace silt
GP-GM = gravel with sand and silt

Table 5
Proposed Soil Sampling
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Soil Borings	Location	Impacted Soil Observed?	Target Soil Sample Depths for Laboratory Analysis
SB-1 SB-2 SB-3	Lower Elevation	Yes	1. Top of impacted soil 2. Middle of impacted soil 3. Bottom of impacted soil
		No	1. 12 ft bgs 2. 25 ft bgs
SB-4 SB-5 SB-6 GWB-1	Higher Elevation	Yes	1. Top of impacted soil 2. Middle of impacted soil 3. Bottom of impacted soil
		No	1. 25 ft bgs 2. 35 ft bgs

Note:

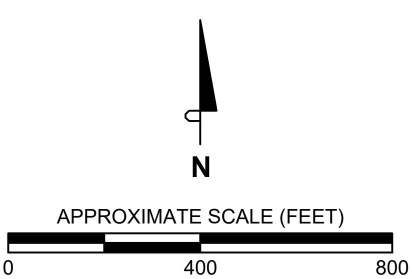
If additional step-out borings are required at locations SB-1, SB-2, or SB-3, the same target soil sample depths and protocols will be followed.

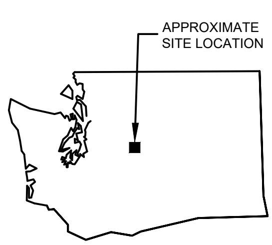
ABBREVIATIONS:

ft bgs = feet below ground surface

Figures

SOURCE AERIAL PHOTO: Google Earth Professional, June 2015.





PROJECT:
BNSF Glacier Park East Site
Chumstick Highway and State Highway 2
Leavenworth, Washington

TITLE:
VICINITY MAP

DRAWN B ·	R. Collins	PROJ NO ·	333710
CHECKED B ·	M. Piovesan		
APPROVED B ·	K. Woodburne	**FIGURE 1**	
DAT ·	April 2020		

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FILE NO · Fig1_Vicinity Map_Aerial.dwg

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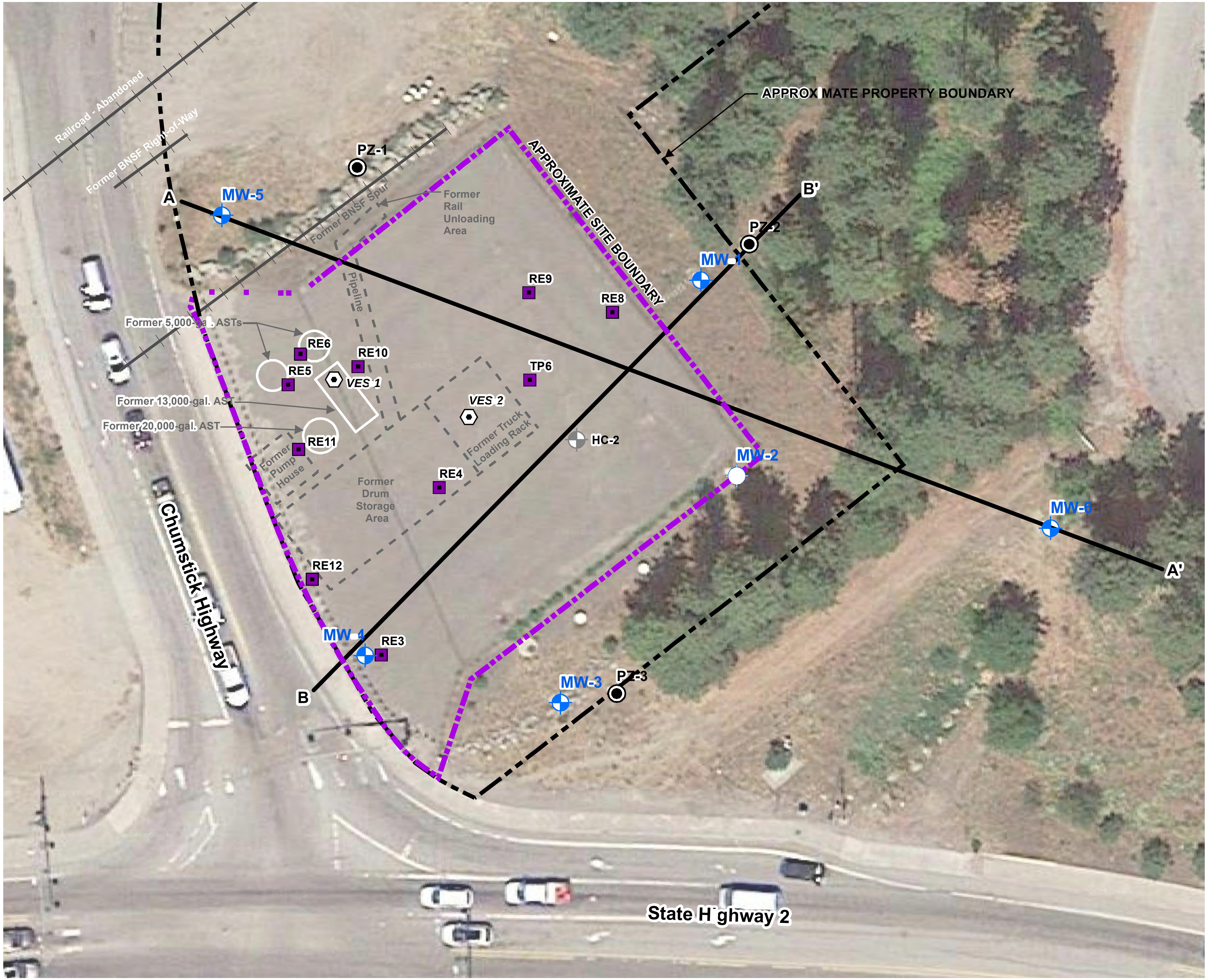
Version: 2017-03-03



Legend

Surveyed locations of:

- Monitoring Well
- Piezometer

Approximate locations of:

- Test Pit
- Abandoned Monitoring Well
- Former Vapor Extraction Well
- A —— A' Cross Section

SOURCES:
AERIAL PHOTO: Google Earth, July 2017.
BASE PLAN:Groundwater Potentiometric Map by Kennedy/Jenks Consultants, December 2013, and site plans by Geo Engineers, March 2002.

NOTES:
Wells and piezometers surveyed in June 2017 by Landline Surveyors, Leavenworth, Washington. Coordinate system: NAD83 Washington State Planes, North Zone, US foot.

Property boundary extends farther to the north east.

AST = aboveground storage tank.

PROJECT:
BNSF GLACIER PARK EAST SITE
CHUMSTICK HIGHWAY AND STATE HIGHWAY 2
LEAVENWORTH, WASHINGTON

TITLE:
SITE PLAN

DRAWN BY:	R. COLLINS	PROJ. NO.:	329229.0000.0000
CHECKED BY:	B. HELLAND		
APPROVED BY:	K. WOODBURNE	**FIGURE 2**	
DATE:	MAY 2020		

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Phone: 425.489.1938
www.trccompanies.com

FILE NO.: 239229_1_SitePlan.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet (Foot US)
Map Rotation: 0

Plot Date: 5/5/2020, 15:48:11 PM by RCOLLINS -- LAYOUT: ANSI B(11"x17")
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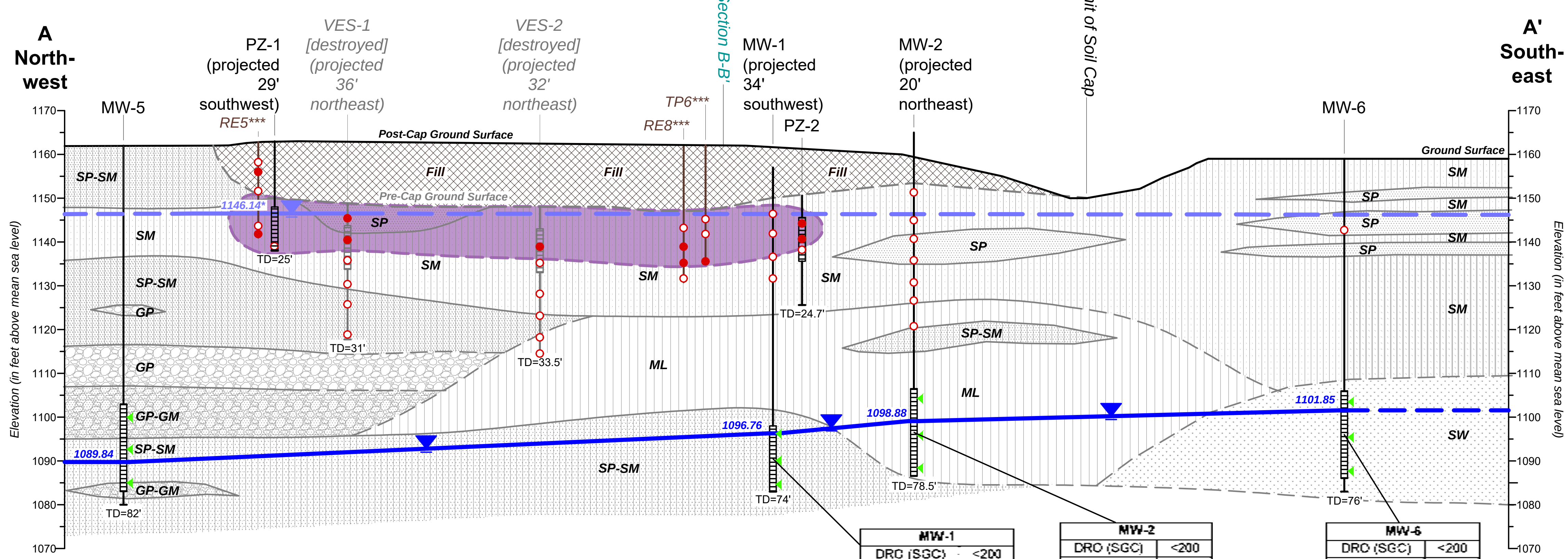
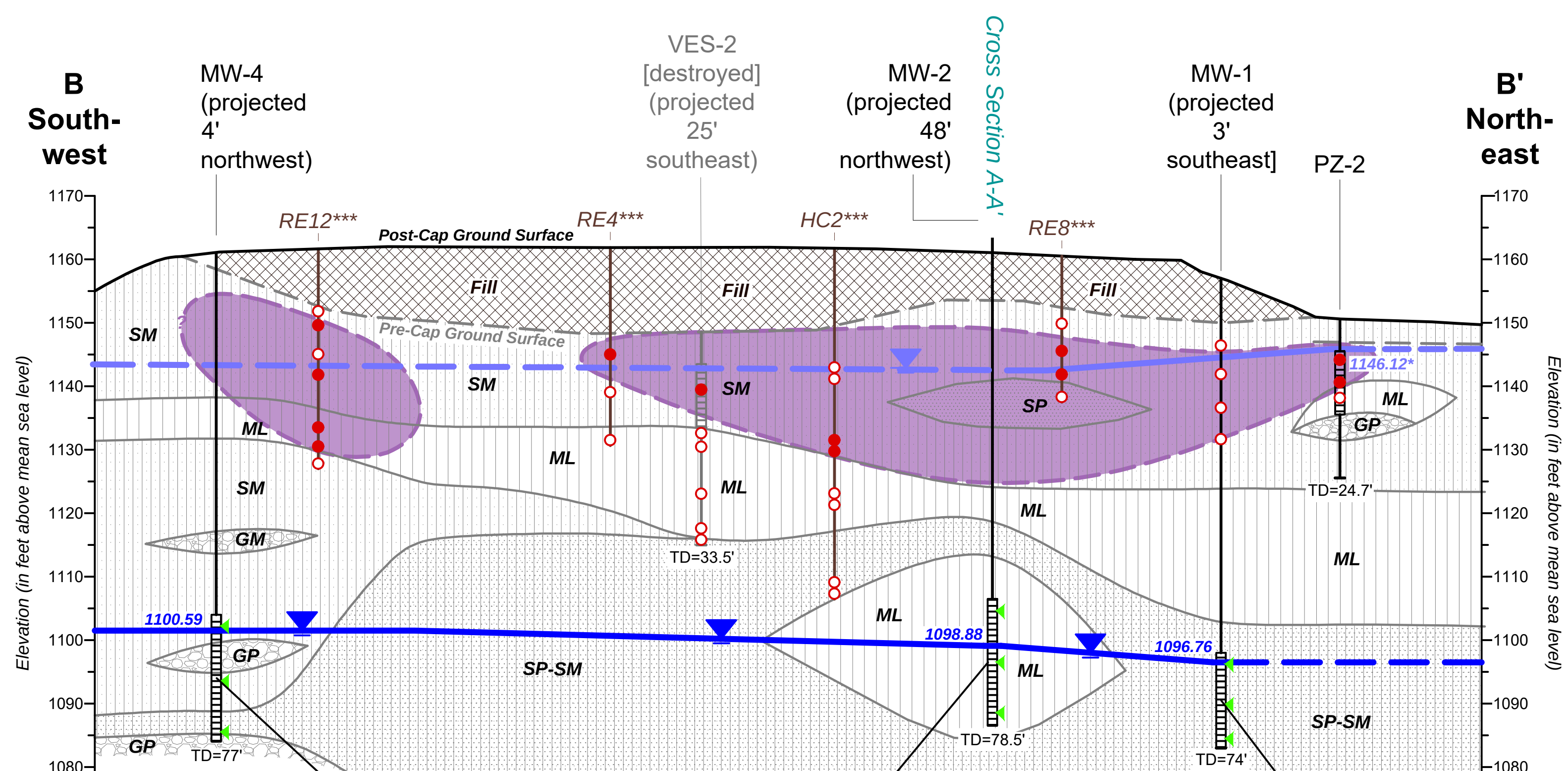


MW-1	
DRO (SGC)	<200
DRO	289
ORO (SGC)	<250
ORO	<250

MW-2	
DRO (SGC)	<200
DRO	247
ORO (SGC)	<250
ORO	<250

MW-6	
DRO (SGC)	<200
DRO	<200
ORO (SGC)	<250
ORO	<250



MW-4		Dup.
DRO (SGC)	<200	<200
DRO	**1,120**	**1,100**
ORO (SGC)	<250	<250
ORO	**551**	**553**

MW-2	
DRO (SGC)	<200
DRO	247
ORO (SGC)	<250
ORO	<250

MW-1	
DRO (SGC)	<200
DRO	289
ORO (SGC)	<250
ORO	<250

LEGEND

- Well / piezometer (surveyed)
- 1146.14 — Transient perched water-bearing zone
- 1098.88 — Approximate groundwater elevation (ft-msl), in piezometers on May 30, 2017* and in wells on November 8, 2017
- Soil sample depth with concentration above MTCA Method A
- Soil sample depth with concentration below MTCA Method A
- Screen
- Proposed Depth Discrete Sample Locations
- Lithology line, dashed where inferred
- TD=78.5' — Total depth
- Groundwater Analytical Results in micrograms per liter (µg/L), November 2019

Well ID	
DRO (SGC)	µg/L
DRO	µg/L
ORO (SGC)	µg/L
ORO	µg/L

- Approximate Area of Impacted Soil

15'
15'
NO VERTICAL EXAGGERATION

HORIZONTAL SCALE (FEET)
0 30

*LITHOLOGY KEY***:

	Fill
GM	Gravel with silty fine to coarse sand
GP-GM	Gravel with sand and silt
GP	Fine to coarse gravel with sand and trace silt
ML	Sandy silt / silt with sand
SM	Silty fine to coarse sand with gravel
SP-SM	Fine to coarse sand with silt and gravel
SP	Medium to coarse sand with silt
SW	Well-graded sands, gravelly sands, little or no fines

NOTES:

See Figure 2 for locations of cross sections.
Well and piezometer elevations are to top of PVC based on June 2017 survey by Landline Surveyors, Leavenworth, Washington. Coordinate system: NAD83 Washington State Planes, North Zone, US foot. Vertical datum: NAVD 1988.
Pre-cap ground surface elevations based on Site Plan/ Temporary Erosion and Sedimentation Control Plan-Cleanup Action by GeoEngineers, January 2003.
Post-cap ground surface elevations based on Grading Plan and Cross-Sections-Cleanup Action by GeoEngineers, January 2003.

** = Denotes groundwater elevation from monitoring event on May 30, 2017.*

*** = Lithologic units are consistent with the Unified Soil Classification System (USCS) classification from ASTM D-2487.*

**** = Locations and depths are approximate.*

SGC = silica gel cleanup
µg/L = micrograms per liter
Total petroleum hydrocarbons as:
DRO = Diesel-range organics
DRO (SGC) = Diesel-range organics with SGC
ORO = Oil-range organics
ORO (SGC) = Oil-range organics with SGC
***BOLD** = Analytical result is greater than or equal to Model Toxics Control Act (MTCA) Method A cleanup levels for GRO (800 µg/L), DRO (500 µg/L), ORO (500 µg/L) and benzene (5 µg/L)*
MTCA (Model Toxics Control Act)

PROJECT:
BNSF GLACIER PARK EAST SITE
CHUMSTICK HIGHWAY AND STATE HIGHWAY 2
LEAVENWORTH, WASHINGTON

TITLE:
CROSS SECTIONS

DRAWN BY:	R. COLLINS	PROJ NO.:	333710.0000.0000
CHECKED BY:	M. PIOVESAN		**FIGURE 3**
APPROVED BY:	K. WOODBURNE		
DATE:	June 2020		

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FILE NO.: Fig3_Cross Sections.dwg

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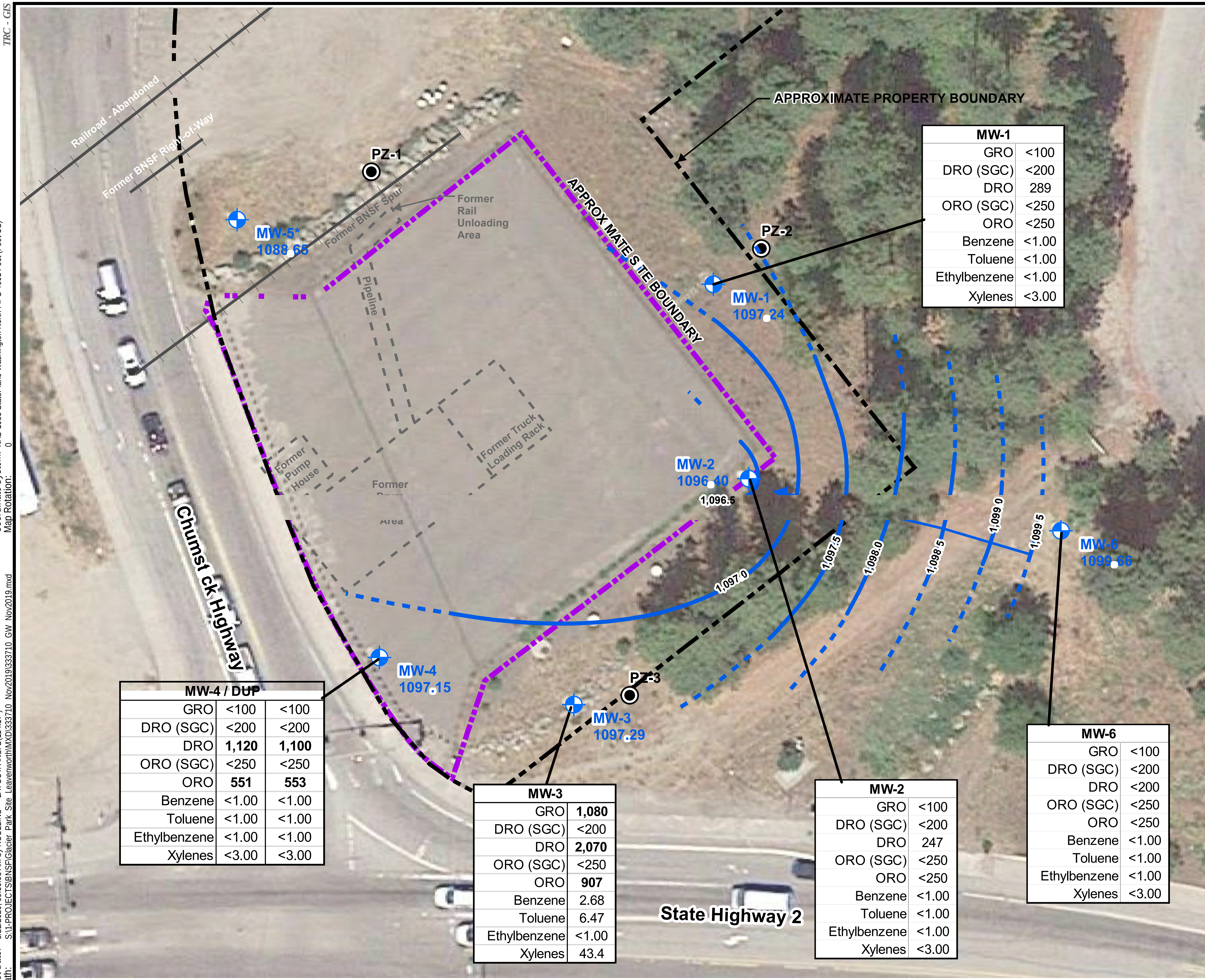
Version: 2017-10-21



MW-1	
GRO	<100
DRO (SGC)	<200
DRO	289
ORO (SGC)	<250
ORO	<250
Benzene	<1.00
Toluene	<1.00
Ethylbenzene	<1.00
Xylenes	<3.00

MW-4 / DUP		
GRO	<100	<100
DRO (SGC)	<200	<200
DRO	**1,120**	**1,100**
ORO (SGC)	<250	<250
ORO	**551**	**553**
Benzene	<1.00	<1.00
Toluene	<1.00	<1.00
Ethylbenzene	<1.00	<1.00
Xylenes	<3.00	<3.00

MW-3	
GRO	**1,080**
DRO (SGC)	<200
DRO	**2,070**
ORO (SGC)	<250
ORO	**907**
Benzene	2.68
Toluene	6.47
Ethylbenzene	<1.00
Xylenes	43.4

MW-2	
GRO	<100
DRO (SGC)	<200
DRO	247
ORO (SGC)	<250
ORO	<250
Benzene	<1.00
Toluene	<1.00
Ethylbenzene	<1.00
Xylenes	<3.00

MW-6	
GRO	<100
DRO (SGC)	<200
DRO	<200
ORO (SGC)	<250
ORO	<250
Benzene	<1.00
Toluene	<1.00
Ethylbenzene	<1.00
Xylenes	<3.00

Legend

- Monitoring Well
- Piezometer
- 1098.66 Groundwater Elevation (November 2019)
- 1,100.5 Groundwater Elevation Contour Line (ft-msl), November 2019, Dashed where inferred
- Inferred Direction of Groundwater Flow (November 2019)

MW-1	
GRO	<100
DRO (SGC)	<200
DRO	289
ORO (SGC)	<250
ORO	<250
Benzene	<1.00
Toluene	<1.00
Ethylbenzene	<1.00
Xylenes	<3.00

Groundwater Analytical Results (µg/L), November 2019

SOURCES:
AERIAL PHOTO: Google Earth, July 2017.
BASE PLAN:Groundwater Potentiometric Map by Kennedy/Jenks Consultants, December 2013, and site plans by Geo Engineers, March 2002.

NOTES:
Wells and piezometers surveyed in June 2017 by Landline Surveyors, Leavenworth, Washington.
Coordinate system: NAD83 Washington State Planes, North Zone, US foot.

Property boundary extends farther to the north east.

SGC = silica gel cleanup
µg/L = micrograms per liter

Total petroleum hydrocarbons as:
DRO = Diesel-range organics
DRO (SGC) = Diesel-range organics with SGC
ORO = Heavy oil-range organics
ORO (SGC) = Heavy oil-range organics with SGC
GRO = Gasoline-range organics
* = location not used in contouring

BOLD = Analytical result is greater than or equal to Model Toxics Control Act (MTCA) Method A cleanup levels for GRO (800 µg/L), DRO (500 µg/L), ORO (500 µg/L) and benzene (5 µg/L).

N

0 30 60 Feet

1:300

PROJECT:
BNSF GLACIER PARK EAST SITE
CHUMSTICK HIGHWAY AND STATE HIGHWAY 2
LEAVENWORTH, WASHINGTON

TITLE:
GROUNDWATER ELEVATION CONTOUR AND ANALYTICAL RESULTS MAP NOVEMBER 2019

DRAWN BY:	R. COLLINS	PROJ. NO.:	333710.0000.0000
CHECKED BY:	M. PIOVESAN		
APPROVED BY:	K. WOODBURNE	FIGURE 4	
DATE:	MAY 2020		

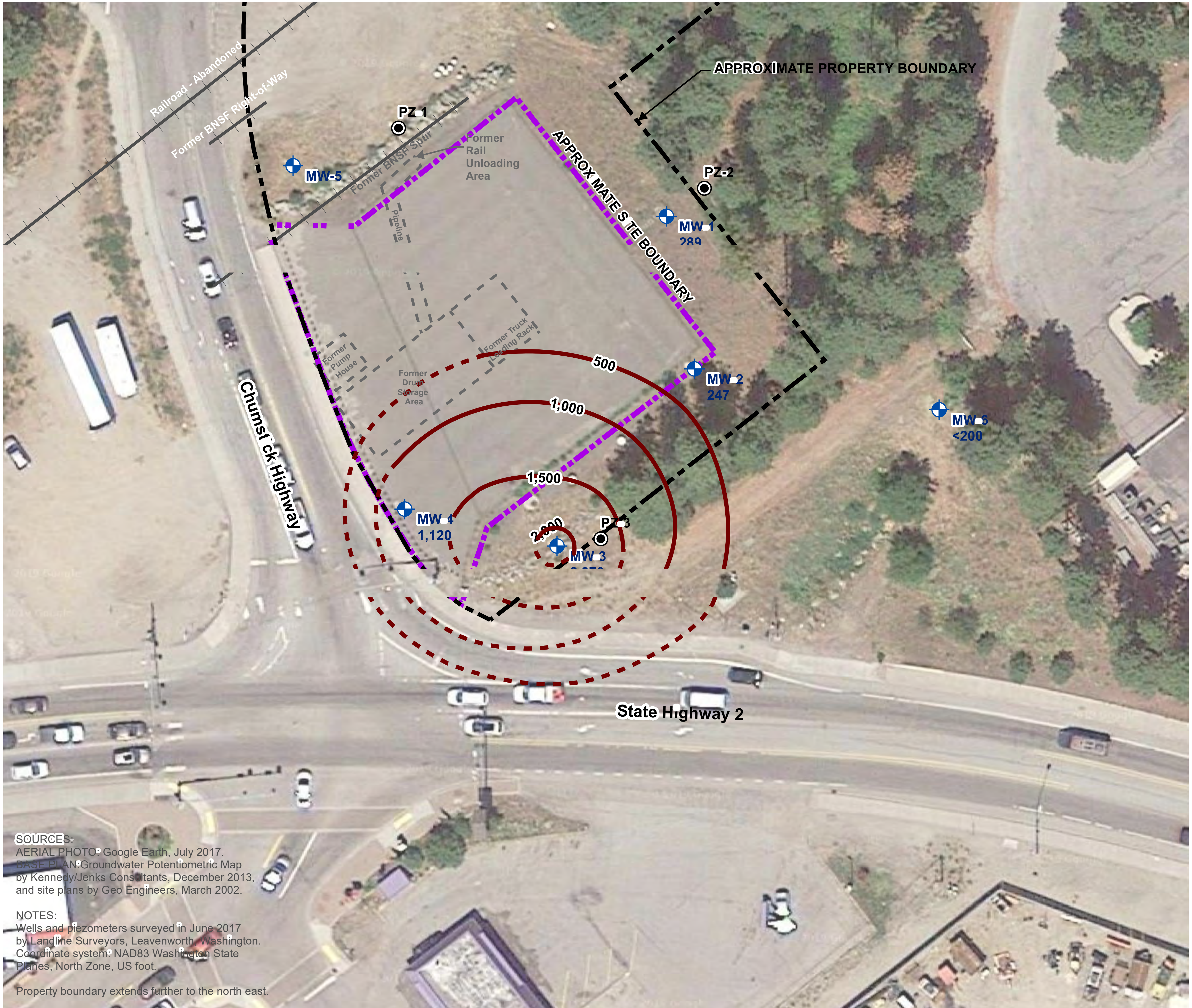
TRC
19874 141st Place N.E.
Woodinville, WA 98072
Phone: 425.489.1938
www.trccompanies.com

FILE NO.: 333710_GW_Nov2019.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet (Foot US)
Map Rotation: 0

Plot Date: 5/22/2020, 09:50:08 AM by RCOLLINS -- LAYOUT: ANSI B(11"x17")
Path: S:\1-PROJECTS\BNSF\Glacier Park Site Leavenworth\MXD\333710 Nov2019\333710 GW Nov2019.mxd



SOURCES:
AERIAL PHOTO: Google Earth, July 2017.
BASE PLAN: Groundwater Potentiometric Map by Kennedy/Jenks Consultants, December 2013, and site plans by Geo Engineers, March 2002.

NOTES:
Wells and piezometers surveyed in June 2017 by Landline Surveyors, Leavenworth, Washington.
Coordinate system: NAD83 Washington State Planes, North Zone, US foot.

Property boundary extends further to the north east.

N

Legend

2,070 DRO Analytical Results, (Without Silica Gel Cleanup), November 2019

—2,000— Approximate diesel-range TPH concentrations in µg/L (dashed where inferred)

Monitoring Well

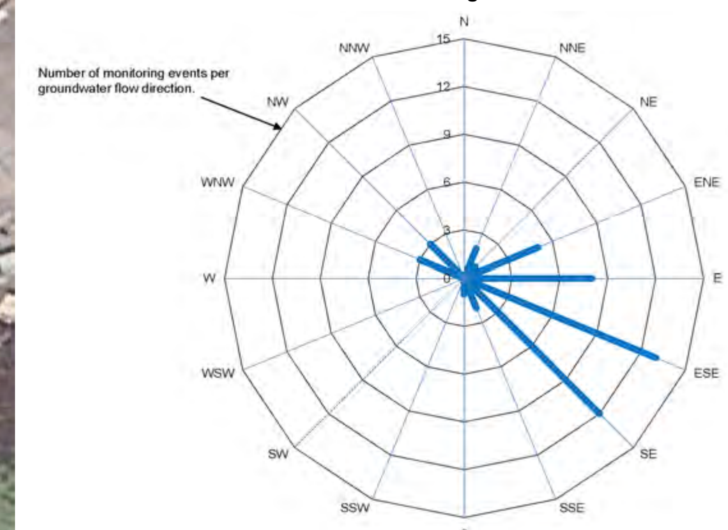
Piezometer

NOTES:

DRO = Diesel-range organics
TPH = Total petroleum hydrocarbons
µg/L = Micrograms per liter

MW-5 has not been sampled since 2007 as it has never had any concentrations exceeding the MTCA Method A cleanup levels.

Historical Groundwater Flow Directions October 2001 through November 2019



NOTES:
Groundwater flow directions do not include MW-5 groundwater elevations.
Groundwater flow directions from 2001 to April 2010 are calculated using historical data provided by Kennedy-Jenks.
Groundwater flow directions from August 2010 to November 2010 are from previous reports provided by Kennedy-Jenks.

0 20 40 Feet

PROJECT:
BNSF GLACIER PARK EAST SITE
CHUMSTICK HIGHWAY AND STATE HIGHWAY 2
LEAVENWORTH, WASHINGTON

TITLE:
DRO GROUNDWATER ANALYTICAL RESULTS NOVEMBER 2019

DRAWN BY:	R. COLLINS	PROJ. NO.:	333710.0000.0000
CHECKED BY:	M. PIOVESAN		
APPROVED BY:	K. WOODBURNE	**FIGURE 5**	
DATE:	MAY 2020		

TRC
19874 141st Place N.E.
Woodinville, WA 98072
Phone: 425.489.1938
www.trccompanies.com

FILE NO.: 333710_DRO_Nov2019.mxd

Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet (Foot US)
Map Rotation: 0

Plot Date: 5/22/2020, 09:47:45 AM by RCOLLINS -- LAYOUT: ANSI B(11"x17")
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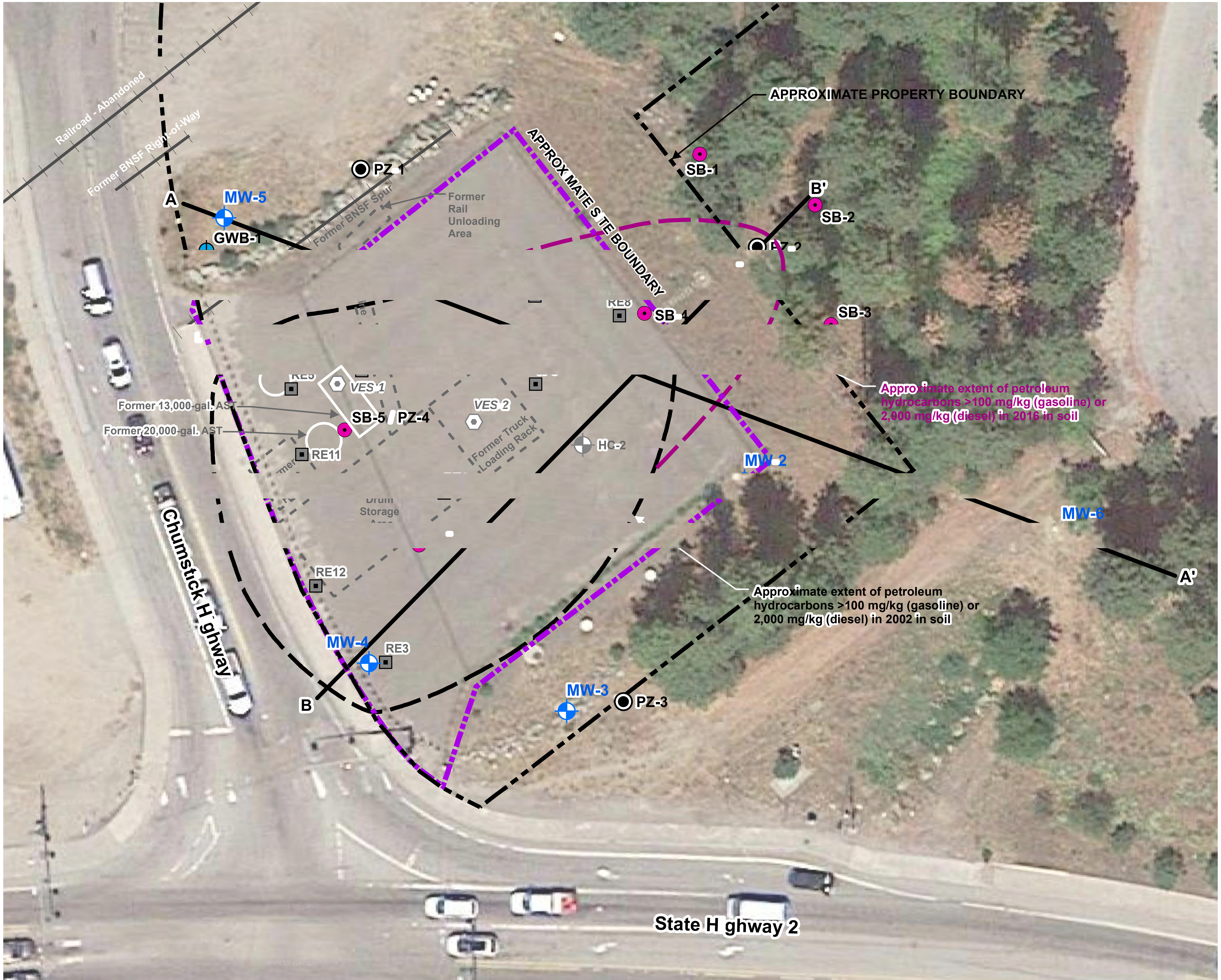


Legend

Surveyed locations of:

- Monitoring Well
- Piezometer

Approximate locations of:

- Proposed Soil Boring Location
- Proposed Soil Boring to Groundwater Location
- Test Pit (1995)
- Abandoned Monitoring Well
- Former Vapor Extraction Well (1995)
- A — A' Cross Section

SOURCES:
AERIAL PHOTO: Google Earth, July 2017.
BASE PLAN: Groundwater Potentiometric Map by Kennedy/Jenks Consultants, December 2013, and site plans by Geo Engineers, March 2002.

NOTES:
Wells and piezometers surveyed in June 2017 by Landline Surveyors, Leavenworth, Washington. Coordinate system: NAD83 Washington State Planes, North Zone, US foot.

Property boundary extends farther to the north east.

One of the proposed soil borings inside the cap boundary will be converted to a perched monitoring well.

mg/kg = milligrams per kilogram.

AST = aboveground storage tank.

N

0 30 60 Feet

1:360

PROJECT:
BNSF GLACIER PARK EAST SITE
CHUMSTICK HIGHWAY AND STATE HIGHWAY 2
LEAVENWORTH, WASHINGTON

TITLE:
APPROXIMATE EXTENT OF PETROLEUM HYDROCARBONS IN SOIL AND PROPOSED SOIL BORING LOCATIONS

DRAWN BY:	R. COLLINS	PROJ. NO.:	333710.0000.0000
CHECKED BY:	B. HELLAND		
APPROVED BY:	K. WOODBURNE		**FIGURE 6**
DATE:	JUNE 2020		

TRC

19874 141st Place N.E.
Woodinville, WA 98072
Phone: 425.489.1938
www.trccompanies.com

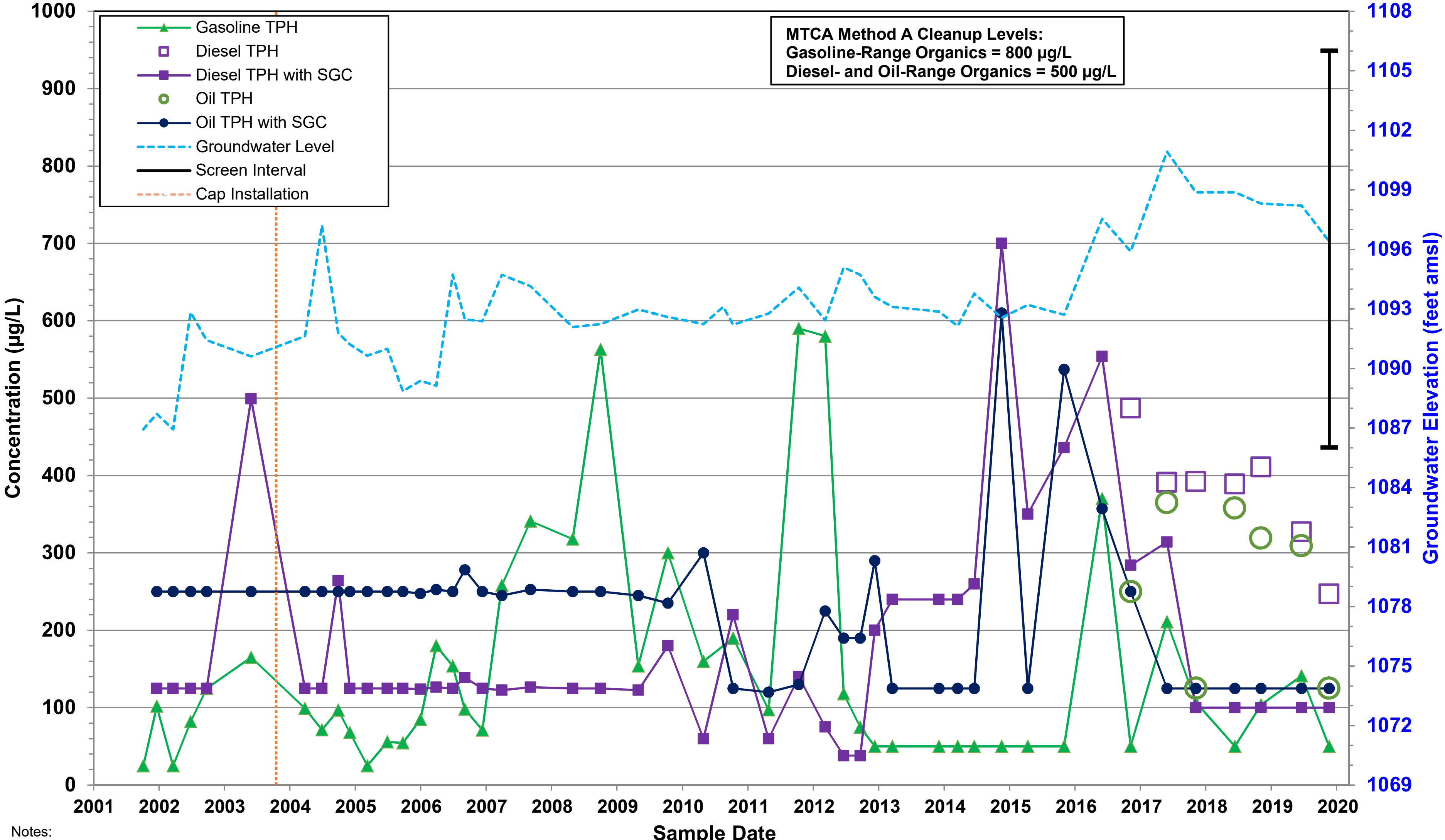
FILE NO.: 333710_Prop_Borings-FIG6.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet (Foot US) Map Rotation: 0

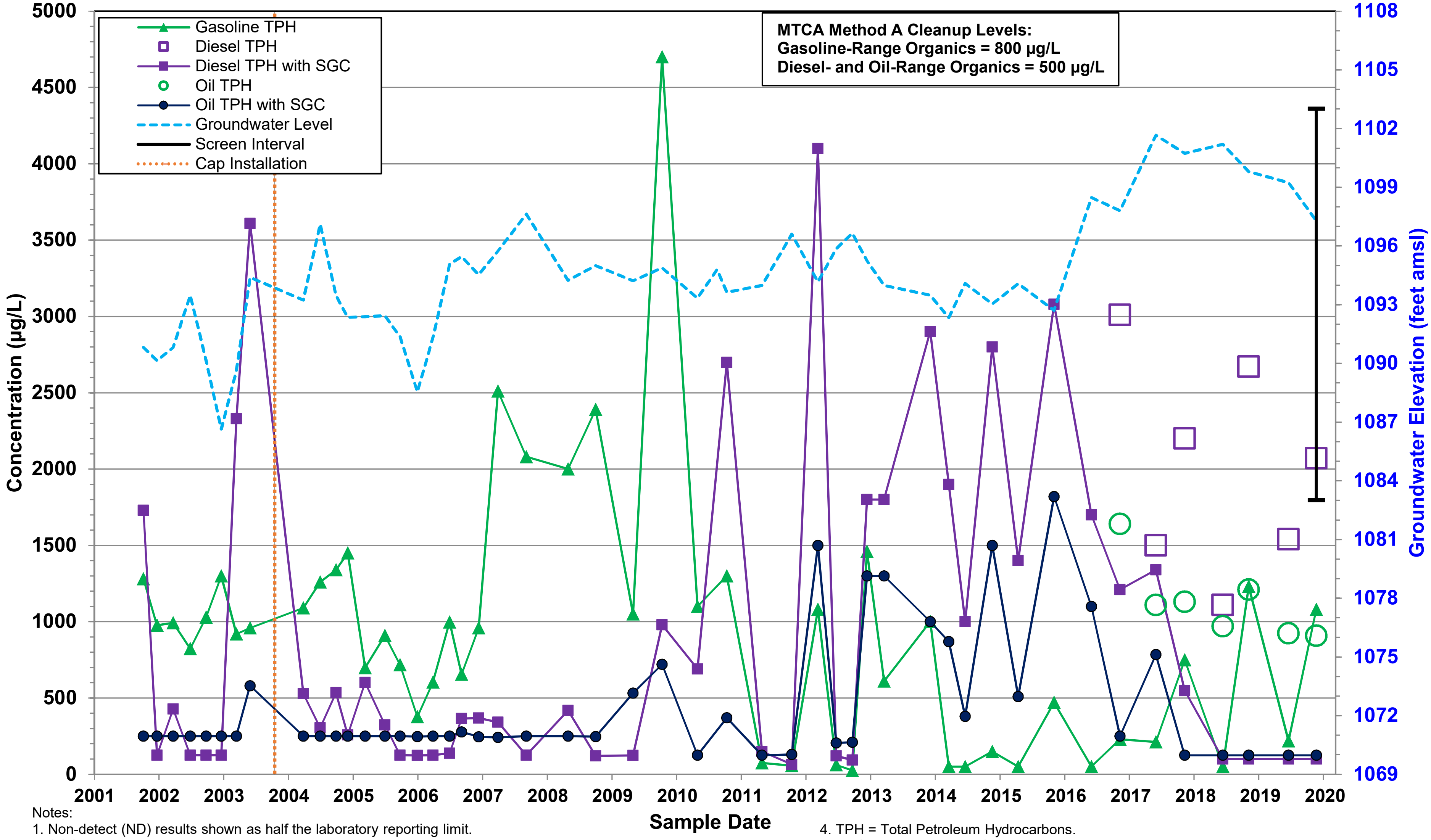
Plot Date: 6/22/2020, 09:23:37 AM by RCOLLINS -- LAYOUT: ANSI B (11"x17")
Path: S:\1-PROJECTS\BNSF\Glacier_Park_Site_Leavenworth\MXD\333710_Nov2019\333710_Prop_Borings-FIG6.mxd

Figure 7
Groundwater Elevation versus Total Petroleum Hydrocarbons - MW-2
BNSF Railway Company
Glacier Park East, Leavenworth, Washington



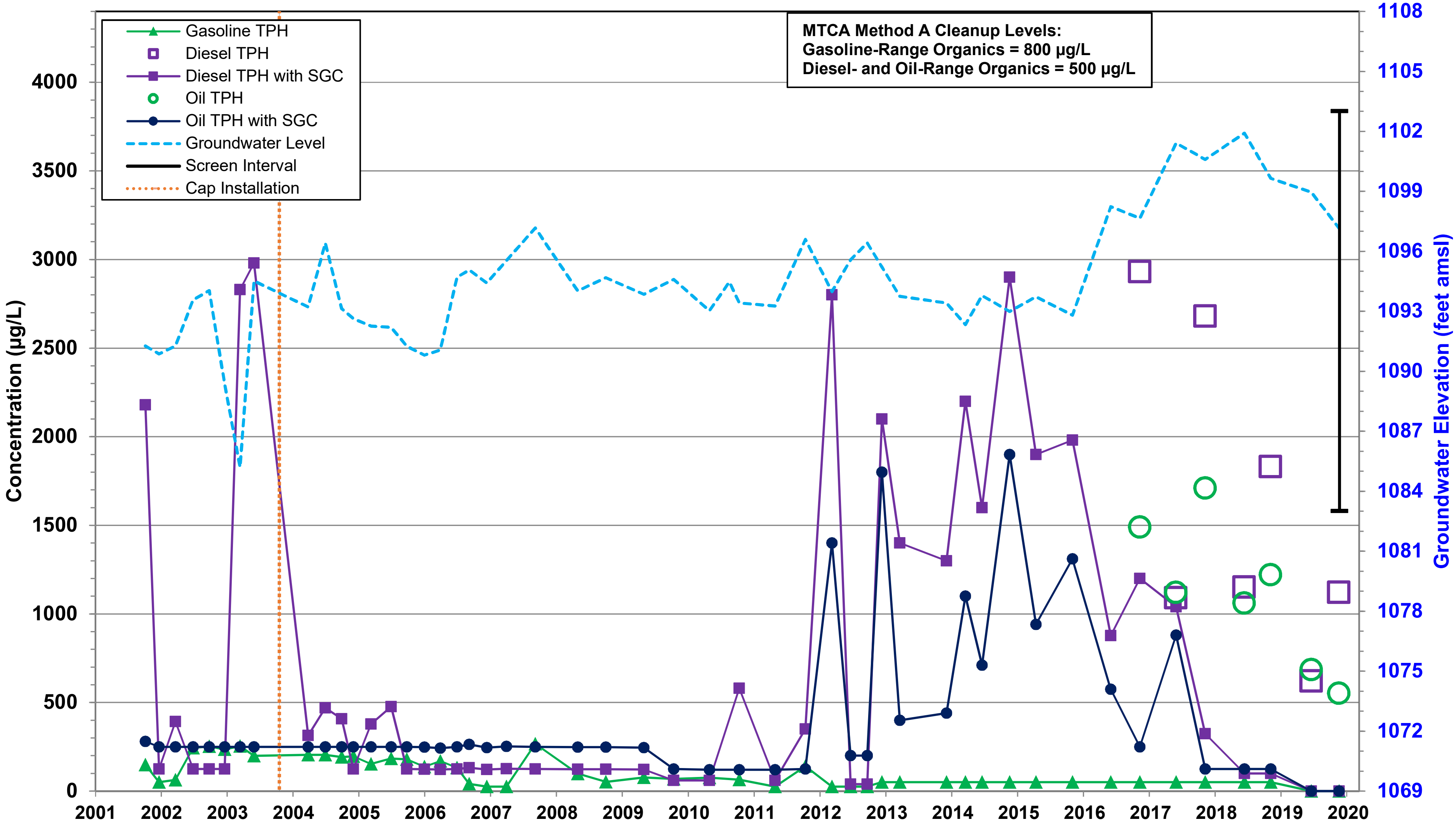
Notes:
1. Non-detect (ND) results shown as half the laboratory reporting limit.
2. SGC = silica gel cleanup.
3. µg/L = micrograms per liter.
4. TPH = Total Petroleum Hydrocarbons.
5. MTCA = Model Toxics Control Act.
6. amsl = above mean sea level.

Figure 8
Groundwater Elevation versus Total Petroleum Hydrocarbons - MW-3
BNSF Railway Company
Glacier Park East, Leavenworth, Washington



Notes:
1. Non-detect (ND) results shown as half the laboratory reporting limit.
2. SGC = silica gel cleanup.
3. µg/L = micrograms per liter.
4. TPH = Total Petroleum Hydrocarbons.
5. MTCA = Model Toxics Control Act.
6. amsl = above mean sea level.

Figure 9
Groundwater Elevation versus Total Petroleum Hydrocarbons - MW-4
BNSF Railway Company
Glacier Park East, Leavenworth, Washington



Notes:
1. Non-detect (ND) results shown as half the laboratory reporting limit.
2. SGC = silica gel cleanup.
3. µg/L = micrograms per liter.
4. TPH = Total Petroleum Hydrocarbons.
5. MTCA = Model Toxics Control Act.
6. amsl = above mean sea level.

TRC

Appendix A

Quality Assurance Project Plan
and
Sampling Analysis Plan

Appendix A:
Quality Assurance Project Plan
and Sampling and Analysis Plan

TABLE OF CONTENTS

TABLES

FIGURES

ATTACHMENTS

ACRONYM LIST

%R	Percent recovery
AO	Agreed Order
ASTM	American Society for Testing and Materials
bgs	Below ground surface
BNSF	Burlington Northern and Santa Fe Railway Company
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CUSA	Chevron U.S.A., Inc.
CUL	Cleanup level
DOT	Department of Transportation
DQO	Data Quality Objective
DRO	Diesel-range organics
EC	Electrical conductivity
Ecology	Washington Department of Ecology
ECR	Engineering, Construction, and Remediation
EDD	Electronic data deliverable
EIM	Environmental Information Management
EPA	United States Environmental Protection Agency
ft bgs	Feet below ground surface
GRO	Gasoline-range organics
HASP	Health & Safety Plan
IDW	Investigation-derived waste
LCS	Laboratory control sample
LNAPL	Light non-aqueous phase liquid
mg/kg	Milligrams per kilogram
mL	Milliliter
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MTCA	Model Toxics Cleanup Act
NAVD88	North American Vertical Datum of 1988
NELAC	National Environmental Laboratory Accreditation Conference
NTU	Nephelometric turbidity units
NUNC	Northwest Utility Notification Center
NWTPH-Dx	Northwest Total Petroleum Hydrocarbons method for diesel-range organics
NWTPH-Gx	Northwest Total Petroleum Hydrocarbons method for gasoline-range organics
ORO	Oil-range organics
PID	Photoionization detector
PPE	Personal protective equipment
PQL	Practical Quantitation Limit
PVC	Polyvinyl chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SGC	Silica gel cleanup
Site	Glacier Park East Site
SOP	Standard Operating Procedure
SRI	Supplemental Remedial Investigation

TPH	Total Petroleum Hydrocarbons
TSA	Technical system audit
USCS	Unified Soil Classification System
VOC	Volatile organic compound
WAC	Washington Administrative Code
WP	Work Plan

1.0 Introduction

This Quality Assurance Project Plan (QAPP) and Sampling Analysis Plan (SAP) has been developed to identify the procedures and criteria to establish technical accuracy, precision, and validity of environmental data collected pursuant to Agreed Order (AO) No. DE16838 for the BNSF Railway Company (BNSF) Glacier Park East Site (the Site) in Leavenworth, Washington (Ecology, 2020). This document was developed in conjunction with and is presented as Appendix A to the *Supplemental Remedial Investigation Work Plan* (SRI WP) and contains protocols regarding sampling, laboratory, and analytical procedures that apply to the investigation activities. These protocols will ensure that data collected for use in project decisions will meet the data quality objectives (DQOs) defined in Section 2.1.

This SAP was prepared in accordance with the Washington Administrative Code (WAC) Title 173 Chapter 340 Section 820.

1.1 Site Description

The Glacier Park East property is a vacant 1-acre lot located in a small depression bordered by U.S. Highway 2 to the southeast, Chumstick Highway to the southwest, the BNSF right-of-way to the northwest, and Chelan County Public Utilities District property to the northeast. Ponderosa pine trees cover most of the eastern portion of the property. The remaining area is sparsely vegetated and generally covered with coarse gravel and an asphaltic concrete soil isolation cap, as described in Section 3.0 of the SRI WP. The Wenatchee River is located about 800 feet to the southeast.

1.2 Site Location

The property is located northeast of the intersection of U.S. Highway 2 and the Chumstick Highway (formerly State Route 209) in Leavenworth, Chelan County, Washington (Figure 1). The City of Leavenworth is located within the upper reaches of the Wenatchee River Valley at an elevation of approximately 1,170 feet above mean seal level.

1.3 Responsible Agency

Investigation and monitoring activities will be conducted under the oversight of the Washington State Department of Ecology (Ecology) pursuant to AO No. DE16838.

TRC Environmental Corporation (TRC) was retained by BNSF to provide environmental consulting services in support of activities at the Site, including continued groundwater monitoring and cap maintenance.

1.4 Project Organization

The project personnel names and contact information are included in Table 1.

1.4.1 Management Responsibilities

1.4.1.1 Ecology Site Manager

The Ecology Site Manager, Mr. Kyle Parker, will oversee the project for Ecology. The Ecology Site Manager is responsible for the overall management of activities performed to ensure that all work is completed in accordance with the AO.

1.4.1.2 Potentially Liable Party Project Leader

BNSF and Chevron U.S.A. Inc. (CUSA) are the Potentially Liable Parties (PLPs) for this Site. The PLP Project Leader, Mr. Scott MacDonald with BNSF, will be the primary client contact. Mr. MacDonald will help in obtaining any necessary approvals for all activities under the project from the Ecology Project Manager.

Contact Information:

Contact:	Mr. Scott MacDonald
Address:	BNSF 605 Puyallup Avenue South Tacoma, WA 98421
Phone:	206-625-6376
Email:	scott.macdonald@bnsf.com

1.4.1.3 TRC Project Manager

The TRC Project Manager, Mr. Keith Woodburne, will provide overall direction to the field investigation team including TRC sampling personnel as well as subcontractors utilized in the field. TRC Project Manager will also ensure that all health and safety requirements are met for all TRC employees and subcontractors performing field activities. A Health and Safety Plan (HASP) is included as an appendix of the SRI WP.

Contact Information:

Contact:	Mr. Keith Woodburne
Address:	TRC 19874 141st Place NE Woodinville, WA 98072
Phone:	425-489-1938
Email:	kwoodburne@trccompanies.com

1.4.1.4 Quality Assurance Officer

The TRC Quality Assurance (QA) Officer, Mr. Doug Kunkel, has overall responsibility for QA oversight. The TRC QA Officer communicates directly to the TRC Project Manager. TRC's QA Officer will initiate and monitor any necessary formal corrective actions. He will assist in preparing QA and Quality Control (QC) project summaries for the final report, including analysis of precision, accuracy and completeness of data collected.

Contact Information:

Contact:	Mr. Doug Kunkel
Address:	TRC 1180 NW Maple Street, Suite 310 Issaquah, WA 98027
Phone:	425-395-0016
Email:	dkunkel@trccompanies.com

1.4.2 Field Responsibilities

1.4.2.1 TRC Field Team Leader

The Field Team Leader, Mr. Mathieu Piovesan, has overall responsibility for completion of all field activities in accordance with the QAPP/SAP and is the communication link between the field team, subcontractors, and TRC project management. The Field Team Leader will be on-site to:

1) Ensure that required QC procedures are followed for sample collection and drilling.
2) Initiate informal and/or formal corrective actions, as necessary.
3) Function as the Site Safety Officer to ensure the HASP is available and followed by all personnel entering the Site.
4) Maintain and report QC records (e.g., chain–of–custody). This individual reports to the TRC Project Manager.

Contact Information:

Contact:	Mr. Mathieu Piovesan
Address:	TRC 19874 141st Place NE Woodinville, WA 98072
Phone:	425-219-2221
Email:	mpiovesan@trccompanies.com

1.4.2.2 Field Staff

The field staff reports directly to the TRC Field Team Leader. The responsibilities of the field team include:

- Understanding and implementing Site-specific QAPP/SAP and WP requirements as they relate to their duties;
- Understanding and complying with the HASP as it relates to their duties;
- Collecting samples, conducting field measurements, and decontaminating equipment according to documented procedures stated in the Site-specific QAPP/SAP;
- Ensuring that field instruments are properly operated, calibrated, and maintained, and that adequate documentation is kept for all instruments;
- Collecting the required QC samples and thoroughly documenting QC sample collection;
- Ensuring that field documentation and data are complete and accurate; and
- Communicating any non-conformance or potential data quality issues to the TRC Field Team Leader.

1.4.3 *Laboratory Responsibilities*

The analytical laboratory will be Pace Analytical. Contact information for the laboratory is provided below.

Contact Information:

Contact:	Mr. Mark Beasley, Technical Service Representative
Address:	Pace Analytical Services 12065 Lebanon Rd. Mount Juliet, TN 37122
Phone:	615-773-9672
Email:	mbeasley@pacenational.com

1.4.3.1 Laboratory Manager

The Laboratory Manager is ultimately responsible for the data produced by the laboratory. Specific responsibilities include:

- Implementing and adhering to the QA and corporate policies and procedures within the laboratory;
- Approving Standard Operating Procedures (SOPs);
- Maintaining adequate staffing; and
- Implementing internal/external audit findings and corrective actions.

1.4.3.2 Laboratory QA Manager

The Laboratory QA Manager reports directly to the QA Director. Specific responsibilities include:

- Approving the laboratory SOPs;
- Ensuring and improving quality within the laboratory;
- Supervising and providing guidance and training to laboratory staff;
- Addressing all client inquiries involving data quality issues;
- Performing QA audits and assessments;
- Tracking external and internal findings of QA audits; and
- Coordinating laboratory certification and accreditation programs.

1.4.3.3 Laboratory Project Manager

The Laboratory Project Manager is the primary point of contact between the laboratory and TRC. Specific responsibilities of the Laboratory Project Manager include:

- Keeping the laboratory and client informed of project status;
- Monitoring, reviewing, and evaluating the progress and performance of projects;
- Reporting client inquiries involving data quality issues or data acceptability to the Laboratory QA Manager and to the operations staff; and
- Reviewing project data packages for completeness and compliance to client needs.

1.4.3.4 Laboratory Section Leader

Specific responsibilities include:

- Supervising daily activities within the group;
- Supervising QC activities;
- Supervising the preparation and maintenance of laboratory records;
- Evaluating instrument performance and supervising the calibration, preventative maintenance, and scheduling of repairs; and
- Overseeing or performing review and approval of all data.

1.4.3.5 Laboratory Analyst/Technician

Each analyst or technician is responsible for:

- Performing technical procedures and data recording in accordance with documented procedures;
- Performing and documenting calibration and preventative maintenance;
- Performing data processing and data review procedures;
- Reporting non-conformances to the appropriate personnel; and
- Ensuring sample and data integrity by adhering to internal chain-of-custody procedures.

1.4.3.6 Laboratory Sample Custodian

The Sample Custodian ensures implementation of proper sample receipt procedures, including maintenance of chain-of-custody. Other specific responsibilities include:

- Notifying the Laboratory Project Manager of any discrepancies or anomalies with incoming samples;
- Logging samples into the laboratory tracking system;
- Ensuring that all samples are stored in the proper environment; and
- Overseeing sample disposal.

1.4.4 Other Subcontractors

Other required subcontractors will be specified prior to commencement of work. These will include drilling and private utility locator services.

2.0 Project and Data Quality Objectives

The goal of the investigation is to address the data gaps described in Section 5.3 of the SRI WP by conducting the proposed field investigations summarized in Section 6.0 of the SRI WP.

2.1 Data Quality Objectives

The Data Quality Objectives (DQOs) for this project were developed to ensure data quality and to define procedures for data collection. DQO steps one through seven are presented in Table 2.

The proposed analytical methodologies and laboratory reporting/quantification limits summarized in Table 3a for soil and 3b for groundwater are capable of detecting the target analytes at concentrations less than the applicable MTCA Method A CUL. These methods provide a sufficient level of data quality and can be used for purposes of risk assessment, evaluation of remedial systems, and verification that cleanup standards have been met. To ensure that the analytical methodologies can achieve the DQOs, measurement performance criteria have been set for the analytical measurements, as described in Section 2.2, for accuracy, precision, representativeness, completeness, selectivity, and comparability.

2.2 Measurement Quality Objectives

This QAPP/SAP was designed produce data of the quality necessary to achieve DQOs and meet or exceed the minimum standard requirements for field and analytical methods. The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting, which will provide results that are scientifically valid, and the levels of which are sufficient to meet DQOs. Specific procedures for sampling, chain of custody, calibration of laboratory and field instruments, laboratory analysis, reporting of data, internal quality control, preventative maintenance of field and laboratory equipment, and corrective action are described in other sections of QAPP/SAP. The purpose of this section is to state the specific, required QA objectives for precision, accuracy, representativeness, comparability, and completeness.

2.2.1 Precision

Precision is the agreement among a set of replicate measurements without consideration of the "true" or accurate value (i.e., variability between measurements of the same material for the same analyte). Precision is measured in a variety of ways including statistically, such as calculating variance or standard deviation.

2.2.1.1 Field Precision Objectives

In general field precision is optimized by following SOPs, utilizing experienced/trained sampling crews, and conducting field audits. Field precision may also be assessed through the collection and measurement of field duplicates (one extra sample in addition to the original field sample). Field duplicates may be collected at a frequency of one per 20 investigative samples for aqueous samples per analytical method. Precision can be evaluated through the calculation of relative percent difference (RPD). The resulting information may be used to assess sample homogeneity, spatial variability at the Site, sample collection reproducibility, and analytical variability. When collected, field duplicate RPDs should be less than 30 for aqueous samples.

2.2.1.2 Laboratory Precision Objectives

Precision in the laboratory is assessed through the calculation of RPD for laboratory duplicate samples (two samples from the same container). Laboratory precision measures both sample preparation and analysis reproducibility.

For the organic analyses of soil and groundwater, laboratory precision will be assessed through the analysis of matrix spike/matrix spike duplicate (MS/MSD) samples and laboratory duplicate samples. In general, these QC samples will be performed at a frequency of one per 20 investigative samples per matrix.

2.2.2 Accuracy

Accuracy is the closeness of agreement between an observed value and an accepted reference value. The difference between the observed value and the reference value includes components of both systematic error (bias) and random error.

2.2.2.1 Field Accuracy Objectives

Accuracy in the field is optimized through the adherence to all field instrument calibration procedures, sample handling, preservation, and holding time requirements. Accuracy will be evaluated using trip and temperature blanks, and the data validation process, which examines field documentation.

Trip blanks will be submitted with each cooler that includes volatile organic compound (VOC) samples. Trip blank samples will be analyzed for the same analytes for which the associated media are being analyzed.

The trip blanks will indicate any adverse effects of sample contamination from an outside source and could result in a positive bias. The bias will be minimized by following standardized SOPs for equipment decontamination, utilizing an experienced/trained sampling crew, conducting field audits, and ensuring the purity of all chemicals used as sample preservatives.

2.2.2.2 Laboratory Accuracy Objectives

Laboratories assess the overall accuracy of their instruments and analytical methods (independent of sample or matrix effects) through the measurement of standards, which are materials of accepted reference value. Accuracy will vary from analysis to analysis because of individual sample and matrix effects. In an individual analysis, accuracy will be measured in terms of method blank results, the percent recovery (%R) of surrogate or internal standard compounds in organic analyses, or %R of spiked compounds in MS and/or MSD samples, and/or laboratory control samples (LCS). This gives an indication of expected recovery for analytes tending to behave chemically like the spiked or surrogate compounds and provides a measure of bias for the parameter of interest. The laboratory method blanks will indicate any adverse effects of sample contamination from an outside source (i.e., sample preparation or sample analysis) and could result in a positive bias.

The frequency of surrogates or internal standards, MS/MSD samples, and LCS are defined in the laboratory SOPs. Laboratory accuracy will be improved by following the EPA methods and laboratory SOPs that include detailed requirements for each analysis, utilizing experienced and trained laboratory personnel, ensuring the purity of all chemicals, and conducting laboratory audits.

2.2.3 Representativeness

Representativeness is a qualitative parameter that expresses the degree to which the data and sampling design accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition within a defined spatial and/or temporal boundary. Representativeness is a qualitative parameter that is dependent upon the proper design of the sampling program and the overall quality assurance program.

2.2.3.1 Measures to Ensure Representativeness of Field Data

Representativeness is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the QAPP/SAP and required sampling procedures are followed and that proper sampling, sample handling, and sample preservation techniques are used. Representativeness may also be assessed using field duplicate samples. By definition, field duplicate samples are collected so they are equally representative of a given point in space and time. In this way, they provide both precision and representativeness information. As stated previously, field duplicate samples will generally be collected at a frequency of one per 20 investigative aqueous samples per analytical method.

In general, representativeness in the field will be maximized by following required procedures, proper sample homogenization procedures, proper sample preservation procedures, utilizing experienced/trained sampling crews, and data validation procedures.

2.2.3.2 Measures to Ensure Representativeness of Laboratory Data

Representativeness in the laboratory is ensured by using the proper analytical procedures, appropriate methods, and meeting sample holding times. Following the detailed requirements specified in the analytical methods and the laboratory SOPs will maximize the representativeness of the laboratory data.

2.2.4 Comparability

Comparability is a qualitative parameter that expresses the confidence with which one dataset can be compared to another.

2.2.4.1 Measures to Ensure Field Comparability

Comparability is dependent upon the proper design of the sampling program and will be satisfied by ensuring that the QAPP/SAP and SOPs are followed, and that proper sampling and preservation techniques are used.

2.2.4.2 Measures to Ensure Laboratory Comparability

Comparability is dependent on the use of analytical methods and approved laboratory SOPs, and the reporting of data in standardized units.

2.2.5 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. "Normal conditions" are defined as the conditions expected if the sampling plan was implemented as planned.

2.2.5.1 Field Completeness Objectives

Field completeness is a measure of the amount of (1) valid measurements obtained from all the measurements taken in the project, and (2) valid samples collected. The field completeness objective is greater than 90 percent. This allows for the potential loss of samples due to sampling problems or bottle breakage during transport.

2.2.5.2 Laboratory Completeness Objectives

Laboratory completeness is a measure of the amount of valid measurements obtained from all valid samples submitted to the laboratory. The laboratory completeness objective is greater than 95 percent. This allows for the potential loss of samples impossible to analyze due to unforeseen interferences and rejected data following data validation.

2.3 Data Review and Validation

All data, as applicable, from the subsurface soil and groundwater sampling will be validated in accordance with EPA Guidance on Environmental Data Verification and Data Validation, Data Quality Assessment: Statistical Methods. Any deviation should be documented and provided with the analytical data report.

Data validation entails comparing the sample descriptions with the field sheets and Chain-of-Custody forms for consistency and ensuring that any anomalies in sample processing and handling are documented. Analytical data validation will occur as described in the analytical SOPs for each parameter and the laboratory SOPs for data review. Data validation is accomplished by the laboratory using control charts and data review checklists. Discrepancies are noted in the analytical file and appropriate data flags are used. If data are determined to be outside of control limits, the data are flagged on the laboratory report. Laboratory personnel will review MS/MSDs, lab blanks, and lab duplicates to ensure they are acceptable. The analytical laboratory will provide data packages that will allow TRC to review of all sample and laboratory QC sample results.

TRC will perform additional data validation to ensure that the analytical data meet the quality objectives of this QAPP/SAP. TRC's review is an independent data validation process and a check on the reviews conducted by the laboratory to ensure consistency of all field and analytical data that are generated for work at the Site.

All data entry performed by TRC will be reviewed for accuracy. Verification will be carried out by proofing against the original data. Data verification includes checking that results have been transferred correctly from the original hand-written, hard copy field and analytical laboratory documentation to the project database. The goal of data verification is to identify and correct data reporting errors.

2.4 Data Management

Measurements and sample collection information will be transcribed directly into the field logbook or onto standardized forms. If errors are made, results will be legibly crossed out, initialed and dated by the person recording the data, and corrected in a space adjacent to the original (erroneous) entry. Daily reviews of the field records will be performed by the TRC Field Team Leader. As appropriate, field data will be tabulated and presented in the associated report.

Data received from the analytical laboratory will be tabulated and presented in the associated report(s). Additionally, electronic data deliverables (EDDs) will be requested from the laboratory and will be managed by TRC for inclusion into Ecology's Environmental Information Management (EIM) System. The EDDs will be formatted and submitted to Ecology for import into the EIM database on a periodic basis pursuant to project schedule requirements.

2.5 Assessment Oversight

The audit is the standard mechanism for performing oversight of the effectiveness and adequacy of a quality system of a program or project collecting environmental measurements. During an audit, the data quality needs of the program as articulated in the quality assurance planning documents are compared against the implementation information and quality of the data obtained. Performance audits may be performed as independent checks on the quality of data obtained from sampling, analysis, and data gathering activities. These audits may show the need for corrective action.

2.5.1 Field Technical System Audits

Technical system audits (TSAs) of field activities may be conducted to verify that sampling and analysis are performed in accordance with the procedures established in the QAPP/SAP.

A system audit of field activities, including sampling and field measurements, may be conducted and documented by the TRC QA Officer (or designee) at the start of sampling. The purpose of this audit is to verify that all established procedures are being followed as planned and documented and to allow for timely corrective action, reducing the impact of the nonconformance. The audit will ensure that all personnel have read the SAP. The audit will cover field sampling records, field measurement results, field instrument operation and calibration records, sample collection, preservation, handling, and packaging procedures, adherence to QA procedures, personnel training, sampling procedures, decontamination procedures, review of sampling design versus the Site-specific SAPs, corrective action procedures, and chain-of-custody, etc. Follow-up surveillance will be conducted by the TRC Field Team Leader to verify that QA procedures are maintained throughout the investigation.

In addition to field TSAs, the Field Team Leader will provide oversight of any on-site subcontractors (e.g., drilling or geophysical survey contractors) and report any issues to the TRC Project Manager.

2.5.2 Laboratory Performance Assessment

Laboratories will comply with EPA and National Environmental Laboratory Accreditation Conference (NELAC) requirements for laboratory QA programs. Data resulting from participation in the NELAC program shall be reviewed by the laboratory Quality Assurance Manager and any problems shall be documented and addressed.

2.5.3 Peer Review of Final Report

As part of TRC's Environmental Sector Quality Management Plan, peer review is required on all project reports. The TRC Project Manager is responsible for the selection of appropriate peer reviewers. At a minimum, peer reviews will ensure that the project objectives are met, the report is technically defensible, the requirements in the SAP are satisfied, and the conclusions or recommendations in the report are supported by the work performed.

2.6 Corrective Action Responses

2.6.1 Intermediate Corrective Action

Corrective action for analytical work may include recalibration of instruments, reanalysis of QC samples and, if necessary, reanalysis of actual field samples. Specific QC procedures and checklists will be in use by the analytical laboratory, designed to help analysts detect the need for corrective action. Often the person's experience will be valuable in alerting the operator to suspicious data or malfunctioning equipment.

If an immediate corrective action can be taken, as part of normal operating procedures, the collection of poor-quality data can be avoided. Instrument and equipment malfunctions are amenable to this type of action and the QC procedures include troubleshooting guides and corrective action suggestions. The actions taken will be noted in field or laboratory notebooks, but no other formal documentation is required, unless further corrective action is necessary. These on-the-spot corrective actions are an everyday part of the QA/QC system.

Corrective action during the field sampling portion of a program is most often a result of equipment failure or an operator oversight and may require recollection of a sample. Operator oversight is best avoided by having field crew members audit each other’s work before and after a test. Every effort will be made by the Field Team Leader to ensure that all QC procedures are followed.

If potential problems are not solved as an immediate corrective action, TRC will apply formalized long-term corrective action if necessary.

2.6.2 Long-Term Corrective Action

The need for long-term corrective action may be identified by standard QC procedures, control charts, and performance or system audits. Any quality problem that cannot be solved by immediate corrective action falls into the long-term category. TRC will use a system to ensure that the quality problem is reported to a person responsible for correcting it, and who is part of a closed-loop action and follow-up plan.

The essential steps in the closed-loop corrective action system are listed below.

- Identify and define the problem.
- Assign responsibility for investigating the problem.
- Investigate and determine the cause of the problem.
- Determine a corrective action to eliminate the problem.
- Assign and accept responsibility for implementing the corrective action.
- Establish effectiveness of the corrective action and implement it.
- Verify that the corrective action has eliminated the problem.

Documentation of the problem is important to the system. A Corrective Action Request Form will be filled out by the person finding the quality problem. This form identifies the problem, possible causes and the person responsible for action on the problem.

The responsible person may be a laboratory analyst, Field Team Leader, Laboratory QA Manager, or the TRC QA Officer. If no person is identified as responsible for the action, the TRC QA Officer will investigate the situation and determines who is responsible in each case.

The Corrective Action Request Form includes a description of the corrective action planned and the date it was taken, and space for follow-up. The TRC QA Officer checks to be sure that initial action has been taken and appears effective and, at an appropriate later date, checks again to see if the problem has been fully solved. The TRC QA Officer receives a copy of all Corrective

Action Request Forms. This permanent record aids the TRC QA Officer in follow-up and makes any quality problems visible to management; the log may also prove valuable in listing a similar problem and its solution.

2.7 Non-Conformances

2.7.1 Field Non-Conformances

Corrective action in the field may be needed when the sample network is changed (i.e., more/fewer samples, sampling locations other than those specified in the SAP), or when sampling procedures and/or field analytical procedures require modification due to unexpected conditions. The field team may identify the need for corrective action. The TRC Field Team Leader will approve the corrective action and notify the TRC Project Manager. The TRC Field Team Leader will ensure that the corrective measure is implemented by the field team. Corrective actions will be implemented and documented in the field logbook. Documentation will include:

- a description of the circumstances that initiated the corrective action;
- the action taken in response;
- the final resolution; and
- any necessary approvals.

No staff member will initiate corrective action without prior communication of findings through the proper channels. If necessary, a problem resolution audit will be conducted.

2.7.2 Laboratory Non-Conformances

Corrective action in the laboratory may occur prior to, during, and after initial analyses. A number of conditions such as broken sample containers, omissions or discrepancies with chain-of-custody documentation, low/high pH readings, and potentially high concentration samples may be identified during sample log-in or just prior to analysis. Following consultation with laboratory analysts and Laboratory Section Leaders, it may be necessary for the Laboratory QA Manager to approve the implementation of corrective action. The EPA methods, and laboratory SOPs specify some conditions during or after analysis that may automatically trigger corrective action or optional procedures. These conditions may include dilution of samples, additional sample extract cleanup, and automatic reinjection/reanalysis when certain QC criteria are not met.

The analyst may identify the need for corrective action. The Laboratory Section Leader, in consultation with the staff, will approve the required corrective action to be implemented by the laboratory staff. The Laboratory QA Manager will ensure implementation and documentation of the corrective action.

These corrective actions are performed prior to release of the data from the laboratory. The corrective action will be documented in both the laboratory's corrective action files, and the narrative data report sent from the laboratory to TRC. If the corrective action does not rectify the situation, the laboratory will contact the TRC QA Manager, who will determine the action to be taken and inform the appropriate personnel. If necessary, a problem resolution audit will be conducted.

2.7.3 *Data Validation and Data Assessment Non-Conformances*

The need for corrective action may be identified during either data validation or data assessment. Potential types of corrective action may include resampling by the field team or reanalysis of samples by the laboratory. If the data validator or data assessor identifies a corrective action situation, the TRC Project Manager will be responsible for informing the appropriate personnel. All corrective actions of this type will be documented by the TRC Project Manager and maintained in the project files.

2.8 Response to Quality Assurance Assessments/Audits

The response to the TSA reports will include a description of the corrective action(s) to be implemented, the identities of the personnel responsible for implementing the corrective action, and the schedule for implementation/completion. All responses must be completed within one week of issuing the TSA report. The response will be reviewed by the TRC QA Manager and, if all issues have been addressed appropriately and in a timely manner, no further action will be required. If the corrective action(s) are inadequate or inappropriate, follow-up activities, including additional audits, or discussions with the TRC Project Manager, will be conducted by the TRC QA Manager. The complete TSA report, including resolution of any deficiencies, will be included in the QA reports to management.

The report will be distributed to the appropriate personnel for response: the TRC Field Team Leader will be responsible for responding to the field sampling TSA report, and the Laboratory QA Manager will be responsible for addressing the fixed laboratory TSA report. Significant issues that are discovered during the TSA and which could potentially affect data quality or usability will be brought to the immediate attention of the TRC Project Manager.

3.0 Sample Design

The scope of work includes the following activities, described in detail in Section 7.0 of the SRI WP:

- Collect three depth-discrete groundwater samples from each existing well (MW-1 through MW-6).
- Advance six shallow soil borings to an anticipated total depth of 25 ft bgs to 35 ft bgs and collect up to three soil samples from each soil boring. Additional borings might be advanced in the area around SB-1, SB-2, and SB-3 based on field screening results to further delineate the lateral extent of petroleum-impacted soil.
- Convert one of the shallow soil borings, SB-5 or SB-6, to a perched groundwater well.
- Advance one deep boring to a total depth of 80 ft bgs near MW-5 to obtain detailed lithological data..
- Collect groundwater samples from the newly installed well.
- Collected transducer data over a one-year period from the six existing monitoring wells (MW-1 through MW-6) to observe fluctuations in groundwater elevation, hydraulic gradient, and potentially in groundwater flow direction through four seasons.
- Collect slug-test data on existing wells (MW-1 through MW-6) to determine hydraulic conductivities in each well.

- Conduct groundwater monitoring at MW-1 through MW-6 and existing and new piezometers PZ-1 through PZ-4 on a semi-annual schedule and analyze samples for groundwater COCs and TOC.

3.1 Depth-Discrete Groundwater Sampling

Three depth-discrete samples will be collected from each of the current monitoring wells. The samples will be collected at the top, middle, and bottom of the screens of each groundwater monitoring well, as described in Table 4. Groundwater samples will be analyzed for the following groundwater COCs:

- DRO and ORO by Northwest Total Petroleum Hydrocarbons (NWTPH-Dx) with and without SGC;
- GRO by Northwest Total Petroleum Hydrocarbons method for gasoline-range organics (NWTPH-Gx); and
- Benzene by EPA Method 8260C.

3.2 Soil Borings and Soil Sampling

Six soil borings are proposed to be advanced to the depth of known or anticipated petroleum-impacted soil (SB-1 through SB-6, Figure 2). Four soil borings (SB-1, SB-2, SB-3, and SB-4) will be advanced near the northeast perimeter of the cap to delineate the extent of petroleum-impacted soil, which is anticipated to differ from what was delineated prior to the cap installation in 2003. Two soil borings (SB-5 and SB-6) will be advanced through the cap in areas of known impacts.

The soil borings located outside of the sloped edge of the cap area (SB-1, SB-2, and SB-3) will be advanced to an anticipated depth of 25 feet bgs. If petroleum-impacted soil is noted at SB-1, SB-2, or SB-3 based on field screening, additional soil borings may be advanced to further delineate the lateral extent of impacts. The soil borings located within the footprint of the cap (SB-4, SB-5, and SB-6) will be advanced to an anticipated depth of 35 feet bgs. The proposed depths represent the maximum anticipated depth of petroleum-impacted soil based on the cross sections presented in Figure 3 of the SRI Work Plan. If petroleum-impacted soil is identified via visual or field screening methods, the soil borings will be advanced to the depth where petroleum-impacted soil is no longer observed, or to the maximum anticipated depth.

One soil boring (GWB-1, Figure 2) will be advanced into the saturated zone to an anticipated depth of 80 feet bgs. GWB-1 will be located just north of the cap and near MW-5. Boring GWB-1 will be continuously logged from grade to total depth of 80 feet bgs to provide a detailed stratigraphic log of lithology with focus on identification of potential transmissive zones within the saturated zone encountered at approximately 50 feet bgs.

If an interval of petroleum-impacted soil is observed, one soil sample will be collected at the top of the interval, one in the middle of interval, and one just below the interval. If several discrete petroleum-impacted soil lenses are observed throughout a boring, a sample will be collected from the top layer and from the bottom layer, and at a depth below the bottom layer of impact to define the maximum depth of impact. If field observations and screening methods do not clearly identify petroleum-impacted soil, two soil samples will be collected from each boring at depths indicated in Table 5. The soil samples will be collected following the methods outlined in Section 5.3 and will be analyzed for the following COCs:

- TPH as DRO and ORO by NWTPH-Dx, with and without SGC;
- TPH as GRO by NWTPH-Gx;
- BTEX by EPA Method 8260C; and
- Naphthalenes by EPA Method 8270 SIM

3.3 Perched Water-Bearing Zone

To provide groundwater data necessary to characterize the potential contact of transient perched groundwater with petroleum-impacted soil beneath the cap, soil boring SB-5 or SB-6 will be converted to perched groundwater piezometer PZ-4. Based on the current understanding of the distribution of petroleum-impacted soil beneath the cap, it is anticipated that SB-5 will be the soil boring converted to piezometer PZ-4. However, if field observations and soil PID readings indicate that the soil is visually more impacted at SB-6 compared to SB-5, PZ-4 will be installed at SB-6. Piezometer PZ-4 will be installed in accordance with the methods outlined in Section 5.3.

If groundwater is present in any of the transient perched groundwater piezometers, including newly installed PZ-4, the transient perched groundwater will be sampled and analyzed for the following COCs:

- DRO and ORO by NWTPH-Dx with and without SGC;
- GRO by NWTPH-Gx; and
- Benzene by EPA Method 8260C.

TOC analysis will be also be performed by EPA Method 9060A to quantify and characterize the amount of organic material that may contribute to elevated DRO and ORO concentrations reported without SGC.

3.4 Groundwater Sampling

Groundwater samples will be collected from all six existing wells (MW-1 through MW-6) to assess current groundwater impacts. Additionally, the transient perched groundwater piezometers will be sampled if sufficient water is present in the well. Groundwater samples will be analyzed for the following COCs:

- DRO and ORO by NWTPH-Dx with and without SGC;
- GRO by NWTPH-Gx; and
- Benzene by EPA Method 8260C.

TOC analysis will be also be performed by EPA Method 9060A to quantify and characterize the amount of organic material that may contribute to elevated DRO and ORO concentrations reported without SGC.

4.0 Request for Analyses

4.1 Analyses Narrative

Tables 3a and 3b detail the analytical methods that will be used for samples collected. In general, the methods will be followed as written. Information on container types, sample volumes, preservatives, special handling, and analytical holding times for each parameter are summarized in Tables 6a and 6b. All analyses will be performed on a standard 10-day turnaround time. Laboratory QC samples include duplicates, spikes, laboratory blanks, and performance evaluation samples, and are performed by the laboratory according to the laboratory QA/QC plan.

4.2 Analytical Laboratory

Laboratory analysts will be responsible for daily checks and calibrations and for reporting any problems with the instruments. The maintenance schedule will follow the manufacturer's recommendations. Laboratory personnel will also be responsible for ensuring that critical parts are kept with the fixed laboratory instruments. Critical spare parts will be immediately available to reduce potential downtime. The inventory will primarily contain parts that are subject to frequent failure, have limited useful lifetimes, and/or cannot be obtained in a timely manner. Laboratory analysts will be responsible for performing routine operator maintenance and cleaning in accordance with the manufacturer's specifications.

5.0 Field Methods and Procedures

The field investigations and sample collection activities under the project will adhere to applicable SOPs and available Ecology guidance. Below describes the field activities and methods for the soil boring and well installation, slug testing, and groundwater monitoring activities. Field methodologies and procedures are further detailed in TRC's Engineering, Construction, and Remediation (ECR) Practice SOPs. Full copies of TRC's applicable field SOPs are included as Attachment 1 of this SAP.

5.1 Pre-Field Activities

5.1.1 Permitting and Access Agreements

Prior to beginning field work, Notice of Intent forms and applicable fees will be submitted to Ecology. In addition, all necessary access agreements and encroachment permits will be obtained for the proposed drilling locations.

5.1.2 Utility Clearance

Soil boring and monitoring well locations will be marked with white paint or staked according to Washington Northwest Utility Notification Center (NUNC) requirements. At least 2 days prior to commencing work, NUNC will be notified. The NUNC ticket will be maintained as long as work continues and will be updated as necessary for any monitoring well location adjustments that are made based upon the field data.

BNSF Signal, Telecommunications, Structures, and Track departments will be contacted to determine whether there are any underground communication lines, electrical lines, or pipes in the proposed drilling locations.

In addition, a private utility locator will be contracted to confirm the absence of buried utilities at each proposed soil boring and monitoring well location. Prior to drilling the soil borings and monitoring well, a pilot hole will be advanced using a hand auger or air-knife to a depth of approximately 5 ft bgs to verify the absence of buried utilities.

5.2 Field Equipment

5.2.1 List of Equipment Needed

Soil and groundwater sampling equipment to be used include (but is not limited to):

- Stainless-steel hand trowel
- PID meter
- Plastic 5-gallon buckets
- Depth-to-water meter
- pH/conductivity/temperature/turbidity meter
- Bladder pump and controller with built-in air compressor
- Disposable polyethylene bladders
- Skip bonded polyethylene tubing
- Disposable nitrile gloves
- Decontamination brushes
- Measuring tape
- Measuring wheel
- Camera

5.2.2 Calibration of Field Equipment

Initial calibration of the PID and water quality meters will be completed by the environmental equipment rental provider. TRC will perform subsequent calibrations daily prior to the beginning of the day using manufacturer specified calibration procedures. All equipment used during monitoring activities will be maintained, calibrated, and operated by field personnel according to manufacturer guidelines and recommendations. Calibration records that are traceable to the equipment will be maintained by field personnel.

5.3 Monitoring Well/Soil Boring Installation and Soil Sampling

The soil borings and monitoring wells will be installed using sonic drilling methods. At each well and soil boring location, a complete lithological log will be developed during advancement of the pilot boring and will include:

- Soil description (color, texture, structure, moisture/wetness, odor);
- Depth to groundwater;
- Total depth;
- Soil field screening results (e.g., PID measurement); and

- Other relevant observations.

Soil samples (cores) will be collected continuously starting at ground surface to total depth and extruded into sonic core barrels for examination. Each core sample will be logged in accordance with the USCS and American Society for Testing and Materials (ASTM) D-2487.

Volatile compound readings (using a PID, or equivalent) will be documented at least every 5 feet, targeting areas displaying visual evidence of impacts. If visual evidence of impacts and/or elevated volatile compound readings are present, a sheen test will be done in the field and the descriptors will be recorded on the lithologic log.

Soil samples will be collected in accordance with TRC's ECR practice SOP for soil sampling (ECR SOP-003, dated January 2020), included in Attachment 1. Specific details and procedures are described below.

Soil samples for VOC (i.e., BTEX) analyses will be collected first. It is Ecology policy that soils collected for volatile and gasoline analyses be collected in hermetically sealed sampling devices (such as Terracore® samplers) and analyzed within the holding time specified in EPA Method 5035, or immediately preserved by one of the processes specified in EPA Method 5035.

Soil samples not analyzed for VOCs will be directly transferred from the plastic sleeve to the appropriate wide-mouth glass jars using decontaminated stainless-steel spoons. All jars designated for a particular analysis will be filled sequentially before jars designated for another analysis are filled. For non-VOC samples, laboratory supplied sample containers will be filled to the top, taking care to prevent soil from remaining in the lid threads prior to being closed to prevent potential contaminant migration to or from the sample.

The transient perched groundwater piezometer (PZ-4) will be constructed with a 4-inch diameter casing and screen with a screen interval appropriate to intersect the observed petroleum-impacted soil beneath the cap. The exact screen length and depth interval will be determined in the field, but the total screen length will not exceed 10 feet. The 4-inch diameter casing will better facilitate evaluation and removal of light non-aqueous phase liquid (LNAPL), if present.

5.4 Groundwater Monitoring Well Development and Sampling

5.4.1 Well Development

The procedures for well development will adhere to TRC's ECR SOP for well development (ECR SOP-006; dated January 2020) included in Attachment 1. The newly installed wellPZ-4 will be developed, if groundwater is present, by surging and pumping of up to 10 well-casing volumes of water to remove fine-grained sediment from the wells. Purge water will be periodically monitored for field parameters including pH, electrical conductivity (EC), temperature, and turbidity. Well development will continue until turbidity readings reach less than 10 Nephelometric Turbidity Units (NTUs), field parameters stabilize (i.e., turbidity readings are within 10%, EC readings are within 3%, and pH is within 0.1 standard units over three successive well volumes), or approximately ten well volumes have been purged from well.

5.4.2 *Monitoring Well Sampling*

An electronic sounder, accurate to the nearest +0.01 feet, will be used to measure depth to water in each well. Water-level sounding equipment will be decontaminated before and after use in each well. Water levels will be measured in wells that have the least amount of known impacts first.

For the depth-discrete sampling, groundwater samples will be collected from six existing wells (MW-1 through MW-6). The samples will be collected at the top, middle, and bottom of the screens of each well, and will target different lithologic units, where present, as described in Table 4. Three samples will be collected from each well. If the water level inside a specific well does not allow for the three specific targeted depths listed on Table 4, the sample depths will be adjusted based on the well boring log and the amount of water inside the well to allow for at least two distinct sample depths per monitoring well while trying to target different lithological units. The results of the depth-discrete groundwater sampling will be used to help identify the lithologic unit that will be screened and sampling in the new groundwater monitoring well(s).

Depth-discrete groundwater samples will be collected using snap samplers, hydrosleeves, or equivalent sampling devices designed for no-purge depth-discrete groundwater sampling. The depth-discrete sampling devices will be deployed at the sample depths summarized in Table 4, allowed to equilibrate for at least one week, and will then be activated and retrieved. Snap samplers and other no-purge depth-discrete sampling devices do not provide purge water or sufficient sample volume to measure and record groundwater field parameters. Despite this limitation, they are preferred over pumps because they are less likely to mix potentially stratified groundwater during deployment and sampling. If no-purge depth-discrete sampling devices do not function as designed in the wells or are not available, groundwater sampling pumps may be used.

If pumps are used for depth-discrete groundwater sampling wells with known or suspected COC impact will be sampled last to avoid cross-contamination. Groundwater will be collected from the wells using a decontaminated bladder pump with single-use disposable polyethylene bladders and single-use polyethylene tubing. In addition, to minimize mixing of the water within each monitoring well, the samples will be collected in a top-down manner, collecting the top sample as the first sample, then the middle sample, and then the bottom sample.

Groundwater samples will be collected from all six existing wells (MW-1 through MW-6) to assess the distribution of COCs in groundwater. Additionally, transient perched groundwater piezometer PZ-4 will be sampled if sufficient water is present in the well. Groundwater will be collected from the wells using a bladder pump with single-use disposable polyethylene bladders, equipped with single-use disposable polyethylene tubing.

The sample collection depth in the six existing monitoring wells will be based on the results of the depth-discrete sampling completed previously in the six existing wells. If no clear stratification can be observed, then the groundwater samples will be collected from the middle of the screens of the wells. The sample depth in perched-zone piezometer PZ-4 will be based on the amount of water in the piezometer, but it is anticipated that the sample depth will be approximately 2 feet below the top of the water column.

A detailed discussion of groundwater sampling standard operating procedures is presented in Attachment 1. Water level measurements will be collected using TRC's ECR SOP for water level and product measurements (ECR SOP-004, dated January 2020).

5.5 Slug Tests

Slug tests will be performed on each of the monitoring wells. Rising-head slug tests will be performed by removing a "slug" of water (creating an "instantaneous" drop in hydraulic head), and monitoring the water level recovery. The head drop will be generated by placing a bailer into the water column, allowing the water level to return to static, and then removing the bailer as quickly as possible. A pressure transducer/data logger will be placed in the well prior to the test and will be used to record water level changes. The slug test data will be analyzed using the Bouwer and Rice method using the AQTESOLV™ software package.

A detailed discussion of slug tests procedures is presented in Attachment 1. Slug tests will be performed in accordance with TRC's ECR SOP for slug tests (ECR SOP-029, dated January 2020).

5.6 Decontamination

The decontamination procedures that will be followed are in accordance with approved procedures. Decontamination of sampling equipment must be conducted consistently as to assure the quality of samples collected. All equipment that comes into contact with potentially contaminated soil or water will be decontaminated. Disposable equipment intended for one-time use will not be decontaminated but will be packaged for appropriate disposal. Decontamination will occur prior to and after each use of a piece of equipment. All sampling devices used, including trowels, hand augers, and drilling equipment will be steam-cleaned or decontaminated. TRC's ECR SOP for equipment decontamination (SOP ECR-010, dated January 2020) included in Attachment 1 will be followed.

The following will be carried out in sequence for the decontamination of sampling equipment:

- Non-phosphate detergent and tap-water wash, using a brush if necessary
- Tap-water rinse
- Deionized/distilled water rinse (twice)

Equipment will be decontaminated in a pre-designated area on plastic sheeting, and clean bulky equipment will be stored on plastic sheeting in uncontaminated areas. Cleaned small equipment will be stored in plastic bags. Materials to be stored more than a few hours will also be covered.

6.0 Sample Containers, Preservation, Packaging, and Shipping

Tables 6a and 6b provide a summary of the sample containers, preservation method and holding time requirements for the laboratory analysis. Procedures for preparing, preserving and shipping soil and groundwater samples are detailed below.

6.1 Soil Samples

Soil samples for GRO and VOC analysis (BTEX) will be collected in Terracore® (or equivalent) sampling devices. Soil samples to be analyzed for GRO and BTEX will be stored in their sealed sampling devices for no more than two days prior to analysis. Soil samples for DRO, ORO, and naphthalenes analysis will be collected in laboratory supplied sample jars.

Soil samples will be labeled with the sample ID, date of collection, time of collection, company name, and requested analysis. Samples will be chilled to 4°C using either blue ice or wet-ice immediately upon collection. Sample containers and preservation for soil samples is outlined in Table 6a.

6.2 Groundwater Samples

Groundwater samples collected will be placed in laboratory supplied sample containers, labeled with the sample ID, date of collection, time of collection, company name, and requested analysis. Samples will be chilled to 4°C using either blue ice or wet-ice immediately upon collection. Sample containers and preservation for groundwater samples is outlined in Table 6b.

6.3 Sample Custody

Custody is one of several factors necessary for the admissibility of environmental data as evidence in a court of law. Custody procedures help to satisfy the two major requirements for admissibility: relevance and authenticity. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files. Refer to TRC's ECR practice SOP for Chain of Custody Procedures (ECR SOP-002, dated January 2020) for more details.

A sample or evidence file is considered to be under a person's custody if:

- the item is in the actual possession of a person;
- the item is in the view of the person after being in actual possession of the person; and
- the item was in the actual physical possession of the person but is locked up to prevent tampering; and, the item is in a designated and identified secure area.

6.4 Packaging and Shipping

The following outlines the packaging procedures that will be followed.

1. Check screw caps for tightness.
2. Wrap all glass sample containers in bubble wrap to prevent breakage.
3. Seal all sample containers in plastic zip-lock bags.
4. Place samples and ice in a sturdy cooler(s) lined with a large plastic trash bag. Enclose the appropriate chain-of-custodies in a zip-lock plastic bag affixed to the underside of the cooler lid.
5. Fill empty space in the cooler with bubble wrap to prevent movement and breakage during shipment.
6. Each ice chest will be securely taped shut and custody seals will be affixed to the front of each cooler.

7.0 Disposal of Residual Materials

In the process of collecting soil and groundwater samples, the sampling team will generate different types of potentially contaminated investigation-derived waste (IDW) that include the following:

- Used personal protective equipment (PPE)
- Disposable sampling equipment
- Decontamination fluids
- Soil cuttings from soil borings
- Purged groundwater and excess groundwater collected for sample container filling

Used PPE and disposable equipment will be double bagged and placed in a municipal refuse dumpster. These wastes are not considered hazardous and can be sent to a municipal landfill. Any PPE and disposable equipment that is to be disposed of which can still be reused will be rendered inoperable before disposal in the refuse dumpster.

Soil cuttings generated during the subsurface investigation and sampling activities will be contained in Department of Transportation (DOT)-approved 55-gallon drums. The drums will be labeled with a non-hazardous waste label which includes the date of generation, name of generator, site name, and contents of drum. Drums will be temporarily stored on-site pending transport to a BNSF-approved waste facility by a Washington state approved waste handler. All waste manifests will be signed and retained by TRC.

Purged groundwater and decontamination fluids will be contained in DOT-approved 55-gallon drums. The drums will be labeled with a non-hazardous waste label which includes the date of generation, name of generator, site name, and contents of drum. Drums will be temporarily stored on-site pending transport to an approved waste facility by a Washington state approved waste handler. All waste manifests will be signed and retained by TRC.

8.0 Sample Documentation

TRC on-site field personnel will document Site conditions and daily field activities throughout the duration of the field activities. This includes daily field activity reports, daily health and safety meeting sign-in, geologic boring logs, well development forms, groundwater purging and sampling forms, and laboratory chain-of-custodies. TRC's ECR SOP on field activity documentation (ECR SOP-001, dated January 2020), included in Attachment 1 will be used as a guide.

8.1 Field Notes

At each boring location, lithological core samples will be continuously logged in accordance with the USCS and ASTM D-2487, and will include:

- Soil description (color, texture, structure, moisture/wetness, odor)
- Depth to groundwater
- Total depth
- Soil field screening results (e.g., PID measurement)

Other relevant observations. Additionally, the following information will be recorded during the collection of each sample:

- Sample location and description
- Site or sampling area sketch showing sample location and measured distances
- Sampler's name(s)
- Date and time of sample collection
- Designation of sample as composite or grab
- Sample matrix (soil or groundwater)
- Type of sampling equipment used
- Field instrument readings and calibration
- Field observations and details related to analysis or integrity of samples (e.g., weather conditions, noticeable odors, colors, etc.)
- Preliminary sample descriptions (e.g., for soils: clay loam, very wet; for water: clear water with strong ammonia-like odor)
- Sample preservation
- Lot numbers of the sample containers, sample identification numbers and any explanatory codes, and chain-of-custody form numbers
- Shipping arrangements (overnight air bill number)
- Name(s) of recipient laboratory(ies)

In addition to the sampling information, the following specific information will also be recorded in the field logbook or field report form for each day of sampling:

- Team members and their responsibilities
- Time of arrival/entry on-site and time of site departure
- Other personnel on-site
- Summary of all site activities
- Deviations from sampling plans, site safety plans, and QA procedures
- Changes in personnel and responsibilities with reasons for the changes
- Levels of safety protection (contained in the HASP)
- Calibration readings for equipment used and equipment model and serial number

8.1.1 Photographs

Photographs will be taken at the sampling locations and at other areas of interest on-site or sampling area. They will serve to verify information entered in the field logbook or on field report forms. For each photograph taken, the following information will be written in the logbook/field report form or recorded in a separate field photography log:

- Time, date, location, and weather conditions
- Description of the subject photographed
- Name of person taking the photograph

8.1.2 Survey of Soil and Groundwater Sample Locations

A Washington-licensed land surveyor will survey the northings and eastings and elevation of the soil borings and the top of the casing for newly installed monitoring wells. The northings and eastings will be based on Washington Coordinate System of 1983, north zone. The elevations will be measured to within a vertical accuracy of 0.01 feet from the top of casing based on the North American Vertical Datum of 1988 (NAVD88).

8.2 Sample Labeling

All samples collected will be labeled in a clear and precise way for proper identification in the field and for tracking in the laboratory. The samples will have pre-assigned, identifiable, and unique numbers. At a minimum, the sample labels will contain the following information: Project name, date and time of collection, analytical parameter(s), and method of preservation. Every sample, including samples collected from a single location but going to separate laboratories, will be assigned a unique sample number.

8.3 Sample Chain-Of-Custody Forms and Custody Seals

All sample shipments for analyses will be accompanied by a chain-of-custody record. A copy of the form is found in Attachment 2. Chain-of-Custody forms will be completed and sent with the samples for each laboratory and each shipment. If multiple coolers are sent to a single laboratory on a single day, forms will be completed and sent with the samples for each cooler.

The Chain-of-Custody form will identify the contents of each shipment and maintain the custodial integrity of the samples. Generally, a sample is considered to be in someone's custody if it is either in someone’s physical possession, in someone's view, locked up, or kept in a secured area that is restricted to authorized personnel. Until the samples are shipped, the custody of the samples will be the responsibility of TRC. The Field Team Leader or designee will sign the chain-of-custody form in the “relinquished by” box and note date, time, and air bill number.

The shipping containers in which samples are stored (usually a sturdy cooler) will be sealed with self-adhesive custody seals any time they are not in someone’s possession before shipping. All custody seals will be signed and dated. TRC’s ECR Practice SOP for chain-of custody procedures (ECR SOP-002, dated January 2020) included in Attachment 1 will be followed.

9.0 Quality Control

Field and laboratory QC samples will be collected and analyzed during this investigation. The types and purposes of the field and laboratory QC samples are described in the following sections.

9.1 Field Quality Control Samples

9.1.1 Trip Blanks

Trip blanks will be prepared to evaluate if the shipping and handling procedures are introducing contaminants into the samples, and if cross contamination in the form of VOC migration has occurred between the collected samples. The use of trip blanks provides a way to determine whether contamination of a sample occurred during shipment from the analytical laboratory, or during analysis at a lab. A minimum of one trip blank will be submitted to the laboratory for analysis with every shipment of samples for GRO or VOC analysis. Trip blanks will be supplied by the laboratory. The sealed trip blanks are not opened in the field and are shipped to the laboratory in the same cooler with the samples collected for volatile analyses. The trip blanks will be preserved, packaged, and sealed in the manner described for the environmental samples. A separate sample number and station number will be assigned to each trip sample and it will be submitted blind to the laboratory. Blind samples submitted for analysis will be assigned consecutive increasing whole numbers for identification. The identification numbers, and their associated well numbers, will be recorded on the field sampling and the Sample Control Log for traceability.

9.1.2 Temperature Blanks

For each cooler that is shipped or transported to an analytical laboratory a 40-milliliter (mL) VOA vial will be included that is marked “temperature blank.” The laboratory uses these temperature blanks to ensure that proper preservation of the samples has been maintained during sample shipment. The temperature of these blanks must be 4ºC ± 2ºC to demonstrate that proper preservation has been maintained. The laboratory records the results of the temperature blanks on the Chain-of-Custody Form or sample login form immediately upon receipt of the samples at the laboratory, prior to inventory and refrigeration.

9.1.3 Field Duplicates

Field duplicates for groundwater samples will be collected at a rate of one per sampling event for each analytical method. Duplicates will be collected using the same equipment as the original sample and will be collected immediately after primary sample collection. A separate sample number and station number will be assigned to each duplicate, and it will be submitted blind to the laboratory. Blind samples submitted for analysis will be assigned consecutive increasing whole numbers for identification. The identification numbers, and their associated well numbers, will be recorded on the field sampling and the Sample Control Log for traceability.

9.2 Laboratory Quality Control Samples

9.2.1 Method Blanks

Method blanks will be performed as part of each analytical batch for each methodology performed. Method blanks are used to evaluate contamination introduced during sample preparation and/or analysis by the laboratory.

9.2.2 Matrix Spike Samples

The MS samples are used to determine laboratory preparation and analysis bias for specific compounds in specific matrices (i.e., sample-specific QC). MS samples are typically performed at a frequency of one per 20 investigative samples.

9.2.3 Surrogate Spike

Surrogate spikes are used to evaluate extraction efficiency or analytical bias on a sample by sample basis for organic parameters. Surrogate spikes are added to all samples for organic parameters. Surrogate spikes are another measure of sample-specific QC.

9.2.4 Laboratory Control Samples

LCS are used to evaluate almost all parameters for the ability of the laboratory to accurately identify and quantify target compounds in a reference matrix when spiked at a known concentration using a secondary source standard. LCS are typically performed as part of each analytical batch for each methodology. LCS are also a self-check for the laboratory to ensure the method is in compliance.

9.2.5 Matrix Spike Duplicate Samples

The MSD samples are used to evaluate laboratory preparation and analysis bias and precision for specific compounds in specific sample matrices (i.e., sample-specific QC). MSD samples are typically performed for organic parameters only.

10.0 Field Variances

As conditions in the field may vary, it might be necessary to implement minor modifications to the proposed SAP due to unforeseen circumstances. When appropriate, the TRC project manager will be notified and a verbal approval will be obtained before implementing the changes. Modifications to the approved plan will be documented in the SRI Report.

11.0 Field Health and Safety Procedures

A comprehensive HASP has been prepared and is included as one of the appendices of the SRI WP. The intent of the HASP is to ensure the health and safety of on-site project employees, visitors, and the public during Site work. The HASP identifies all policy, procedures, and systems to be followed by project personnel, and is required to be followed by TRC employees, subcontractors, vendors, visitors, and agency representatives.

A copy of the HASP will be readily available during the all field activities. “Tailgate” health and safety meetings will be conducted with all workers to discuss the health and safety issues and concerns related to the specific work, including safety concerns regarding coordination of drilling and sampling activities and the current COVID-19 guidance for safe distancing, PPE, and other mitigation measures. All workers involved in the investigation and monitoring activities will be required to review and sign the TRC HASP before conducting work.

12.0 References

Washington State Department of Ecology (Ecology), 2020. Agreed Order No. DE 16838. January 22.

Ecology, 2013. *Model Toxics Control Act Regulation and Statute, MTCA Cleanup Regulation Chapter 173-340 WAC, Model Toxics Control Act Chapter 70.105D RCW, Uniform Environmental Covenants Act Chapter 64.70 RCW*. Publication No. 94-06. Revised 2013.

Ecology, 2018. *Ecology determination of insufficiency in meeting the cleanup standards following the implementation of the cleanup action plan*, Glacier Park Budget Fuel East, March 15.

Tables

Table 1
Key Project Personnel Contact Information and Responsibilities
BNSF Glacier Park East Site
Leavenworth, Washington

Title	Name	Phone Number Email Address	Responsibilities
Washington State Department of Ecology (Ecology)			
Ecology Site Manager	Kyle Parker	(509) 454-7833 kyle.parker@ecy.wa.gov	Site Manager
BNSF Railway Company (BNSF)			
Assistant Manager Environmental Remediation	Scott MacDonald	(206) 635-6276 scott.macdonald@bnsf.com	Project Manager
TRC			
Contractor Project Manager	Keith Woodburne	(425) 489-1938 ext.18177 kwoodburne@trccompanies.com	Project Manager
Contractor QA/QC Officer	Doug Kunkel	(425) 395-0016 dkunkel@trccompanies.com	Quality Assurance/Quality Control (QA/QC)
Contractor Field Team Leader	Mathieu Piovesan	(425) 219-2221 mpiovesan@trccompanies.com	Conduct Permitting and Field Sampling
Pace Analytical (Pace)			
Laboratory Technical Services Representative	Mark Beasley	(615) 773-9672 mbeasley@pacenational.com	Laboratory QA/QC

Table 2
Data Quality Objectives Summary
BNSF Glacier Park East Site
Leavenworth, Washington

Study Objective	To update the conceptual site model (CSM) in support of an updated Remedial Investigation/Feasibility by conducting a soil and groundwater investigation. The updated CSM will be used to support definition and optimization of remedy implementation at the Site.
Problem (Step 1)	The distribution of petroleum hydrocarbons in groundwater is uncertain. Additional soil and groundwater characterization is needed to better define the hydrogeologic CSM, which will inform the measures needed to improve the remedy for the site.
Overall Approach	To meet this study objective vertical profiling of groundwater will be performed to assess if there is stratification of contaminants in the screened interval. One new well will be installed and screened across the water table. Hydraulic conductivity tests coupled with a transducer study will be performed to better understand groundwater flow and velocity. Soil sampling will be performed in the cap to assess uncharacterized conditions and evaluate if a seasonally/transient perched groundwater zone exists and is a potential source to groundwater.

Study Goals (Step 2)	**Study Questions** (Step 2)	**Data Needs** (Step 3)	**Boundaries of the Study** (Step 4)	**Analytical Approach: Sampling Methods, Data Evaluation Approach and Draft Decision Rules** (Step 5)	**Performance and Acceptance Criteria** (Step 6)	**Sampling Design** (Step 7)
Task 1. Hydrogeologic CSM Update						
Update understanding of petroleum hydrocarbon impacts to groundwater, assess representativeness of data from long screened wells and evaluate migration pathways.	Is vertical stratification of petroleum hydrocarbons in groundwater present, and should future samples be adjusted to capture the appropriate zone in each well?	Laboratory analytical results for DRO, ORO, GRO and benzene from groundwater at the upper, middle and lower part of the screen in each existing well.	Existing extent of the groundwater monitoring well network. One round of multi-level sample collection.	Perform multi-level sampling in MW-1 through MW-6 using either an in-situ sampler or via adjusting the pump inlet. If multi-level sampling indicates future sample collection should be biased to high/middle/low screen intervals, then future sampling will be attempted at that zone. Otherwise samples will be collected per conventional protocol (middle of the flooded interval).	Measurement errors that arise during the various steps of the sample-measurement process (e.g., sample collection, handling, preparation, analysis, data reduction, and data handling) are possible regardless of the sampling design. Neither measurement errors nor variability can be eliminated, but they can be controlled by selecting approved standard procedures and using properly trained personnel. Measurement error will be minimized by using a trained and experienced field team under the guidance of the Project Manager and Quality Assurance Officer. Measurement error will be further minimized by adherence to SOPs. Analytical methods and Practical Quantitation Limits (PQLs) are listed in Tables 3a and 3b. Decision uncertainty will be managed by comparing newly collected data with surrounding site data, evaluating data in a weight of evidence approach, and stakeholder meetings to discuss results.	A total of 18 depth-discrete groundwater samples will be collected from the six current monitoring wells (MW-1 through MW-6) and analyzed for DRO and ORO with and without silica gel cleanup (SGC), GRO, and benzene.
	What is the extent of petroleum hydrocarbons in groundwater?	Laboratory analytical results for DRO, ORO, GRO and benzene from groundwater at the appropriate sample depth, defined in the prior step.	Existing extent of the groundwater monitoring well network. One round of groundwater samples.	Add MW-5 to the monitoring program and perform semi-annual groundwater monitoring in wells MW-1 through MW-6 for one year.		Groundwater samples will be collected from monitoring wells MW-1 through MW-6 on a semi-annual schedule for a period of one year and analyzed for DRO and ORO with and without SGC, GRO, benzene, and total organic carbon (TOC). TOC analysis will be used to characterize the amount of organic material that may contribute to elevated DRO and ORO concentrations reported without SGC.

Table 2
Data Quality Objectives Summary
BNSF Glacier Park East Site
Leavenworth, Washington

Study Goals (Step 2)	**Study Questions** (Step 2)	**Data Needs** (Step 3)	**Boundaries of the Study** (Step 4)	**Analytical Approach: Sampling Methods, Data Evaluation Approach and Draft Decision Rules** (Step 5)	**Performance and Acceptance Criteria** (Step 6)	**Sampling Design** (Step 7)
	What is the hydraulic conductivity and gradient?	Hydraulic conductivity and groundwater elevation data.	Existing extent of the groundwater monitoring well network (MW-1 through MW-6). Hydraulic conductivity data from one event, and transducer data collected in 2019/2020 for monitoring wells MW-1 through MW-6.	Slug tests will be performed in all wells. Transducers have been deployed in wells MW-1 through MW-6 since August 20, 2019, and data will be evaluated after one year of collection.		Groundwater levels will be measured in surveyed, permanent monitoring well(s), following well development, to assess groundwater flow direction and gradient. Hydraulic conductivity data will be obtained from wells (MW-1 through MW-6) via slug testing and evaluation of those results.
Task 2. Soil CSM Update						
Update the understanding of hydrocarbon impacted soil immediately below the cap and potentially beyond in un-capped areas.	What is the horizontal extent of petroleum impacted soil below the cap and to the northeast? Is soil beneath the cap and potentially un-capped soil a source to petroleum hydrocarbons in groundwater?	Laboratory analytical results from soil samples analyzed for DRO, GRO, ORO, BTEX, and naphthalenes.	Six soil borings, SB-1 through SB-6, see Figure 2.	Soil samples will be collected from boring locations northeast of the cap at the top, middle and bottom of hydrocarbon impacted zones. If soil exceeding MTCA Method A is present beyond the extent of the current asphalt cap, then uncapped soil may be a source of petroleum hydrocarbons to groundwater. Otherwise soil beyond the existing cap is not a source to groundwater.	In addition to the criteria listed above, soil sampling design error will be managed by use of a judgmental sampling design, incorporating the results of existing and historical data from previous investigations, hydrogeological data, and site reconnaissance. The source area was historically delineated and remediated with an asphalt cap, but recent soil samples collected in 2016 indicate that soil impacts are located outside the lateral extent of the cap.	If staining and/or odors are present during the performance of soil borings SB-4, SB-5, and SB-6, up to three soil samples will be collected and analyzed for DRO, GRO, ORO, BTEX, and naphthalenes. At borings located outside the existing cap, up to three soil samples will be collected from each soil boring and analyzed for DRO, GRO, ORO, BTEX, and naphthalenes.

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Table 3a
Analytical Parameters for Soil
Laboratory Reporting/Quantitation Limits
BNSF Glacier Park East Site
Leavenworth, Washington

Analytical Parameter	Analytical Method	Laboratory Reporting or Quantitation Limits (mg/kg)	Screening Levels MTCA Method A[a] (mg/kg)
TPH as DRO	NWTPH-Dx	4	2,000
TPH as ORO	NWTPH-Dx	10	2,000
TPH as GRO (w/o benzene)	NWTPH-Gx	0.10	100
TPH as GRO (w/ benzene)	NWTPH-Gx	0.10	30
Benzene	EPA 8260C	0.001	0.03
Toluene	EPA 8260C	0.005	7
Ethylbenzene	EPA 8260C	0.001	6
Total Xylenes	EPA 8260C	0.003	9
Naphthalenes[b]	EPA 8270 SIM	0.02	5

ABBREVIATIONS:
TPH = total petroleum hydrocarbons
DRO = diesel-range organics
ORO = oil-range organics
GRO = gasoline-range organics
mg/kg = milligrams per kilogram
MTCA = Model Toxics Control Act

FOOTNOTES:
[a] Washington State Department of Ecology, Model Toxics Control Act (MTCA) Cleanup Level and Risk Calculations (CLARC) Tables Method A values for Soil, Chapter 173-340 WAC, MTCA Chapter 70.105D RCW, Uniform Environmental Covenants Act Chapter 64.70 TCW. Publication No. 94-06. Revised May 2019.
[b] Naphthalenes are naphthalene, 1-methyl-naphthalene, and 2-methyl-naphthalene.

Table 3b
Analytical Parameters for Groundwater
Laboratory Reporting/Quantitation Limits
BNSF Glacier Park East Site
Leavenworth, Washington

Analytical Parameter	Analytical Method	Laboratory Reporting or Quantitation Limits (µg/L)	Screening Levels MTCA Method A[a] (µg/L)
TPH as DRO	NWTPH-Dx	200	500
TPH as ORO	NWTPH-Dx	250	500
TPH as GRO (w/o benzene)	NWTPH-Gx	100	1,000
TPH as GRO (w/ benzene)	NWTPH-Gx	100	800
Benzene	EPA 8260C	1	5
Total Organic Carbon	EPA 9060A	1,000	NE

ABBREVIATIONS:
TPH = total petroleum hydrocarbons
DRO = diesel-range organics
ORO = oil-range organics
GRO = gasoline-range organics
µg/L = micrograms per liter
MTCA = Model Toxics Control Act
NE = no cleanup level established

FOOTNOTES:
[a] Washington State Department of Ecology, Model Toxics Control Act (MTCA) Cleanup Level and Risk Calculations(CLARC) Tables Method A values for Groundwater, Chapter 173-340 WAC, MTCA Chapter 70.105D RCW, Uniform Environmental Covenants Act Chapter 64.70 TCW. Publication No. 94-06. Revised May 2019.

Table 4
Proposed Groundwater Depth-Discrete Sampling
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Well ID	Date Installed	Well Diameter (in)	Total Depth (ft bgs)	Screen Interval (ft bgs)	Sample Interval #1 (ft bgs)	Sample Interval #2 (ft bgs)	Sample Interval #3 (ft bgs)	Comments
MW-1	11/8/1995	2	77	62-77	64	70	75	All intervals in SP-SM unit
MW-2	NA	2	83	63-83	65	72	78	All intervals in SM unit, to depth logged
MW-3	9/18/2001	2	78	58-78	60	67	75	All intervals in SP-SM unit
MW-4	9/19/2001	2	74	54-74	57	64	72	Intervals target GP, SM, and GP units
MW-5	9/20/2001	2	80.5	60.5-80.5	63	70	78	Intervals target GP-GM, SP-SM, and GP-GM units
MW-6	5/23/2017	2	76.0	53-73	55	63	71	All intervals in SW unit

ABBREVIATIONS:
in = inches
ft bgs = feet below ground surface
NA = Not available
SP-SM = fine to coarse sand with silt and gravel
SM = silty fine to coarse sand with gravel
GP = fine to coarse gravel with sand and trace silt
GP-GM = gravel with sand and silt

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Table 5
Proposed Soil Sampling
BNSF Railway Company
Glacier Park East
Leavenworth, Washington

Soil Borings	Location	Impacted Soil Observed?	Target Soil Sample Depths for Laboratory Analysis
SB-1 SB-2 SB-3	Lower Elevation	Yes	1. Top of impacted soil 2. Middle of impacted soil 3. Bottom of impacted soil
		No	1. 12 ft bgs 2. 25 ft bgs
SB-4 SB-5 SB-6 GWB-1	Higher Elevation	Yes	1. Top of impacted soil 2. Middle of impacted soil 3. Bottom of impacted soil
		No	1. 25 ft bgs 2. 35 ft bgs

Note:

If additional step-out borings are required at locations SB-1, SB-2, or SB-3, the same target soil sample depths and protocols will be followed.

ABBREVIATIONS:

ft bgs = feet below ground surface

Table 6a
Analytical Methods, Containers, Preservation, and Holding Times for Soil
BNSF Glacier Park East Site
Leavenworth, Washington

Analytical Parameter	Analytical Method	Container(s)	Preservation Method	Holding Time
TPH as DRO and ORO	NWTPH-Dx	4-oz sample jar	Cool, 4°C	14 days to extraction; 40 days to analyze after extraction
TPH as GRO	EPA 5035/NWTPH-Gx	Terracore kit (2 40-mL glass vials Na2SO4, 1 40-mL glass vial MeOH)	Na2SO4/ MeOH; Cool, 4°C	14 days to analyze
BTEX	EPA 5035/8260	Terracore kit (2 40-mL glass vials Na2SO4, 1 40-mL glass vial MeOH)	Na2SO4/ MeOH; Cool, 4°C	14 days to analyze
Naphthalenes[a]	EPA 8270 SIM	4-oz sample jar	Cool, 4°C	14 days to analyze

ABBREVIATIONS:
TPH = total petroleum hydrocarbons
DRO = diesel-range organics
ORO = oil-range organics
GRO = gasoline-range organics
BTEX = benzene, toluene, ethylbenzene, and (total) xylenes
EPA = United States Environmental Protection Agency
oz = ounces
mL = milliliters
Na2SO4 = sodium sulfate
MeOH = methanol
°C = degrees Celsius

FOOTNOTE:
[a] Naphthalenes are naphthalene, 1-methyl-naphthalene, and 2-methyl-naphthalene.

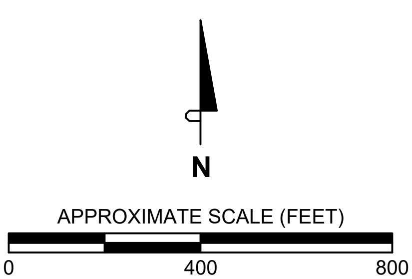
Table 6b
Analytical Methods, Containers, Preservation, and Holding Times for Groundwater
BNSF Glacier Park East Site
Leavenworth, Washington

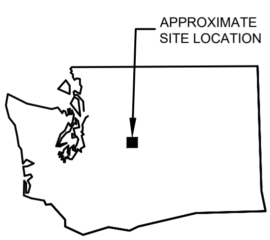
Analytical Parameter	Analytical Method	Container(s)	Preservation Method	Holding Time
TPH as DRO and ORO	NWTPH-Dx	2 X 40 mL glass VOA vials	Cool, 4°C	14 days to extraction; 40 days to analyze after extraction
TPH as GRO	NWTPH-Gx	2 X 40 mL glass VOA vials	HCl to pH<2; cool, 4°C; no headspace	14 days to analyze
TOC	EPA 9060A	1 x 250 mL HDPE bottle	HCl to pH<2; cool, 4°C	28 days to analyze
BTEX (Benzene only)	EPA 8260C	2 X 40 mL glass VOA vials	HCl to pH<2; cool, 4°C; no headspace	14 days to analyze

ABBREVIATIONS:
TPH = total petroleum hydrocarbons
DRO = diesel-range organics
ORO = oil-range organics
GRO = gasoline-range organics
TOC = total organic carbon
BTEX = benzene, toluene, ethylbenzene, and (total) xylenes
EPA = United States Environmental Protection Agency
HDPE = high-density polyethylene
oz = ounces
mL = milliliters
HCl = hydrochloric acid
VOA = volatile organics analysis
°C = degrees Celsius

Figures

SOURCE AERIAL PHOTO: Google Earth Professional, June 2015.





PROJECT:	**BNSF Glacier Park East Site** **Chumstick Highway and State Highway 2** **Leavenworth, Washington**
TITLE:	**VICINITY MAP**

DRAWN B ·	R. Collins	PROJ NO ·	333710
CHECKED B ·	M. Piovesan	**FIGURE 1**	
APPROVED B ·	K. Woodburne		
DAT ·	April 2020		

19874 141st Place N.E.
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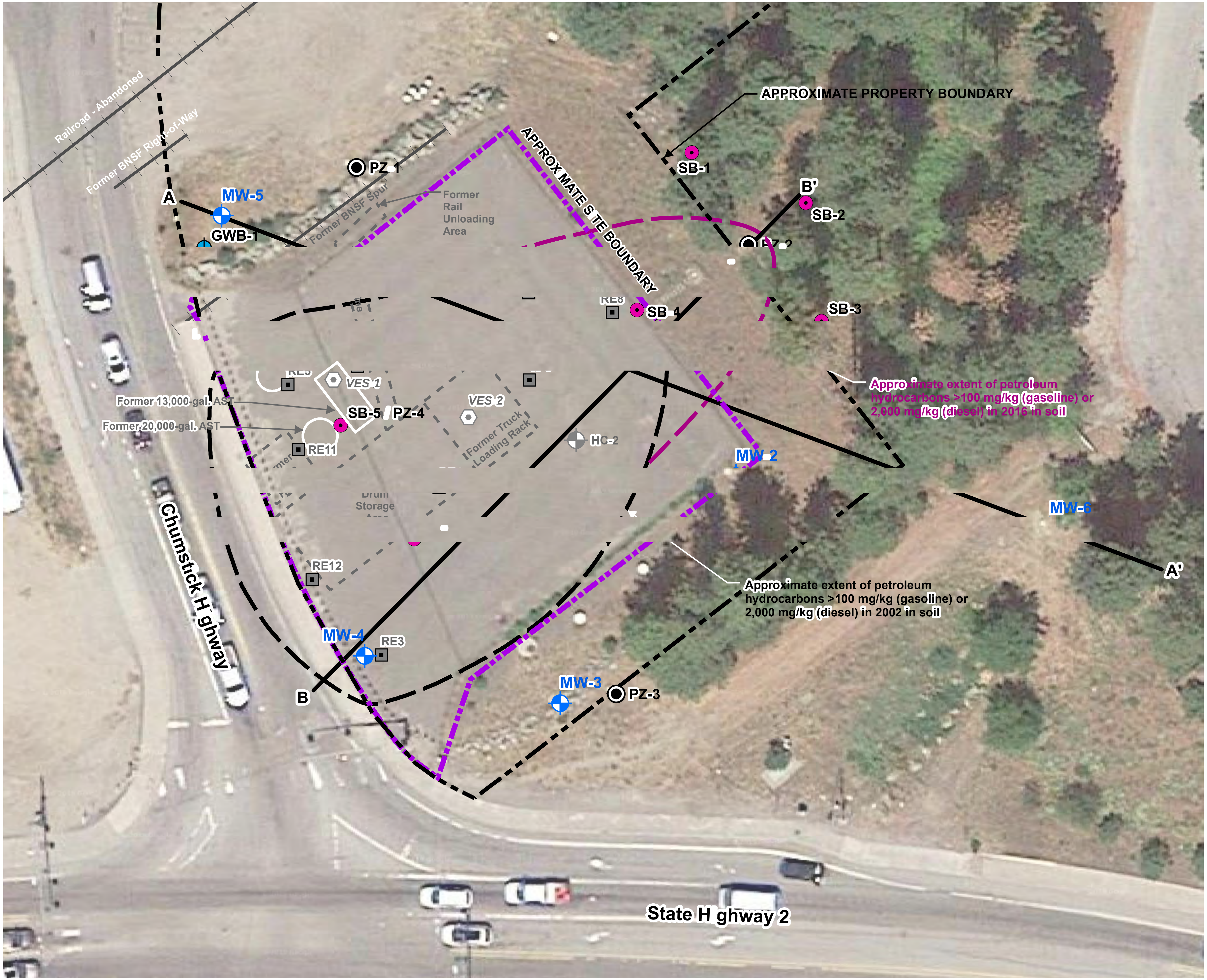
www.trcsolu ·

FILE NO · Fig1_Vicinity Map_Aerial.dwg

8.5x11 --- ATTACHED XREF'S: --- ATTACHED IMAGES: Aerial_Leavenworth_June15;
DRAWING NAME: S:\1-PROJECTS\BNSF\Glacier_Park_Site_Leavenworth\CAD\ Fig1_Vicinity Map_Aerial.dwg --- PLOT DATE: April 16, 2020 - 11:18AM --- LAYOUT: 8x11
Version: 2017-03-03



Legend

Surveyed locations of:

- Monitoring Well
- Piezometer

Approximate locations of:

- Proposed Soil Boring Location
- Proposed Soil Boring to Groundwater Location
- Test Pit (1995)
- Abandoned Monitoring Well
- Former Vapor Extraction Well (1995)
- A —— A' Cross Section

SOURCES:
AERIAL PHOTO: Google Earth, July 2017.
BASE PLAN: Groundwater Potentiometric Map by Kennedy/Jenks Consultants, December 2013, and site plans by Geo Engineers, March 2002.

NOTES:
Wells and piezometers surveyed in June 2017 by Landline Surveyors, Leavenworth, Washington.
Coordinate system: NAD83 Washington State Planes, North Zone, US foot.

Property boundary extends farther to the north east.

One of the proposed soil borings inside the cap boundary will be converted to a perched monitoring well.

mg/kg = milligrams per kilogram.

AST = aboveground storage tank.

PROJECT: BNSF GLACIER PARK EAST SITE, CHUMSTICK HIGHWAY AND STATE HIGHWAY 2, LEAVENWORTH, WASHINGTON			
TITLE: APPROXIMATE EXTENT OF PETROLEUM HYDROCARBONS IN SOIL AND PROPOSED SOIL BORING LOCATIONS			
DRAWN BY:	R. COLLINS	PROJ. NO.:	333710.0000.0000
CHECKED BY:	B. HELLAND		FIGURE 2
APPROVED BY:	K. WOODBURNE		
DATE:	JUNE 2020		

TRC
19874 141st Place N.E.
Woodinville, WA 98072
Phone: 425.489.1938
www.trccompanies.com

FILE NO.: 333710_Prop_Borings-FIG6.mxd

TRC - GIS

Plot Date: 6/22/2020, 09:24:42 AM by RCOLLINS -- LAYOUT: ANSI B (11"x17")
Path: S:\1-PROJECTS\BNSF\Glacier Park Site Leavenworth\MXD\333710 Nov2019\333710 Prop Borings-FIG6.mxd Map Rotation: 0
Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet (Foot US)

Attachment 1: TRC Standard Operating Procedures (SOPs)

Title: **Field Activity Documentation for Environmental Investigations**	Procedure Number: **ECR 001**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures

Technical Reviewer	Date	Environmental Sector Quality Director	Date
Terrance Hertz	1/1/20	Elizabeth Denly	1/1/20

TABLE OF CONTENTS

Page No.

ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) guides TRC personnel in the documentation of field activities for environmental investigations.

Field activity documentation is one of the most important activities that occur during field work. There is abundant information available for documenting the details of field work at the time the field work is taking place. It is critical that sufficient detail be documented during field work as it happens to allow others not present during the field activities to fully comprehend the field procedures and conditions at the time of the field work.

The objective of documenting field activities is to ensure that a collection of facts is recorded, the activities can be reconstructed from the documentation, and that the field activities are adequately logged in a manner that will be acceptable if the record is required as evidence in legal proceedings. An additional objective of adequately documenting field activities is to provide complete information that is useful and understandable to someone other than the note taker. Because the field books and field data forms provide the basis for future reports and analysis, facts and observations must be accurately recorded. Some regulatory agencies require that a copy of the field notes be included as part of the report submittal.

This SOP was not intended for use if computer tablets will be used. Consult with the ECR Practice Quality Coordinator for procedures when tablets will be used.

1.2 Equipment

The following list is an example of items that may be utilized for field activity documentation. Project-specific conditions or requirements may warrant the use of additional items or deletion of items from this list.

- Field book(s) – bound book with water-resistant pages
- Indelible marking pens
- Field data forms – generic or project-specific
- Digital camera
- Pocket ruler
- GPS device

2.0 PROCEDURES

All entries must be legible and must be made in blue or black permanent ink, signed or initialed, and dated. No erasures or obliterations can be made. If an incorrect entry is made, the information must be crossed out with a single strike mark which is signed or initialed and dated by the person recording the information. The correction must be written adjacent to the error.

The original entry should still be legible even though crossed out. Pages should never be removed from a field book.

2.1 Setup of Field Book and Logs

When multiple field personnel are on site, the Field Team Leader should decide the appropriate distribution of field books, field logs or project-specific forms necessary to document field activities. It is not necessary for each participant to take field notes.

1. Each field book assigned to a project should have the following information on the title page (the inside cover of the field book):

    - Project name
    - Site address
    - Site contact, if available
    - Project number(s)
    - TRC's name, address and phone number
    - Start and end dates of field book entries

2. Each field book may have a designated number (i.e., Book #1, Book #2, etc.) listed on the outside front cover.

3. Each field book will be a bound field survey book or notebook, water-resistant, and have sequentially numbered pages.

4. Other field books may or may not be required, dependent on the project needs, at the discretion of the Project Manager.

2.2 Documentation Requirements for Field Books or Daily Field Report Logs

Data collection activities performed during the field effort will be recorded in field books or on Daily Field Report Logs. Entries will be of adequate detail so that others will be able to comprehend a particular situation and it will be possible to reconstruct each activity without reliance on memory.

Entries into the field book or Daily Field Report Log may contain a variety of information. The terminology used in recording all field data should be objective, factual, and free of personal interpretation that may prove inappropriate. At the beginning of each daily entry, the date, start time, weather, and names of all field team members present will be entered. It is good practice to record the date on every page. The start and end of each day's entries in the field book or Daily Field Report Log will be signed or initialed and dated by the person(s) making the entry.

In general, it is expected that field notes will be collected every 15 minutes, as appropriate. Information included in the field book or Daily Field Report Log may include, but need not be limited to, the following:

- Chronology of activities, including entry and exit times;
- Names of all people involved in field activities and organizational affiliations;
- Level of personal protection used (if different from site-specific protocol/plan);

- Any changes made to site-specific protocol/plan
- Names of visitors to the site during field work and reason for their visit (unless in Daily Personnel Log)
- Sample location and identification
- Weather conditions, including temperature and any precipitation
- Day's objectives/scope of work
- Vehicle used (personal, rental) with travel time to site and mileage
- Measurement equipment identification (model/manufacturer) and calibration information
- Summary of equipment brought by subcontractor
- Communications while on site impacting site-specific protocol/plan
- Field screening results
- Site observations
- Sample collection methods and equipment
- Sample collection date (month/day/year) and time (military)
- Sample depths
- Whether grab or composite sample collected
- How sample composited, if applicable
- Sample description (color, odor, texture, etc.)
- Tests or analyses to be performed
- Sample preservation and storage conditions
- Equipment decontamination procedures
- QC sample collection
- Sample shipping methods, including tracking numbers, if applicable
- Unusual events or observations
- Record of photographs (unless in Photograph Log)
- Volume and type of investigation derived waste generated
- Sketches or diagrams
- Signature or initials of person recording the information

Upon receipt of the field book or Daily Field Report Log for a particular activity, the designated person recording the notes will begin recording notes on a new page. The person(s) recording the notes will sign/initial the new page and indicate the date, time, and weather conditions, prior to recording information about the field activity. The field book or Daily Field Report Log should indicate whether any Field Data Forms are being used. When the designated person recording the notes either relinquishes the field book or Daily Field Report Log to another team member or turns the book or log in at the end of the day, the person relinquishing the field book or Daily Field Report Log will affix a signature and date to the bottom of the last page used. If the page is not full, a diagonal line should be struck across the blank portion of the page. An example field book page is provided in Attachment A. An example Daily Field Report Log is provided in Attachment B.

Field data forms may be used to document sampling information for routine activities that have an associated form. A stockpile of blank forms will be kept in the field trailer/office or with the Field Team Leader. The field book or Daily Field Report Log should reference the form used during that event. Examples of TRC field data forms include:

- Sample log sheets (e.g., groundwater, sediment, soil gas, indoor air)
- Groundwater static water level data sheet
- Slug test data sheet

- Monitoring well construction summary/well development
- Monitoring well decommissioning
- Photograph log
- Soil boring/Rock core log
- Equipment log
- Calibration log

2.3 Documentation Requirements for Daily Personnel Logs

If applicable, the Daily Personnel Log will be maintained in the field trailer/office or by the Field Team Leader for the duration of the project to record the identities of all personnel who are on site. The following information will be recorded on Daily Personnel Logs:

- Names of field personnel
- Names of subcontractor personnel
- Names of visitors
- Affiliation of each person on site
- Date/time of entry and exit

2.4 Documentation Requirements for Photograph Logs

A field book/Daily Field Report Log entry or Photograph Log will be used to record the date and time of photographs taken at the project site. Digital cameras that imprint the date and time of the photograph may also be used to document conditions; however, prior to taking any site photographs with a digital camera, the photographer must verify the correct clock and calendar settings in the camera. An appropriate site figure may be used to note the location and direction of photographic documentation and should be referenced and attached to the log, if used. Examples of items that warrant photographic documentation include:

- General site topography
- Sampling and/or drilling locations
- Existing monitoring well locations
- Pre-existing property conditions and conditions following restoration
- Physical appearance of environmental samples
- Evidence of possible contamination
- Well casing or pad damage
- Rock cores

2.5 Documentation Requirements for Equipment Calibration Logs

A field book/Daily Field Report Log entry or Equipment Calibration Log will be completed to record appropriate information for the instruments calibrated each day. This information may include:

- Equipment manufacturer, model number and serial number
- Dates and times of calibration
- Supplies used (e.g., calibration gas)
- Individual who performed the calibration
- Adjustments made to the instrument during calibration

- Notes regarding the maintenance of the instrument

2.6 Documentation Requirements for Health and Safety Logs

A field book/Daily Field Report Log entry or Health and Safety Log will be completed to record Health and Safety issues during field activities. Entries may include:

- Daily health and safety meeting prior to performing work
- Any injuries, illnesses, near-misses, or the use of first aid supplies
- Activity under Level D conditions or the use of specific personal protective equipment (for Levels A, B or C only, if needed)
- Occurrence of possible work-related symptoms
- The date, name(s) of affected individuals and a description of the issue or incident and response
- A record of air monitoring results, any action level exceedances, and actions taken as the result of any action level exceedances

2.7 Documentation Requirements for Air Monitoring Logs

A field book/Daily Field Report Log entry or Air Monitoring Log will be completed to record monitoring results from real-time air monitoring instruments during field activities. The air monitoring devices will be located and operated in accordance with the Air Monitoring Plan. For hand-held instruments without data logging capabilities, readings will be recorded in the field book/Daily Field Report Log or on the Air Monitoring Log. For instruments with data logging capabilities, the instruments will be periodically checked, with results recorded in the field book/Daily Field Report Log or on the Air Monitoring Log. Data will be downloaded at the end of each workday and maintained in the project files.

3.0 QUALITY ASSURANCE/QUALITY CONTROL

The Field Team Leader has the responsibility to maintain the various logs, forms, and books that document daily field activities. Individual responsibilities may be delegated to other field staff, as appropriate.

Quality control procedures will place emphasis on the completeness and accuracy of all information recorded in the field and will be used to confirm that field notes contain statements that are legible, accurate, and comprehensive documentation of project activities. Field books/Daily Field Report Logs should be reviewed on a frequent basis by the Field Team Leader to confirm that:

- Field books/Daily Field Report Logs and standardized forms have been filled out completely and that the information recorded accurately reflects the activities that were performed.

- Records are legible and in accordance with good record-keeping procedures, i.e., entries are signed or initialed and dated, data are not obliterated, and changes are initialed, dated, and explained.

- Sample collection, handling, preservation, and storage procedures were conducted in accordance with the protocols described in the project plans, and that any deviations were documented and approved by the appropriate personnel.

- Instruments were calibrated and operated in accordance with the procedures specified in the project plans.

4.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation requirements for investigation-derived waste disposal with the Project Manager.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

The Project Manager or Field Team Leader will maintain an inventory of all field books/Daily Field Report Logs used during the program and will be responsible for ensuring that they are archived in the project files following the completion of the field work.

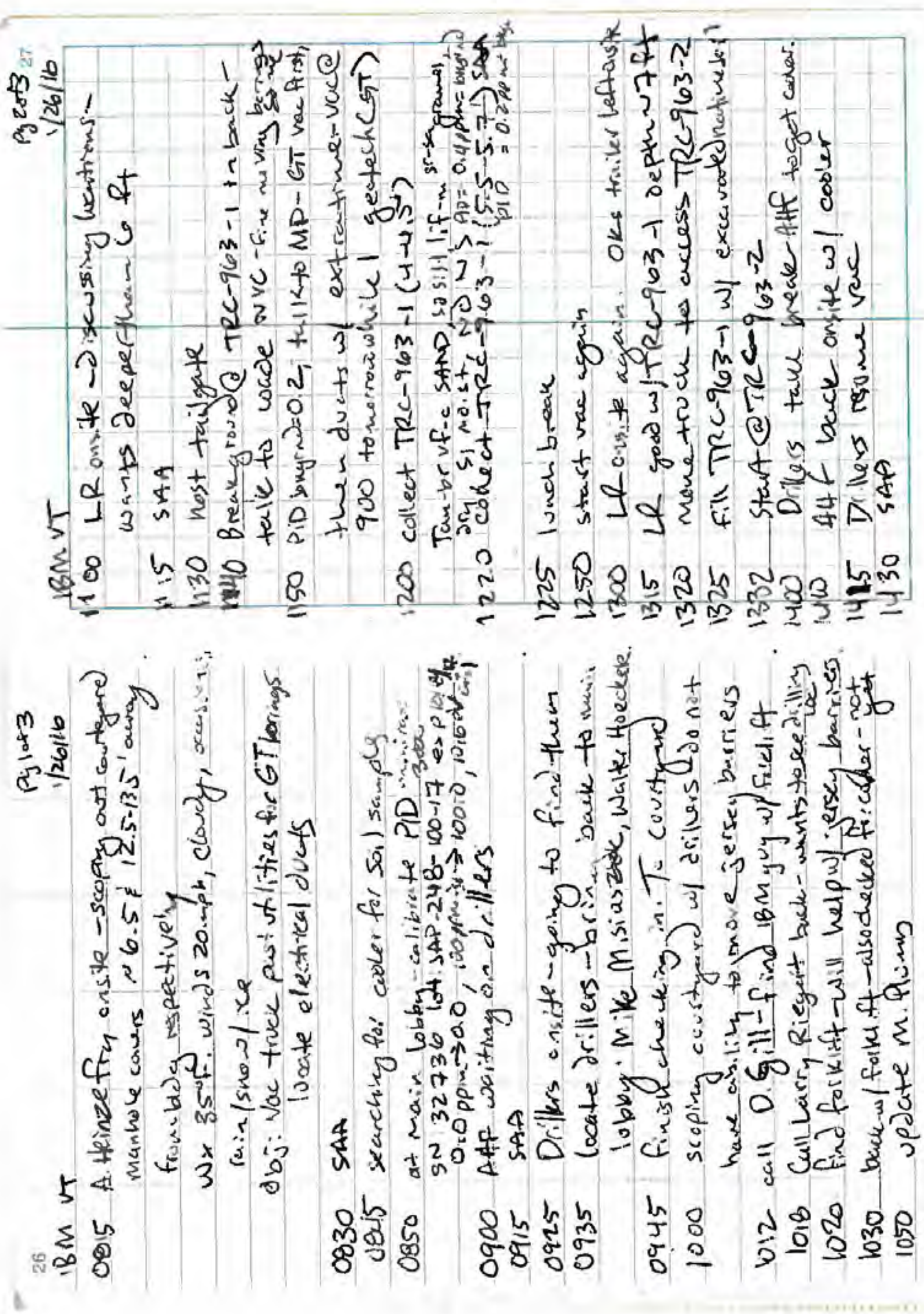
Completed standardized forms will be maintained by the Project Manager or Field Team Leader during the duration of the program and will be archived in the project files following completion of the field effort.

It is good practice to scan field notes and logs at the conclusion of field activities and store the resulting pdf files in the project directory.

6.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	JANUARY 2013	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

Attachment A: Example Page from Field Book


26
IBM VT
Pg 1 of 3
1/26/16
0815 A. Heinzeffry onsite - scoping out courtyard
manhole covers ~6.5 & 12.5-13.5' away
from bldg respectively
Wx 35°F, winds 20 mph, cloudy,
rain/snow/ice
obj: Vac truck past utilities for GT borings
locate electrical ducts
0830 SAA
0845 searching for cooler for soil samples
0850 at main lobby - calibrate PID
SN 32736 lot SAP-248-100-17
0.0 ppm → 0.0, 100 ppm → 100.0
0900 AHF waiting on drillers
0915 SAA
0925 Drillers onsite - going to find them
0935 locate drillers - bring back to main
lobby: Mike Misiaszek, Walter Hoecker
0945 Finish checking in. To courtyard
1000 scoping courtyard w/ drillers
have ability to move jersey barriers
1012 call D. Gill - find IBM guy w/ forklift
1018 Call Larry Riegert back - wants to see drilling
1020 find forklift - will help w/ jersey barriers
1030 back w/ forklift - also checked for cooler - not yet
1050 update M. Plumb
Pg 2 of 3 27
1/26/16
IBM VT
1100 LR onsite - discussing locations -
wants deeper than 6 ft
1115 SAA
1130 host tailgate
1140 Break ground @ TRC-963-1 in back -
talk to wade
1150 PID bkgrnd = 0.2, talk to MP - GT vac first,
then ducts w/ extra time - vac @
900 tomorrow while geotech (GT)
1200 collect TRC-963-1 (4-4.5')
Tan-br vf-c SAND, so silt
1220 collect TRC-963-1 (5.5-5.7') SAA
1225 lunch break
1250 start vac again
1300 LR onsite again. OKs trailer left outside
1315 LR good w/ TRC-963-1 depth ~7 ft
1320 Move truck to access TRC-963-2
1325 Fill TRC-963-1 w/ excavated native soil
1332 Start @ TRC-963-2
1400 Drillers take break - AHF to get cooler.
1410 AHF back onsite w/ cooler
1415 Drillers resume vac
1430 SAA

Attachment B: Example Daily Field Report Log

DAILY FIELD REPORT LOG

Client: Project:	Date:
Address:	Project #:
Weather:	Page:
Field Activity:	

Time	Description of Daily Activities

This field report provides only the results of observations and tests by TRC Personnel. This report should not be construed as supervision, direction or a recommendation.

Prepared by: Date/Time:	

Attachment C: SOP Fact Sheet

FIELD ACTIVITY DOCUMENTATION

PURPOSE AND OBJECTIVE

The objective of documenting field activities is to ensure that a collection of facts is recorded, the activities can be reconstructed from the documentation, and the field activities are adequately logged in a manner that will be acceptable if the record is required as evidence in legal proceedings. An additional objective of adequately documenting field activities is to provide complete information that is useful and understandable to someone other than the note taker. Facts and observations must be accurately recorded because the field books and field data forms provide the basis for future reports and analysis.

WHAT TO BRING

- Field book(s) – bound book with water-resistant pages
- Indelible marking pens
- Field data forms – generic or project-specific
- Digital camera
- Pocket ruler
- GPS device

OFFICE

- Ensure that there is adequate space for notes on the upcoming field event in the existing field book.
- If a new field book must be issued, note the field book number on the spine.
- A new field book should contain the following information on the inside cover: Project name; site address; site contact, if available; project number(s); TRC's name, address and phone number; and start and end dates of field book entries.
- Each field book may have a designated number (i.e., Book #1, Book #2, etc.) listed on the outside front cover.

ON-SITE

- Data collection activities will be recorded in field books. Entries will be of adequate detail so that individuals who were not onsite can reconstruct the day.
- The terminology used in recording all field data should be objective, factual and free of personal interpretation.
- At the beginning of each daily entry, the date, start time, weather, and names of all field team members present will be entered.
- The start and end of each day's entries in the field book or Daily Field Report Log will be signed or initialed and dated by the person(s) making the entry.
- It is expected that field notes will generally be collected every 15 minutes. Information included in the field book may include, but need not be limited to, the following:
  - Names of all people involved in field activities;
  - Weather conditions;
  - Day's objectives/scope of work;
  - Vehicle used, travel time to site and mileage;
  - Equipment calibration information;
  - Summary of equipment brought by subcontractor;
  - Any changes made to site-specific protocol/plan;
  - Sample location and identification;
  - Communications while on site;
  - Field screening results;
  - Sample collection methods and equipment;
  - Sample collection date (month/day/year) and time (24-hour);
  - Sample depths;
  - Sample description (color, odor, texture, etc.);
  - Tests or analyses to be performed;
  - Sample preservation and storage conditions;
  - Unusual events or observations;
  - Volume and type of waste generated;
  - Sketches or diagrams.
- Upon receipt of the field book or Daily Field Report Log for a particular activity, the designated person recording the notes will begin recording notes on a new page.
- The person(s) recording the notes will sign/initial the new page and indicate the date, time, and weather conditions, prior to recording information about the field activity.
- The field book or Daily Field Report Log should indicate whether any Field Data Forms are being used.
- Additional logs such as photo logs, health and safety logs or equipment logs may be required depending on the site requirements.

1

FIELD ACTIVITY DOCUMENTATION

DOS AND DO NOTS OF FIELD ACTIVITY DOCUMENTATION

DOs:

- DO have the following items when going into the field: Field Book and an indelible marking pen (i.e. ball-point pen) ONLY; field forms; contact phone numbers; business cards.
- DO review all available figures and workplans.
- DO take note of any atypical conditions at the site.
- DO call the Project Manager or Field Team Leader if unexpected conditions are encountered or at least twice during the work day to update them. It is also recommended to call when activities are winding down for the day to make sure that the workplan has been fully implemented and there are no additional tasks to complete.
- DO have the numbers for contractors, vehicle and equipment rental providers and utility companies readily available while in the field.

DO NOTs:

- DO NOT sign anything in the field. This includes disposal documentation, statements, etc.; call the Project Manager if there are any concerns.
- DO NOT use markers to label samples or record field notes.

2

Title: **Chain-of-Custody Procedures**	Procedure Number: **ECR 002**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures

Technical Review	Date	Environmental Sector Quality Director	Date
James Peronto	1/1/20	Elizabeth Denly	1/1/20

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Page No.

FIGURES

ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) guides TRC personnel in proper Chain-of-Custody practices.

This SOP was prepared to direct TRC personnel in the sample custody procedure requirements associated with field sample collection. Other state or federal requirements may be above and beyond the scope of this SOP and will be followed, if applicable. Sample custody procedures are an important part of the field investigation program in order to maintain data quality and to be able to document proof of proper handling. Sample custody begins at the collection of the samples and continues until the samples have been analyzed. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files.

Custody is one of several factors that are necessary for the admissibility of environmental data as evidence in a court of law or other evidentiary venue. Custody procedures help to satisfy the two major requirements for admissibility: relevance and authenticity. An overriding consideration essential for the validation of environmental measurement data is the necessity to demonstrate that samples have been obtained from the locations stated and that they have reached the laboratory without alteration (i.e., representative of the identified sample media).

1.2 Summary of Method

Evidence of the sample tracking from collection to shipment, laboratory receipt, and laboratory custody (until proper sample disposal and the introduction of field investigation results as evidence in legal proceedings when pertinent) must be properly documented.

A sample or evidence file is considered to be in a person's custody if the item is:

- In a person's possession
- In the view of the person after being in a person's possession
- Secured and preserved so that no one can tamper with it after having been in a person's possession
- In a secured area, restricted to authorized personnel

The Field Team Leader or designee is responsible for overseeing and supervising the implementation of proper sample custody procedures in the field. The Field Team Leader or designee is also responsible for ensuring sample custody until the samples have been transferred to a courier or directly to the laboratory. Once received by the laboratory, the samples proceed through an orderly processing sequence specifically designed to ensure continuous integrity of both the sample and its documentation.

1.3 Equipment

The following list is an example of items that may be utilized when implementing sample custody procedures in the field. Project-specific conditions or requirements may warrant the use of additional items or deletion of items from this list. Many of these items may be provided by the selected analytical laboratory for a given project.

- Chain-of-Custody forms
- Sample labels
- Sample tags
- Custody seals
- Computer
- Indelible/waterproof ink
- Printer

2.0 PROCEDURES

Sample custody and transfer procedures are summarized below. These procedures are intended to ensure that the samples will arrive at the laboratory with the Chain-of-Custody intact. The Chain-of-Custody procedures are initiated in the field immediately following sample collection. The procedures consist of four main components: (1) preparing and attaching a unique sample label to each sample collected, (2) completing the Chain-of-Custody (COC) form, (3) reviewing the COC form for accuracy and (4) preparing the samples for shipment and transfer of custody.

2.1 Specific Chain-of-Custody Procedures

2.1.1 Sample Labels

Field personnel are responsible for uniquely identifying and labeling all samples collected during a field investigation program. All labeling must be completed in indelible/waterproof ink and securely affixed to the sample container. Individual sample containers may be pre-labeled or labeled in the field at the time of collection. Sufficient sample information should be cross-referenced in the field documentation for tracking purposes.

Sample labels typically contain the following information:

- Unique sample identification
- Sample location and/or depth/description number, if different from above
- Sample matrix
- Type of analysis to be performed
- Type of chemical preservation used
- Grab or composite designation
- Filtered or unfiltered
- Sampling date and time
- Sampler's affiliation and initials
- Site and/or client name

An example of a sample label is provided in Figure 1.

2.1.2 Custody Seals

Custody seals may be secured across the shipping container to ensure content integrity. The seals contain both the date and the signature of the person affixing them and must be completed in indelible/waterproof ink. Custody seals are attached to the cover seal of the cooler and can be covered with clear plastic tape after being signed and dated by field personnel. An example of a custody seal is shown in Figure 1. The use of custody seals will be determined on a project-specific basis by the Project Manager.

2.1.3 Chain-of-Custody Form

For all analyses, COC forms must be completed for each sample set submitted. COC forms are initiated by the samplers in the field and maintained until samples are analyzed by the laboratory. If multiple laboratories are being used, a separate set of COC forms must be completed for each laboratory receiving samples to ensure proper transfer of custody from the time of sample collection to analysis. These forms serve as a record of sample collection, transfer, shipment, and receipt by the laboratory. These forms typically contain the following pertinent information:

- Project/site name and/or project number
- Carrier name, if applicable
- Air bill numbers(s), if known and applicable
- Laboratory name and address
- Sample identifications
- Sample matrix (e.g., soil, water)
- Type of sample (i.e., grab or composite)
- Date/time sample collected
- Size, type, and number of containers
- Preservative used
- Required analysis or method
- Turnaround time
- Names of individuals responsible for custody of samples
- Date shipped or otherwise transferred

Figure 2 provides an example COC form. It should be noted that this is an example format only. Laboratories typically provide their own laboratory-specific COC form. Other COC formats may be used as long as all of the applicable information is included. COC forms will be initiated in the field.

All entries on the COC form must be legible and must be made in blue or black permanent ink. No erasures or obliterations can be made. If an incorrect entry is made, the information must be crossed out with a single strike mark which is signed or initialed and dated by the person recording the information. The correction must be written adjacent to the error. The original entry should still be legible even though crossed out.

2.1.4 Transfer of Custody

Samples will be accompanied by a properly completed COC form during each step of custody transfer and shipment. When physical possession of samples is transferred, both the individual relinquishing the samples and the individual receiving them will sign, date, and record the time of transfer on the COC form.

All samples will be shipped directly to the laboratories by a TRC employee, an overnight commercial carrier, or a laboratory-supplied courier service.

In the case of sample shipment by an overnight commercial carrier, a properly prepared air bill, including the project number (Figure 3), will serve as an extension of the COC form while the samples are in transit. The COC forms will be sealed inside the sample cooler within a clear plastic bag and the custody seals, if used, will be completed on the outside of the cooler prior to shipment. Commercial carriers are not required to sign off on the custody forms since the forms are sealed inside the cooler prior to shipment so any custody seal remains intact. The original COC form will accompany the samples at all times. A copy of all COC forms submitted to the laboratory will be retained by the sampler along with field records/logbooks documenting sample collection and will be placed in the project files.

If at the completion of sampling the samples are not shipped directly from the field or point of collection to the analytical laboratory, the samples will be temporarily stored in an iced cooler at a secure location (e.g., locked vehicle, residence, office) or in a locked refrigerator at the TRC office. Access to the secure location and transfer of the sample containers for laboratory delivery shall only be provided by a TRC employee and such sample transfer shall be recorded on the COC form.

3.0 QUALITY ASSURANCE/QUALITY CONTROL

Following sample collection, all samples will be brought to a location for batching and paperwork checks. At this location, labels and logbook information are cross-checked to ensure there is no error in sample identification or sample collection time and that all samples are accounted for. The sample information is transferred to the COC form. The samples are packaged to prevent breakage and/or leakage, and the shipping containers are labeled for transport.

The Field Team Leader has the responsibility of maintaining the COC and air bill documentation. Individual responsibilities may be delegated to other field staff, as appropriate. Quality control procedures will place emphasis on ensuring that appropriate samples were collected and submitted to the laboratory for the correct analyses. The COC forms will also be reviewed by the Field Team Leader or designee to ensure that all required information is clearly presented.

Many laboratories will provide a sample receipt confirmation via electronic mail upon request. COC forms should be cross-checked with laboratory sample receipt confirmations, if applicable, to ensure that all samples were received and logged-in correctly by the laboratory.

4.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Not applicable.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

The Project Manager or Field Team Leader will maintain an inventory of all COC forms completed during the program and will be responsible for ensuring that they are archived in the project files following the completion of the field work.

It is good practice to scan all completed COC forms at the conclusion of field activities and store the resulting electronic PDF files in the project directory.

6.0 REFERENCES

A Compendium of Superfund Field Operations Methods EPA/540/P-87/001. December 1987.

U.S. Environmental Protection Agency (EPA) Office of Enforcement and Compliance Monitoring – National Enforcement Investigations Center (NEIC) requirements (NEIC, 1986)

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	MARCH 2013	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

Figure 1 Example Sample Label and Custody Seal

Sample Label

CLIENT/SOURCE	☐ GRAB ☐ COMPOSITE OTHER
SITE NAME	DATE
SAMPLE #	TIME
ANALYSIS	PRESERVATIVE
	COLL. BY

Custody Seal

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CUSTODY SEAL

Date

Signature

Figure 2 Example Chain-of-Custody Form

TRC

Boott Mills South, Foot of John Street • Lowell, Massachusetts 01852
Telephone 978-970-5600 • Fax 978-453-1995

Chain-of-Custody Record

Page ____ of ____

Project Name: ____________
Project No.: ____________
Sampling Date(s): ____________
Laboratory Name: ____________
Laboratory Location: ____________
Sampler Name(s): ____________

Shipping Carrier ❑ FED EX ❑ COURIER
Date Shipped ____________
Airbill No. ____________

MCP Work Only: Have the appropriate number of field samples been collected for this program? ❑ YES ❑ NO

Turnaround Time (Circle One)
15 Day 10 Day 5 Day 3 Day Other: ________

ANALYSIS AND PRESERVATIVE

SAMPLE ID	DATE/TIME SAMPLED	COMPOSITE OR GRAB	MATRIX	VOLUME / CONTAINER TYPES	NUMBER OF CONTAINERS							
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								
	/			/								

COMMENTS

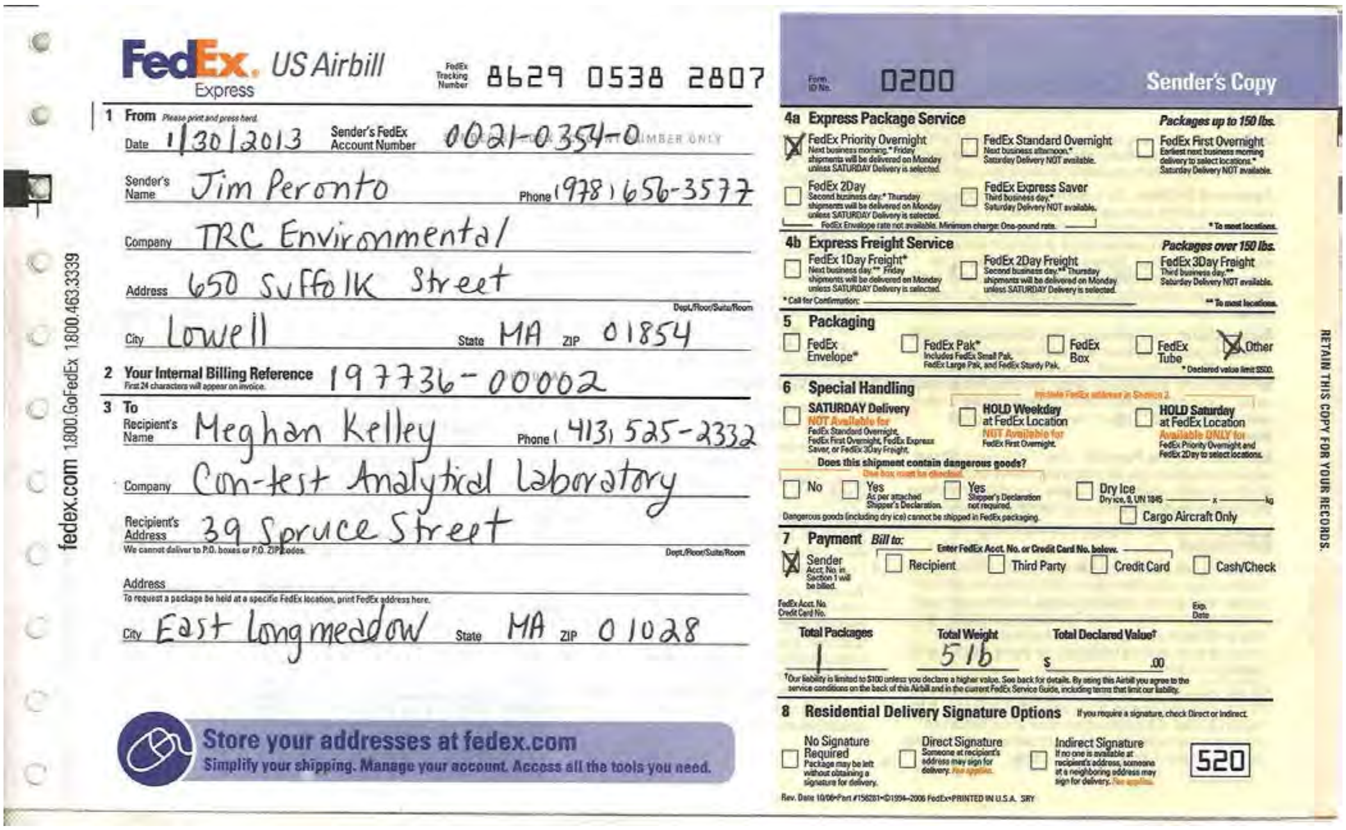
Send results to: ____________
Cooler temperature: ____________

Relinquished By:(Signature)	/ Date/Time	Received By:(Signature)	/ Date/Time
Relinquished By:(Signature)	/ Date/Time	Received By:(Signature)	/ Date/Time

№ 0020

WHITE – LABORATORY YELLOW – LABORATORY COPY PINK – OFFICE COPY GOLD – FIELD COPY

Figure 3 Example Federal Express Air Bill



FedEx Express US Airbill
FedEx Tracking Number 8629 0538 2807
Form ID No. 0200
Sender's Copy

1 From
Date 1/30/2013
Sender's FedEx Account Number 0021-0354-0
Sender's Name Jim Peronto
Phone (978) 656-3577
Company TRC Environmental
Address 650 Suffolk Street
City Lowell State MA ZIP 01854

2 Your Internal Billing Reference 197736-00002

3 To
Recipient's Name Meghan Kelley
Phone (413) 525-2332
Company Con-test Analytical Laboratory
Recipient's Address 39 Spruce Street
City East Longmeadow State MA ZIP 01028

Store your addresses at fedex.com
Simplify your shipping. Manage your account. Access all the tools you need.

4a Express Package Service — Packages up to 150 lbs.
[X] FedEx Priority Overnight
[ ] FedEx Standard Overnight
[ ] FedEx First Overnight
[ ] FedEx 2Day
[ ] FedEx Express Saver

4b Express Freight Service — Packages over 150 lbs.
[ ] FedEx 1Day Freight
[ ] FedEx 2Day Freight
[ ] FedEx 3Day Freight

5 Packaging
[ ] FedEx Envelope
[ ] FedEx Pak
[ ] FedEx Box
[ ] FedEx Tube
[X] Other

6 Special Handling
[ ] SATURDAY Delivery
[ ] HOLD Weekday at FedEx Location
[ ] HOLD Saturday at FedEx Location
Does this shipment contain dangerous goods?
[ ] No [ ] Yes As per attached Shipper's Declaration [ ] Yes Shipper's Declaration not required [ ] Dry Ice
[ ] Cargo Aircraft Only

7 Payment Bill to:
[X] Sender [ ] Recipient [ ] Third Party [ ] Credit Card [ ] Cash/Check

Total Packages 1
Total Weight 5 lb
Total Declared Value $ .00

8 Residential Delivery Signature Options
[ ] No Signature Required
[ ] Direct Signature
[ ] Indirect Signature

520

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Attachment A: SOP Fact Sheet

CHAIN-OF-CUSTODY PROCEDURES

PURPOSE AND OBJECTIVE

Chain-of-Custody procedures have been developed to direct TRC personnel in the sample custody procedure requirements associated with field sample collection. Other state or federal requirements may be above and beyond the scope of this SOP and should be followed, if applicable. Sample custody procedures are an important part of the field investigation program to maintain data quality and to be able to document proof of proper handling. Sample custody begins at the collection of the samples and continues until the samples have been analyzed. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files.

WHAT TO BRING

- Chain-of-Custody (COC) forms
- Sample Labels
- Custody Seals (if required)
- Indelible/waterproof ink

ON-SITE

- Complete all sample labels with indelible/waterproof ink.
- At a minimum, sample labels should include: site name; unique sample identification; sample date and time.
- COC forms must be completed for each sample set and must be initiated in the field by the sampler.
- COC forms must be completed in blue or black permanent ink.
- At a minimum, the COC forms should include: site name; sample identification; sample matrix; type of preservative; type of analysis; sampling date; and sampler's name.
- Once sampling activity is completed and the COC form is filled out, place samples in sample coolers.
- Package samples to prevent breakage and/or leakage.
- The COC forms will be reviewed by the Field Team Leader or designee prior to relinquishing the samples.
- The original COC form must accompany samples to the laboratory.
- When samples are transferred from one person to another, both the relinquisher and the person receiving the samples should sign, date and record the date of transfer on the COC form.
- If samples are not sent directly to laboratory, samples need to remain on ice and be stored in a secure location.

Title: **Soil Sampling**	Procedure Number: **ECR 003**
	Revision Number: **02**
	Effective Date: **January 2020**

Authorization Signatures

Technical Reviewer	Date	Environmental Sector Quality Director	Date
Darby Litz	1/1/20	Elizabeth Denly	1/1/20

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LIST OF ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the logistics, collection techniques, and documentation requirements for collecting representative soil samples. These are standard (i.e., typically applicable) operating procedures that may be changed, as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. In addition, other state or federal requirements may be above and beyond the scope of this SOP and will be followed, if applicable. In all instances, the actual procedures used should be documented and described in the field notes. Portions of this SOP may be applicable to soil sample collection for geotechnical analysis. However, specific instructions for collection of geotechnical samples are not provided; these samples should be collected in accordance with ASTM methods or other applicable standards.

1.2 Summary of Method

The objective of soil sampling is to obtain a representative sample of soil for laboratory analysis of constituents of interest at a given site. This objective requires that the sample be of sufficient quantity and quality for analysis by the selected analytical method. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment D for further details. Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be sampled using a spade, trowel, and/or scoop. Sampling at greater depths typically is performed using a hand auger, continuous flight auger, a split-spoon, direct-push methods (i.e., Geoprobe®), sonic drilling, a backhoe or an excavator. The following reference may be used as a guide to aid in selecting an appropriate method or sampling device for the collection of subsurface soil samples with a drill rig: ASTM D6169–98 Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigation.

1.3 Equipment

The following equipment may be utilized when collecting soil samples. Project-specific conditions or laboratory requirements may warrant the addition or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP).
- Sample containers (may be supplied by the laboratory, depending upon the regulatory program): The proper containers should be determined in conjunction with the analytical laboratory in the planning stages of the project.

  For non-volatile organic compound (VOC) parameters, glass containers with Teflon®-lined caps are typically utilized. Typical containers used for VOC parameters are provided in Attachment A. Brass liners, steel liners, or soil core acetate liners with Teflon® tape and plastic end caps may also be used.
- En-Core® samplers.

- Disposable plastic syringes or Terra Core™ samplers.
- Stainless steel mixing bowl.
- Stainless steel spoon or spatula.
- Hand auger, mud auger, sand auger, bucket auger and T-handle.
- Post hole auger.
- Extension rods.
- Stainless steel trowel.
- Shovel.
- Tape measure, folding ruler.
- Wooden stakes and spray paint, plastic flagging (highly visible), or steel pin flags.
- Field book and/or boring log.
- Sample container labels.
- Chain-of-custody (COC) forms (TRC or laboratory, as appropriate).
- Camera.
- Maps/site plan.
- Survey equipment and/or global positioning system (GPS) and/or other means of measuring sample locations.
- Indelible marking pens or markers.
- Organic absorbent (e.g., Slickwick, ground corn cob, sawdust).
- Sample coolers.
- Bubble wrap.
- Ice (for sample storage/preservation).
- Zip-loc® plastic bags (for ice and COCs).
- Equipment decontamination supplies.

1.4 Definitions

Composite sample	Composed of a number of grab samples collected over a period of time or space during a single sampling event and mixed together.
En-Core® sampler	A disposable volumetric sampling device with an airtight sealing cap.
Grab sample	Individual discrete sample collected at a particular time.

High-level VOC analysis	VOC soil analysis that yields high reporting limits (approximately 50-200 µg/kg, depending on the laboratory). Samples are typically preserved in methanol and cooled to 4°C. High-level VOC analyses are used for samples that are expected to contain elevated concentrations of VOCs (>200 µg/kg).
Low-level VOC analysis	VOC soil analysis that yields low reporting limits (approximately 5 µg/kg, depending on the laboratory). Samples are typically preserved in water, cooled to 4°C, and frozen within 48 hours of collection. Low-level VOC analyses are used for samples that are expected to contain lower concentrations of VOCs (≤200 µg/kg).
Terra Core™ sampler	A disposable volumetric sampling device used to transfer soil samples to the appropriate sample containers.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE, as defined in the HASP.

Soil samples containing chemical contaminants may be handled during implementation of this SOP. Additionally, sample preservatives including caustics and/or acids may be considered hazardous materials and TRC employees will appropriately handle and store them at all times Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate. Hazardous substances may be incompatible or may react to produce heat, chemical reactions, or toxic products. Hazardous substances may be incompatible with clothing or equipment; some substances can permeate or degrade protective clothing or equipment. Also, hazardous substances may pose a direct health hazard to workers through inhalation or skin contact or if exposed to heat/flame and they combust. Material safety data sheets for chemicals handled by TRC should be maintained in the field.

1.6 Cautions and Potential Problems

- Cross contamination: Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary.

- Improper sample collection: Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample, or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

- Special considerations for the different soil sampling techniques are provided below in the applicable sections. Cautions and potential problems associated with soil sampling for VOCs are provided in Attachment A.

- Special care should be taken when sampling for PFAS. Please refer to Attachment D for details.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Always review the site-specific work plan and/or scope of work for any site-specific sampling procedures.

2.1 Pre-Sampling Activities

Pre-sampling activities that the sampling team should consider include the following: preparing a sampling strategy; reviewing the work plan approved by the regulatory agency; selecting a laboratory, and determining laboratory-specific procedures related to bottle orders, holding times, work orders, methods of analysis, COC procedures, data deliverables, schedule, and cost. Additional activities include determining shipping logistics, utility clearance, and handling of investigation-derived waste disposal. Pre-labeling bottles can help to reduce sampling and labeling errors.

The following steps should also be employed.

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.

2. Obtain necessary sampling and monitoring equipment.

3. Decontaminate or clean equipment, and ensure that it is in working order.

4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.

5. Perform a general site survey prior to site entry in accordance with the site-specific HASP.

6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminants, should be considered when selecting sample locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

NOTE: If spray paint is used to mark stakes, the spray paint should be carefully isolated from the space used to hold sample bottles, sampling equipment, etc.

7. Prior to any subsurface soil sampling, especially that completed with a drill rig or backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities by conducting a utility survey/markout.

2.2 General Soil Sampling Procedures

1. Refer to other TRC SOPs for the proper procedures for classifying soil samples and for screening of samples for VOCs. Special care is required when sampling for PFAS. Please refer to Attachment D for details.

2. **<u>For sampling in the State of California only:</u>** When the sampling interval is predetermined and soil samples are collected by direct-push methods into an acetate liner, the section of the liner corresponding to the predetermined depth interval may be cut off and submitted to the laboratory for analysis with the exception of samples for VOC, volatile petroleum hydrocarbon (VPH), or gasoline-range organics (GRO) analysis. If VOC, VPH, or GRO analysis is required, then these samples can be collected from either open end of the acetate liner section according to the procedures outlined in Attachment A prior to packaging and submitting it to the laboratory. The laboratory should be consulted for the required length of liner tube (i.e., sample volume) depending on the analytical suite and to ensure that the use of acetate liners is appropriate for the analytical method(s). After collecting material for the VOC, VPH, or GRO analysis samples (if required), seal each end of the acetate liner section with Teflon tape and plastic end caps. Wrap the ends with non-volatile tape and label the acetate liner with the sample identification (ID) and date and time of collection. Ensure that the laboratory will perform homogenization of the soil sample within the acetate liner and proceed to Step #9.

3. Prior to the collection of soil samples from a particular location or depth, the soil is typically screened for organic vapors with a portable meter equipped with a flame ionization detector (FID) and/or photoionization detector (PID) depending upon the suspected contaminants of concern and site-specific work plan requirements. Such organic vapor screening may be used to determine appropriate soil sample locations or depths for laboratory VOC analysis depending upon established site-specific work plan requirements. Soil should be screened *in situ* or immediately upon retrieval of the soil sample from the subsurface.

4. Samples for VOC, VPH or GRO analysis are then collected as soon as possible after the soil has been exposed to the atmosphere and prior to sample collection for other analyses.

    - **These samples are NOT homogenized.**
    - These samples are generally collected using an open-barrel disposable syringe, a Terra Core™ sampler, or an En-Core® sampler, or equivalent. Note that En-Core® samplers are not recommended for non-cohesive soils (see Attachment A).
    - Refer to the site-specific work plan or governing regulatory authority for preservation requirements for VOC, VPH or GRO analysis. Attachment A of this SOP includes typical procedures on the collection and preservation of soil samples for VOC, VPH and GRO analysis.

5. After collecting the sample for VOC analysis, the sample portion for the remaining analysis should be well homogenized, *in situ* (if possible, such as with surface soil sampling), or in a decontaminated stainless steel bowl or disposable new aluminum pie pan. These soil samples must be thoroughly mixed to ensure that the sample is as representative as possible of the sample media. Soil can be homogenized and transferred to sample containers using soil sampling devices that have been decontaminated prior to use or individually wrapped, sterile, new polystyrene devices. Such sterile, polystyrene devices are generally for one-time use. Stainless steel devices may be decontaminated and individually foil wrapped, plastic bagged, or field decontaminated and foil wrapped between uses. Decontamination of sampling equipment shall be conducted in accordance with TRC's SOP on equipment decontamination.

6. Stones, gravel, or vegetation should be removed from the soil sample as much as practical prior to placement in sample containers, since these materials will not be analyzed. Visible asphalt, concrete, ash, slag, and coal debris should also be removed from the sample as much as possible to ensure sufficient soil quantity for laboratory analyses, unless these matrices are part of the overall characterization program. The soil sample must be representative of what the end user is trying to characterize. In addition, if such debris is to be tested, further sample preparation (e.g., pulverizing) will likely be necessary in the field or laboratory. In any case, the presence of any such materials in the soil at the sample location must be documented in the field book.

7. Filling of the sample bottles should be completed immediately after sample collection to minimize losses due to volatilization and biodegradation. Soil classification can be completed following sample collection.

8. Place the sample into an appropriate, labeled container(s) by using the alternate shoveling method and secure the cap(s) tightly. The alternate shoveling method involves placing a spoonful of soil in each container in sequence and repeating until the containers are full or the sample volume has been exhausted. Threads on the container and lid should be cleaned to ensure a tight seal when closed.

9. Restore the sampling location to grade in accordance with applicable state or federal guidelines and/or the site-specific work plan. Options include backfilling the sample location with the remaining removed soil, bentonite pellets or, cement/bentonite grout depending on site conditions and patching the surface to match the surrounding area (e.g., topsoil with grass seed, asphalt or concrete patch), as necessary. Boreholes must be abandoned or backfilled after the completion of sampling. In general, shallow boreholes (e.g., less than 10 feet deep) that remain open and do not approach the water table may be abandoned by pouring a cement/bentonite grout mixture from the surface or pouring bentonite pellets from the surface and hydrating the pellets in lifts. The grout mixture should be based on site-specific conditions (e.g., boring depth, groundwater depth, and formation permeability), site-specific work plan procedures, and local regulatory requirements. Boreholes where bridging of the bentonite may be an issue, such as boreholes that intercept groundwater or are greater than approximately 10 feet in depth, should be backfilled by pressure grouting with a cement/bentonite grout mixture, either through a re-entry tool string or through a tremie pipe introduced to within several feet of the borehole bottom.

10. Record locations of soil borings/samples in the field book by sketching a map and/or providing a description of the location. Always measure and record distances to fixed landmarks, such as buildings, fences, curbs, existing surveyed wells, etc. Additionally, a GPS unit with real-time sub-meter accuracy (not applicable for interior samples or other site conditions such as heavy tree/brush cover and thick cloud cover that limit unit connection with satellites) could be used to document sample locations. Note observations about elevation changes between sample locations.

2.2.1 Surface Soil Sampling Methods

The depth of surface soil samples will be determined on a site-specific basis and may be influenced by site-specific conditions and/or applicable local, state, or federal regulatory programs and potential exposure pathways. Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface (bgs). The most common interval is 0 to 6 inches; however, the data quality objectives of the investigation may dictate another interval, such as 0 to 3 inches for risk assessment purposes.

The following procedure should be used for surface soil sampling:

1. If a thick, matted root zone, leaf layer, gravel, surface debris, concrete, etc. is present at or near the surface, it should be carefully removed using clean decontaminated tools or clean nitrile gloves before the soil sample is collected. The presence and thickness of any such material should be recorded in the field book for each location. The depth measurement for the soil sample begins at the top of the soil horizon, immediately following any such removed materials.

2. A decontaminated stainless steel spoon, scoop or trowel is typically used for surface soil sampling depths from 0 to 12 inches bgs where conditions are generally soft, and there is no problematic vegetative layer to penetrate. A hand auger or shovel may also be used to dig down to the desired depth and then after careful removal of the dug soils from the hole, a decontaminated stainless steel spoon, scoop or trowel is used to collect the soil sample from the bottom of the hole for laboratory chemical analysis. Plated trowels typically available from garden supply centers should not be used due to potential heavy metal impacts from the trowel plating.

3. When using stainless steel spoons or trowels, consideration must be given to the procedure used to collect a soil sample for VOC analysis. Samples for VOC, VPH or GRO analysis must be collected first and never homogenized or composited. These samples are collected using an open-barrel disposable syringe, a Terra Core™ sampler, or an En-Core® sampler, or equivalent. If the soil being sampled is cohesive and holds its *in situ* texture in the spoon or trowel, the En-Core® sampler or disposable syringe used to collect the sub-sample should be plugged directly from the spoon or trowel. However, if the soil is not cohesive and crumbles when removed from the ground surface for sampling, the sub-sample should be plugged directly from the surface of the appropriate sample depth. Additionally, note that En-Core® samplers are not recommended for non-cohesive soils (see Attachment A). Generally, the sample portion for VOC analysis is collected from several inches below grade to minimize volatilization from the *in situ* soil.

4. Continue by following the General Soil Sampling Procedures in Section 2.2.

2.2.2 Hand Auger Sampling Methods

The shallow subsurface interval may be considered to extend from approximately 12 inches bgs to a site-specific depth at which sample collection using manual collection with a spoon or trowel becomes difficult or impractical. Hand augers may be used to advance boreholes and collect soil samples in shallow subsurface intervals. Often, 4-inch diameter stainless steel auger buckets with cutting heads are used. The auger is advanced by simultaneously pushing and turning using an attached T-handle with extensions (if needed).

Auger holes are advanced one bucket at a time until the appropriate sample depth is achieved. When the sample depth is reached, the bucket used to advance the hole is removed and decontaminated or a clean bucket is attached. The clean auger bucket is then placed in the hole and filled with soil to make up the sample and then carefully removed. The practical depth of investigation using a hand auger largely depends upon the soil properties and depth of investigation. In sand, augering is typically easy to perform, but the depth of collection is limited to the depth at which the sand begins to flow or collapse. The use of hand augers may be of limited use in soils containing large amounts of unnatural fill (e.g., brick, slag, concrete), coarse gravel and cobbles (or larger grain size), and in tight clays or cemented sands. In these soil types, it becomes more difficult to recover a sample due to increased friction and torqueing of the hand auger extensions as the depth increases. At some point, these problems become so severe that alternate methods (i.e., power equipment) must be used.

The following procedure is used for collecting soil samples with the hand auger:

1. Attach the auger head to a drill rod extension and attach the T-handle to the rod.

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first several inches of surface soil and any root layer for an area approximately 6 inches in radius around the borehole location.

3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the borehole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding rod extensions. It also facilitates refilling the borehole and avoids possible contamination of the surrounding area.

4. When the sample depth is reached, remove the bucket used to advance the borehole and attach a decontaminated or clean bucket. Place the clean auger bucket in the borehole, advance the clean auger bucket to fill it with the soil sample and then carefully remove the clean auger bucket.

5. If VOC analysis is to be performed, collect a sample directly at the bottom of the boring, if within reach, and not from the auger bucket. If not within reach, collect the sample directly from the auger bucket or from minimally disturbed material immediately after the auger bucket is emptied. Use an En-Core® sampler or other coring device (i.e., syringe, Terra Core™) to collect the sub-sample as described in Attachment A. Note: some regulatory agencies do not allow for subsurface VOC sample collection directly with a hand auger; refer to the site-specific work plan and regulatory requirements to ensure the collection of VOC samples with a hand auger is appropriate.

6. Continue by following the General Soil Sampling Procedures in Section 2.2. Note that if another sample is to be collected in the same borehole, but at a greater depth, reattach the auger bucket to the rod assembly, and follow steps 1 through 5 above, making sure to decontaminate the sampling device between samples.

Special Considerations for Hand Auger Sampling

- *Utility Clearance* - Prior to any subsurface soil sampling, it is important to ensure that all sampling locations are clear of overhead and buried utilities through the conduct of a utility survey/markout. Locations on private properties should also be reviewed with the owner prior to installation.
- *Slough* - Because of the tendency for the auger bucket to scrape material from the sides of the auger hole while being extracted, the top several inches of soil in the auger bucket should be discarded prior to placing the bucket contents in the homogenization container for processing.
- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- *Decontamination* - If sampling equipment is to be reused at a new sampling location or at a deeper depth in the same location, proper decontamination of sampling equipment is required.

2.2.3 Direct-Push Sampling Methods

Direct-push sampling methods are used primarily to collect shallow and deep subsurface soil samples. Soil sampling probes may range from simple hand tools to truck-mounted or track-mounted hydraulically operated rigs. The basic concept is the same for all of these samplers: the tool is hydraulically driven into the soil, filling the tube, and then the tool is withdrawn. All of the sampling tools involve the collection and retrieval of the soil sample within a thin-walled liner. The following sections describe two specific sampling methods using direct-push techniques, along with details specific to each method.

- *Macro-Core® Sampler (Direct-push)* **-** The Macro-Core® (MC®) sampler is a solid barrel, direct-push sampler equipped with a piston-rod point assembly used primarily for collection of either continuous or depth-discrete subsurface soil samples. Although other lengths are available, the standard MC® sampler has an assembled length of approximately 52 inches (1321 mm) with an outside diameter (OD) of 2.2 inches (56 mm). The MC® sampler is capable of recovering a discrete sample core 45 inches x 1.5 inches (1143 mm x 38 mm) contained inside a removable liner. The resultant sample volume is a maximum of 1300 mL. The MC® sampler may be used in either an open-tube or closed-point configuration.

- *Dual-tube Soil Sampling System (Direct-push)* - The Dual-tube 21 soil sampling system is a direct-push system for collecting continuous core samples of unconsolidated materials from within a sealed outer casing of 2.125-inch (54 mm) OD probe rod. The samples are collected within a liner that is threaded onto the leading end of a string of 1.0-inch diameter probe rod. Collected samples have a volume of up to 800 mL in the form of a 1.125-inch x 48-inch (29 mm x 1219 mm) core. Use of this method allows for collection of a continuous core inside a cased hole, minimizing or preventing cross contamination between different intervals during sample collection. The outer casing is advanced, one core length at a time, with only the inner probe rod and core being removed and replaced between samples. If the sampling zone of interest begins at some depth below ground surface, a solid drive tip must be used to drive the dual-tube assembly and core to its initial sample depth.

The following procedure is used for collecting soil samples from direct-push soil cores:

1. The driller will advance and extract the soil sampler liner which will then be given to the field sampler - confirm with the driller which end is top and which end is bottom. Record the time of core collection (military time), the soil boring ID and the depth interval in feet bgs in the field book.

2. Measurement of vertical depth should start from the top of soil; surface asphalt, surficial concrete slabs, or gravel sub-base should be excluded from the depth measurement unless otherwise specified in the site-specific work plan. However, the presence and thickness of these items should be noted in the field book.

3. Measure the length of recovered soil in inches and record in the field book.

4. Continue by following the General Soil Sampling Procedures in Section 2.2.

   If a specific depth interval is targeted for sampling, be sure to give consideration to the percent recovery of soil when selecting the sample interval. For example, if the targeted sample interval was from 2.0 to 2.5-ft, and the core barrel was advanced from 0 to 4 ft bgs, and 30 inches (2.5 ft) of soil was recovered, the sample should be collected immediately below the mid-point of the recovered soil, or 15- inches below the top of the recovered soil (not including slough). The sample designation will indicate that the depth was 2.0 to 2.5 ft bgs.

Special Considerations for Direct-push Sampling

- *Utility Clearance* - Prior to any subsurface soil sampling, especially that completed with a drill rig, it is important to ensure that all sampling locations are clear of overhead and buried utilities through the conduct of a utility survey/markout. Locations on private properties should also be reviewed with the owner prior to installation.
- *Liner Use and Material Selection* - Direct-push soil samples are collected within a dedicated new or decontaminated liner to facilitate removal of sample material from the sample barrel. The liners may only be available in a limited number of materials for a given sample tool, although overall, liners are available in brass, stainless steel, cellulose acetate butyrate (CAB), polyethylene terephthalate glycol (PETG), polyvinyl chloride (PVC) and Teflon®. For most investigations, the standard disposable new polymer liner material for a sampling tool will be acceptable. When the study objectives require very low reporting levels or unusual contaminants of concern, the use of more inert liner materials such as Teflon® or stainless steel may be necessary. However, such costly liner materials typically are not disposable and therefore require decontamination between each use.
- *Sample Orientation* - When the liners and associated sample are removed from the sample tubes, it is important to confirm and maintain the proper orientation of the sample. This is particularly important when multiple sample depths are collected from the same push. It is also important to maintain proper orientation to define precisely the depth at which an aliquot was collected. Maintaining proper orientation is typically accomplished using vinyl end caps.

Convention is to place red caps on the top of the liner and black caps on the bottom to maintain proper sample orientation. Orientation can also be indicated by marking on the exterior of the liner with a permanent marker.

- *Core Catchers* - Occasionally the material being sampled lacks cohesiveness and is subject to crumbling and falling out of the sample liner. In such cases, the use of core catchers on the leading end of the sampler may help retain the soil until it is retrieved to the surface. Core catchers may only be available in specific materials and should be evaluated for suitability. However, given the limited sample contact that core catchers have with the sample material, most standard core catchers available for a tool system will be acceptable.
- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- *Decontamination* - The cutting shoe and piston rod point are to be decontaminated between each sample. Within a borehole, the sample barrel, rods, and drive head may be subjected to an abbreviated cleaning to remove obvious and loose material, but must be cleaned between boreholes, such as with high-pressure water or steam.

2.2.4 Split-spoon Sampling Methods

All split-spoon samplers, regardless of size, are basically split cylindrical barrels that are threaded on each end. The leading end is held together with a beveled threaded collar that functions as a cutting shoe. The other end is held together with a threaded collar that serves as the stub used to attach the spoon to a string of drill rod.

- <u>Standard Split Spoon</u> - A drill rig auger is used to advance a borehole to the target depth. The drill auger string is then removed and a standard split spoon is attached to a string of drill rod. Split spoons used for soil sampling must be constructed of stainless steel and are typically 2.0- inches OD (1.5-inches inside diameter) and 18- inches to 24- inches in length. Other diameters and lengths are common and may be used if constructed of the proper material. After the spoon is attached to the string of drill rod, it is lowered into the borehole. The safety hammer is then used to drive the split spoon into the soil at the bottom of the borehole. After the split spoon has been driven into the soil, filling the spoon, it is retrieved to the surface, where it is removed from the drill rod string and opened for sample acquisition. Split-spoon soil sampling for geotechnical purposes should be conducted in accordance with ASTM Method D1586 *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soil*.

The following procedure is used for collecting soil samples from split-spoon soil cores:

1. Record the blow count per 6-inch interval when advancing split-spoon samplers with the hollow stem auger rig. Record the hammer weight (e.g., 140 pounds [lb] is standard, but 300 lb may also be used to advance the spoon). Blow counts are an indication of soil density and are a measure of the number of blows it takes for a 140 lb slide hammer falling over a distance of 30- inches to penetrate 6- inches of soil. The drillers will keep the count and will repeat them to the field sampler (e.g., 11, 13, 16 – means the number of blows the hammer advanced the spoon every 6 inches over a total depth interval of the split-spoon sampler, in this case over 18 inches). If refusal is encountered, the count is recorded in the book as "# of hammer blows / depth in inches the spoon is driven" (e.g., 50/3 – means 50 blows of the hammer advanced the spoon 3 inches).

2. The driller will advance, extract, and open the split spoon, which will then be given to the field sampler - confirm with the driller which end is top and which end is bottom, if a soil sampler liner is used and removed from the spoon. Record the time of core collection (military time), the soil boring ID and the depth interval in feet bgs in the field book.

3. Measurement of vertical depth should start from the top of soil; surface asphalt, surficial concrete slabs or gravel sub-base should be excluded from the depth measurement unless otherwise specified in the site-specific work plan. However, the presence and thickness of these items should be noted in the field book.

4. Measure the length of recovered soil in inches and record in the field book.

5. Continue by following the General Soil Sampling Procedures in Section 2.2.

Special Considerations for Split-spoon Sampling

- *Utility Clearance* - Prior to any subsurface soil sampling, especially that completed with a drill rig, it is important to ensure that all sampling locations are clear of overhead and buried utilities through the conduct of a utility survey/markout. Locations on private properties should also be reviewed with the owner prior to installation.
- *Slough* - Generally discard the top several inches of material in the spoon before removing any portion for sampling. This material normally consists of borehole wall material that has sloughed off of the borehole wall after removal of the drill string prior to and during insertion of the split spoon.
- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- *Decontamination* - The split-spoon sampler(s) is to be decontaminated between each sample. Within a borehole, the split spoon sample barrels must be cleaned between each sample - the driller typically has multiple barrels and can alternate between clean and dirty barrels so drilling progress is not affected by decontamination of the barrels. The augers should be decontaminated between boreholes (such as with high-pressure steam).

2.2.5 Shelby Tube/Thin-walled Sampling Methods

Shelby tubes, also referred to generically as thin-walled push tubes or Acker thin-walled samplers, are used to collect subsurface soil samples in cohesive soils and clays during drilling activities. In addition to samples for chemical analyses, Shelby tubes are also used to collect relatively undisturbed soil samples for geotechnical analyses of physical properties such as shear strength, grain size distribution, density, hydraulic conductivity and permeability, to support engineering design, construction, and hydrogeologic characterizations at hazardous waste and other sites.

A typical Shelby tube is 30 inches in length, has a 3.0-inch OD (2.875-inch inside diameter) and may be constructed of steel, stainless steel, galvanized steel, or brass. They are typically attached to push heads constructed with a ball check to aid in holding the sample in the tube during retrieval. If used for collecting samples for chemical analyses, it must be constructed of stainless steel. If used for collecting samples for standard geotechnical parameters, any material is acceptable. To collect a sample, the tube is attached to a string of drill rod and is lowered into the borehole, where the sampler is then pressed into the undisturbed material by hydraulic force from the drill rig. Shelby tube or thin-walled soil sampling should be conducted in accordance with ASTM Method D1587 *Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes*.

After retrieval to the surface, the tube containing the sample is then removed from the sampler head. If samples for chemical analyses are needed, the soil contained inside the tube is then removed for sample acquisition by following the direct-push sampling procedures in Section 2.2.3. If the sample is collected for geotechnical parameters, the tube is typically sealed, to maintain the sample in its relatively undisturbed state, capped, labeled appropriately (including sample ID, top end of sample, inches of recovery, etc.), and shipped to the appropriate geotechnical laboratory. The tube is typically stored in an upright position to maintain the integrity of the undisturbed sample. For geotechnical use, check with the laboratory prior to sampling to understand sample volume recoveries needed to perform the actual tests.

2.2.6 Sonic Drilling Sampling Methods

Sonic drilling/rotary vibratory drilling employs the use of high-frequency, resonant energy to advance a core barrel or casing into subsurface formations. Although sonic drilling is not technically a direct-push method of soil sampling, it is similar because soil sample collection from cores of recovered unconsolidated soil would follow the same procedures as described for direct-push methodologies. The soil core is extruded from the core barrel or casing into a plastic sleeve.

Sonic drilling is different than conventional drilling, as sonic drilling minimizes the friction between the borehole wall and the drilling tool by maintaining the resonance of the drill string with a sonic drill head. Typically the drilling method utilizes dual casings that independently resonate into the subsurface with an inner core barrel that is overrun by an outer casing.

Typically core runs are 10-feet. The core barrel is removed from the borehole and the core is extruded into a plastic sleeve. The plastic sleeve is placed on dedicated plastic sheeting. The plastic sleeve is then slit with a razor knife (or similar) vertically along the core run, exposing the soil inside.

The procedures for collecting soil samples from sonic cores are the same as the procedures presented for collecting soil samples from direct-push sampling methods in Section 2.2.3.

<u>Special Considerations for Sonic Drilling Sampling</u>

- *Utility Clearance* - Prior to any subsurface soil sampling, especially that completed with a drill rig, it is important to ensure that all sampling locations are clear of overhead and buried utilities through the conduct of a utility survey/markout. Locations on private properties should also be reviewed with the owner prior to installation.
- Sonic-generated soils are not undisturbed. The resonation of the core barrel during advancement energizes the skin of the sample immediately adjacent to the barrel, approximately ⅛ to ¼ inch around the OD of the sample. Heating of the soils is possible.
- Coring is always accomplished without air or fluids. Depending on site conditions, the outer casing may require adding some water to the borehole if heaving or flowing sands/sand and gravel are present.

- Resistance is not measured during core barrel advancement, as in split-spoon sampling where blow counts are measured. To collect conventional split-spoon samples and obtain blow counts, the sonic drill rigs can be outfitted with automatic hammers to advance split spoons or thin-walled push tubes, although the advantage of drilling speed with the sonic drilling technique is diminished.

2.2.7 Excavator Sampling Methods

A backhoe or excavator can be used to assist with soil sampling. This method is typically used during remedial excavation activities (to collect floor and sidewall samples within the excavation), test pit installation, or trenching operations. Test pit excavations are commonly completed to allow for greater observation of physical soil characteristics (e.g., stockpiles) and/or to further investigate buried suspect areas of concern (e.g., petroleum tanks, drums, waste, fill).

The following procedures are used for collecting soil samples excavated with a backhoe or excavator:

1. Prior to any excavation, it is important to ensure that all sampling locations are clear of overhead and buried utilities through the conduct of a utility survey/markout.

2. For test pits or trench excavation, excavate in accordance with the site-specific work plan. Typically, this will be approximately 3 feet wide and approximately 1 foot deep below the cleared sampling location with the backhoe. Remedial excavations may be much wider and deeper. The work plan may also require that excavated soils be placed on plastic sheets or another impervious surface and protected from rain.

3. Refer to the site-specific work plan for the number of floor and/or sidewall samples, which is typically driven by the surface area and can vary depending on the governing regulatory agency.

4. Samples can be collected using a trowel, spoon, or coring device at the desired intervals. A clean shovel may be used to remove a 1 to 2- inch layer of soil from the vertical face of the pit that contacted the backhoe bucket and where soil sampling is planned. Scrape the vertical face at the point of sampling to remove any soil that may have fallen from above and to expose fresh soil for sampling. In many instances, soil sample locations within the excavation area are inaccessible (do not physically enter backhoe excavations to collect a sample). In these cases, soil samples can be collected directly from the backhoe bucket – use caution not to collect a soil sample from edges that may have come into contact with the backhoe bucket.

5. If VOC analyses are required, collect the sample in accordance with the procedures in Attachment A and/or the site-specific work plan. With a dedicated decontaminated spoon, or equivalent, place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

6. Abandon the pit or excavation according to applicable state regulations and the site-specific work plan. Generally, shallow excavations can simply be backfilled with the removed soil material.

Special Considerations for Excavator Sampling

- *Utility Clearance* - Prior to any subsurface soil sampling, it is important to ensure that all sampling locations are clear of overhead and buried utilities through the conduct of a utility survey/markout. Locations on private properties should also be reviewed with the owner prior to installation.
- *VOC Sample Collection* - Observe precautions for VOC sample collection found in Attachment A and/or the site-specific work plan.
- Do not physically enter backhoe excavations to collect a sample if the excavations are unstable or not sloped and protected with shoring. A trench with non-cohesive soils (i.e., sand, saturated/wet muds, or flowing water at the base) is particularly susceptible to collapsing suddenly. Never enter a trench without a confined space entry permit, as required by OSHA regulations.
- Smearing is an important issue when sampling with a backhoe or excavator. Any time a vertical or near vertical surface is sampled, such as achieved when shovels or similar devices are used for subsurface sampling, the surface should be dressed (scraped) to remove smeared soil. This is necessary to minimize the effects of contaminant migration interferences due to smearing of material from other levels.
- Loose paint, grease and rust should be removed and the backhoe bucket decontaminated prior to use for sample collection if the bucket will come in direct contact with the material to be sampled. Care should be taken to collect the soil sample from the center of the excavated material within the bucket (i.e., material that has not touched the bucket walls).

2.2.8 Stockpile Soil Sampling Methods

Stockpiled soils are typically sampled to characterize the soils for reuse or disposal. The stockpile sampling strategy used must consider the source of the soil and all available data, field observations, shape/dimensions and volume of the pile, and sampling frequency requirements established by oversight regulatory agencies or potential soil disposal facilities.

If the stockpile is known to be a representative mixture of soil with no known or suspected significant variability of contamination with depth in the pile, the stockpile sampling may be conducted according to the surface soil sampling method described in Section 2.2.1. However, if the soil characteristics are not known or are known or suspected to vary with depth in the pile, both surface soil and deeper subsurface soil samples will be required to properly characterize the soil pile.

A backhoe or excavator equipped with a bucket can be used to collect subsurface soil samples from stockpiles. This method is often preferred for collecting subsurface soil samples from a stockpile, since it allows the sampler greater opportunity to inspect the physical characteristics of the pile for any potential signs of variability for determining appropriate sample depths and locations.

Typically, based on the minimum required number of samples for the estimated stockpile volume, the stockpile is divided into the appropriate number of estimated volumes equal to that sample number. For example, if the specified sample frequency is 1 sample per 1,000 cubic yards (cy) and the estimated stockpile size is 4,000 cy, the stockpile would be broken down into approximately four equal volumes or quadrants. Grab VOC samples and composite non-VOC samples, as required, would then be collected from each of the areas for characterization of the stockpile.

2.3 Post-sampling Activities

1. After the samples have been collected, the sampling location may be marked with wooden stakes colored with highly visible spray paint and/or flagging in order to identify the sample location for surveying purposes. The sample and/or location identification should be written on the stake in indelible ink or marking pen. The sample location should be surveyed in the field with a GPS unit if not surveyed later by some other means. A sketch of the sampling locations should also be included in the field book.

2. Package the samples with bubble wrap and/or organic absorbent, as necessary.

3. Place the samples into a shipping container and cool to 4ºC. If wet ice is used to cool the samples, place the ice in double-bags to prevent water from the melting ice from damaging the samples during shipment.

4. Complete the COC form.

5. Decontaminate non-disposable sampling equipment.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The collection of specific field quality control (QC) samples will be specified in the project-specific planning documents and may include one or more of the following: field blank, equipment blank, trip blank, field duplicate, and matrix spike/matrix spike duplicates.

4.1 Duplicate Soil Sample Collection

The following procedures should be used for collecting duplicate soil samples:

1. For QC purposes, each duplicate sample will be submitted to the laboratory as a "blind" duplicate sample, in that a unique sample identification not tied to the primary sample identification will be assigned to the duplicate (e.g., DUP-01). Standard labeling procedures used for soil sampling will be employed. However, a sample collection time will not be included on the sample label or the COC form. The actual source of the duplicate sample will be recorded in the field book.

2. Each duplicate sample will be collected simultaneously with the actual sample. At the coincident step in the sampling procedures that the VOC, VPH and/or GRO containers are filled and sealed, the duplicate sample VOC, VPH and/or GRO containers will also be filled and sealed. Duplicates for all parameters other than VOCs, VPH and GRO should be filled from the homogenized sample to ensure consistency between the sample and the duplicate. Following the order of collection specified for each set of containers (i.e., VOCs, VPH, GRO, semivolatile organic compounds [SVOCs], other organics and then inorganic compounds), the duplicate sample containers will be filled simultaneously with each parameter.

3. All collection and preservation procedures outlined for soil sampling will be followed for each duplicate sample.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record the general sample collection information such as location, identification, and date/time in the field book or on a field data sheet. Typical field documentation recorded in a field book includes the following information:

- Sample identification number
- Sample location (description or sketch of the sample point)
- Sample depth interval
- GPS coordinates and coordinate system
- Time and date sample was collected
- Personnel performing the task
- Visual or sensory description of the sample (e.g., odors, staining)
- Brief soil descriptions (e.g., color, texture, appearance)
- Presence of any fill materials (e.g., concrete, asphalt, ash)
- Readings from field screening equipment (e.g., PID)
- Weather conditions during sampling
- Other pertinent observations including whether photographs were taken
- Sample collection equipment used
- Decontamination procedure
- Analytical parameters

Affix a properly completed label to each sample container.

All sample numbers must be documented on the COC form that accompanies the samples during shipment. Any deviations from the record management procedures specified in the site-specific work plan must be approved by the Project Manager and documented in the field book.

6.0 REFERENCES

ASTM Methods D1586 *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soil*, D1587 *Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes*, ASTM D6169 *Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigation*, ASTM International, Most Current Version.

MassDEP, *Method for the Determination of Volatile Petroleum Hydrocarbons (VPH)*, May 2004.

U.S, EPA, SW-846 Method 5035A, *Closed System Purge-and-Trap and Extraction for Volatile Organics in Soil and Waste Samples*, Draft Revision 1, July 2002.

U.S. EPA Environmental Response Team, Soil Sampling SOP #2012, February 18, 2000.

U.S. EPA Science and Ecosystem Support Division, Soil Sampling Operating Procedure (SESDPROC-300-R2), December 20, 2011.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	SEPTEMBER 2013	NOT APPLICABLE
1	NOVEMBER 2016	ADDED ATTACHMENT D TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING

Attachment A:

Procedure for Collection of Samples for VOCs, VPH or GRO (SW-846 Method 5035A)

1.0 SAMPLING FOR VOLATILE ORGANIC COMPOUNDS IN SOIL BY EPA METHOD 5035/5035A

The following sampling protocol is recommended for site investigations assessing the extent of VOCs (including VPH and GRO) in soils at a project site. Because of the large number of options available, careful coordination between field and laboratory personnel is needed. The specific sampling containers and sampling tools required will depend upon the required detection levels and intended data use. Once this information has been established, selection of the appropriate sampling procedure and preservation method best applicable to the investigation can be made.

SW-846 Method 5035 provides instructions and options on the preservation of soil samples for low-level and high-level VOC analyses:

- Low-level (≤ 200 µg/kg) and
- High-level (> 200 µg/kg).

The choice of low-level or high-level analysis is determined by the requirements of the project. However, since the low-level method is only valid for a certain concentration range, a sample for analysis by the high-level method must also be collected to ensure quantification of all target analytes is possible, if needed.

The low-level method uses one or more of the following options for the sampling/preservation of soils:

- Soil sampled into a vial with a sodium bisulfate ($NaHSO_4$) solution.
- Soil collected in an En-Core® sampler and immediately shipped to the laboratory for further preservation (within 48 hours).
- Soil collected in a vial with organic-free water, sealed in the field, and shipped to the laboratory immediately in order to meet the method preservation requirement to freeze within 48 hours of collection.

Based on project-specific requirements, trip blanks may be recommended. Refer to the site-specific work plan for quality assurance (QA)/QC requirements.

1.1 Low-level Method (VOCs)

Option A - Direct sampling into En-Core® samplers

- Three 5 gram size En-Core® samplers for each sample.
- One nonpreserved container for moisture determination.

Option B - Direct sampling into vial with chemical preservative

- Two 5 gram size cores are added to volatile organic analysis (VOA) vials (one soil core is added to each of two VOA vials with sodium bisulfate solution) for each sample using a Terra Core™ or other coring sampler (e.g., disposable syringe). Once the vials are sealed in the field, these are not opened again.
- One nonpreserved container for moisture determination.

Option C - Direct sampling into vial with water (to be frozen at the laboratory)

- Two 5 gram size cores are added to VOA vials (one soil core is added to each of two VOA vials with water) for each sample using a Terra Core™ or other coring sampler (e.g., disposable syringe). Once the vials are sealed in the field, these are not opened again.
- One nonpreserved container for moisture determination.

1.2 High-level Method (VOC, VPH, GRO)

Option D - Direct sampling into En-Core® samplers

- One 5 gram size En-Core® sampler for each sample.
- One nonpreserved container for moisture determination.

Option E - Direct sampling into a methanol-preserved vial

- For VOCs: 5 or 10 grams of soil is added to a VOA vial (with 5 or 10 grams of methanol, respectively) for each sample using a Terra Core™ or other coring sampler (e.g., disposable syringe). This may also depend upon the regulatory agency (e.g., New Jersey Department of Environmental Protection requires 8 to 12 grams in 25 mL methanol or 5 grams in 10 mL methanol).
- For VPH or GRO: The coring device will be filled with 25 grams of undisturbed soil if 60-ml vials with 25 ml of methanol are used, or 15 grams of undisturbed soil if 40-ml vials with 15 ml of methanol are used. The goal is to have a 1:1 ratio of soil- to-methanol.
- One nonpreserved container for moisture determination.

1.3 Cautions and Potential Problems

1. Potential leaking sample containers for VOC, VPH and GRO analyses:

   Options for evaluating containers for leaking preservatives:

   a. When ordering pre-preserved sample containers, laboratories should be encouraged to mark the meniscus of the preservative on all sample containers. The preservative level should be checked before sampling as a quick check that there has not been any loss of liquid.
   b. Compare preservative level in multiple bottles and select one for comparison purposes to subsequent sample bottles.
   c. Weigh methanol-preserved sample containers prior to sampling. Sample containers found to have lost greater than 0.2 grams of methanol compared to their initial weight should not be used. In order to perform this option, initial container weights must be provided by the laboratory.

2. Potential methanol absorption:

   Soil may be encountered that absorbs all of the methanol preservative (e.g., organic-rich soil, fine-grain soil). These soils can absorb the methanol leaving no methanol extract for the laboratory to analyze. In these instances, the use of additional methanol is required. The laboratory must be contacted for sample containers with an increased volume of methanol.

Using a 1:2 ratio of soil to methanol will help to ensure that there will be adequate volume of methanol remaining for analysis. **NOTE: Additional methanol should <u>not</u> be added to the sample container by the sampler in the field. Containers with additional methanol must be obtained from the laboratory.**

3. <u>Collection of samples with high moisture content:</u>

   Soil samples with high (>50%) moisture content (e.g., sediments, soil samples below the water table) may prevent the attainment of the ideal 1:1 soil-to-preservative ratio. In these instances, depending on the data quality objectives, it may be necessary to evaluate the soil to determine what level in the disposable syringe corresponds to the required weight (typically 5 grams for VOCs and 15 or 25 grams for VPH). This can be performed by collecting several trial samples with disposable syringes. Weigh each trial sample and note the length of the soil in the syringe. These measurements would be used to determine how much soil in the syringe corresponds to 5 $\pm$ 0.5 grams (or the desired weight $\pm$ 0.5). All trial samples should be discarded and not used for analysis.

4. <u>En-Core® sampler cautions:</u>

   a. En-Core® samplers, or equivalent, should only be used on fine-grain or cohesive soils (soils that stay together in the En-Core® sampler and do not fall apart). En-Core® samplers should not be used to collect soil samples that consist of dry sand, gravel, or a mixture of gravel and fines, or samples with high moisture (e.g., sediments and soil samples below the water table). In the case of soil samples that consist of dry sand, gravel, or a mixture of gravel and fines, or samples with high moisture (e.g., sediments and soil samples below the water table), a stainless steel spatula or scoop should be used with field preservation techniques.
   b. The En-Core® sampler is a single-use device and cannot be decontaminated and reused.
   c. The volume of material collected in an En-Core® sampler should not cause excessive stress on the coring tool.
   d. The volume of material collected should not be so large that the sample easily falls apart during extrusion.
   e. The En-Core® sampler should not be used if any of the components are damaged as the seals may be compromised. Under no circumstances should any components be removed or disturbed.
   f. It is important to make sure air is not trapped behind the sample, as this could cause air to pass through the sample, resulting in a loss of VOCs, or it could cause the sample to be pushed prematurely from the coring tool.

5. <u>Potential effervescence with use of sodium bisulfate as a preservative for low-level VOC analysis of soils:</u>

   This method of preservation is not preferred and, therefore, is not outlined below. If it is used, the following cautions exist:

   a. Carbonaceous or strongly alkaline soils may cause potential effervescence when reacting with the sodium bisulfate and may result in a loss of VOCs and a shattered vial. If effervescence occurs, sodium bisulfate should not be used. The laboratory must be contacted and low-level preservation techniques, using water only, should be followed.

b. Loamy materials or materials containing decayed material may result in false positive results for acetone due to the interaction with the sodium bisulfate.

c. Some VOCs may be lost due to the resulting acidification when sodium bisulfate is used (e.g., styrene, 2-chloroethyl vinyl ether, acrylonitrile).

d. Some VOCs may be lost if the laboratory is using a heated purge in combination with the sodium bisulfate preservative (e.g., methyl tert butyl ether [MTBE] and other fuel oxygenates).

1.4 Sample Containers and VOC Sampling Equipment

- Method 5035A-compatible containers or kits (for VOCs, VPH and GRO). Preservatives may be required for some samples with certain variations of SW-846 method 5035A – consult the governing regulatory agency or principal analytical chemist to determine which preservatives are necessary.
  - <u>Low-level VOCs:</u> two 40-mL VOA vials pre-preserved with 5 mL organic-free water and also containing a magnetic stir bar.
  - <u>High-level (or medium-level) VOCs:</u> one 40-mL VOA vial pre-preserved with 5 or 10 mL of purge-and-trap-grade methanol. Volume will be dependent upon laboratory's preference or regulatory agency requirements (e.g., New Jersey Department of Environmental Protection prefers vials with 10 or 25 mL of purge-and-trap-grade methanol).
  - <u>VPH and GRO</u>: One 60-mL vial pre-preserved with 25 mL of purge-and-trap-grade methanol **or** One 40-mL VOA vial pre-preserved with 15 mL of purge-and-trap-grade methanol
    and
  - One glass container (or other appropriate container) with no preservative to allow the laboratory to perform the percent solids measurement. NOTE: The laboratory typically requires a minimum of 20 grams to perform this test. Therefore, submitting a sample size less than 4 ounces may be acceptable. This additional container will not be required if the sample is also being submitted for other non-VOC parameters.

- En-Core® samplers, or equivalent, for VOC, VPH and/or GRO analysis:
  - High-level VOC or GRO analysis: one 5-gram En-Core® sampler.
  - Low-level VOC analysis: two 5-gram En-Core® samplers.
  - VPH, GRO or toxicity characteristic leaching procedure (TCLP) VOC analysis: one 25-gram En-Core® sampler.

- Disposable plastic syringes or Terra Core™ samplers.

- Foam VOC vial holders.

- Portable digital scale (accurate to ± 0.01 grams) with calibration weights.

2.0 COLLECTION OF SAMPLES USING EN-CORE® SAMPLERS, OR EQUIVALENT

- The sample will be collected using an En-Core® sampler, or equivalent, as soon as possible after the soil has been exposed to the atmosphere.
- Check that the En-Core® sampler, or equivalent, is full using both of the following procedures:
  a. Be sure that the back o-ring on the plunger can be seen when looking through the viewing hole on the handle. This will mean that the soil has pushed the plunger fully to the back.
  b. The plunger can only be rotated when it is fully pushed to the back of the body. Therefore, it is important to twist the plunger to guarantee that the soil has filled the sampler and the back o-rings have sealed.
- Immediately seal the En-Core® sampler, or equivalent. Be sure to twist the cap as it is pushed on. The cap is properly sealed when the two locking arms are completely and symmetrically over the body ridge.
- The samples must be shipped to a laboratory within 24 hours of sampling to ensure the 48-hour hold time for preservation will be met.
- In the event that a field screening technique (instrument reading or visual staining of the soil) indicates the possible presence of VOCs or hydrocarbons, note the observations or instrument readings in the field book. If the field screening technique does not indicate the presence of VOCs, this should also be noted.
- If samples are collected for only VOC and VPH analyses, a separate aliquot must be collected in an unpreserved container in order for the laboratory to perform a dry weight determination.

3.0 COLLECTION OF SAMPLES USING FIELD PRESERVATION

- Samples for VOCs will be collected as soon as possible after the soil has been exposed to the atmosphere.
- Samples for VOCs will be collected first (prior to collection of samples for other parameters) using an open-barrel disposable syringe, Terra Core™ sampler, or equivalent. In the case of soil samples that consist of dry sand, gravel, or a mixture of gravel and fines, or samples with high moisture (e.g., sediments and soil samples below the water table), an open-barrel disposable syringe may not be practical; a stainless steel spatula or scoop can be used with field preservation techniques.
- Soil samples for VOC analyses should **never** be homogenized.
- Each pre-preserved sample container will be weighed prior to sample collection, and the container/preservative weight will be recorded. This procedure will generally be performed by the laboratory prior to shipping the containers to the field.
- Depending upon project requirements, samples for VOC analysis will be collected as low-level, high-level, or both.

A. Low-level VOCs

1. The syringe will be filled with undisturbed soil of the following volume: 5 grams of soil.

   As an option to the syringes, 5-gram Terra Core™ samplers, or equivalent, can be used. The goal is to have a 1:1 ratio of soil- to- preservative.

2. The soil will be extruded into a pre-preserved VOA vial containing a magnetic stir bar and 5 mL organic-free water. This will be done in replicate.

3. Any sand grains present on the container rim or cap must be removed to ensure an air-tight seal of the vial. The VOA vial will be capped quickly and labeled with the sample ID, date, and time of collection. Labels should not be written on the cap of the vial.

4. Gently swirl sample to break up the soil aggregate, if necessary, until the soil is covered with preservative. It is imperative that the soil sample be completely immersed in the preservative solution.

5. In the event that a field screening technique (instrument reading or visual staining of the soil) indicates the possible presence of VOCs or hydrocarbons, note the observations or instrument readings in the field book. If the field screening technique does not indicate the presence of VOCs, this should also be noted.

6. If samples are collected for only VOC analysis, a separate aliquot must be collected in an unpreserved container in order for the laboratory to perform a dry weight determination.

B. High-level VOCs, VPH, or GRO

1. High-level VOCs: The syringe will be filled with undisturbed soil of the following volume: 5 or 10 grams of soil for high-level analysis (added to the 5 or 10 ml of methanol, respectively). This may also depend upon the regulatory agency (e.g., New Jersey Department of Environmental Protection requires 8 to 12 grams in 25 mL methanol or 5 grams in 10 mL methanol).

   VPH or GRO: The syringe will be filled with 25 grams of undisturbed soil if 60-ml vials with 25 ml of methanol are used, or 15 grams of undisturbed soil if 40-ml vials with 15 ml of methanol are used. The goal is to have a 1:1 ratio of soil- to- methanol.

   As an option to the syringes, 5-gram Terra Core™ samplers, or equivalent, can be used. Typically, the goal is to have a 1:1 ratio of soil- to- preservative.

2. The sample will be extruded into a VOA vial containing purge-and-trap grade methanol

3. Any sand grains present on the container rim or cap must be removed to ensure an air-tight seal of the vial. The VOA vial will be capped quickly and labeled with the sample ID, date, and time of collection. Labels should not be written on the cap of the vial.

4. Gently swirl sample to break up the soil aggregate, if necessary, until the soil is covered with preservative. It is imperative that the soil sample be completely immersed in the preservative solution.

5. In the event that a field screening technique (instrument reading or visual staining of the soil) indicates the possible presence of VOCs or hydrocarbons, note the observations or instrument readings in the field book. If the field screening technique does not indicate the presence of VOCs, this should also be noted.

6. Methanol is considered to be a hazardous material by the US Department of Transportation (DOT) and the International Air Transportation Association (IATA). Shipments containing methanol between the field and the laboratory must conform to the rules established in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179) and the most current edition of the IATA Dangerous Goods Regulations. The volumes of methanol recommended in the VOC method fall under the small quantity exemption of 49 CFR section 173.4. Refer to Attachment B for further details.
7. If samples are collected for only VOC analysis, a separate aliquot must be collected in an unpreserved container in order for the laboratory to perform a dry weight determination.

Attachment B:

Shipping Methanol-preserved Samples

Shipping of Hazardous Materials

Methanol is considered a hazardous material by the US Department of Transportation (DOT) and the International Air Transport Association (IATA). Shipments of methanol between the field and the laboratory must conform to the rules established in Title 49 of the Code of Federal Regulations (49 CFR parts 171 to 179) and the most current edition of the IATA Dangerous Goods Regulations. Consult these documents or your shipping company for complete details.

Small Quantity Exemption

The volumes of methanol recommended in the high-level VOC, VPH and GRO methods fall under the small quantity exemption of 49 CFR section 173.4. To qualify for this exemption, all of the following conditions must be met:

- ◊ the maximum volume of methanol in each sample container must not exceed 30 mL
- ◊ the sample container must not be full of methanol
- ◊ the sample container must be securely packed and cushioned in an upright position and be surrounded by a sorbent material capable of absorbing spills from leaks or breakage of sample containers
- ◊ the package weight must not exceed 64 pounds
- ◊ the volume of methanol per shipping container must not exceed 500 mL
- ◊ the packaging and shipping container must be strong enough to hold up to the intended use
- ◊ the package must not be opened or altered while in transit
- ◊ the shipper must mark the shipping container as follows:

"This package conforms to 49 CFR 173.4"

When shipping domestically by Federal Express via ground or air, the following rules apply:

- ◊ follow the inner packaging requirements of 49 CFR 173.4
- ◊ no labels, placards, up arrows, or dangerous goods shipping papers are required
- ◊ if the Federal Express airbill has a shipper's declaration for hazardous goods on it, check the Yes box under *Shipper's Declaration not Required*

When shipping internationally by Federal Express, the following rules apply*:*

- ◊ follow the inner packaging requirements of 49 CFR 173.4
- ◊ use dangerous goods shipping papers
- ◊ apply orientation arrows on opposite vertical sides on the exterior of the package

Shipping Papers for International Shipments

International shipments must be accompanied by dangerous goods shipping papers that include the following:

Proper Shipping Name:	Methyl Alcohol
Hazardous Class:	Flammable Liquid
Identification Number:	UN1230
Total Quantity:	*(mL methanol/container x the number of containers)*
Emergency Response Info:	Methanol MSDS attached
Emergency Response Phone:	1-800-424-9300

Attachment C:

SOP Fact Sheet

SOIL SAMPLING PROCEDURES

PURPOSE AND OBJECTIVE

Soil sampling is conducted in order to obtain a representative sample for laboratory analysis of constituents of interest at a given site. Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type.

WHAT TO BRING

- Stainless steel mixing bowl and stainless steel spoon or spatula
- Hand auger or post hole auger, if applicable
- Stainless steel trowel and/or shovel
- Tape measure, folding ruler
- Wooden stakes and spray paint, plastic flagging (highly visible), or steel pin flags
- Field book and/or boring log
- Camera
- Maps/site plan
- Survey equipment and/or GPS and/or other means of measuring sample locations
- Indelible marking pens or markers
- Sample coolers, sample containers (including any necessary En-Core® samplers, disposable plastic syringes or Terra Core™ samplers), sample container labels, COCs, and ice
- Bubble wrap and Zip-loc® plastic bags (for ice and COCs)
- Equipment decontamination supplies
- Any required field screening equipment, such as PID

OFFICE

- Prepare/update the HASP; make sure the field team is familiar with the latest version.
- Discuss the objective for the soil sampling program with the Project Manager and/or the field lead. Discuss sample order, collection method, designation, analytical parameters, turn-around times, laboratory, etc.
    - Are the soil cuttings to be containerized in drums or returned to borehole?
    - Volume of soil required for each sample?
    - QA/QC sample collection?
    - Field decontamination required?
- Verify whether police traffic control will be required for work completed on or near public roadways.
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure, test equipment and make sure it is in proper working order.
- Verify that a utility survey/mark-out has been performed to ensure that sample locations are clear of overhead and buried utilities. Obtain a copy of the markout ticket or confirmation number. Additionally, a private geophysical sub-surface survey may be necessary.
- Review sample bottle order for accuracy and completeness.
- Make sure soil boring locations (or specific sampling areas) are clearly identified on figure and that soil boring and sample designations are understood.

ON-SITE

- Verify that underground utilities have been marked out and that the markouts are clear. Stay at least two feet away from any marked utility. Identify if any overhead obstructions or limited access areas exist near proposed borings and contact the Project Manager if any proposed locations need to be moved. Sketch/photograph markout locations.
- Review the HASP with all field personnel, conduct Health & Safety tailgate meeting.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities and pedestrian traffic, etc.)
- Calibrate equipment (if applicable) and record all rental equipment serial numbers in the field book.

GENERAL SOIL SAMPLING PROCEDURES

- Refer to other TRC SOPs for the proper procedures for classifying soil samples and for screening of samples for VOCs.
- Perform any required field screening in situ or immediately upon retrieval of the soil sample from the subsurface.

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SOIL SAMPLING PROCEDURES

- Samples for VOC, VPH or GRO analysis are then collected as soon as possible after the soil has been exposed to the atmosphere and prior to sample collection for other analyses.
  - **These samples are NOT homogenized.**
  - These samples are generally collected using an open-barrel disposable syringe, a Terra Core™ sampler, or an En-Core® sampler, or equivalent. Refer to the site-specific work plan or governing regulatory authority for preservation requirements for VOC, VPH or GRO analysis and Attachment A of ECR 003.
- After collecting the sample for VOC analysis, the sample portion for the remaining analysis should be well homogenized, in situ (if possible, such as with surface soil sampling), or in a decontaminated stainless steel bowl or disposable new aluminum pie pan to ensure that the sample is as representative as possible of the sample media.
- Stones, gravel, vegetation or debris (such as concrete, asphalt, ash or slag) should be removed from the soil sample as much as practical prior to placement in sample containers, unless these matrices are part of the overall characterization program.
- Transfer to sample containers using clean new or decontaminated spoons/scoops.
- Filling of the sample bottles should be completed immediately after sample collection to minimize losses due to volatilization and biodegradation. Soil classification can be completed following sample collection.
- Place the sample into an appropriate, labeled container(s) by using the alternate shoveling method and secure the cap(s) tightly. The alternate shoveling method involves placing a spoonful of soil in each container in sequence and repeating until the containers are full or the sample volume has been exhausted. Threads on the container and lid should be cleaned to ensure a tight seal when closed.
- Make sure ALL sample containers are clearly labeled with the site name, sample date, sample collection time and sample designation including depth in indelible ink. Samples should be entered on the COC as they are collected. Make sure to clearly identify requested sample analyses on the COC.
- Labeled samples should be immediately put into a cooler with ice, sample coolers should always be kept within eyesight or stored within the cab of the vehicle or other secured place such as a locked office.
- Be aware of sample holding times, and arrange for samples to be in the laboratory's possession accordingly.
- Restore the sampling location to grade in accordance with applicable state regulations and/or the site-specific work plan. Options include backfilling the sample location with the remaining removed soil, bentonite pellets or, cement/bentonite grout depending on site conditions and patching the surface to match the surrounding area (e.g., topsoil with grass seed, asphalt or concrete patch), as necessary.
- Record locations of soil borings/samples in the field book by sketching a map and/or providing a description of the location. When measuring locations of soil borings/samples, always use fixed landmarks such as buildings, fences, curbs, etc.
- Decontaminate sampling equipment in accordance with TRC's SOP on equipment decontamination.
- Ensure any IDW is appropriately managed. If IDW cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

SURFACE SOIL SAMPLING PROCEDURES

The depth of surface soil samples are typically collected from 0-6 in. or 0-12 in. and will be determined on a site-specific basis and may be influenced by site-specific conditions. The following procedure should be used for surface soil sampling:

- If a thick, matted root zone, leaf layer, gravel, surface debris, concrete, etc. is present at or near the surface, it should be carefully removed using clean decontaminated tools before the soil sample is collected. The presence and thickness of any such material should be recorded in the field book for each location. The depth measurement for the soil sample begins at the top of the soil horizon, immediately following any such removed materials.
- A decontaminated stainless steel spoon, scoop or trowel is typically used for surface soil sampling depths from 0 to 12 inches bgs. A hand auger or shovel may also be used to dig down to the desired depth and then after careful removal of the dug soils from the hole, a decontaminated stainless steel spoon, scoop or trowel is used to collect the soil sample from the bottom of the hole for laboratory chemical analysis.
- Continue by following the General Soil Sampling Procedures.

HAND AUGER SAMPLING PROCEDURES

Hand augers may be used to advance boreholes and collect soil samples in shallow subsurface intervals. Often, 4-inch diameter stainless steel auger buckets with cutting heads are used. The auger is advanced by simultaneously pushing and turning using an attached T-handle with extensions (if needed). Auger holes are advanced one bucket at a time until the appropriate sample depth is achieved. The following procedure should be used for hand auger sampling:

- Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the borehole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding rod extensions. It also facilitates refilling the borehole and avoids possible contamination of the surrounding area.

SOIL SAMPLING PROCEDURES

- When the sample depth is reached, remove the bucket used to advance the borehole and attach a decontaminated or clean bucket. Place the clean auger bucket in the borehole, advance the clean auger bucket to fill it with the soil sample and then carefully remove the clean auger bucket.
- If VOC analysis is to be performed, collect a sample directly at the bottom of the boring, if within reach, and not from the auger bucket. If not within reach, collect the sample directly from the auger bucket or from minimally disturbed material immediately after the auger bucket is emptied.
- Continue by following the General Soil Sampling Procedures.

DIRECT PUSH/SPLIT SPOON/SONIC DRILLING SAMPLING PROCEDURES

For some soil investigations, soil logs provide justification for sample locations and intervals so be descriptive and precise.

- The driller will advance the soil sampler (macrocore, split spoon, sonic casing, etc.) which will then be given to the sampler - confirm with driller which end is top and which end is bottom. Record the time of core collection in the field book (military time). Begin the soil record by indicating the soil boring location, followed by the depth interval in feet bgs [e.g., B-1/0-4].
- Record the blow count per six inch interval when collecting split-spoon samplers with hollow stem auger rig. The drillers will keep the count and repeat them to you. If refusal is encountered, the count is recorded in the book as "# of hammer blows / depth in inches the spoon is driven" (e.g., 50/3 – means 50 blows of the hammer advanced the spoon 3 inches).
- Measurement of vertical depth should start from the top of soil; surface asphalt, surficial concrete slabs or gravel sub-base should be excluded from depth measurement (however, the presence and thickness of these items should be noted in the field book).
- Measure the length of recovered soil in inches and record in the field book.
- Continue by following the General Soil Sampling Procedures. If a specific depth interval is targeted for sampling, be sure to account for percent recovery when selecting the sample interval.

SHELBY TUBE SAMPLING PROCEDURES

A typical Shelby tube is 30 inches in length, has a 3.0-inch OD (2.875-inch inside diameter) and may be constructed of steel, stainless steel, galvanized steel, or brass, depending on the specific application. They are typically attached to push heads constructed with a ball check to aid in holding the sample in the tube during retrieval. To collect a sample, the tube is attached to a string of drill rod and is lowered into the borehole, where the sampler is then pressed into the undisturbed material by hydraulic force from the drill rig. After retrieval to the surface, the tube containing the sample is then removed from the sampler head.

- If samples for chemical analyses are needed, the soil contained inside the tube is then removed for sample acquisition by following the direct-push sampling procedures.
- If the sample is collected for geotechnical parameters, the tube is typically sealed, to maintain the sample in its relatively undisturbed state, capped, labeled appropriately (including sample ID, top end of sample, inches of recovery, etc.), and shipped to the appropriate geotechnical laboratory. The tube is typically stored in an upright position to maintain the integrity of the undisturbed sample.
- For geotechnical use, check with the laboratory prior to sampling to understand sample volume recoveries needed to perform the actual tests.

EXCAVATOR SAMPLING PROCEDURES

A backhoe or excavator can be used to assist with soil sampling such as during remedial excavation activities (to collect floor and sidewall samples within the excavation), test pit installation, or trenching operations. Test pit excavations are commonly completed to allow for greater observation of physical soil characteristics (e.g., stockpiles) and/or to further investigate buried suspect areas of concern (e.g., petroleum tanks, drums, waste, fill). The following procedures are used for collecting soil samples excavated with a backhoe or excavator:

- For test pits or trench excavation, excavate in accordance with the site-specific work plan. Typically, this will be approximately 3 feet wide and approximately 1 foot deep below the cleared sampling location with the backhoe. Remedial excavations may be much wider and deeper. The work plan may also require that excavated soils be placed on plastic sheets or another impervious surface and protected from rain.
- Refer to the site-specific work plan for the number of floor and/or sidewall samples, which is typically driven by the surface area and can vary depending on the governing regulatory agency.
- Samples can be collected using a trowel, spoon, or coring device at the desired intervals. A clean shovel may be used to remove a 1 to 2- inch layer of soil from the vertical face of the pit that contacted the backhoe bucket and where soil sampling is planned. Scrape the vertical face at the point of sampling to remove any soil that may have fallen from above and to expose fresh soil for sampling. In many instances, soil sample locations within the excavation area are inaccessible (do not physically enter backhoe excavations to collect a sample). In these cases, soil samples can be collected directly from the backhoe bucket – use caution not to collect a soil sample from edges that may have come into contact with the backhoe bucket.
- Continue by following the General Soil Sampling Procedures.
- Abandon the pit or excavation according to applicable state regulations and the site-specific work plan. Generally, shallow excavations can simply be backfilled with the removed soil material.

SOIL SAMPLING PROCEDURES

STOCKPILE SOIL SAMPLING PROCEDURES

Stockpiled soils are typically sampled to characterize the soils for reuse or disposal. The stockpile sampling strategy used must consider the source of the soil and all available data, field observations, shape/dimensions and volume of the pile, and sampling frequency requirements established by oversight regulatory agencies or potential soil disposal facilities.

If the stockpile is known to be a representative mixture of soil with no known or suspected significant variability of contamination with depth in the pile, the stockpile sampling may be conducted according to the surface soil sampling method described above. However, if the soil characteristics are not known or are known or suspected to vary with depth in the pile, both surface soil and deeper subsurface soil samples will be required to properly characterize the soil pile. Based on the minimum required number of samples for the estimated stockpile volume, the stockpile is divided into the appropriate number of estimated volumes equal to that sample number.

POST SAMPLING ACTIVITIES

- After the samples have been collected, the sampling location may be marked with wooden stakes colored with highly visible spray paint and/or flagging with the sample location identification written on the stake in indelible ink. The sample location should be surveyed in the field with a GPS unit if not surveyed later by some other means. A sketch of the sampling locations should also be included in the field book.
- Package the samples with bubble wrap as necessary.
- Place the samples into a shipping container and cool to 4°C. If wet ice is used to cool the samples, place the ice in double-bags to prevent water from the melting ice from damaging the samples during shipment.
- Complete and cross check the COC form.
- Decontaminate non-disposable sampling equipment.

DOs AND DO NOTs OF SOIL SAMPLING

DOs:

- No matter the work plan or the site, DO have the following items when going into the field:
  - Site-Specific HASP
  - Steel-toed boots
  - Field book and a pen with indelible ink.
  - Nitrile gloves
  - Business cards
- DO review soil boring logs or cross sections from previous sampling events, if available.
- DO call the Project Manager or field team leader if unexpected conditions are encountered or at least twice during the work day to update them. Even if everything is fine and there are no questions, call with an update. It is also recommended to call when sampling is winding down for the day to make sure that the work plan has been fully implemented and there are no additional tasks to complete.
- DO have the numbers for laboratory, vehicle rental and equipment rental providers readily available while in the field.
- DO decontaminate any heavy equipment used for the advancement of sampling devices by steam cleaning or high pressure/hot water wash prior to and between sample locations. This would include, but is not limited to auger flights, drill rods, backhoe buckets and other respective accessories.
- DO review and count the sample bottles and compare to the COC prior to leaving the site.
- DO record sampler type (e.g., macrocore, split spoon, etc.) and boring method (e.g., direct push, hammer, etc.) in the field book.
- DO record the hammer weight, the distance of the hammer drop and the method for hammer lift (i.e., cathead and rope, hydraulic, etc.) in the field book at least once per day when collecting split-spoon samples with a drill rig.

DO NOTs:

- DO NOT sign anything in the field. This includes disposal documentation, statements, etc; call the Project Manager if there is an issue.
- DO NOT use non-indelible ink to label samples or record field notes – if the field book gets wet, notes become illegible.
- DO NOT include any upper soils which may "fall" as a result of the open borehole caving in (slough) when recording recovery.
- DO NOT use general terms such as "Fill" or "Till" as a sole description for layers – always give detailed description of soil components.

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Attachment D:

SOP Modifications for PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® during sample handling or mobilization/demobilization. This includes waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. • Blue Ice® (chemical ice packs) must not be used to cool samples or be used in sample coolers. Regular ice in Ziploc® bags can be used. • Do not use low density polyethylene (LDPE)[1] or glass sample containers or containers with Teflon-lined lids. HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. • Do not use aluminum foil • Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Field notes should be attached to the project-specific field book or folder upon returning to the office. • Avoid using waterproof labels for sample bottles. The use of paper labels covered with clear tape or placed in Ziploc® bags to avoid moisture on the sample label is acceptable. • Do not use Post-It Notes during sample handling or mobilization/ demobilization. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan (HASP) prior to conducting field work. The following considerations should be made with regards to field preparation during PFAS sampling: • Tyvek® suits should not be worn during PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
	only. • Personnel involved with sample collection and handling should wear nitrile gloves at all times while collecting and handling samples or sampling equipment. Avoid handling unnecessary items with nitrile gloves. A new pair of gloves must be donned prior to collecting each sample. • Wash hands with Alconox or Liquinox and deionized water after leaving vehicle before setting up at a soil sampling location.
1.6	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering on the day of sampling. • Avoid using sunscreens or insect repellants that are not natural or chemical free.
2.2	• LDPE and/or glass containers should not be used for sampling. Teflon®-lined caps should also not be used during sample collection. Instead, HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. Do not homogenize soil in aluminum pie pans. Use a decontaminated stainless steel bowl. • Stainless steel tools should not be wrapped in aluminum foil after decontaminating prior to and in between uses. • Homogenize the soil sample in a decontaminated, stainless steel bowl and place in an appropriate laboratory-provided sample container (as listed above) following the collection of VOC, VPH or GRO samples.
2.2.3	Do not use Teflon® liners for direct push sampling methods. Cellulose acetate butyrate (CAB) liners are acceptable.
2.2.7	Homogenize the soil sample in a decontaminated, stainless steel bowl and place in an appropriate laboratory-provided sample container (as listed above) following the collection of VOC, VPH or GRO samples.
2.3	Samples for PFAS analysis must be shipped at <10°C. Standard coolers are acceptable.

[1]PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces.

Title: **Water Level and Product Measurements**			Procedure Number: **ECR 004**
			Revision Number: **2**
			Effective Date: **January 2020**
Authorization Signatures			
Rebecca L. Armes		Elizabeth Denly	
Technical Reviewer Rebecca Armes	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

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ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for conducting water level, separate-phase product, and/or total well depth measurements in monitoring wells, piezometers, and boreholes during field investigations.

1.2 Summary of Method

Depth-to-water (DTW) measurements are used to evaluate pressure and/or elevation changes within the aquifer. The procedure involves using a water level indicator capable of an accuracy of ±0.01 feet, or a similar piece of equipment, to measure the DTW in a monitoring well, piezometer, or borehole from a set reference point. When used in conjunction with an accurate site elevation survey, DTW data can be converted to potentiometric surface elevations to support groundwater flow direction analysis, as well as other aquifer characteristics. In addition, pressure changes recorded in a well during a slug, pumping, or packer test can be used to determine aquifer characteristics, such as hydraulic conductivity and storage parameters.

It is also a good practice to gauge the total depth of a monitoring well while taking water levels. This practice can help confirm: 1) the correct well in a cluster of wells screened at different depths; 2) that the well is clear of obstructions; 3) whether the well may be silting up and need further development; and 4) the correct purge volume for a well when sampling. Total depth measurements in a well may be necessary when TRC is taking over project work at a site with existing monitoring wells or the site wells have not been accessed for a significant amount of time.

The objective of separate-phase product measurements is to obtain measurements of the thickness of separate-phase product in the water column. The thickness of both dense non-aqueous phase liquid (DNAPL) and light non-aqueous phase liquid (LNAPL) can be determined using an oil/water interface probe. It should be noted that the thickness of LNAPL or DNAPL in a well ("apparent thickness") most likely differs from the thickness in the formation ("actual thickness").

- For LNAPL, the procedure involves measuring the depth to the separate-phase product and the depth to the underlying groundwater from a set reference point. The difference between these two measurements is the thickness of the LNAPL in the well.

- For DNAPL, the procedure involves measuring the depth to the separate-phase product and the depth to the bottom of the well, borehole, etc. The difference between these two measurements is the thickness of the DNAPL in the well.

1.3 Equipment

The following list of equipment may be utilized when conducting water level and separate-phase product measurements. Site-specific conditions may warrant the use of additional items or deletion of items from this list. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment D for further details.

- Appropriate level of personal protection
- Electronic water level indicator
- Oil/water interface probe
- Extra batteries for water level/interface probe
- Field book and monitoring form
- Well keys
- Socket-wrench
- Containers to hold water and isopropanol for calibration
- Tap water
- Isopropanol
- Previous measurement data (if available)
- Precision ruler or measuring tape
- Permanent marker (e.g., Sharpie®)
- Decontamination supplies

1.4 Definitions

Borehole	A hole drilled into the soil or bedrock using a drill rig or similar equipment.
Dense Non-aqueous Phase Liquid (DNAPL)	Separate-phase product that is denser than water and, therefore, sinks to the bottom of the water column.
Depth To Water (DTW)	The distance to the groundwater surface from an established measuring point.
Light Non-aqueous Phase Liquid (LNAPL)	Separate-phase product that is less dense than water and, therefore, floats on the surface of the water.
Monitoring Well	A well made from a polyvinyl chloride (PVC) pipe, or other appropriate material, with slotted screen installed across or within a saturated zone. A monitoring well is typically constructed with a PVC or stainless steel pipe in unconsolidated deposits and with steel casing in bedrock.
Non-aqueous Phase Liquid (NAPL)	Petroleum or other fluid that is immiscible in water and tends to remain as a separate liquid in the subsurface.
Piezometer	A well made from PVC or metal with a slotted screen installed across or within a saturated zone. Piezometers are primarily installed to monitor changes in the potentiometric surface elevation.
Potentiometric Surface	A surface representing the hydraulic head of groundwater.

Separate-phase Product A liquid that does not easily dissolve in water. Separate-phase product can be more dense (i.e., DNAPL) or less dense (i.e., LNAPL) than water and, therefore, can be found at different depths in the water column.

Low-permeability Formation A geologic formation that has very slow recharge and discharge rates due to small pore spaces in the formation material. A clay formation is considered to have low permeability and has a very slow recharge rate compared to a more permeable formation, such as sand or gravel.

Total Depth of Well Distance from the measuring point to the bottom of the well.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific health and safety plan (HASP). TRC personnel will use the appropriate level of personal protective equipment (PPE) as defined in the HASP.

When present, special care should be taken to avoid contact with LNAPL or DNAPL. The use of an air monitoring program, as well as the proper PPE designated by the site-specific HASP, can identify and/or mitigate potential health hazards.

1.6 Cautions and Potential Problems

Special care should be taken when using equipment if PFAS are known or suspected to be present. Please refer to Attachment D for details.

- DTW measurements of all wells in a water level survey should be collected within the shortest amount of time possible but, at a minimum, within a 24-hour period to ensure near contemporaneous data collection during a groundwater elevation recording event. However, note that certain conditions may produce relatively rapid changes in groundwater elevations, which might necessitate collecting readings over a shorter time period. Such conditions should be noted in the field book. Rapid groundwater elevation changes may occur due to:
  - Rapid changes in atmospheric pressure
  - Variable pumping of nearby wells
  - Precipitation events
  - Tidal influences
  - Rapid changes in nearby surface water levels (e.g., dam release, upstream thunderstorm)
- Allow water levels in newly installed wells to stabilize for approximately 24 hours before taking measurements for the purpose of a water level survey. Recovery might take longer in wells installed in low permeability formations.
- Because the tops of monitoring wells and piezometers are often cut unevenly, be sure to take DTW measurements from a pre-marked or notched spot on the well to ensure consistent data collection over time. Since land survey vertical elevation measurements are generally taken

from the highest point on the well casing (i.e., where survey rod rests), this point should also be marked and used for water level measurements. If the tops of the monitoring wells and piezometers are not marked, the DTW measurement should be taken from the north side of the riser and the location marked on the casing top edge.

- To limit the possibility of cross contamination, DTW measurements should be collected in order from the least to the most contaminated wells and piezometers when contamination is known or suspected. Be sure to decontaminate the entire length of the submerged tape between well measurements to reduce the potential for cross contamination. Refer to Attachment D and ECR SOP 010 for decontamination of PFAS. Some wells with NAPL or excessive condensation may have residues on the side of the riser that may also contaminate the tape.
- If the presence of NAPL is suspected at a site, an oil/water interface probe should be used to conduct water level measurements. When DNAPL is a suspected contaminant characteristic at a site, the interface probe should be lowered to the bottom of the well until DNAPL is encountered, if present.
- NAPL may foul the probe and could cause a delayed response when going from NAPL to water. Resolution may require taking repeated measurements by raising and/or lowering the probe through the interface.
- Most water level meters have a "sensitivity" setting, which is often located on the on/off dial. The sensitivity setting may need adjustment depending on the site water chemistry.
- Excessive condensation on the inside well materials may cause the tape to stick on the well casing and/or cause a false reading above the water level. This is especially true of deeper wells. Previous elevation data should be consulted to determine if a reading is consistent and plausible for that well. The above mentioned sensitivity adjustment can be used to compensate. In some cases, the line may have to be weighted to remedy the line sticking to the casing.
- Tight well caps and low permeability formations may not have allowed the potentiometric surface to equilibrate in the well after seasonal, tidal or other area groundwater level fluctuations. If this is the case, allow the wells to equilibrate before collecting measurements by taking readings several minutes after removing the well plug; in addition, re-measure the first well after the last well to verify that the water level is not fluctuating. Another round of water levels may need to be collected if a significant discrepancy from the first set of measurements is observed; this should be discussed with the Project Manager. If this is a concern, vented well caps or plugs may need to be used.
- In some instances, artesian well conditions may exist, where the potentiometric surface is higher in elevation than the top of the well casing (TOC). In these situations, it is pertinent to note the water level elevation as above the TOC or add a known length of riser pipe in order to measure an actual elevation. Once the water level has equilibrated in the riser pipe, the same procedures can be followed for measuring water level when separate-phase product is not suspected. Note that when converting the DTW measurement to an elevation, the riser pipe length needs to be added to the surveyed TOC.

- Groundwater gradients at some sites can be very shallow and if gradient and groundwater flow pattern (gradient direction) determination are part of the project objectives, it is critical that groundwater level measurements obtained from wells are as accurate as possible. Special care should be taken to allow the water level to equilibrate after removing sealing caps, and the same water level indicator should be used for all measurements if possible. All wells should be measured within the minimum possible time. This is particularly important in areas with potential tidal influences.

- If more than one measuring device must be used for multiple wells across an area with a shallow groundwater gradient, the "zero calibration check" (see Section 2.1.1) becomes especially important.

- If the monitoring well or piezometer is secured with an air- and water-tight lockable cap, caution should be taken when removing the cap due to the possible buildup of pressure in the well casing. Try to ease the cap off and relieve the pressure slowly in order to prevent injury. Do not stand or lean over top of well when releasing cap.

- Flush-mounted wells may be subject to water collection in the well can around the top of the riser pipe. In such instances, sufficient water should be evacuated from the well can prior to removing the well cap to ensure that ambient water does not enter the riser. The condition should be documented and the potential need for repair discussed with the Project Manager.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Workers (HAZWOPER)
- 8-hour annual refresher training

2.0 PROCEDURES

To be useful for establishing groundwater gradient, the reference point should be tied with a known vertical datum, such as the National Geodetic Vertical Datum (NGVD), or a local datum (e.g., site-specific arbitrary datum).

Water levels should be allowed to equilibrate prior to measurement after removing sealing well caps. There are no set guidelines, and appropriate equilibration times can range from minutes to hours depending on well recharge, local geology, and project objectives.

If available, prior site water and product level measurement data should be reviewed and available to field personnel during the collection of new data for direct comparison to aid in identifying and resolving potential measurement errors while in the field.

When measuring well depths with an electronic water level indicator, measure and add the length of the probe beneath the circuit closing electrodes to the depth measured to obtain the true depth.

The following procedures must be followed during the collection of water level and product measurements. Procedures may vary depending on the equipment used and contaminants present at the site. Special care should be taken when using measurement equipment if PFAS are known or suspected to be present. Please refer to Attachment D for details.

2.1 Calibration and Operational Checks

Refer to the project's Quality Assurance Project Plan (QAPP) for calibration frequency and any site-specific calibration procedures for water and separate-phase product level meters. Calibration of the meters is optional; the need for calibration and the frequency of calibration will be dependent upon the meter used and project-specific data quality objectives. Operational checks of meters will be performed prior to use in the field at the start of each day and several times throughout the day, as appropriate.

2.1.1 Operational Check of Water Level Meters

1. Push the Start or Test button (typically provided) on the meter to test the battery and circuitry on the water level indicator. The meter audible indicator should sound and test light illuminate (if equipped).

2. Release the start/test button and lower the water level probe into a container filled with tap water until the meter audible indicator sounds or visual indicator light turns on. During this check, set sensitivity adjustment (if provided) to highest setting, then decrease if necessary (e.g., saline water).

Inspect the measuring tape and water level probe connection for any signs of visible damage (e.g., cuts, kinks, separating splices). If the tape appears damaged at the connection to the probe, while the meter is sounding, perform the procedure in Section 2.1.2.

2.1.2 Calibration of Water Level Meters

1. While the meter is sounding from the procedure used in Section 2.1.1, use a ruler or measuring tape to measure the distance between the water surface and the 1-foot increment mark on the water level tape.

2. Check that the 1-foot increment is actually 1 foot from the water surface. Note any discrepancy in the field book and discuss with the Project Manager. If necessary, repair and/or replace the water level meter.

2.1.3 Calibration and Operational Check of Oil/Water Interface Meters

1. Oil/water interface meters will have one distinguishing sound and/or colored light to represent detection of water and a separate distinguishing sound to represent detection of separate-phase product. Read the instrument manufacturer's operations manual to determine the instrument's audible sound or light differentiation for water and separate-phase product (e.g., continuous beep for product and intermittent beep for water).

2. Push the Start or Test button (typically provided) on the meter to test the battery and circuitry on the water level indicator. The meter audible indicator should sound and test light illuminate (if equipped).

3. Water Level Sensor Operational and Calibration Checks

   a. Lower the water level probe into a container filled with tap water until the appropriate sound for water is heard as determined in Step 1.
   b. While the meter is sounding, use a ruler or measuring tape to measure the distance between the water surface and the 1-foot increment mark on the water level tape.
   c. Check that the 1-foot increment is actually 1 foot from the water surface. Note any discrepancy in the field book and discuss with the Project Manager.

4. Oil Level Sensor Operational and Calibration Checks

   a. If the operation or calibration of the oil level probe is suspected to be faulty, consult with the meter manufacturer for additional troubleshooting.

2.2 Procedures for Measuring Depth to Water When Separate-phase Product is Not Suspected

If possible, and when applicable, start at wells that are least contaminated and proceed to those wells that are most contaminated. Additionally, allow sufficient time for each monitoring well or piezometer to equilibrate after removing the protective cap prior to taking readings.

1. Record the condition of the well (e.g., protective casing, concrete collar, lock in place, etc.), equipment being used, and the current weather conditions in the field book or on the water level monitoring form or well inspection report.

2. Use HASP-specified gloves. Stand upwind of the well and remove the well lid. Unlock and remove the well cap slowly to relieve pressure build up that may have occurred in the well casing. Follow HASP requirements for well head and breathing zone air monitoring.

3. Identify the previous measuring point marking or notch on the riser or casing (if present). If no previous measuring point exists, use a permanent marker to mark a location on the rim of the riser or casing (typically the highest point). Record this location in the field book or on the water level monitoring form (e.g., top of riser or top of casing).

4. Using a previously decontaminated water level meter, turn on the meter, check the audible/visual indicator (push the "Test" button), reel the electronic probe into the well riser (with the increments visible) slowly until the meter sounds.

5. Grasp the tape with hand, withdraw the tape, and lower it again slowly until the sound is again audible. Check the DTW on the tape and make a mental note of the depth to within 0.01 feet.

6. Lower the probe again slowly and repeat the measurement for precision. In the field book or on the water level monitoring form, record the DTW from the measuring point noted in

Step #3 to the nearest 0.01 feet. If measuring the total depth of the well, proceed to Section 2.4).

7. Decontaminate the probe and the entire length of the submerged tape in accordance with the manufacturer specifications. Refer to Attachment D and ECR SOP 010, Equipment Decontamination, for decontamination procedures for sites with known or suspected PFAS contamination.

2.3 Procedure for Measuring Depth to Water and Product Levels When Separate-phase Product is Suspected

If possible, and when applicable, start at wells that are least contaminated and proceed to those wells that are most contaminated. Additionally, allow sufficient time for each monitoring well or piezometer to equilibrate after removing the protective cap prior to taking readings.

1. Record the condition of the well (e.g., protective casing, concrete collar, lock in place, etc.), equipment being used, and the current weather conditions in the field book, water level monitoring form, or well inspection report.

2. Use HASP-specified gloves. Stand upwind of the well and remove the well lid. Unlock and remove the well cap slowly to relieve pressure build up that may have occurred in the well casing. Follow HASP requirements for well head and breathing zone air monitoring.

3. Identify the previous measuring point marking or notch on the riser or casing (if present). If no previous measuring point exists, use a permanent marker to mark a location on the rim of the riser or casing (typically the highest point). Record this location in the field book or on the water level monitoring form (e.g., top of riser or top of casing).

4. Using a previously decontaminated oil/water interface probe, turn on the meter, check the audible indicator, and slowly reel the electronic probe into the well riser (with the increments visible) until the appropriate sound for water or separate-phase product is heard as determined in Section 2.1.3.

5. If water is encountered first (as determined by the audible sound on the meter, which represents water), follow steps 5 and 6 from Section 2.2. In the field book or on the water level monitoring form, record the DTW from the measuring point noted in Step 3 to the nearest 0.01 feet.

6. If water is encountered first and DNAPL is suspected, continue lowering the probe until product is encountered (as determined by the audible sound on the meter, which represents product). In the field book or on the water level monitoring form, record the depth to product from the measuring point noted in Step #3.

7. Calculate the thickness of the DNAPL in the well using the following equation:

   (Total depth of well) - (Depth to product) = DNAPL thickness

8. If LNAPL is encountered before water, record the depth to product from the measuring point noted in Step #3 in the field book and continue lowering the probe until water is encountered.

   NOTE: For LNAPL, it is necessary to take both the air/product interface measurement on the way down into the product and the water/product interface measurement on the way back up. This is required when passing through product into water, since some product may adhere to the probe sensors due to surface tension and, as a result, a greater product thickness measurement may be erroneously obtained. Therefore, when LNAPL is detected, the probe should be lightly shaken or raised and lowered rapidly in a short vertical motion while the probe is within the water column to remove any product that may have been carried down with the probe. After passing through the product, the water/product interface should then be measured as the probe is raised very slowly back up from the underlying water into the product. Once the interface is detected, the probe can be raised and lowered in small increments to precisely determine the interface and obtain accurate measurements. Repeat these measurements as needed to confirm water/product interfaces and product thickness on multiple measurements.

9. In the field book or on the water level monitoring form, record the DTW from the measuring point noted in Step #3. If measuring the total depth of the well, proceed to Section 2.4.

10. Calculate the thickness of the LNAPL in the well using the following equation:

    (DTW) - (Depth to product) = LNAPL thickness

11. Decontaminate the probe and the entire length of the submerged tape in accordance with the manufacturer specifications. Refer to Attachment D for measurement equipment used at sites with known or suspected PFAS contamination and ECR SOP 010, Equipment Decontamination, for PFAS decontamination procedures.

2.4 Procedure for Measuring Total Well Depth

When measuring the total depth of a well, the water level and separate-phase product level, if present, should be determined first (see Section 2.2 or 2.3). It is recommended that the tone function of the instrument remain engaged during the total depth measurement.

1. After the water level and product level, if present, have been determined, continue reeling the electronic probe into the well riser (with the increments visible) until the probe encounters resistance. Resistance may be inferred when the probe appears to stop descending and the tape slackens against the side of the riser.

2. Determine whether the observed resistance likely represents the total depth of the well by raising and then lowering the probe to the level of the previously encountered resistance several times at different positions in the well. Then compare the observed level of resistance to available information about the total depth of the well, such as well log data or previous total depth measurements.

3. Measure the total depth of the well by: 1) noting the depth (to the nearest 0.01 feet) at which the probe first touches bottom before the tape begins to slacken; 2) adding the measured length from the bottom of the probe to the fluid level sensor in the probe; and 3) recording the combined lengths as the total depth.

4. In the field book or on the water level monitoring form, record the total depth of the well from the measuring point.

5. Also, note any observations about the conditions encountered in the well during the total depth measurement. A clear and distinct bottom reading would indicate little or no sediment in the bottom of the well. A soft and indistinct probe landing would indicate the presence of silt or sediment in the bottom of the well. A total depth measurement inconsistent with the well log or previous total depth measurements may indicate an obstruction in the well or significant sedimentation at the bottom of the well.

6. Decontaminate the probe and the portion of the tape inserted in the riser in accordance with the manufacturer specifications. Refer to Attachment D for measurement equipment used at sites with known or suspected PFAS contamination and ECR SOP 010, Equipment Decontamination, for PFAS decontamination procedures.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following Quality Assurance/Quality Control procedures apply:

- Operate field instruments according to the manufacturers' manuals.

- Calibrate field instruments at the proper frequency.

- Check the DTW at least two times in order to compare results. If results do not agree to within 0.02 feet, take a third measurement. If results still do not agree, check for possible equipment failure or review the cautions and potential problems listed in Section 1.6. Repeat the measurement when the cause of the precision nonconformance has been discovered and corrected.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

- Record water and separate-phase product level measurements on field forms or in a field book. See Attachment A for an example of a Water and Product Level Monitoring Form and Attachment B for an example of field book documentation.
- The following additional information may be recorded in the field book:
  - Well/piezometer or monitoring point identification number
  - Well/piezometer or monitoring point location (sketch of the sample point or reference to a location figure)
  - Visual or sensory description (e.g., odors, product, etc.)
  - Time and date measurements were taken
  - Personnel performing the task
  - Weather conditions during task
  - Other pertinent observations
  - Measurement equipment used
  - Calibration procedures used
  - Decontamination procedures used
  - Fixed measuring point used for DTW measurements

6.0 REFERENCES

Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

U.S. EPA Environmental Response Team, Standard Operating Procedures, *Manual Water Level Measurements*, SOP 2043. February 11, 2000.

U.S. EPA Region 4. Science and Ecosystem Support Division (SESD) Operating Procedure, *Groundwater Level and Well Depth Measurement*, SESDPROC-105-R2. January 29, 2013.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
1	DECEMBER 2016	ADDED ATTACHMENT D TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING

ATTACHMENT A

EXAMPLE WATER AND PRODUCT LEVEL MONITORING FORM

WATER AND PRODUCT LEVEL MONITORING FORM

Technician:______________ **Job #/Task #:** ________________ **Date:** ______________

Site # ______________ **Project Manager** ________________ **Page** _____ **of** ______

Well #	TOC	Time Gauged	Total Depth (feet)	Depth to Water (feet)	Depth to Product (feet)	Product Thickness (feet)	Time Sampled	Misc. Well Notes

FIELD DATA COMPLETE QA/QC COC WELL BOX CONDITION SHEETS

MANIFEST DRUM INVENTORY TRAFFIC CONTROL

RMB SOP 004_Water Level Field Form 10/28/2019

ATTACHMENT B

EXAMPLE FIELD BOOK DOCUMENTATION FOR WATER LEVELS

Location ____________ Date 3/4/1999 109

Project / Client ____________

sunny, 80°F, slight westerly breeze

WELL I.D.	Depth To Water (ft)	Depth To Product (ft)	Measuring Point	Comments
MW-1A	2.10	–	TOC	no lock present
MW-1B	2.15	–	TOR	–
MW-2A	3.42	–	TOR	–
MW-2B	3.41	–	TOR	expansion plug missing
MW-3A	3.64	3.60	TOR	petro odor
MW-3B	3.70	–	TOC	–
MW-4A	1.55	–	TOR	–
MW-4B	1.57	–	TOR	–
MW-5A	6.30	–	TOR	–
MW-5B	6.64	–	TOR	concrete collar gone
PZ-10	4.33	–	TOR	–
PZ-11	4.22	–	TOR	–
PZ-12	4.47	–	TOR	–
PZ-13	8.03	–	TOR	–
PZ-14	8.88	–	TOR	well cap broken
PZ-15	5.09	–	TOR	–

Note: TOC = Top of casing
TOR = Top of riser

Thomas S. Weyrauch 3/4/99

ATTACHMENT C

SOP FACT SHEET

WATER LEVEL AND PRODUCT MEASUREMENT PROCEDURES

PURPOSE AND OBJECTIVE

The following water level and product measurement procedures have been developed to direct TRC personnel in the methods of collecting water levels and product measurements in the field. Other state or federal requirements may be above and beyond the scope of this SOP and should be followed, if applicable. Depth-to-water (DTW) measurements are used to evaluate pressure and/or elevation changes within the aquifer. The objective of separate-phase product measurements is to obtain measurements of the thickness of separate-phase product in the water column. Both of these measurements are very important as they drive remediation decisions.

WHAT TO USE

- Water level meter
- Oil/Water interface probe
- Extra batteries
- Well keys
- Socket set
- Decontamination supplies
- Field book
- Indelible/waterproof ink

ON-SITE WELL GAUGING

- Prior to well gauging, site water level measurement data should be reviewed for direct comparison to aid in identifying and resolving potential measurement errors while in the field.
- Conduct an operational check of the water level meter by pushing the Start or Test button on the meter to test the battery and circuitry on the water level indicator. The meter audible indicator should sound and test light illuminate.
- If possible and when applicable, start at wells that are least contaminated and proceed to those wells that are most contaminated.
- Prior to collecting a water level, record the condition of the well (e.g., protective casing, concrete collar, lock in place, etc.).
- Stand upwind of the well and remove the well lid. Unlock and remove the well cap slowly to relieve pressure buildup that may have occurred in the well casing. Allow the well time to equilibrate.
- Identify the previous measuring point marking or notch on the riser or casing (if present). If no previous measuring point exists, use a permanent marker to mark a location on the rim of the riser or casing (typically the highest point). Record this location in the field book.
- Grasp the tape with hand, withdraw the tape, and lower it slowly until the sound is audible. Check the DTW on the tape and make a mental note of the depth to within 0.01 feet. Lower the probe again slowly and repeat the measurement for precision.
- If total depth measurements were not recorded recently, advance the tape to the bottom of the well to record a total depth.
- Decontaminate the probe and tape between each well.

ON-SITE PRODUCT MONITORING

- Prior to product gauging, product measurement data should be reviewed for direct comparison to aid in identifying and resolving potential measurement errors while in the field.
- Using a previously decontaminated oil/water interface probe, turn on the meter, check the audible indicator, and slowly reel the electronic probe into the well riser (with the increments visible) until the appropriate sound for water or separate-phase product is heard (intermittent tone for water; steady tone for product).
- If water is encountered first (as determined by the audible sound on the meter, which represents water), record the DTW from the measuring point to the nearest 0.01 feet.
- If water is encountered first and dense non-aqueous phase liquid (DNAPL) is suspected, continue lowering the probe until product is encountered (as determined by the audible sound on the meter, which represents product). In the field book or on the water level monitoring form, record the depth to product from the measuring point. If light non-aqueous phase liquid (LNAPL) is encountered before water, record the depth to product from the measuring point and continue lowering the probe until water is encountered and record the depth to water.
- Decontaminate the probe and tape between each well.

WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

ATTACHMENT D

SOP MODIFICATIONS FOR PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

Water Level and Product Measurement Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
1.3	• Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-it® Notes. • Use new plastic buckets for wash and rinse water. • Do not use “tap” water for operational check of the water level sensor of the oil/water interface meter. • Ensure that PFAS-free water is used during the decontamination procedure. • Do not use a plastic ruler to check measurements. • Refer to SOP 010, Equipment Decontamination, for decontamination supplies.
1.5	Always consult the Site-specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to procedures: • Tyvek® suits should not be worn. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Food and drink should not be allowed within the data measurement collection area. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only. • Personnel involved with measurement data collection should wear a new pair of nitrile gloves between each well measurement. Avoid handling unnecessary items with nitrile gloves. • Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended six washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering the morning of sampling and decontamination field work.
2.1.1	• Do not use potable “tap” water for operational check of the water level meter. Use deionized, distilled, or organic-free water.
2.1.2 and 2.1.3	• Do not use potable “tap” water for operational check of the water level sensor of the oil/water interface meter. Use deionized, distilled, or organic-free water. • Do not use a plastic ruler to check measurements.
2.2 (7) ; 2.3 (11); and 2.4 (6)	• Use only Alconox® or Liquinox® soap; do not use Decon 90. • Ensure that PFAS-free water is used during the decontamination

Water Level and Product Measurement Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
	procedure.
5.0	• Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards, and spiral bound notebooks should not be used.

Title: **Visual-Manual Procedure for Soil Description and Identification**		Procedure Number: **ECR 005**
		Revision Number: **1**
		Effective Date: **January 2020**

Authorization Signatures	
Technical Reviewer Date Jamie Stapleton 1/1/20	Environmental Sector Quality Director Date Elizabeth Denly 1/1/20

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Page No.

ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the method for identifying and describing soil samples in soil borings, test pits, and soil grab samples. The SOP was prepared in general conformance with American Society for Testing and Materials (ASTM) Standard D2488, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)* and other pertinent technical publications.

1.2 Summary of Method

The objective of this method is to standardize the collection and documentation of information on soil that is useful for the purpose of hydrogeological or geotechnical evaluation of a site. The use of standardized visual examination and manual test methods by all field personnel results in standardized data that can be evaluated later for geologic and engineering uses. Consistent soil description is important because during many projects multiple employees may be involved at different times. Hence, being able to compare or correlate soil classification logs that were created by different geologists is essential for creating consistent subsurface interpretations. The methods outlined in this SOP can be utilized for the characterization of soils in the field, field office, or other setting. Characterization of the soils in a relatively undisturbed state is preferred, but is subject to the limitations of the collection methods utilized.

Soil samples may be collected by various means, as discussed in TRC's Soil Sampling SOP. Regardless of the sample collection method, the resulting soil sample should be visually described and characterized. Visual examination of the sample will result in identifying grain size, particle size percentages, geologic and geotechnical modifiers and/or classifications, and a host of secondary characteristics. Manual and laboratory test methods also may be utilized to provide additional characteristics of the material, aiding in the description of fine-grained soils and providing more detailed geotechnical characterization.

The data gathered from the visual observations and manual test results are then recorded following an industry recognized classification system in a field log.

1.3 Equipment

The following list of equipment may be utilized when identifying and describing soil samples. Site-specific conditions may warrant the use of additional items or deletion of items from this list.

- Appropriate level of personal protection
- Field book, boring logs, test pit logs (as applicable)
- A copy of boring logs or field notes from previous work performed at or near the site
- Pocket penetrometer or miniature vane shear device
- Munsell Soil Color Chart
- Burmister and/or Unified Soil Classification System (USCS) classification chart/reference sheets
- Sand grading chart
- Appropriate knife

- Spoon and/or small spatula
- Tape measure, folding ruler or yard stick
- Portable table
- Polyethylene sheeting
- Hand lens
- Deionized water in squeeze bottle
- Small squirt bottle with dilute hydrochloric acid (1 part 10N HC1 to 3 parts water)

1.4 Definitions

Not Applicable; terms defined throughout SOP.

1.5 Health & Safety Considerations

TRC personnel may be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific health and safety plan (HASP). TRC personnel will use the appropriate level of personal protective equipment (PPE) as defined in the HASP.

1.6 Cautions and Potential Problems

- Samples collected for identification and description may contain hazardous substances or petroleum hydrocarbons. Consult the site-specific HASP for air monitoring and PPE requirements.

- One of the most common problems encountered when identifying soil types is the misidentification of fine-grained soils. If new to the identification process, take time to perform the manual field tests presented herein and/or consult with an experienced geologist or engineer.

- Geologic and engineering principles are both utilized in this method. Remember a well or widely graded soil (engineering term) is a poorly sorted soil (geologic term).

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Workers (HAZWOPER)
- 8-hour annual refresher training

2.0 PROCEDURES

This SOP includes procedures for both the modified Burmister and USCS soil classification systems. Consult the Project Manager and site work plan for guidance on the appropriate system. Several components of the soil description overlap between the two methods; however, there are some slight differences, such as the descriptors for percent composition (e.g., Burmister: "some" means 20-35% and USCS: "some" means 30-45%). Again, consistent soil description is important because during many projects multiple employees may be involved in performing field work. Hence, being able to compare between logs that were created by different geologists is essential for creating subsurface interpretations.

2.1 Modified Burmister Soil Classification System

The general description of a soil sample should be in the following order:

1. Color
2. Major Constituent – capitalized
3. Minor Constituent(s)
4. Geologic modifiers or classifications (e.g., glacial deposit, fill material) in parentheses
5. Density
6. Moisture content
7. Modifiers for fine fraction of sample (plasticity, dilatancy and toughness)
8. Other significant observations (e.g., odors, staining, sheen, petroleum product, debris)

Use the following guidelines when recording soil descriptions:

- If the major constituent comprises more than 50% of the soil, then fully capitalize the major component descriptor (e.g., SAND);
- If the major constituent comprises less than 50% of the soil, capitalize the descriptor (e.g., Sand);
- Place a comma after the major and minor constituent descriptors;
- Place size qualifiers such as coarse, medium, or fine before the major constituent descriptors (see Section 2.7);
- Use the appropriate adjectives for proportions in Section 2.3.2 (e.g., and, some, little, trace) when describing the minor fraction(s); and
- Use the modifiers for fine grained soils described in Section 2.8.

EXAMPLES:
Tan, medium SAND, little fine sand, trace coarse sand, trace silt, statified (Outwash), loose, wet.

Or

Gray, CLAY, soft, wet, medium plasticity, no dilatancy and low toughness.

When logging a soil sample collected from a boring (e.g., split spoon or acetate liner) where more than one soil type is present, describe each one separately, using additional line(s) on the boring log form. Start the description from the top and log each change in stratigraphy in sequence to the bottom. Record the length (e.g., 0-0.5 ft.) at the beginning of each separate sequence description, followed by a colon. Draw a line below the bottom of the complete sample description.

2.2 USCS Soil Classification System

The USCS is based on grain size and response to physical manipulation at various water contents. This system is often used for classifying soils encountered in boreholes, test pits, and surface sampling. The following properties form the basis of USCS soil classification:

- Percentage of gravel, sand, and fines;
- Shape of the grain size distribution curve; and
- Plasticity and compressibility characteristics.

Four soil fractions are recognized: cobbles, gravel, sand, and fines (silt or clay). The soils are divided as coarse-grained soils, fine-grained soils, and highly organic soils. The coarse grained soils contain 50 percent of grains coarser than a number 200 sieve (approximately 0.08 mm). Fine grained soils contain more than 50 percent of material smaller than the number 200 sieve. Organic soils contain a significant percentage of organic material (leaves, roots, peat, *etc*. in various stages of decomposition). Soil description should be concise and stress major constituents and characteristics for fine-grained, organic, or coarse-grained soils.

The general description of a soil sample should be in the following order:

1. Group Name (Group Symbol)
2. Percent and Range of Particle Sizes
3. Plasticity
4. Color (Munsell Color Chart)
5. Odor
6. Moisture
7. Density
8. Additional Comments
9. Geological Origin (Stratigraphic Unit)

EXAMPLES:
Well Graded Gravel with Sand (GW): mostly fine to coarse subangular gravel, little fine to coarse subangular sand, yellowish brown (10YR 5/4), no odor, moist, loose, few small cinders, fill.

Or

Silt (ML): mostly silt, nonplastic, gray (7.5YR 5/1), slight hydrocarbon odor, moist, medium dense, lacustrine.

2.2.1 Group Name (Group Symbol)

The USCS recognizes 15 soil groups and uses names and letter symbols to distinguish between these groups. The coarse grained soils are subdivided into gravels (G) and sands (S). Both the gravel and sand groups are divided into four secondary groups. Fine grained soils are subdivided into silts (M) and clays (C). Soils are also classified according to their plasticity and grading. Plastic soils are able to change shape under the influence of applied stress and to retain the shape once the stress is removed. Soils are referred to either low (L) or high (H) plasticity. The grading of a soil sample refers to the particle size distribution of the sample. A well graded (W) sand or gravel has a wide range of particle sizes and substantial amounts of particles sized between the coarsest and finest grains. A poorly graded (P) sand or gravel consists predominately of one size or has a wide range of sizes with some intermediate sizes missing.

The flow charts included in Attachment B: USCS Field Reference Sheets, for fine- and coarse-grained soils, can be used to assign the appropriate group symbol(s) and name and are replicated from ASTM Standard D2488. If the soil has properties which do not distinctly place it into a specific group, borderline symbols (e.g., SP-SM, GP-GC, etc.) may be used.

Soils which have characteristics of two groups are given boundary classifications using the names that most nearly describe the soil. The two groups are separated by a slash. The same is true when a soil could be well or poorly graded. Again the two groups are separated by a slash.

2.3 Soil Identification Based on Grain Size

2.3.1 Grain-Size Scales

Determination of grain size can be difficult, especially for the fine grained particles. Identification of coarse grained particles can be aided by grain size particle charts with actual samples affixed to the card. In general, fine grained particles are not visible with the naked eye or a hand lens and require manual field tests to differentiate between silts and clays.

Peat, organic material in various stages of decomposition, usually appears dark brown to black, has a fibrous to amorphous texture, with an organic odor. This material should be classified as highly organic soil (Peat; Hummus; or Swamp/bog deposit). This material is not subject to grain size classification described herein.

Grain size classification should be based on the following method.

COARSE GRAINED PARTICLES

- **Boulder:** > 300 mm (>12 in.)
- **Cobble:** 75 - 300 mm (3 in. – 12 in.)
- **Coarse Gravel:** 19 - 75 mm (¾ in. – 3 in.)
- **Fine Gravel:** 4.75 - 19 mm (No. 4 sieve – ¾ in.)
- **Coarse Sand:** 2.0 - 4.75 mm (No. 10 sieve – No. 4 sieve)
- **Medium Sand:** 0.425 - 2.0 mm (No. 40 sieve – No. 10 sieve)
- **Fine Sand:** 0.075 - 0.425 mm (No. 200 sieve – No. 40 sieve)

FINE GRAINED PARTICLES

Note that these particle sizes cannot be visually differentiated with standard field equipment. Silts and clays are distinguished in the field by cohesion and plasticity.

Burmister:
- **Silt:** 0.002 - 0.075 mm
- **Clay:** <0.002 mm

USCS:
- **Silt & Clay:** <0.075 mm (< No. 200 sieve)

2.3.2 Proportions

Proportions of grain sizes need to be described in accordance with one of the two following classification systems. Note that in either system minor constituents also include ancillary materials such as mica flakes, dark minerals, naturally occurring organic matter, or anthropogenic material (e.g., fill, brick, concrete).

Modified Burmister:
For geologic description, proportions of grain sizes will be based upon the following nomenclature:

- **Trace:** 0-10%
- **Little:** 10-20%
- **Some:** 20-35%
- **And:** 35-50%

The major soil sample constituent is always capitalized and listed first.

USCS:
For geologic description, proportions of grain sizes will be based upon the following nomenclature:

- **Trace:** < 5%
- **Few:** 5-10%
- **Little:** 15-25%
- **Some:** 30-45%
- **Mostly:** > 50%

The soil is *fine grained* if it contains 50% or more fines (<0.075 mm or passes #200 sieve)

The soil is *coarse grained* if it contains less than 50% fines.

2.4 Color

The main color value should be stated, along with a modifier, if appropriate. For example:

- light brown
- dark brown
- reddish brown
- brown

The presence of mottling (patches or spots of differing colors) should be included in the description, where present. For example:

Gray, poorly sorted angular fine to medium SAND, some silt, trace angular coarse sand, trace clay (lodgement glacial till), slightly mottled, dense, moist (Modified Burmister description)

Or

Well Graded Sand (SW), mostly angular fine to medium sand, little to some silt, few angular coarse sand, few clay, gray, no odor, moist, dense, lodgement glacial till. (USCS description)

As with other components of soil classification, consistent soil color descriptions can be very helpful when preparing subsurface interpretations from soil data collected by different personnel. To that end, the use of Munsell Soil Color charts may be implemented to standardize color nomenclature. Just as paint stores have pages of color chips, soil scientists use a book of color chips that follow the Munsell System of Color Notation. The system has three components: Hue (a specific color), Value (lightness and darkness) and Chroma (color intensity). For example, a brown soil may be noted as: hue value/chroma (10YR 5/3).

2.5 Relative Density

The modifiers used to describe soil relative density depend on whether the soil is cohesive (e.g., clay) or granular/non-cohesive (gravel, sand or silt). Field evaluation of the density of non-cohesive soils is based the ease of penetration by the sampling equipment used. The density of cohesive soils is based the compressive soil strength of soil or soil stiffness (i.e., how much the soil compresses under a given pressure). Density can be directly measured in the field, such as with the ASTM Standard D1586: Standard Penetration Test during split spoon sample collection or with a pocket penetrometer. Alternatively, the density can be measured qualitatively, such as the ease of thumb penetration. Methods of determining density and the appropriate density modifiers are discussed in the following sections.

2.5.1 Soil Samples Collected with Split Spoons

During soil sample collection using split spoons, the density can be based on the N-Value, which is the sum of the middle two 6-inch blow counts of a two foot split spoon or the last two 6-inch blow counts of an 18-inch split spoon (ASTM Standard D1586: Standard Penetration Test). Professional judgment should be used when applying the density modifier. If high blow counts are due to the presence of a cobble, boulder or large piece of gravel that impedes forward progress of the split spoon, density should be based upon the character of the material in the split spoon, if any, or omitted from the description. A notation should be made in the sample description when this situation occurs. Appropriate modifiers are described in the following table:

Non-Cohesive (Granular Soils)		**Cohesive Soils**	
N-Value (Blows/ft)	**Density**	**N-Value (Blows/ft)**	**Density**
0-4	very loose	<2	very soft
4-10	loose	2-4	soft
10-30	medium dense	4-8	medium
30-50	dense	8-15	stiff
>50	very dense	15-30	very stiff
		>30	hard

2.5.2 Test Pit Samples

In test pits, density is subjective and should be based upon the ease of excavation. The above modifiers in Section 2.5.1 for granular and cohesive soils should be used in the description. The following should be used as a guide for test pits:

- **Very Loose/Very Soft –** The bucket of the excavating equipment easily penetrates the soil and fills in one pass.
- **Medium Dense/Medium –** Several passes are required to fill the bucket.
- **Very Dense/Very Stiff –** The bucket has difficulty penetrating the soil.

2.5.3 Soil Samples Collected Via Direct Push Technology

In borings advanced by direct push methods, field evaluation of density is more subjective. Blow counts along with visible qualifiers such as number of passes to fill an excavation bucket are not applicable to direct push methods. Samplers therefore need to pay attention to the progress of the sampling tool being advanced, as well as gather information from the driller advancing the tool. Driller's input is very valuable as the macro core might be advanced at varying speeds to best achieve the goal of the boring. Below are approximations for estimating soil densities while utilizing direct push methods:

- **Very Loose/Very Soft** – Macro core advances easily, penetrates within a few seconds.
- **Medium Dense/Medium** – Macro core advances slowly but steadily, penetrates within a minute or two.
- **Very Dense/Very Stiff** – Macro core advances very slowly if at all, penetration may take several minutes.

Granular Soils	Cohesive Soils	Thumb Penetration Key
very loose	very soft	very easily – inches
loose	soft	easily – inches
medium dense	medium	moderate effort – inches
dense	stiff	indented easily
very dense	very stiff	indented by nail
	hard	difficult by nail

Similar to above, if drilling progress is slowed due to the presence of a cobble, boulder or large piece of gravel that impedes forward progress of the direct push sampler, density should be based upon the character of the material in the sampler, if any, or omitted from the description. A notation should be made in the sample description when this situation occurs.

2.5.4 Pocket Penetrometer

A pocket penetrometer is a field tool which can be implemented to directly measure compressive soil strength. The unit is spring-operated, and it is measures strength in tons/sq. ft. (tsf) or kg/sq. cm by pushing a loading piston into soil until the calibration mark is level with soil. Compressive load is indicated by reading a scale on the piston barrel. A friction ring indicates maximum reading. The reading correlates to the density description as follows:

Cohesive Soils	Compressive Strength (tsf)
very soft	< 0.25
soft	0.25 – 0.50
medium	0.50 – 1.0
stiff	1.0 – 2.0
very stiff	2.0 – 4.0
hard	> 4.0

The user should refer to the pocket penetrometer instruction manual for specifics on operation. It is recommended that several pocket penetrometer readings be collected for each soil horizon and averaged to determine the density, as opposed to one single reading.

A miniature vane shear device can also be used to directly measure compressive soil strength of cohesive soils. The device is a spring-operated torsional test that provides shear strength by measuring the resistance of turning a vane inserted into the sample.

2.6 Moisture Content

Moisture content should be described using the following modifiers:

- **Dry** – no apparent moisture, dusty.
- **Moist** – slight moisture content but no visible water, soils may stick together.
- **Wet** – water dripping from sample; usually soil is below the water table.

2.7 Geologic Modifiers or Classifications

Sedimentological descriptions aid in the geologic classification of a soil material. Only insert geologic modifiers when present.

2.7.1 Stratification

The presence of alternating layers of non-cohesive materials of different grain sizes or color with layers ***at least 6 mm*** thick. Note thickness of layers.

2.7.2 Lamination or Varves

The presence of alternating very thin layers of fine materials or color, such as silt and clay, with layers ***less than 6 mm*** thick. Note thickness of layers.

2.7.3 Sorting

A geological term used to describe how close in size the grains in a sample are to each other. For example, a *well sorted* sample contains grains of similar size; a *poorly sorted* sample contains grains of many sizes. **Caution:** Sorting and grading both describe grain size distribution and can easily be confused (e.g., well sorted is the opposite of well graded). If possible, either sorting or grading terminology, NOT both, should be used for a given project.

2.7.4 Grading

An engineering term used to describe the range in grain sizes present in a sample. For example, a *narrowly graded* or *poorly graded* sample contains grains of similar size; a *widely graded* or *well graded* sample contains grains of many different sizes. **Caution:** Sorting and grading both describe grain size distribution and can easily be confused (e.g., well sorted is the opposite of well graded). If possible, either sorting or grading terminology, NOT both, should be used for a given project.

2.7.5 Angularity or Rounding

Geological terms that are used to describe the general appearance of visible grains in the soil sample. This term is useful in determining the origin and depositional environment of a material. Water transported materials may be rounded. Glacial tills will be more angular.

- **Angular** – Particles have sharp edges and relatively plane sides with unpolished surfaces.
- **Subangular** – Particles are similar to angular description but have rounded edges.
- **Subrounded** – Particles have nearly plane sides but have well-rounded corners and edges.
- **Rounded** – Particles have smoothly curved sides and no edges.

2.7.6 Shape

A term used to describe the shape of gravel, cobbles, and boulders. Terms are as follows where the particle shape shall be described based on the ratio of the dimensions where the length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle.

- **Flat** – Particles with width:thickness > 3.
- **Elongated –** Particles with length:width > 3.
- **Flat and Elongated –** Particles meet criteria for both flat and elongated.

2.7.7 Odor

Soils containing a significant amount of organic material may have a distinct odor of decaying vegetation. Soils may also have a petroleum, sewage or chemical type odor. Note the type of odor but avoid trying to identify the specific chemical; any contaminants in the soil should be identified only by chemical analysis. **Caution - Safety Note**: Odors should be noted if observed. However soil samples may contain contaminants that are harmful if inhaled. Field personnel should NOT inhale deeply near the sample in an attempt to better determine if an odor is present.

Olfactory characteristics are subject to field conditions such as temperature and wind, as well as individual nasal sensitivities. The strength of the odor may also be noted (e.g., strong or slight).

2.7.8 Cementation

Describe the cementation of intact coarse-grained soils as follows.

- **Weak** – Crumbles or breaks with handling or little finger pressure.

- **Moderate** – Crumbles or breaks with considerable finger pressure.
- **Strong** – Will not crumble or break with finger pressure.

2.7.9 Hydrochloric Acid Reaction (HCl)

As appropriate for the geologic environment, describe the reaction with HCl as none, weak, or strong. As calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid (1 part 10N HCl to 3 parts water) is appropriate for certain projects.

- **None** – No visible reaction.
- **Weak** – Some reaction, with bubbles forming slowly.
- **Strong** – Violent reaction, with bubbles forming immediately.

2.8 Fine Grained Soils

Fine grained soils can be identified based on several manual field tests described below.

2.8.1 Dilatancy

Dilatancy is the appearance/disappearance of surface water during shaking, indicating a change in the pore volume of the material during deformation. Of the fine grained soils, silts are more likely to exhibit dilatancy. In order to test for dilatancy, obtain a small sample of soil and mold into a ½-inch diameter ball adding water as needed until the sample is soft but not sticky. Flatten the ball with the blade of a knife or spatula and shake the sample horizontally striking the side of the hand with the other hand. Note the rate at which water appears on the surface of the sample, if any. Squeeze the sample and note the reaction of the water, if any. Describe the dilatancy of the sample as follows:

Description	Criteria
None	No visible water at surface
Slow	Water appears slowly on shaking, does not disappear or disappears slowly on squeezing
Rapid	Water appears quickly on shaking, disappears quickly on squeezing

2.8.2 Toughness and Plasticity

Toughness is a measure of the amount of effort required to roll a 1/8-inch thick thread of soil at the plastic limit. Plasticity is a property of the soil that is exhibited when the soil is at a specific water content known as the plastic limit; that is, the degree at which soil is permanently deformed without rupturing by force applied in any direction.

2.8.2.1 Toughness Procedure

Roll a sample of the soil against a flat surface or between the palms of the hand to a thickness of 1/8-inch. If the thread crumbles and breaks prior to reaching the 1/8-inch thickness, add water and repeat. If the sample is too wet to roll easily, dry the sample by spreading into a thin layer or re-rolling repeatedly. The sample is at the plastic limit when the soil breaks apart and crumbles just when the thread reaches the 1/8-inch thickness. Note the pressure required to roll the thread at the plastic limit, the strength of the thread, and the pressure required to mold the sample back into a lump.

Describe the toughness of the sample as follows:

Description	Criteria
Low	Slight pressure required to roll the thread and the thread and lump are soft and weak
Medium	Moderate pressure required to roll the thread and the thread and lump have medium stiffness
High	Considerable pressure required to roll the thread and the thread and lump have very high stiffness

2.8.2.2 Plasticity Procedure

Soil plasticity is a measure of the soil's ability to be molded into a shape, and is the primary mechanism for distinguishing between silt and clay in the field. Silts are non-plastic; they are non-cohesive and cannot be molded and shaped. Clays exhibit varying degrees of plasticity. The plasticity of the soil can be determined using the observations made during the toughness test. Based on those observations, the plasticity of the soil can be described as follows:

Description	Criteria
Nonplastic	The soil cannot be molded at any water content
Low	When moistened the soil can be molded into a ball or cylinder. A 1/8-inch diameter thread may be formed if kept very moist, but crumbles easily if dried slightly.
Medium	When moistened a 1/8-inch thread of soil is easy to roll. Crumbles if manipulated.
High	When moistened a 1/8-inch thread of soil is easy to roll. Thread does not crumble easily even if bent and manipulated.

2.8.3 Identification of Fine Grained Soils

Fine grained soils can be identified using the dilatancy, toughness and plasticity tests and the criteria identified in the following table. These criteria should only be used for inorganic soils.

Soil Type	Dilatancy	Toughness	Plasticity
Silt	Slow to Rapid	Low	Nonplastic to Low
Elastic Silt	None to Slow	Low to Medium	Low to Medium
Lean Clay	None to Slow	Medium	Medium
Fat Clay	None	High	High

2.8.4 Identification of Organic Soils

Organic soils contain enough organic particles to influence the soil properties and usually have a dark brown to black color and often have an organic odor. Organic soils are typically fine grained and are identified as either organic silts or clays. Peat is a particular type of organic soil composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor. When present the sample shall be designated as highly organic soil or peat. Laboratory tests are usually required to differentiate between organic silts and clays.

2.9 Fill Soils

Frequently soils are encountered that have been placed in an area for the purpose of changing or modifying the surface elevation. These fill soils can be reworked native soils or soils imported from another location. Indications that a soil is a non-native fill material include the following:

- The presence of anthropogenic materials (e.g., bricks, concrete, plastic);
- A heterogeneous mixture of soils with a random or unnatural distribution;
- Soils with an unnatural particle size distribution (e.g., clean pea stone).

Environmental and geotechnical projects often require that the extent and depth of fill soils be characterized. Fill soils are usually considered unsuitable for geotechnical uses due to the potential variation of soil types and engineering properties, and the uncertain compaction history of the material.

Fill soils can also contain anthropogenic materials that can be sources of contamination. Examples of anthropogenic materials that can be sources of contamination include the following:

- Construction and demolition debris especially with coatings or materials that contain tar or asphalt;
- Ash;
- Slag;
- Coal; and
- Asphalt pavement.

Regardless of the potential for contamination, all anthropogenic materials should be listed in the soil description. Contact the Project Manager immediately if any of these materials are unexpectedly encountered. This is especially important if environmental samples are being collected for site characterization.

2.10 Geologic Origin

Where possible based on existing site data, local research, or geologic understanding of the local region, include the apparent geologic origin of the material, such as glacial deposit (e.g., till, outwash), aeolian deposit, residual soil, colluvium, alluvium, regolith, residuum, saprolite, or fill material. Do not utilize geologic origin if not certain.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pick-up and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

Other than having another person peer review and duplicate the visual identification, samples of identified soils can be submitted to a geotechnical laboratory for classification in accordance with *ASTM D 2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*. The laboratory classification can then be compared to the visual identification which can be changed as needed. It is recommended that Project Managers include laboratory classification of site soils in work plans for environmental projects. Laboratory classification should always be included for geotechnical projects. TRC field staff shall consult the site-specific work plan to determine laboratory soil classification requirements, if any.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

All soil identification information must be documented in the field book and/or on an appropriate field form (TRC Sample Log Sheet, Boring Logs, Test Pit Logs or gINT). Example field forms are included in Attachment A. Field notes should neatly convey the soil descriptions. Providing soil classifications following this SOP will allow for consistent data interpretation and increase project efficiency when soil descriptions are taken from field logs and converted to electronic report logs (e.g., gINT). Record the following information in the field book:

- Sample identification number
- Sample location (sketch of the sample point)
- Time and date sample was taken
- Personnel performing the task
- Visual description of the sample
- Weather conditions during sampling
- Other pertinent observations as prescribed in TRC's SOP for field activity documentation

6.0 REFERENCES

ASTM D2487 *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System),* Annual Book of ASTM Standards, Vol. 04.08, Current edition.

ASTM D2488 *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure),* Annual Book of ASTM Standards, Vol. 04.08, Current edition.

ASTM D1586-11 *Standard Test Method for Standard Penetration Test (SPT) and Split Barrel-Sampling of Soils*, Annual Book of ASTM Standards, Vol. 04.08, Current edition.

Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

Procedures for Testing Soils. Burmister, D.M., 1958. Suggested Methods of Test for Identification of Soils.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	SEPTEMBER 2013	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING

ATTACHMENT A
FIELD FORMS

TRC Soil Boring Log

Project/Client	Project No.	Boring No.	Sheet
		Well No.	1 of __
Location Description		TRC Geologist	

Drilling Contractor/Foreman	Drill Rig Make/Model	Auger/Drive Casing Size/Type

Sampler Description	Drilling Method	Coordinates X= Y=
Filter Seal Amount/Type:	Drill Bit/Auger Diameter:	Ref. El.:
Sand Pack Amount/Type:	Hammer Weight/Fall:	Riser Stick Up:
Screen Length/Type:	Water Table Depth:	Surface Elevation:
Riser Length/Type:	Total Depth:	Date Start: Date Finish:

Depth	Sample Number	Blows/ RQD	Pen/Rec Core Rec	Sample Description	Strati-graphic Description	Field Testing	Lab Sample Number	Well Construction
	S-1							
1								
2								
	S-2							
3								
4								
	S-3							
5								
6								
	S-4							
7								
8								
	S-5							
9								
10								
	S-6							
11								
12								
	S-7							
13								

Granular Soils

Blows/ft	Density
0-4	v. loose
4-10	loose
10-30	m. dense
30-50	dense
>50	v. dense

Proportions Used
trace 0-10% some 20-35%
little 10-20% and 35-50%

Cohesive Soils

Blows/ft	Density
<2	v. soft
2-4	soft
4-8	m. stiff
8-15	stiff
15-30	v. stiff
>30	hard

Grain Size (USCS)

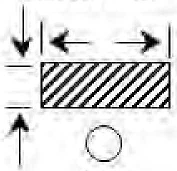
silt/clay	<0.08 mm
f. sand	0.43-0.08 mm
m. sand	2.0-0.43 mm
c. sand	4.8-2.0 mm
f. gravel	19-4.8 mm
c. gravel	75-19 mm
cobble	300-75 mm
boulder	>300 mm

Notes:
1)
2)
3)

TRC Test Pit Log	Project:	Date/Time:	Sheet __ of __
	Contractor Personnel:	TRC Personnel:	
Equipment/Contractor Used:	Location:	Test Pit Number:	
Reach/Capacity:	Total Depth:	Piezometer Installed?	
Depth to Ground Water:	Weather:	Elevation:	Top of Pit ______

Depth	Sample Number	Stratigraphic Description	REMARKS:
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

TEST PIT PLAN



North

Vol. = _____ cu. yd.

PROPORTIONS BURMISTER USED

Trace (TR)	0 - 10%
Little (LI.)	10 - 20%
Some (SO.)	20 - 35%
And	35 - 50%

GRAIN SIZE (USCS)

silt/clay	<0.08 mm
f. sand	0.43-0.08 mm
m. Sand	2.0-0.43 mm
c. Sand	4.8-2.0 mm
f. gravel	19-4.8 mm
c. gravel	19-4.8 mm
cobble	300-75 mm
boulder	>300 mm

Rev: February 2006

PAGE ____ OF ____

LOG OF SOIL BORING

PROJECT NAME:		SOIL BORING ID:	
PROJECT NUMBER:		LOCATION:	SHEET 1 OF
LOGGED BY:			SURFACE ELEV.:
PROJECT LOCATION:		N: E:	DATE STARTED:
DRILLED BY:	DRILLER NAME:		DATE COMPLETED:

NO.	TYPE	%	BLOWS	PID	DEPTH	VISUAL CLASSIFICATION AND OBSERVATIONS	COMMENT
					2.5		
					5.0		
					7.5		
					10.0		
					12.5		
					15.0		
					17.5		
					20.0		

DRILLING METHOD
DRILL RIG
BORING DIAMETER

WATER LEVEL OBSERVATIONS			
FIRST OCCURRENCE:			
DATE	TIME	DEPTH TO WATER	DEPTH TO BOTTOM

SIGNED ____________ DATE ____________ CHECKED ____________ DATE ____________

REVISED 06/2011

ATTACHMENT B

USCS FIELD REFERENCE SHEETS

GENERAL NOTES - BORING LOGS (UNIFIED SOIL CLASSIFICATION SYSTEM)

TRC

SAMPLE DESCRIPTION FORMAT

Group Name (Group Symbol), Percent and Range of Particle Sizes, Plasticity, Color, Odor, Moisture, Density, Additional Comments, Geological Origin (Stratigraphic Unit)

USCS CLASSIFICATION

MAJOR DIVISIONS		SYM	TYPICAL NAMES AND DESCRIPTIONS
COARSE GRAINED (more than 50% > no. 200 sieve)	GRAVELS (more than 50% of coarse fraction > no. 4 sieve)	GW	Well graded gravels or gravel/sand mixtures, little or no fines
		GP	Poorly graded gravels or gravel/sand mixtures, little or no fines
		GM	Silty gravels, gravel/sand/silt mixtures
		CC	Clayey gravels, gravel/sand/clay mixtures
	SANDS (more than 50% of coarse fraction < no. 4 sieve)	SW	Well graded sands or gravelly sands, little or no fines
		SP	Poorly graded sands or gravelly sands, little or no fines
		SM	Silty sands, sand/silt mixtures
		SC	Clayey sands, sand/clay mixtures
FINE GRAINED (more than 50% < no. 200 sieve)	SILTS AND CLAYS High Liquid Limit (> 50)	ML	Inorganic silts, silty or clayey fine sands, clayey silts, low plasticity
		CL	Inorganic clays, silty/sandy/gravelly clays, low to medium plasticity (lean)
		OL	Organic silts and organic silty clays, low plasticity
	SILTS AND CLAYS Low Liquid Limit (< 50)	MH	Inorganic silts, elastic silts
		CH	Inorganic clays with high plasticity (fat clays)
		OH	Organic clays, medium to high plasticity or organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic silts

DENSITY

RELATIVE DENSITY				
COHESIVE			**NONCOHESIVE**	
DESCRIPTION	N-VALUE(1)	q_u (tsf)(2)	DESCRIPTION	N-VALUE(1)
Very Soft	0 - 2	< 0.25	Very Loose	0 - 4
Soft	2 - 4	0.25 - 0.50	Loose	4 - 10
Medium	4 - 8	0.50 - 1.0	Medium Dense	10 - 30
Stiff	8 - 15	1.0 - 2.0	Dense	30 - 50
Very Stiff	15 - 30	2.0 - 4.0	Very Dense	> 50
Hard	> 30	> 4.0		

(1) Number of blows of 140 LB hammer falling 30 inches to drive a 2-in O.D. split-barrel sampler the last 12 inches of an 18-in drive (ASTM 1586 Standard Penetration Test).

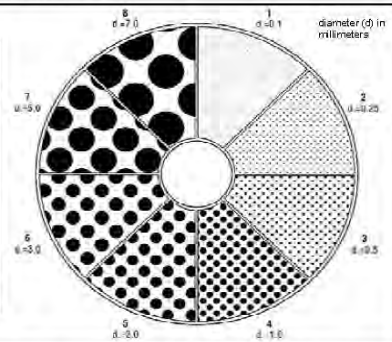
(2) Compressive Strength in tons per square foot (tsf) (typically measured with a pocket penetrometer).

PLASTICITY

DESC.	CRITERIA
Nonplastic	The soil cannot be molded at any water content
Low	When moistened the soil can be molded into a ball/cylinder. A 1/8" diameter thread may be formed if kept very moist, but crumbles easily if dried slightly.
Medium	When moistened a 1/8" thread of soil is easy to roll. Crumbles if manipulated.
High	When moistened a 1/8" thread of soil is easy to roll. Thread does not crumble easily even if bent and manipulated.

GRAIN SIZE

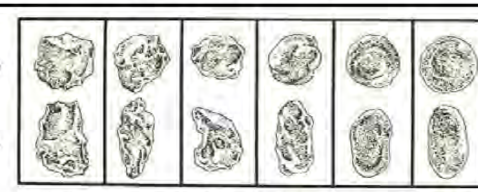
GRAIN SIZE			GRADE DESCRIPTION	
MM	INCHES	SIEVE SIZE		
300	12	--	--	BOULDER
75	3	--	--	COBBLE
19	0.75	--	COARSE	GRAVEL
4.75	0.19	4	FINE	GRAVEL
2.0	0.08	10	COARSE	SAND
0.425	0.02	40	MEDIUM	SAND
0.075	0.003	200	FINE	SAND
<0.075	<0.003	325	--	SILT
<0.075	<0.003	--	--	CLAY



MOISTURE

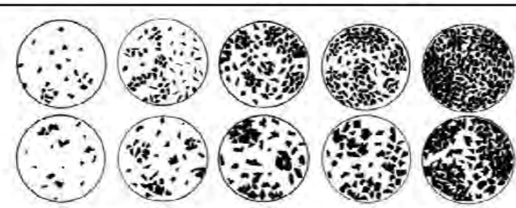
DESC.	CRITERIA
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp, but no visible water
Wet	Visible free water, usually soil is below the water table

GRAIN SHAPE



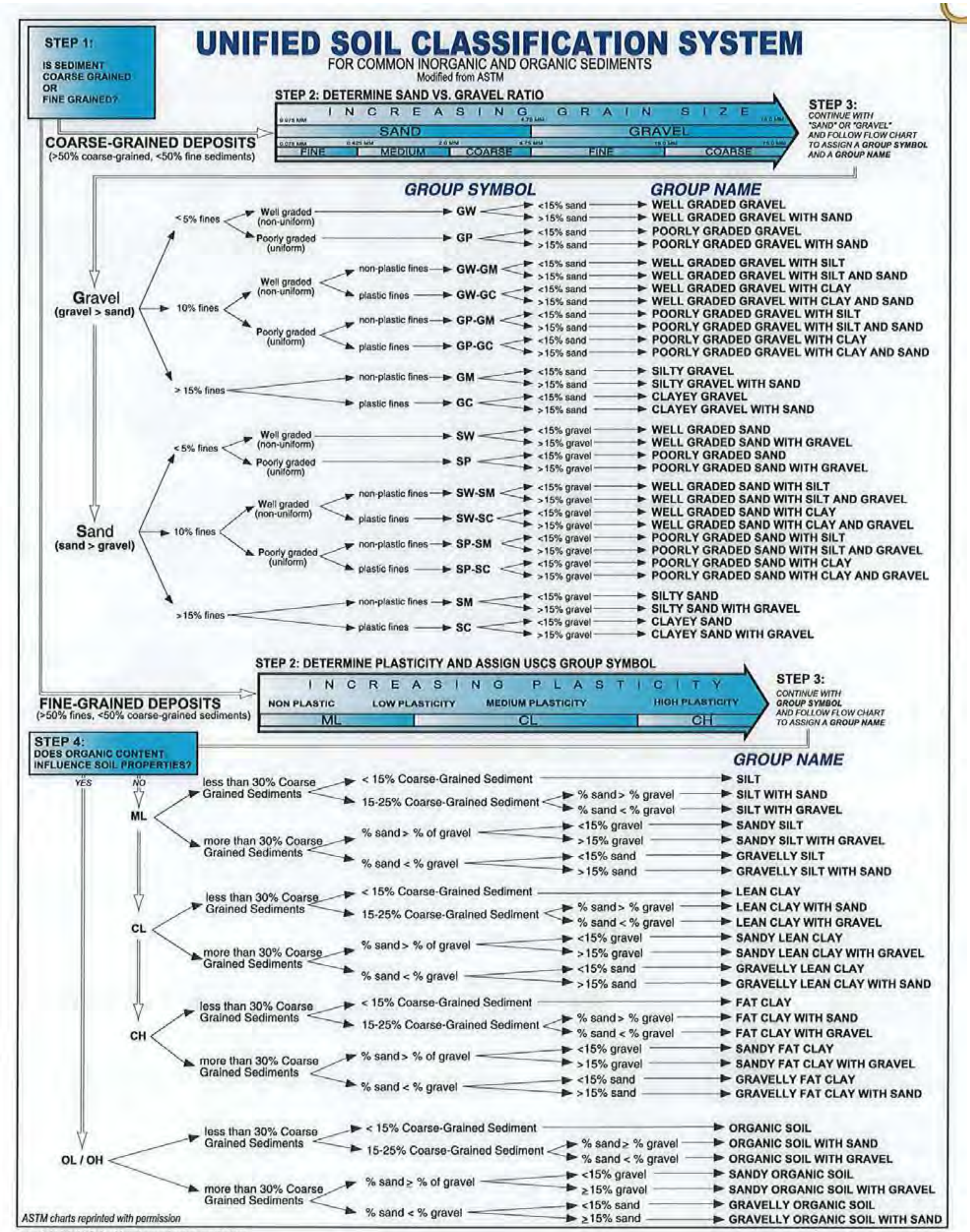
GRAIN DISTRIBUTION

PROPORTIONS	
DESC.	% RANGE
Trace	< 5%
Few	5% - 10%
Little	15% - 25%
Some	30% - 45%
Mostly	> 50%



ADDITIONAL INFORMATION TO BE INCLUDED IN FIELD NOTES

- Project/Boring Identification
- Contractor/Crew Identification
- Date/Time of Contractor Operations
- Equipment Identification
- Sample Identification
- Sampled Interval
- Recovery
- Drilling Challenges/Resolution
- Sample Chain of Custody
- Well Construction
  - Materials
  - Screen Length/Slot Size
  - Screen Depth
  - Filter Pack Depth
  - All Seal Depth(s)
  - Riser Pipe Length (Stick-up/flush mount)


STEP 1:
IS SEDIMENT COARSE GRAINED OR FINE GRAINED?
UNIFIED SOIL CLASSIFICATION SYSTEM
FOR COMMON INORGANIC AND ORGANIC SEDIMENTS
Modified from ASTM
STEP 2: DETERMINE SAND VS. GRAVEL RATIO
INCREASING GRAIN SIZE
SAND
GRAVEL
FINE
MEDIUM
COARSE
FINE
COARSE
COARSE-GRAINED DEPOSITS
(>50% coarse-grained, <50% fine sediments)
STEP 3:
CONTINUE WITH "SAND" OR "GRAVEL" AND FOLLOW FLOW CHART TO ASSIGN A GROUP SYMBOL AND A GROUP NAME
GROUP SYMBOL
GROUP NAME
Gravel
(gravel > sand)
<5% fines
10% fines
> 15% fines
Well graded (non-uniform)
Poorly graded (uniform)
non-plastic fines
plastic fines
GW
GP
GW-GM
GW-GC
GP-GM
GP-GC
GM
GC
<15% sand
>15% sand
WELL GRADED GRAVEL
WELL GRADED GRAVEL WITH SAND
POORLY GRADED GRAVEL
POORLY GRADED GRAVEL WITH SAND
WELL GRADED GRAVEL WITH SILT
WELL GRADED GRAVEL WITH SILT AND SAND
WELL GRADED GRAVEL WITH CLAY
WELL GRADED GRAVEL WITH CLAY AND SAND
POORLY GRADED GRAVEL WITH SILT
POORLY GRADED GRAVEL WITH SILT AND SAND
POORLY GRADED GRAVEL WITH CLAY
POORLY GRADED GRAVEL WITH CLAY AND SAND
SILTY GRAVEL
SILTY GRAVEL WITH SAND
CLAYEY GRAVEL
CLAYEY GRAVEL WITH SAND
Sand
(sand > gravel)
<5% fines
10% fines
>15% fines
SW
SP
SW-SM
SW-SC
SP-SM
SP-SC
SM
SC
<15% gravel
>15% gravel
WELL GRADED SAND
WELL GRADED SAND WITH GRAVEL
POORLY GRADED SAND
POORLY GRADED SAND WITH GRAVEL
WELL GRADED SAND WITH SILT
WELL GRADED SAND WITH SILT AND GRAVEL
WELL GRADED SAND WITH CLAY
WELL GRADED SAND WITH CLAY AND GRAVEL
POORLY GRADED SAND WITH SILT
POORLY GRADED SAND WITH SILT AND GRAVEL
POORLY GRADED SAND WITH CLAY
POORLY GRADED SAND WITH CLAY AND GRAVEL
SILTY SAND
SILTY SAND WITH GRAVEL
CLAYEY SAND
CLAYEY SAND WITH GRAVEL
STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL
INCREASING PLASTICITY
NON PLASTIC
LOW PLASTICITY
MEDIUM PLASTICITY
HIGH PLASTICITY
ML
CL
CH
FINE-GRAINED DEPOSITS
(>50% fines, <50% coarse-grained sediments)
STEP 3:
CONTINUE WITH GROUP SYMBOL AND FOLLOW FLOW CHART TO ASSIGN A GROUP NAME
STEP 4:
DOES ORGANIC CONTENT INFLUENCE SOIL PROPERTIES?
YES
NO
GROUP NAME
less than 30% Coarse Grained Sediments
more than 30% Coarse Grained Sediments
< 15% Coarse-Grained Sediment
15-25% Coarse-Grained Sediment
% sand > % gravel
% sand < % gravel
% sand > % of gravel
<15% gravel
>15% gravel
<15% sand
>15% sand
SILT
SILT WITH SAND
SILT WITH GRAVEL
SANDY SILT
SANDY SILT WITH GRAVEL
GRAVELLY SILT
GRAVELLY SILT WITH SAND
LEAN CLAY
LEAN CLAY WITH SAND
LEAN CLAY WITH GRAVEL
SANDY LEAN CLAY
SANDY LEAN CLAY WITH GRAVEL
GRAVELLY LEAN CLAY
GRAVELLY LEAN CLAY WITH SAND
FAT CLAY
FAT CLAY WITH SAND
FAT CLAY WITH GRAVEL
SANDY FAT CLAY
SANDY FAT CLAY WITH GRAVEL
GRAVELLY FAT CLAY
GRAVELLY FAT CLAY WITH SAND
OL / OH
% sand ≥ % gravel
% sand ≥ % of gravel
≥15% gravel
≥15% sand
ORGANIC SOIL
ORGANIC SOIL WITH SAND
ORGANIC SOIL WITH GRAVEL
SANDY ORGANIC SOIL
SANDY ORGANIC SOIL WITH GRAVEL
GRAVELLY ORGANIC SOIL
GRAVELLY ORGANIC SOIL WITH SAND
ASTM charts reprinted with permission

ATTACHMENT C

SOP FACT SHEET

SOIL CLASSIFICATION PROCEDURES

PURPOSE AND OBJECTIVE

The objective of this method is to standardize the collection and documentation of information on soil that is useful for the purpose of hydrogeological or geotechnical evaluation of a site. The use of standardized visual examination and manual test methods by all field personnel results in standardized data that can be evaluated later for geologic and engineering uses.

Soil samples may be collected by various means, as discussed in TRC's Soil Sampling SOP. Regardless of the sample collection method, the resulting soil sample should be visually described and characterized. Visual examination of the sample will result in identifying grain size, particle size percentages, geologic and geotechnical modifiers and/or classifications, and a host of secondary characteristics.

WHAT TO BRING

- Field book, boring logs, test pit logs (as applicable)
- A copy of boring logs or field notes from previous work performed at or near the site
- Pocket penetrometer or miniature vane shear device
- Munsell Soil Color Chart
- Burmister and/or Unified Soil Classification System (USCS) classification chart/reference sheets
- Sand grading chart
- Camera
- Appropriate knife
- Spoon and/or small spatula
- Tape measure, folding ruler or yard stick
- Portable table
- Polyethylene sheeting
- Hand lens
- Equipment decontamination supplies
- Deionized water in squeeze bottle
- Small squirt bottle with dilute hydrochloric acid (1 part 10N HC1 to 3 parts water)PID
- Garbage bags

OFFICE

- Prepare/update the HASP; make sure the field team is familiar with the latest version.
- Discuss the objective for the soil sampling program with the project manager and/or the field lead. Discuss sample order, collection method, designation, analytical parameters, turn-around times, laboratory, etc.
  - Are the soil cuttings to be containerized in drums or returned to borehole?
  - Field decontamination required?
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure, test equipment and make sure it is in proper working order.
- Verify that a utility survey/mark-out has been performed to ensure that sample locations are clear of overhead and buried utilities. Obtain a copy of the markout ticket or confirmation number. Additionally, a private geophysical sub-surface survey may be necessary.

ON-SITE

- Verify that underground utilities have been marked out and that the markouts are clear. Stay at least two feet away from any marked utility. Identify if any overhead obstructions or limited access areas exist near proposed borings and contact the Project Manager if any proposed locations need to be moved. Sketch/photograph markout locations.
- Review the HASP with all field personnel, conduct Health & Safety tailgate meeting.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities and pedestrian traffic, etc.).
- Calibrate equipment (if applicable) and record all rental equipment serial numbers in the field book.

MODIFIED BURMISTER SOIL CLASSIFICATION SYSTEM

The general description of a soil sample should be in the following order:

1. Color
2. Major Constituent – capitalized
3. Minor Constituent(s)
4. Geologic modifiers or classifications (e.g., glacial deposit, fill material) in parentheses
5. Density
6. Moisture content
7. Modifiers for fine fraction of sample (plasticity, dilatancy and toughness)
8. Other significant observations (e.g., odors, staining, sheen, petroleum product, debris)

1

SOIL CLASSIFICATION PROCEDURES

Use the following guidelines when recording soil descriptions:

-If the major constituent comprises more than 50% of the soil, then fully capitalize the major component descriptor (e.g., SAND);
-If the major constituent comprises less than 50% of the soil, capitalize the descriptor (e.g., Sand);
-Place a comma after the major and minor constituent descriptors;
-Place size qualifiers such as coarse, medium, or fine before the major constituent descriptors;
-Use the appropriate adjectives for proportions (e.g., and, some, little, trace) when describing the minor fraction(s); and
-Use the modifiers for fine grained soils described (plasticity, dilatancy and toughness).

EXAMPLE 1: Tan, medium SAND, little fine sand, trace coarse sand, trace silt, stratified (Outwash), loose, wet.

EXAMPLE 2: Gray, CLAY, soft, wet, medium plasticity, no dilatancy and low toughness.

When logging a soil sample collected from a boring (e.g., split spoon or acetate liner) where more than one soil type is present, describe each one separately, using additional line(s) on the boring log form. Start the description from the top and log each change in stratigraphy in sequence to the bottom. Record the length (e.g., 0-0.5 ft.) at the beginning of each separate sequence description, followed by a colon. Draw a line below the bottom of the complete sample description.

USCS CLASSIFICATION SYSTEM

The USCS is based on grain size and response to physical manipulation at various water contents. This system is often used for classifying soils encountered in boreholes, test pits, and surface sampling. The following properties form the basis of USCS soil classification:

- Percentage of gravel, sand, and fines;
- Shape of the grain size distribution curve; and
- Plasticity and compressibility characteristics.

Four soil fractions are recognized: cobbles, gravel, sand, and fines (silt or clay). The soils are divided as coarse grained soils, fine grained soils, and highly organic soils. Soil description should be concise and stress major constituents and characteristics for fine-grained, organic, or coarse-grained soils.

The general description of a soil sample should be in the following order:

1. Group Name (Group Symbol)
2. Percent and Range of Particle Sizes
3. Plasticity
4. Color (Munsell Color Chart)
5. Odor
6. Moisture
7. Density
8. Additional Comments
9. Geological Origin (Stratigraphic Unit)

EXAMPLE 1: Well Graded Gravel with Sand (GW): mostly fine to coarse subangular gravel, little fine to coarse subangular sand, yellowish brown (10YR 5/4), no odor, moist, loose, few small cinders, fill.

EXAMPLE 2: Silt (ML): mostly silt, non-plastic, gray (7.5YR 5/1), slight hydrocarbon odor, moist, medium dense, lacustrine.

The USCS recognizes 15 soil groups and uses names and letters to distinguish between these groups. The flow charts included in Attachment B: USCS Field Reference Guide, for fine- and coarse-grained soils, can be used to assign the appropriate group symbol(s) and name and are replicated from ASTM D2488. If the soil has properties which do not distinctly place it into a specific group, borderline symbols (example SP-SM, GP-GC, etc.) may be used.

GRAIN SIZE

Grain size classification should be based on the following method.

COARSE GRAINED PARTICLES

Boulder: > 300 mm (>12 in.)
Cobble: 75 - 300 mm (3 in. – 12 in.)
Coarse Gravel: 19 - 75 mm (¾ in. - 3 in.)
Fine Gravel: 4.75 - 19 mm (No. 4 sieve – ¾ in.)
Coarse Sand: 2.0 - 4.75 mm (No. 10 sieve – No. 4 sieve)
Medium Sand: 0.425 - 2.0 mm (No. 40 sieve – No. 10 sieve)
Fine Sand: 0.075 – 0.425 mm (No. 200 sieve – No. 40 sieve)

FINE GRAINED PARTICLES

Note that these particle sizes cannot be visually differentiated with standard field equipment. Silts and clays are distinguished in the field by cohesion and plasticity.

SOIL CLASSIFICATION PROCEDURES

PROPORTIONS

Proportions of grain sizes need to be described in accordance with one of the two following classification systems. Note that in either system minor constituents also include ancillary materials such as mica flakes, dark minerals, naturally occurring organic matter, or anthropogenic material (e.g., fill, brick, concrete).

Modified Burmister:
For geologic description, proportions of grain sizes will be based upon the following nomenclature:

Trace:	0-10%
Little:	10-20%
Some:	20-35%
And:	35-50%

The major soil sample constituent is always capitalized and listed first.

USCS:
For geologic description, proportions of grain sizes will be based upon the following nomenclature:

Trace:	< 5%
Few:	5-10%
Little:	15-25%
Some:	30-45%
Mostly:	> 50%

COLOR

The main color value should be stated, along with a modifier, if appropriate. For example *light brown* or *reddish brown*

EXAMPLE 1: Gray, poorly sorted angular fine to medium SAND, some silt, trace angular coarse sand, trace clay (lodgement glacial till), slightly mottled, dense, moist *(Modified Burmister description)*

EXAMPLE 2: Well Graded Sand (SW), mostly angular fine to medium sand, little to some silt, few angular coarse sand, few clay, gray, no odor, moist, dense, lodgement glacial till *(USCS description)*

As with other components of soil classification, consistent soil color descriptions can be very helpful when preparing subsurface interpretations from soil data collected by different personnel. To that end, the use of Munsell Soil Color charts may be implemented to standardize color nomenclature. Just as paint stores have pages of color chips, soil scientists use a book of color chips that follow the Munsell System of Color Notation. The system has three components: Hue (a specific color), Value (lightness and darkness) and Chroma (color intensity). For example, a brown soil may be noted as: hue value/chroma (10YR 5/3).

RELATIVE DENSITY

The modifiers used to describe soil relative density depend on whether the soil is cohesive (i.e. clay) or granular/non-cohesive (gravel, sand or silt). Field evaluation of the density of non-cohesive soils is based the ease of penetration by the sampling equipment used. The density of cohesive soils is based the compressive soil strength of soil or soil stiffness (i.e. how much the soil compresses under a given pressure).

Density can be directly measured in the field, such as with the ASTM 1586: Standard Penetration Test during split spoon sample collection or with a pocket penetrometer. Alternatively, the density can be measured qualitatively, such as the ease of thumb penetration.

MOISTURE CONTENT

Moisture content should be described using the following modifiers:

- Dry – no apparent moisture, dusty
- Moist – slight moisture content but no visible water, soils may stick together
- Wet – water dripping from sample; usually soil is below the water table

GEOLOGIC MODIFIERS

Sedimentological descriptions aid in the geologic classification of a soil material. Only insert geologic modifiers when present.

- **Stratification**

The presence of alternating layers of non-cohesive materials of different grain sizes or color with layers at least 6 mm thick. Note thickness of layers.

- **Lamination or Varves**

The presence of alternating very thin layers of fine materials or color, such as silt and clay, with layers less than 6 mm thick. Note thickness of layers.

- **Sorting**

A geological term used to describe how close in size the grains in a sample are to each other.

SOIL CLASSIFICATION PROCEDURES

- **Grading**

An engineering term used to describe the range in grain sizes present in a sample.

- **Angularity or Rounding**

Geological terms that are used to describe the general appearance of visible grains in the soil sample.

- Angular – Particles have sharp edges and relatively plane sides with unpolished surfaces.
- Subangular – Particles are similar to angular description but have rounded edges.
- Subrounded – Particles have nearly plane sides but have well-rounded corners and edges.
- Rounded – Particles have smoothly curved sides and no edges.

- **Shape**

A term used to describe the shape of gravel, cobbles, and boulders.

- Flat – Particles with width:thickness > 3.
- Elongated – Particles with length:width > 3.
- Flat and Elongated – Particles meet both criteria.

- **Odor**

Soils containing a significant amount of organic material may have a distinct odor of decaying vegetation. Soils may also have a petroleum, sewage or chemical type odor.

- **Cementation**

Describe the cementation of intact coarse-grained soils as follows.

- Weak – Crumbles or breaks with handling or little finger pressure.
- Moderate – Crumbles or breaks with considerable finger pressure.
- Strong – Will not crumble or break with finger pressure.

FINE GRAINED SOILS

Dilatancy

Dilatancy is the appearance/disappearance of surface water during shaking, indicating a change in the pore volume of the material during deformation. Flatten the ball with the blade of a knife or spatula and shake the sample horizontally striking the side of the hand with the other hand. Note the rate at which water appears on the surface of the sample, if any. Squeeze the sample and note the reaction of the water, if any. Describe the dilatancy as follows:

- None: no visible water at surface
- Slow: water appears slowly on shaking, does not disappear or disappears slowly on squeezing
- Rapid: water appears quickly on shaking, disappears quickly on squeezing

Toughness and Plasticity

Toughness is a measure of the amount of effort required to roll a 1/8-inch thick thread of soil at the plastic limit. Plasticity is a property of the soil that is exhibited when the soil is at a specific water content known as the plastic limit; that is, the degree at which soil is permanently deformed without rupturing by force applied in any direction.

Soil plasticity is a measure of the soil's ability to be molded into a shape, and is the primary mechanism for distinguishing between silt and clay in the field. Silts are non-plastic; they are non-cohesive and cannot be molded and shaped. Clays exhibit varying degrees of plasticity. The plasticity of the soil can be determined using the observations made during a toughness test.

FILL SOILS

Frequently soils are encountered that have been placed in an area for the purpose of changing or modifying the surface elevation. These fill soils can be reworked native soils or soils imported from another location. Indications that a soil is a non-native fill material include the following:

- The presence of anthropogenic materials (e.g., bricks, concrete, plastic);
- A heterogeneous mixture of soils with a random or unnatural distribution;
- Soils with an unnatural particle size distribution (e.g., clean pea stone).

Environmental and geotechnical projects often require that the extent and depth of fill soils be characterized. Fill soils are usually considered unsuitable for geotechnical uses due to the potential variation of soil types and engineering properties, and the uncertain compaction history of the material.

Fill soils can also contain anthropogenic materials that can be sources of contamination. Examples of anthropogenic materials that can be sources of contamination include the following:

- Construction and demolition debris especially with coatings or materials that contain tar or asphalt;
- Ash;
- Slag;
- Coal; and
- Asphalt pavement.

4

Title: **Well Development**	Procedure Number: **ECR 006**
	Revision Number: **2**
	Effective Date: **January 2020**

Authorization Signatures

Technical Reviewer	Date	Environmental Sector Quality Director	Date
James Peronto	1/1/20	Elizabeth Denly	1/1/20

TABLE OF CONTENTS

Page No.

ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope and Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for the development of wells. Well development is completed to (1) evacuate any water added during the drilling of wells, (2) establish a good hydraulic connection between the well and the surrounding water-bearing zone, (3) settle the sand pack and formation following the disruptive drilling and installation activities, (4) alleviate clogging, smearing or compaction of formation materials at the borehole wall due to the drilling process, and (5) remove fine particles (e.g., silt or clay) from the water column and sand pack in order to obtain groundwater samples that are representative of the water-bearing zone in which the well is installed and/or enhance groundwater extraction and injection rates. Well development typically occurs for all newly installed wells and can also be implemented to refurbish an older well where significant silt/sediment build-up has occurred, as may be observed when the measured depth to bottom of a well is notably shallower than the recorded constructed depth to bottom.

1.2 Summary of Method

Proper well development includes initial and ongoing water-level and water quality measurements, implementation of the development method, management of the development wastes, equipment decontamination, and documentation. First, the well should be opened and initial measurements (e.g., headspace air monitoring readings, depth to water, total depth of the well) are collected and recorded. The well is developed using the method selected for each project based on the lithology, site conditions, and objectives and requirements of the project. Development of the well continues until the water is visually clear and free of sediments (e.g., turbidity <10 nephelometric turbidity units [NTU]), until a minimum number of well volumes has been evacuated (depending on regulatory requirements) or until water quality parameters such as pH, temperature, and specific conductivity stabilize, depending on project requirements. All purge water is containerized for proper characterization and disposal at an appropriate facility unless prior approval to discharge to land surface has been obtained from appropriate sources (e.g., governing regulatory agency). Final measurements (e.g., depth to water, total depth of the well, total water removed) are recorded in the field book or on the Well Development Form (Attachment A). Equipment is decontaminated, as appropriate, prior to use in the next well.

After well installation, development of a well should occur as soon as reasonably possible to enable representative sampling within the parameters of the project schedule. Some regulatory agencies require minimum timeframes for the newly-installed well materials, such as the bentonite seal or grout column, to cure before initiating well development (e.g., 24 or 48 hours). In addition, more vigorous well development methods (e.g., surging) may require a relatively longer setup time before development. If a less vigorous method (e.g., bailing) is being used, development may be initiated shortly after installation when grout is not used in well installation or if the sealant is above the water table. Regardless, the method used for development should not interfere with the setting of the well seal, which should be considered in preparing the work plan.

Well development also provides an opportunity to collect data that can be used to estimate the hydraulic conductivity (permeability) of the screened water-bearing formation. These estimates can be used to estimate groundwater flow velocities, and are often needed to project the extent of plume migration, estimate monitored natural attenuation rates, and other investigative tasks. Estimates of hydraulic conductivity and aquifer transmissivity can be derived from a measure of a well's specific capacity; i.e., flow rate divided by water-level drawdown (expressed in gallons per minute per foot [gpm/ft] of drawdown). The data needed to estimate specific capacity are the flow rate (purge rate during development, measured with a flow meter or a 5-gallon bucket and stopwatch), the static (pre-pumping) depth to water, and the pumping depth to water. The duration of pumping when the pumping depth to water is measured should also be noted.

Several development methods may be used depending on site conditions and project requirements. There are several regulatory agency guidance documents (e.g., USGS, 1997) as well as ASTM standards available for reference. If possible, select a development method that avoids introduction of air, foreign water, or chemicals to the aquifer during development. A few development methods are outlined in Section 2.0. For specialized well development programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment C for further details.

1.3 Equipment

The following list of equipment may be utilized during the development of wells. Site-specific conditions may warrant the use of additional items or deletion of items from this list.

- Appropriate level of personal protection equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator
- Oil/water interface probe
- Extra batteries for water level/interface probe
- Field book and forms
- Well keys
- Socket wrench
- Centrifugal or submersible pump and tubing/hosing
- Water quality meter (including parameters such as pH, temperature, specific conductivity, oxidation-reduction potential (ORP) and dissolved oxygen (DO)
- Flow-through cell
- Turbidity meter
- Plastic beaker, jar, or disposable plastic cups
- Bailer and cord
- Large-capacity DOT-approved containers (if required)
- Five-gallon buckets
- Surge block
- Bulk supply of deionized/organic-free water
- Well construction diagrams and previous well development data (if available)
- Equipment decontamination supplies

1.4 Definitions

Bailer	A cylindrical device suspended from a rope or cable, which is used to remove water, non-aqueous phase liquid (NAPL), sediment or other materials from a well or open borehole. Usually equipped with some type of check valve at the base to allow water, NAPL, and/or sediment to enter the bailer and be retained as it is lifted to the surface.
Dense Non-aqueous Phase Liquid (DNAPL)	Separate-phase product that is denser than water and, therefore, sinks to the bottom of the water column.
Depth To Water (DTW)	The distance to the groundwater surface from an established measuring point.
Light Non-aqueous Phase Liquid (LNAPL)	Separate-phase product that is less dense than water and, therefore, floats on the surface of the water.
Monitoring Well	A well made from a polyvinyl chloride (PVC) pipe, or other appropriate material, with slotted screen installed across or within a saturated zone. A monitoring well is typically constructed with a PVC or stainless steel pipe in unconsolidated deposits and with steel casing in bedrock.
Non-aqueous Phase Liquid (NAPL)	Petroleum or other fluid that is immiscible in water and tends to remain as a separate liquid in the subsurface.
Piezometer	A well made from PVC or metal with a slotted screen installed across or within a saturated zone. Piezometers are primarily installed to monitor changes in the potentiometric surface elevation.
Separate-phase Product	A liquid that does not easily dissolve in water. Separate-phase product can be more dense (i.e., DNAPL) or less dense (i.e., LNAPL) than water and, therefore, can be found at different depths in the water column.
Low-permeability Formation	A geologic formation that has very slow recharge and discharge rates due to small pore spaces in the formation material. A clay formation is considered to have low permeability and a very slow recharge rate compared to a more permeable formation, such as sand or gravel.
Surge Block	A disc-shaped or cylindrical device that closely fits the well casing interior and is operated like a plunger below the water table to force water in and out of the well as a well development tool.

Total Depth of Well Distance from the measuring point to the bottom of the well.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

When present, special care should be taken to avoid contact with contaminated groundwater, LNAPL or DNAPL. The use of an air monitoring program, as well as the proper PPE designated by the site-specific HASP, can identify and/or mitigate potential health hazards (special care should be taken when sampling for PFAS. Please refer to Attachment C for details).

1.6 Cautions and Potential Problems

The following cautions or problems may be associated with well development:

- The observed presence of NAPL may warrant alternative goals and objectives for the well other than immediate development. The Project Manager should be contacted for direction on how to proceed.
- Low-yielding wells (e.g., at clay-bedrock interface, tight bedrock formations, etc.) may produce insufficient water to achieve optimal development including parameter stabilization.
- High-yielding wells (e.g., in coarse sand and gravel aquifers) may require the removal of large quantities of water to approach optimal development.
- Long well screens and/or larger diameter wells may require more time and effort to ensure adequate development of the entire interval depending on the development method employed.
- Development of wells should occur from the least-contaminated well to the most-contaminated well, if known.
- Overpumping is not as vigorous as surging and jetting and is probably the most desirable method for the development of new wells. The possibility of disturbing the filter pack is greatest with jetting well development methods, which are generally reserved for redevelopment of clogged extraction or injection wells. Surging or jetting may be preferred methods for supply, recovery, or injection wells (if constructed with metal screens) to achieve higher well efficiencies.
- The introduction of external water or air by jetting may alter the chemistry of the aquifer.
- Surging with compressed air may produce "air locking" in the water-bearing zone, preventing water from flowing into the well.
- Exercise caution with the use of surge blocks in PVC screen and pipe as the well could be damaged.
- Small (2-inch nominal diameter) submersible pumps that will fit in 2-inch diameter well casings are especially susceptible to becoming lodged (stuck) if used in well development applications.
- Prior to sampling a well, sufficient time should be allowed for equilibration with the formation after development. Refer to the governing regulatory agency for guidance regarding the required/recommended time interval between well development and sampling.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Well development will be completed on wells after the grout, annular seals, and protective casings are deemed sufficiently stable (i.e., 24 to 48 hours after installation) for the development method being utilized and/or after required regulatory agency timeframe requirements. Development may be performed immediately after well installation if grout is not used during well installation or if the sealant (i.e., bentonite seal) is above the water table, in accordance with the regulatory requirements. Various well development methods, including surging, pumping, hand bailing, and jetting, are summarized below, followed by step-by-step well development procedures.

2.1 Well Development Methods

<u>Surging Method</u>

Surge and Pump: To increase the effectiveness of well development, the well can be surged and then pumped. Surging may be accomplished in several ways, but essentially water is rapidly forced into and out of a well in a wash and backwash action. One method of surging is to simply turn the pump on for a few minutes and then turn it off for a few minutes. Surging can also be accomplished with a surge block, which is a piston-like device attached to the end of a drill rod or pipe. The block is plunged up and down along the screened interval, similar to a piston in a cylinder, to flush water in and out of the well. Periods of surging are typically followed by a period of water extraction to remove the sediment brought into the well. Surge blocks are best utilized for wells screened in lithologies of medium to high porosities and hydraulic conductivities. Exercise caution with the use of surge blocks in PVC screens which can be damaged by tight-fitting surge blocks.

A surge block method is used alternately with either a bailer or pump, so that materials that have been agitated and loosened by the surging action are removed. The cycle of surging-pumping/bailing is repeated until satisfactory development is achieved.

The surge block, usually attached and operated by a drill rig, is lowered to the top of the well screen and then operated in a surging action with a typical stroke of about three feet. The surging action is usually initiated at the top of the well screen and gradually worked downward through the screened interval so that sand or silt loosened by the surging action cannot cascade down on top of the surge block and prevent removal from the well. The surge block is removed at regular intervals and the fine material that has been loosened is removed by a bailer or pump.

Surging is initially gentle and the energy of the action is gradually increased during the development process. By controlling the speed, length and stroke of the surge block, the surging activity can range from very rigorous to very gentle.

Pumping Method

Pumping develops a well by creating a surging action as a result of variable flow rates. An electric submersible pump or compressed air-operated air displacement pump is installed into the well. The rate of flow is varied at levels adjacent to the well screen.

Overpumping: A simple method of well development is overpumping, where water is simply pumped from the well at a high rate.

Many pumps can also be used to surge a well, employing a similar method as with the surge block. While either off or running, the pump may be plunged up and down along the screened interval, in effect flushing water and sediment in and out of the well and adjacent filter pack.

Hand Bailing Method

Surge and Bail: Instead of a surge block, a bailer can be used in a similar manner since the diameter of the bailer is commonly slightly smaller than the diameter of the well. A water-filled bailer can be plunged up and down, followed by periods of bailing out sediment suspended in the water column. The impact of the bailer as it strikes the surface of the water produces an outward surge of water through the well construction and into the formation. This action tends to break sediment bridges that may have formed during well installation. Movement of water back into the well suspends fine sediments into the water column, which are removed with the bailer.

Bailers are good well development tools for wells screened in low-permeable formations. Deep wells or large purge volume wells should not be developed with bailers, as development with a bailer would be very labor intensive.

Jetting Method

Another method of development is high-velocity hydraulic jetting. Using a specialized jetting tool, jets of water are directed horizontally at the sides of the well from inside the well to loosen fine-grained material and drilling mud residue from the formation. The loosened material is flushed into the well and can be removed through concurrent pumping or by bailing. Caution should be used when using a jetting method of development as there is the possibility of disturbing the well filter pack. For product recovery, a jetting method of development can push product away from the well and can delay or completely prevent product from coming back into the well.

2.2 General Procedures for Well Development

1. The project plan will be consulted regarding any project-specific well development requirements.

2. Consult the well completion diagram and boring log to determine the well construction (well diameter, depth and length of screen), soil core vapor screening results, lithology of the screened interval, and depth to water.

3. If potable water was introduced into the water-bearing zone during well installation, the estimated amount of water lost to the formation during the drilling process should be removed during well development to ensure connection with formation water during the development process.

4. Select the appropriate method and equipment to implement development of the well. Ensure any non-dedicated equipment is clean and decontaminated prior to use and also in between wells. The development equipment should be the appropriate length to reach the entire length of the well screen. The method should be capable of evacuating the development water to the surface and into containers if required.

5. Measure the static DTW and total depth of the well using ECR SOP 004, and determine the amount of standing water in the well (well volume). Record the DTW and calculate the water column volume of the well.

   To calculate the volume of water in the well, the following equation (Equation 1) is used:

   Well Volume (V) = πr^2 h (cf)
   where:
   π = pi (3.14)
   r = radius of well in feet (ft)
   h = height of the water column in ft. [This may be determined by subtracting the DTW from the total depth of the well as measured from the same reference point.]
   cf = conversion factor in gallons per cubic foot (gal/ft^3) = 7.48 gal/ft^3.

   The volume in gallons/linear foot (gal/ft) for common size wells are as follows:

Well Diameter (inches)	Volume (gal/ft)	Volume in Liters
2	0.1631	0.6174
3	0.3670	1.389
4	0.6524	2.470
6	1.4680	5.557

   If the volumes for the common size wells above are utilized, Equation 1 is modified as follows:

   Well volume = (h)(f)
   where:
   h = height of the water column (feet)
   f = the volume in gal/ft

6. Using the appropriate length of dedicated or decontaminated hosing/tubing and the selected pumping apparatus, insert the equipment into the well.

7. Initiate water removal from the well and record the initial water quality measurements including pH, temperature, specific conductivity, DO, ORP and turbidity (as required by project specifications) in the field book or on the Well Development Form. Record any odors, water color/clarity, changes in air monitoring results or other observations in the field book or on the Well Development Form.

8. Optional step to estimate the permeability of the formation: Estimate flow rate of extracted water, in gallons per minute (gpm). The flow rate can be measured with a 5-gallon bucket and stop watch, or timed transfer to any vessel which can be measured. Measure DTW in the well during pumping to derive an estimate of water-level drawdown. Calculate the approximate specific capacity (gpm/ft of drawdown). Tracking the improvement of specific capacity can provide a direct measure of the effectiveness of well development and can determine when development is no longer providing improvement.

9. In general, well development should proceed until the following criteria are met (note: certain regulatory agencies may have more stringent well development requirements):

    a. Water can enter as readily as hydraulic conditions allow.

    b. A representative sample can be collected.

    - In general, representative conditions can be assumed when the water is visibly clear of sediments (e.g., turbidity <10 NTU).
    - In addition to clear water, a further criterion for completed well development is that the other water quality parameters mentioned above stabilize to within 10 percent between readings over one well volume. During well development, pH, specific conductivity, DO, ORP, temperature and turbidity can additionally be monitored to establish natural conditions and evaluate whether the well has been completely developed.

    c. The duration, along with any measured water quality parameters (e.g. pH, temperature, specific conductivity, DO, ORP and turbidity) should be recorded on the Well Development Form.

    In some instances, collection of a sample with a turbidity of 10 NTU or less is difficult or unattainable. If a well does not provide a sediment-free sample, development can stop when all of the following conditions are met:

    - Several procedures have been tried,
    - Proper well construction has been verified,
    - Turbidity has stabilized within 10 percent over three successive well volumes, and
    - Specific conductivity and pH have stabilized over at least three successive well volumes.
      (It should be noted that pH, temperature, and specific conductivity may not stabilize if water quality has been degraded).

    d. The sediment thickness remaining in the well is less than 1 percent of the screen length or less than 0.1 foot for screens equal to or less than 10 feet.

    e. A minimum of three times the standing water volume in the well (to include the well screen, casing, plus saturated annulus, assuming 30 percent annular porosity) should be removed. If water was added as part of the well installation and development, attempts should be made to recover the volume of water added, plus the three well volumes.

10. Measure the total depth of the well, to determine the amount, if any, of sand/silt removed during development of the well.

11. Note the final water quality parameters in the field book or on the Well Development Form. The time between well development and sampling will depend on project objectives and regulatory requirements.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following Quality Assurance/Quality Control procedures apply:

- Operate field instruments according to the manufacturers' manuals.
- Calibrate field instruments at the proper frequency.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

- Record well development measurements on field forms or in a field book. See Attachment A for an example of a Well Development Form.
- The following additional information should be recorded on the field form or in a field book:
  - Well/piezometer or monitoring point identification number
  - Well/piezometer or monitoring point location (sketch of the sample point or reference to a location figure)
  - Date of well installation
  - Date(s) and time of well development
  - Static DTW before and after development
  - Quantity of water removed and initial and completion times
  - Quantity and source of water added to well to facilitate development, if applicable
  - Type and capacity of pump or bailer used
  - Description of well development techniques
  - Visual or sensory description (e.g., odors, product, etc.)
  - Time and date measurements were taken
  - Personnel performing the task
  - Weather conditions during task
  - Other pertinent observations
  - Measurement equipment used
  - Calibration procedures used
  - Decontamination procedures used

6.0 REFERENCES

U.S. EPA *A Compendium of Superfund Field Operations Methods*. EPA/540/P-87/001. December 1987.

U.S. EPA Environmental Response Team, Standard Operating Procedures, *Monitor Well Development*, SOP 2044. October 23, 2001.

U.S. Geological Survey, Guidelines and Standard Procedures for Studies of Ground-Water Quality: *Selection and Installation of Wells, and Supporting Documentation*. Water-Resources Investigations Report 96-4233. 1997.

Ohio EPA, Division of Drinking and Ground Waters, *Chapter 8: Monitoring Well Development, Maintenance, and Redevelopment.* Technical Guidance Manual for Ground Water Investigations. February 2009 (Rev 2).

Sanders, Laura L. *A Manual of Field Hydrogeology*. New Jersey: Prentice-Hall, 1998. pp. 260-261.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	OCTOBER 2013	NOT APPLICABLE
1	AUGUST 2017	ADDED ATTACHMENT C TO ACCOMMODATE MODIFICATIONS REQUIRED WHEN DEVELOPING WELLS WHICH WILL BE SAMPLED FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING

ATTACHMENT A

EXAMPLE WELL DEVELOPMENT FORM

Well Development Form

Project: **Project No.:** **Date/Time:** **Sheet ___ of ___**

TRC Personnel:

Well Identification:

WELL INTEGRITY

	YES	NO
Protect. Casing Secure	☐	☐
Concrete Collar Intact	☐	☐
PVC Stick-up Intact	☐	☐
Well Cap Present	☐	☐
Security Lock Present	☐	☐

PID SCREENING MEAS.

Background	
Well Mouth	

Protective Casing Stick-up (from ground) ______ ft.

Riser Stick-up (from ground) _______ ft.

WELL DIAMETER ☐ 2 inch ☐ 4 inch ☐ 6 inch ☐ ____

WELL MATERIAL ☐ PVC ☐ SS ☐ ____

Well Depth ____ ft. ☐ top of riser ☐ top of casing ☐ ________ ☐ measured ☐ historical

Water Depth ____ ft.

Height of Water Column ____ ft. x ☐ .16 gal/ft (2 in.) ☐ .65 gal/ft (4 in.) ☐ 1.5 gal/ft (6 in.) ☐ __ gal/ft (__ in.)

Volume of Water in Well = _____ gallon(s)

[Vol. = r^2 h(0.163)]

_____ Total gallons purged

FIELD WATER QUALITY MEASUREMENTS

Time									
pH (Std. Units)									
Eh (millivolts)									
Conduct. (µmhos/cm)									
Temp. (C)									
Turb. (NTU)									
DO (mg/l)									
Purge Volume (gal.)									
Estimated purge rate (gpm)									
Static (pre-pumping) Depth to Water (ft)									
Pumping Depth to Water (ft)									
Time									
pH (Std. Units)									
Eh (millivolts)									
Conduct. (µmhos/cm)									
Temp. (C)									
Turb. (NTU)									
DO (mg/l)									
Purge Volume (gal.)									
Estimated purge rate (gpm)									
Static (pre-pumping) Depth to Water (ft)									
Pumping Depth to Water (ft)									

EQUIPMENT USED:

NOTES/COMMENTS:

Signed:______________________

September 2013

ATTACHMENT B

SOP FACT SHEET

WELL DEVELOPMENT

PURPOSE AND OBJECTIVE

Well development is completed to (1) evacuate any water added during the drilling of wells, (2) establish a good hydraulic connection between the well and the surrounding water-bearing zone, (3) settle the sand pack and formation following the disruptive drilling and installation activities, (4) alleviate clogging, smearing or compaction of formation materials at the borehole wall due to the drilling process, and (5) remove fine particles (e.g., silt or clay) from the water column and sand pack in order to obtain groundwater samples that are representative of the water-bearing zone in which the well is installed and/or enhance groundwater extraction and injection rates. State and federal requirements may be above and beyond the scope of this SOP and should be followed, if applicable.

WHAT TO BRING

- Field book or field forms
- Well keys, socket wrench, and device to remove standing water from flush-mount manholes.
- Water level meter and extra batteries
- Water quality meters, including turbidity meter
- Decontaminated pump, control box, power source (i.e., battery, generator, etc.)
- Tubing
- Bailer and cord
- Surge block
- Equipment decontamination supplies
- Indelible marking pens or markers
- Means of containerizing purge water

OFFICE

- Prepare/update the HASP; make sure the field team is familiar with the latest version.
- Review the work plan with the Project Manager and/or the field lead.
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure, test equipment and make sure it is in proper working order.

ON-SITE

- Review the HASP with all field personnel, conduct Health & Safety tailgate meeting.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities, pedestrian traffic etc.)
- Calibrate equipment (if applicable) and record all rental equipment serial numbers in the field book.

GENERAL DEVELOPMENT PROCEDURES

- Well development will be completed on wells after the grout, annular seals, and protective casings are deemed sufficiently stable (i.e., 24 to 48 hours after installation) for the development method being utilized and/or after required regulatory agency timeframe requirements.
- Measure the static water level and total depth of the well using ECR SOP 004, and determine the amount of standing water in the well (well volume). Calculate volume of water in one well volume.
- Using the appropriate length of dedicated or decontaminated hosing/tubing and the selected pumping apparatus, insert the equipment into the well.
- Initiate water removal from the well and record the initial field water quality measurements including pH, temperature, conductivity, DO, ORP and turbidity (as required by project specifications) in the field book or on the Well Development Form. Record any odors, water color/clarity, changes in air monitoring results or other observations in the field book or on the Well Development Form.
- Well development procedures may include surging, overpumping, bailing, and jetting.
- Continue well development procedures until criteria have been met (e.g., turbidity <10 NTU, stabilization of water quality parameters, sediment thickness remaining in well is less than 1 percent of screen length) and a minimum of three times the standing water volume in the well has been removed.

WATER DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

ATTACHMENT C

SOP MODIFICATIONS FOR PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when developing wells where PFAS may be sampled. The following table highlights the required modifications to this SOP when sampling for PFAS.

Well Development Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® or low density polyethylene (LDPE)[1] during well development. This includes bailers, tubing, bailer cord/wire, waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. • High density polyethylene (HDPE) or silicone tubing should be used in lieu of Teflon® or Teflon®-lined tubing. • Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-It Notes during sample handling or mobilization/demobilization. • Do not use potable water for decontamination. Use deionized, distilled or organic-free water. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to procedures: • Tyvek® suits should not be worn during well development prior to conducting PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. PFAS-free rain gear (ponchos and umbrellas) that could be used during sampling can be purchased at IKEA stores. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (*e.g.*, Gatorade®) may be consumed in the staging area only. • Personnel involved with well development should wear powderless nitrile gloves at all times while handling tubing or equipment. Avoid handling unnecessary items with powderless nitrile gloves. A new pair of gloves must be donned prior to developing each well.

Well Development Protocols for PFAS	
SOP Section Number	**Modifications to SOP**
	• Wash hands with Alconox® or Liquinox® and deionized water after leaving vehicle before setting up at a well development location.
1.6	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering the morning of sampling and decontamination field work. • Avoid using sunscreens or insect repellants that are not natural or chemical free.

Notes:

[1] – PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces and, in the case of LDPE tubing, to allow for less turbulent flow along the surface of the tubing.

Title: **Groundwater Monitoring Well Installation**		Procedure Number: **ECR 007**	
		Revision Number: **1**	
		Effective Date: **January 2020**	
Authorization Signatures			
Technical Reviewer James Peronto	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

TABLE OF CONTENTS

Page No.

ATTACHMENTS

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the construction and installation of groundwater monitoring wells. TRC typically employs a drilling subcontractor to perform the actual construction and installation. The SOP conforms to *A Compendium of Superfund Field Operations Methods* (EPA/540/P-87/001) and American Society for Testing and Materials (ASTM) standard D5092, *Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers* (ASTM 2004). A thorough discussion of well design, installation, materials, and potential problems is found in *Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring*, Chapter 10: Design and Installation of Ground-Water Monitoring Wells (Nielsen and Schalla 2006). In general, this SOP conforms to typical practices utilized in the field; project-specific and local or state regulatory requirements should be applied, as needed.

1.1 Scope and Applicability

The objective of a groundwater monitoring well is to provide for the collection of representative groundwater samples and hydrologic data on the target saturated zone. These objectives require that the well be installed and developed (well development is presented in ECR SOP 006) using suitable materials, equipment, and procedures that will best represent the actual hydraulic conditions. Specific monitoring well design and installation procedures depend on project-specific objectives and subsurface conditions. The well construction activity should include consideration of the potential impact on the groundwater quality and measures to rectify that impact to the extent practicable. The following aspects should to be considered prior to well installation:

- Borehole drilling method
- Well construction materials
- Well depth
- Screen length
- Location, thickness, and composition of annular seals
- Well completion and protection requirements

Monitoring well installation will be performed in accordance with the applicable regulatory agency standards and the project-specific work plan. Drilling methods used to pilot the borehole for monitoring well installation will be dependent on the physical nature of the subsurface materials (unconsolidated materials and/or consolidated materials) at the project site.

1.2 Summary of Method

The most common type of monitoring well installations are single-screen, single casing wells designed to monitor one specific interval within the groundwater. Monitoring wells are typically 2 inches (inside) diameter, but may be larger or smaller depending on the project requirements. With direct push technology being used more frequently, 1-inch diameter wells are also frequently used. Monitoring wells most commonly consist of 5 or 10 feet of well screen with an interconnected length of blank well casing that extends to the surface. The annulus between the screen and the formation is filled with a filter pack of appropriately-sized sand depending on the formation material. The annulus between the blank casing and the borehole is filled with an annular seal to the ground surface. A surface completion usually consisting of a traffic-rated well vault or monument that protects the well from damage or unauthorized use is installed at or above the surface.

For more complicated monitoring well installations, such as situations requiring very small screen intervals (such as with fractured rock), open boreholes, or multiple zones of interest, the well design can be modified to suit the application. See Nielsen and Schalla (2006) for additional information on less conventional well installations.

In general, all well materials (other than filter sand, seals, and grout) are typically provided by the manufacturer and are individually plastic-wrapped. If required by the project-specific work plan or at the discretion of the TRC inspector, well materials (other than filter sand, seals, and grout) may be steam-cleaned, rinsed with deionized water, and covered in plastic prior to installation of the well to prevent the introduction of foreign contaminants into the aquifer. Decontamination and bagging can be conducted by the manufacturer, prior to delivery to the site. Furthermore, well construction materials shall be properly stored until use to ensure their good condition and cleanliness.

1.3 Equipment

The following list of equipment may be used during the installation of groundwater monitoring wells. Many of these materials may be supplied by the drilling subcontractor. Specific details on these materials are described in Section 2.2. Site-specific conditions may warrant the use of additional items or deletion of items from the list.

- Appropriate level of personal protection equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator
- Weighted tape measure appropriate to the depth of well
- Well screens with appropriately sized slot openings
- Well casings/risers
- Well end caps
- Centralizers
- Graded sand for filter pack (appropriate for formation and screen slot size)
- Fine-grained sand (for use between filter pack and annular seal)
- Bentonite pellets or granules/chips
- Powdered bentonite
- Type I Portland cement
- Redi-Mix concrete
- Protective surface casing (for aboveground or “stick-up” wells)
- Lockable well cover
- Steel manhole/curb box (for flush-mounted wells)
- Equipment decontamination supplies

1.4 Definitions

Annulus/annular space	The space between the well casing/screen and the borehole wall.
Annular seal	An interval of low-permeability material placed above the filter pack designed to inhibit the flow of water into or through the annulus.
Bentonite	A naturally occurring deposit of volcanic ash that has partially weathered to form an absorbent swelling clay, consisting mostly of montmorillonite.
Bridge(-ing)	An obstruction within the annulus that may prevent circulation or complete installation of annular materials.
Casing – pipe (well casing)	Rigid pipe constructed in threaded or welded sections installed to temporarily or permanently counteract caving of the borehole or to isolate an interval to be monitored.
Casing - protective	A section of larger diameter pipe placed over the uppermost end of a monitoring well riser or casing to provide structural protection to the well and restrict unauthorized access.
Caving (sloughing)	The inflow or collapse of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesive strength, or a detached section of consolidated material is dislodged into the borehole.
Cement (Portland cement)	A mixture of calcareous, argillaceous, or other silica-, alumina-, and iron-oxide-bearing materials that is manufactured and formulated to produce a hardened material when mixed with water. Type I Portland cement as classified by ASTM C150 Standard Specification for Portland Cement is a general purpose cement most commonly used for monitoring wells when the special properties (e.g., sulfate resistance, high early strength, low heat of hydration) specified for other types are not required.
Centralizer	A device that assists in centering the riser pipe and screen in the borehole or casing.
Filter pack (gravel pack; sand pack)	An annular material composed of clean silica sand or sand and gravel of selected grain size and gradation that is placed in the annulus between the screened interval and the borehole wall in a well for the purpose of retaining and stabilizing the formation material.

Flush-threaded	Casing or riser that is threaded and sized in such a manner that the inside and outside diameters are maintained between sections and joints.
Grout	A low-permeability material placed in the annulus between the well casing or riser and the borehole wall (typical well construction), or between the riser and casing, to maintain the alignment of the casing and riser and to prevent movement of groundwater or surface water into the annular space.
Riser	Sections of blank pipe that connect to the well screen and extend to or above the ground surface.
Tamping device	A heavy object attached to a measuring tape, rope or wire used to slip inside the annular space to ensure annular materials are properly placed per the designed depth criteria and to prevent bridging.
Tremie pipe	A tube or string of piping used to convey filter pack and annular seal materials from the ground surface to fill the annulus.
Vented end cap	A covering device that slips over or into the top of the well riser with a hole drilled in it to allow continuous equilibration of the potentiometric surface with the atmospheric pressure.
Well screen	Pipe (typically polyvinyl chloride [PVC] or stainless steel) used to retain the formation or filter pack materials outside of the well. The pipe has openings/slots of a uniform width, orientation, and spacing.

1.5 Health & Safety Considerations

Drilling operations can create a hazardous environment. The potential for injury is fairly high around a drill rig. Level D PPE, including a hardhat, gloves, steel-toed safety shoes, and safety glasses, must be worn at a minimum. Hearing protection is also standard for drilling personnel. Tyvek clothing is recommended when mixing grout. Most well installations are performed with the assistance of the hoist on the drill rig mast as the downhole drill pipe or augers are removed when the well materials are placed. Therefore, TRC personnel must be mindful of the same hazards that apply during drilling. TRC staff should only approach the drill rig if necessary to monitor the breathing zone, confirm depths of materials, or confer with the driller. Before approaching the drill rig, direct eye contact should be made with the driller so they are aware of your presence. The following safety requirements should be adhered to while performing drilling activities:

- The drill rig should not be operated within a minimum distance of 20 feet of overhead electrical power lines and/or buried utilities that might cause a safety hazard. In addition, the drill rig should not be operated while there is lightening in the area of the drilling site. If an electrical storm moves in during drilling activities, the area will be vacated until it is safe to return.

- Serious injuries have occurred while the driller removes casing using a cable and winch. The winch should only be used to move augers or piping – NOT to pull casing, piping or augers from the ground. Use of the drill string is the safest means to pull casing, auger, or piping as the well materials are placed.

- Exposure to potential contaminants can occur from vapors coming from the open boring and from contaminated groundwater being forced out of the boring when grouting.

- While the exposure duration is very low, the dusts from well sand, bentonite, and cement can harm the lungs. Workers should avoid the dust produced when placing the well materials.

- Cement is highly caustic and can irritate the skin. Chemical-resistant gloves should be worn if contact with cement is necessary.

- The bags of sand, cement, and bentonite typically do not require a knife to cut them open. A dull instrument, such as a screwdriver, is sufficient.

- Cutting PVC well casing or screen should be conducted using a PVC cutting tool or hacksaw.

1.6 Cautions and Potential Problems

Well installation is typically conducted by the drilling subcontractor. TRC personnel serve to observe and document the installation and to serve as quality control that the well is installed according to the project specifications. The following cautions or problems may be associated with well installation

- Wells are often specified to be installed as "water table" wells with the screen designed to intersect the top of the water table. The difficulty arises in being able to determine if the water surface as measured in the open borehole will remain the same once the well is installed.

- It is also common that "water table" conditions do not exist due to a confining layer or fractured rock environments. In such cases, the well screen is placed in the producing formation or fracture, and the screen may not intersect the potentiometric surface.

- A well screen should never be placed such that the screen straddles a confining unit, thus connecting two separate aquifer units.

- Flush-mount well constructions require appropriate design to account for vehicular traffic and potential water infiltration into the surface completion among other things. In general, wells with flush-mount completions should not be located in low-lying areas or drainage paths where water influx can be a recurring problem. Appropriate design should consider a drainage layer of sand or gravel with a weep hole so water that accumulates in the vault can drain.

- Aquifer or other pressure conditions at some locations may warrant consideration of a vent hole in the well cap. For flush-mount well completions, a vent hole can provide a means for ambient surface water to enter the well if the if the completion is not designed properly.

Careful consideration should be given to well completion design, including vented well caps, depending on the circumstances at the location.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Monitoring well installation is typically conducted by a subcontractor experienced in such installations following completion of a soil boring. A qualified TRC representative provides oversight and documentation that the well is properly installed. Subcontractor personnel should not be on the site without a TRC representative being present unless specific prior approval has been given by TRC. The TRC representative should prepare a Monitoring Well Installation Form (Attachment A) that documents the well completion details.

2.1 Preparation

Prior to the initiation of field work, the Project Manager or field technical lead (site manager) will secure the services of a qualified drilling contractor. A contract between TRC and the drilling contractor should be executed before mobilization. At a minimum, the drilling contractor must meet the following requirements:

- have the appropriate licenses, registrations and/or certifications for drilling and monitoring well installation in the state in which the work is being conducted,
- have the proper equipment in good operating condition and free of leaks (fuel, hydraulic fluid, lubricants, and similar compounds) available to perform the type of well installation required, and
- have experienced personnel who are OSHA-trained to work on hazardous waste sites.

Before the start of field tasks, the TRC field representative is responsible for coordinating the following items with the drilling subcontractor personnel:

- familiarizing the subcontractor with the objectives of the investigation,
- providing and reviewing a copy of the project-specific work plan with the subcontractor,
- providing and reviewing a copy of the project HASP with the subcontractor,
- determining overhead hazards including power lines, buildings, trees and verifying local/city regulatory requirements if tree roots will be damaged, and
- performing a daily health and safety review with the subcontractor.

Compliance with state and federal requirements is required prior to the installation of monitoring wells. TRC is responsible for ensuring that all required permits have been obtained prior to the start of work. If state regulations require the driller to obtain drilling permits and/or utility clearance approvals, TRC personnel must review the documentation prior to the start of work. This documentation may include, but is not limited to, the following:

- notification and approval to drill/install a monitoring well (access agreement),
- registration or notification of the well installation,
- permit for water withdrawals,
- well abandonment when the project is completed, and
- applicable dig-safe permits or approvals (utility clearance).

Copies of any permits and notification forms must be provided to TRC.

2.2 Materials

Unless approved in writing by TRC, no lubricants or glue shall be used in any manner that could possibly contaminate samples, boreholes, or monitoring wells. The following provides a detailed description of the key features of well installation and how their proper selection and use is necessary to complete an effective groundwater monitoring well.

2.2.1 Well Screens

Monitoring well screens most commonly consist of two-inch diameter, flush-threaded, Schedule 40, PVC, machine-cut, slotted, wire wrap and/or V-wire screen. Up to two-inch or smaller diameter PVC is often used for wells installed using direct-push drilling methods. Four-inch diameter (and larger) wells are most typically used to accommodate larger pumps for groundwater and/or non-aqueous phase liquid (NAPL) recovery – but may also be used for groundwater monitoring. The screen slot size should be selected to retain a minimum of 90% of the filter pack material (see below). The most commonly used slot size is 0.010-inch (0.25 mm) slot openings.

In wells installed at depths greater than 100 feet, Schedule 80 PVC well screens can be used to minimize narrowing of the slots from the increased weight of the riser string. Note that the inside diameter of Schedule 80 riser pipe is slightly smaller than Schedule 40. That difference may cause difficulty when inserting some downhole monitoring equipment or instrumentation.

PVC screens can be adversely affected (typically by weakening or swelling) by concentrations of organic solvents that exceed 25% of the solubility limit. If such subsurface contaminant conditions are possible, the type and concentration of solvent should be researched in more detail prior to well installation. Stainless steel is also a common choice for well screens, but under certain conditions, metals (including iron, nickel, lead, and chromium) have been known to leach from stainless steel screens; in addition, stainless steel screens are costly. Other materials or sizes may be specified in the project-specific work plan as required by site conditions or local regulations.

Manufactured prepacked well screens are commercially available and generally consist of a standard, slotted Schedule 40 PVC well screen pipe (typically 0.5 to 2.0 inch diameter) wrapped in a stainless steel mesh filled with filter sand (typically 20-40 grade silica sand). Additional finer sand pack is commonly added directly above the installed prepack as a grout barrier. Since the sand is packed around the slotted PVC before the well screen is installed, using prepacked screens guarantees that sand will be located directly adjacent to and uniformly around the well screen. Prepacked well screens are typically installed by direct push drilling techniques. The use of prepacked well screens generally makes well installation quicker and more efficient than traditional methods. However, their use for permanent groundwater wells for chemical groundwater quality monitoring should first be verified to determine consistency with project-specific and state regulatory requirements.

2.2.2 Riser and End Caps

Monitoring well riser and end caps will consist of appropriately sized, flush-threaded material compatible with the well screen. Other materials or sizes may be specified in the project-specific work plan as required by site conditions or local regulations. The top cap should be vented to allow the passage of air, unless the well is to be installed at or below the ground surface (i.e., "flush mount well"). In that case, the top of the well should be sealed with an expansion cap/plug or a protective watertight manhole provided to prevent the inflow of storm water runoff into the well.

2.2.3 Filter Pack

A filter pack (also known as "sand pack" or "gravel pack") will be required in any formation other than coarse sand and gravels containing less than 10% fines (silts and clays) by weight. In such formations (i.e. well-to-moderately sorted sands and gravels), a filter pack may not be necessary and the formation can be allowed to collapse around the screen; however, most regulatory guidance requires a filter pack be constructed. The purpose of the filter pack is to inhibit transport of fine-grained formation material into the well screen and stabilize the formation so as to avoid excessive caving/sloughing during installation and development. The introduction of coarser material than the natural formation also results in increasing the effective diameter of the well.

The filter pack material shall be composed of washed, graded, commercially-produced silica sand. Based upon field estimates of grain size distribution of the screened aquifer materials, a sand pack should be selected. A detailed discussion of filter pack determination is found in Nielsen and Schalla (2006). ASTM Standard D5092, *Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers* (ASTM 2004), may also be consulted for further guidance on specifications for sand packs for various conditions. If grain size information is not known for the formation, several sand packs should be available during well construction based upon known or presumed geological information for the site. The most common choice of filter pack sand is 20-40 mesh for 0.010-inch screen slots.

One to two feet of clean, fine sand can be used (required in some states) as a buffer between the annular seal and the filter pack to provide added protection that grout invasion into the filter pack and/or the well screen will not occur. This layer is sometimes referred to as the "secondary filter pack." The sand should be well sorted quartz sand; 40-60 mesh sand is typically used for this purpose.

2.2.4 Annular Seal

An annular seal, typically a minimum of 2 feet thick, is placed above the filter pack and screen to inhibit the boring from serving as a pathway for the vertical movement of water. Without an annular seal, the wellbore annulus can serve to transport contaminants between geologic units (for example, from unconfined to confined aquifer or from the vadose zone to the groundwater). The annular seal will consist of bentonite pellets, chips, granules, or slurry (produced from powdered bentonite). Bentonite swells rapidly when in contact with water. Coated bentonite pellets are preferable in situations where the bentonite must travel through a water column greater than 30 feet, because uncoated pellets may expand and bridge the annulus above the desired depth. Larger bentonite chips may also be used since they also swell at a slower rate than pellets and granules. The selection of the form of bentonite will depend upon the location of the top of the filter pack relative to the water table. If the seal is placed in the vadose zone, the seal will be hydrated with potable water. The volume of water necessary to hydrate the bentonite chips or pellets is dependent on the pellet size, volume of pellets used, and manufacturer's requirements. Granular bentonite is the best choice in situations where the seal is placed in the vadose zone – particularly in arid climates. Other forms of bentonite require longer contact times with water to form an adequate seal. Note that if the seal may be exposed to NAPL, it can shrink and crack. In addition, in situations with total dissolved solids (TDS) concentrations >5,000 parts per million (ppm) or chloride concentrations >8,000 ppm, bentonite will not swell; in these situations, neat cement should be considered as an alternative seal.

2.2.5 Grout

In certain wells, the annular space above the bentonite seal to the ground surface may be grouted with a mixture of 95% Portland cement or equivalent, and 5% bentonite grout, mixed with potable water to the specifications of the concrete manufacturer. This equates to 6 gallons of water added to each 94-pound sack of Type I Portland cement with 3- to 8% powdered bentonite added to improve the workability of the slurry. Bentonite should be prehydrated before adding to the cement to limit clumping. Note that bentonite does not swell considerably when mixed with cement. Grout is generally mixed in a container or barrel using pumps and may include an electric paddle or rotating vane blender.

Note: Grout mixtures may vary based on applicable regulatory requirements or site-specific subsurface conditions.

2.2.6 Surface Protective Casing

The primary purpose of a protective surface completion is to prevent surface water runoff from entering the well, and to prevent unauthorized access to the well. There are two types of protective casings used for surface completions of monitoring wells: (1) the above ground completion and (2) the below ground or flush-mount manhole-type completion, which is typically used in high traffic or public areas where the well could be damaged by equipment or is deemed unsightly.

Above-Ground Completion

An above-grade surface completion (i.e., a well monument) consists of rigid surface casing (typically galvanized or steel coated with rust-proofing or anodized aluminum). The inside diameter of the casing should be at least 2 inches larger than the well casing and be long enough to extend 2.5 to 3 feet above and below the ground surface. The casing is set in the annular seal and/or the surface seal that consists of either concrete (in warm to moderate climates) or bentonite (in cold climates). Bollards are often used around the aboveground surface casing to prevent vehicular damage.

The surface casing shall have a cap with provision for a lock that cannot be easily removed and leave at least 3 to 6 inches of clearance between the top of the well casing and the cap. The base of the casing, at the point where it shall extend above the concrete pad, should have a small weep hole drilled through the casing to prevent the build-up of precipitation or ice between the steel casing and well riser.

Flush-Mount Completion

Flush-mount well completions are generally selected or may be required in areas where vehicular traffic or equipment operation is an important consideration and an above-ground completion may not be a viable option. Depending on the expected activity in the area of the flush-mount completion and the existing surface conditions, the strength and durability of the completion will need to be designed appropriately. An appropriate completion may not be noticed, but a poor completion will generate negative comments with increasing wear and tear. In general, flush-mount completions should be located away from local low areas that drain or accumulate water, if at all possible.

Well completions flush with the pavement or ground surface may be accomplished by various means including the use of well can cylinders or elaborate vaults, and sufficient concrete to stabilize the structure within its surroundings. Regardless of the surface completion, the interior of the flush-mount completion should include the following characteristics: 1) rubber gasket to provide a cover seal; 2) locking capability for well security; 3) drainage management; and 4) sufficient interior space to accommodate any equipment (e.g., dedicated pump) that may be placed in the well.

Flush-mount well completions should provide a minimum of 2 inches of annular space around the outside of the well (i.e., a 6-inch diameter vault for a 2-inch well). The protective steel “skirt” should extent at least 1 foot below the top of the well vault. As most flush-mount wells are installed in paved areas, the concrete used to set the well vault should be compatible with the bearing capacity of the existing pavement. Depending on location considerations, the well completion may be sloped slightly away from the well or completed truly flush with the surroundings. The inside of the manhole annulus should be filled with a drainage layer of sand or gravel with a weep hole so water that accumulates in the vault will drain.

2.3 Monitoring Well Installation

Boreholes to be completed as monitoring wells will be advanced and logged in accordance with ECR SOP 005 (Visual-Manual Procedure for Soil Description and Identification). Equipment used to advance the boring and install the monitoring well will be decontaminated prior to the start of the boring.

All downhole well construction materials (with the exception of the protective casing) should be clean prior to use at the site. In general, all well materials (other than filter sand, seals, and grout) are typically provided individually plastic-wrapped by the manufacturer. If required by the project-specific work plan or at the discretion of the TRC inspector, well materials (other than filter sand, seals, and grout) may be steam-cleaned, rinsed with deionized water, and covered in plastic prior to installation of the well to prevent the introduction of foreign contaminants into the aquifer. Decontamination and bagging can also be conducted by the manufacturer, prior to delivery to the site. Furthermore, well construction materials shall be properly stored until use to ensure their good condition and cleanliness.

2.3.1 Procedures

Monitoring wells will be installed by the drilling subcontractor under the direction of a qualified TRC geologist, environmental scientist, or engineer. Monitoring wells will be installed using the following general procedures which may be dependent on the site-specific requirements.

1. Prior to mobilizing to the site, the construction details of the well to be installed will be provided to the driller, including well identifiers, locations of wells, boring diameter, well materials, screen slot size, screen lengths/depths, riser length, well depths, filter pack materials and depths, annular seal, grouting requirements, and well surface completion requirements.

2. All well materials shall be inspected to ensure that they are new and clean prior to installation.

3. Sections of screen and riser will be threaded together and lowered into the borehole to the predetermined depth. It is preferable to keep the drilling string or temporary casing in the hole while well materials are placed and slowly remove them as the well materials are installed. Centralizers may be used on the well riser in deeper wells to ensure proper well placement within the center of the borehole. Centralizers should not be placed within the location of the annular seal. Once the well is completed, the well cap should have a hole drilled in the top for venting, if possible.

4. The selected well packing materials will be introduced into the annulus in a manner so as to ensure an adequate well pack and seal. Approximately 0.5 to 1.0 foot of filter pack may be placed at the base of the boring to establish a stable base for the well materials. The thickness of each layer of well materials placed in the annulus will be measured with a weighted measurement tape and recorded to the nearest 0.10 foot. The weighted tape may also act as a tamping device to reduce bridging. Augers or casing will be removed sequentially during sand pack installation and the well will remain at the desired depth during auger or casing withdrawal.

   The primary filter pack may be placed using a rigid tremie pipe to minimize the potential for sand bridging in the annulus. The primary filter pack should extend at least 2 feet above the top of the well screened interval. One to 2 feet of fine sand as the secondary filter pack can then be placed above the primary filter pack (if required). However, the height of the filter pack may differ from that specified here due to shallow well depth limitations and project-specific work plan requirements. The secondary filter pack should not extend into a different aquifer unit as the primary filter pack. The depth of each interval of filter pack and volume of material used must be recorded on the Monitoring Well Installation Form and/or the field book.

5. The annular bentonite seal installation technique will vary with the depth of the water table. The appropriate type of bentonite will be selected to suit the objectives of the installation program. The bentonite should be poured slowly into the annular space to minimize

bridging, with periodic tamping. The volume of the annular space should be calculated and compared to the volume of bentonite used as a check to make sure bridging in the annular space has not occurred. If a tremie pipe is used for installation of the annular seal, either coated pellets or slurry should be used because bridging may occur as the bentonite swells. The preferred method of annular seal placement is by using the drilling rods or augers as a conductor casing, except in deep or difficult wells. The annular seal typically ranges from 1 to 5 feet in thickness. Annular seals in wells installed above the water table will be hydrated typically with 10 to 20 gallons (added in 5-gallon increments) of water and allowed to swell prior to the emplacement of a cement-bentonite grout mixture (if the well is to be grouted). In arid or highly permeable formations, the bentonite pellets should be allowed to swell for 1 hour. The high TDS concentration of cement grout does not act to hydrate bentonite, so it is important to allow the bentonite to hydrate fully in water. The level and volume of material(s) used for the annular seal are then recorded on the Monitoring Well Installation Form and/or the field book.

6. Once the annular seal is sufficiently hydrated, a cement-bentonite grout (or other type depending on local regulation) is placed to fill the remaining annulus of the boring. Depending on the depth of the well and water table, the grout may be tremied into the desired location from the bottom up. A side-discharge tremie is preferred so as to not disturb the annular seal. The tremie can remain near the bottom until grouting is completed. Grout requires 8 to 48 hours to set, but it does not become rigid like cement. The grout mixture (percentage of cement to bentonite) will be recorded and will be in accordance with the project-specific work plan or recommended guidance and Section 2.2.5 of this SOP. The grout will be pumped into the boring around the well materials to the surface. If necessary, after solidification of the grout and settling occurs, the grout may need to be topped off with additional grout mixture. The need for additional grout will be based on the intended surface completion for the well. The composition and volume of material(s) used for the grout are then recorded on the Monitoring Well Installation Form and/or the field book.

7. For wells finished above-grade, the protective casing may be cemented in place as described in Section 2.2.6 or completed with grout and bentonite in areas subject to frost heave. The protective casing should be in a plumb position and installed with at least half of the casing below ground and below the frost line (3- to 5 feet below ground surface). The protective casing should have a granular material placed in the base and a weep hole drilled through the casing to allow drainage of water that accumulates in the protective casing. Once completed, the well will be locked and typically allowed to settle for a minimum of 24 hours prior to well development. After well installation, development of a well should occur as soon as reasonably possible to enable representative sampling within the parameters of the project schedule. Some regulatory agencies require minimum timeframes for the newly-installed well materials, such as the bentonite seal or grout column, to cure before initiating well development (e.g., 24 or 48 hours).

   In some instances, a concrete pad is often constructed around wells to provide a working surface and more significant protective surface seal; this concrete pad is required by law in some states. These pads should be a minimum of 4 inches in thickness and are typically a minimum of 2 feet by 2 feet. It is recommended that the concrete pad extend 4 to 6 inches below the ground surface within six inches of the borehole. In areas of traffic or periodic mowing, three or four guard posts ("bumper guards" or bollards) may be positioned around the well to protect the well from equipment. The ground or pad around the well head should be sloped away from the well to promote drainage away from the surface completion. The guard posts consist of 3- to 4-inch diameter steel pipes set 3 to 4 feet outside the concrete pad. The pipes are set at least 3 feet in the ground and are filled with concrete. The well "stickup" and the guard posts should be painted a bright color (typically "safety yellow") for visibility. The type and details of the surface completion should be sketched, photographed or otherwise recorded on the Monitoring Well Installation Form and/or the field book.

8. Depending on the location of the well, flush-mounted utility boxes (i.e., well vaults or manholes) or above-ground, steel, protective casings with locking caps will be used to complete the well. Flush-mount wells should be located outside of areas that accumulate ponded water or areas of runoff, if at all possible, to minimize the potential for well damage by freeze/thaw conditions or for surface water to flow into the completed well.

   The well top should extend a minimum of 4 inches from the bottom of the cement or grout base with sufficient distance to the vault cover to accommodate any equipment (e.g., dedicated pump) that may be placed in the well. The well vault should also include a rubber gasket to make it water tight and is typically tightened with lug bolts.

   Flush-mount well vaults should provide a minimum of 2 inches of free space around the outside of the well (i.e., a 6-inch diameter vault for a 2-inch well). The protective, steel "skirt" should extent at least 1 foot below the top of the well vault. The vault will be sealed in concrete or cement grout that extends 4 to 6 inches away from the vault and extends a minimum of 1 foot below the frost depth. As most flush-mount wells are installed in paved areas, the concrete used to set the well vault should be compatible with the bearing capacity of the existing pavement. The vault should be set slightly higher than the existing grade and the concrete sloped (1- to 2% slope) away from the manhole to promote drainage away from the well. In cold-weather areas where snow removal occurs, the well may have to be set flush with the pavement to avoid damage. The inside of the manhole annulus should be filled with a drainage layer of sand or gravel with a weep hole, so water that accumulates in the vault will drain. Below-grade wells should be fitted with a locking, water-tight friction cap or expandable plug because below-grade wells often fill with water.

9. The wells should be permanently marked with the well identification number either on the cover or an appropriate place (i.e., in concrete pad) that will not be easily damaged and/or vandalized. Keyed-alike weatherproof brass padlocks should be installed on each well casing.

10. The manufacturer, type, weight, and number of bags or other containers of each type of well sand, cement, bentonite, and any other grout materials should be counted and documented on the Monitoring Well Installation Form and/or the field book as a means of determining if the amount used is consistent with the information obtained by the drilling subcontractor.

11. All information concerning well installation details will be recorded on a Monitoring Well Installation Form (examples provided in Attachment A).

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

There are minimal wastes other than general refuse and PPE that is generated during well installation. Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following quality assurance/quality control procedures apply:

- Check well construction materials to ensure these materials conform with the project-specific work plan and project specifications.
- Operate field instruments according to the manufacturers' manuals.
- Calibrate field instruments at the proper frequency, if utilized.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record well installation measurements on field forms or in a field book. See Attachment A for an example of a Monitoring Well Installation Form.

The following additional information should be recorded in the field book and/or Monitoring Well Installation Form:

- Well/piezometer or monitoring point identification number
- Well permit number (if applicable)
- Date of well installation
- Type of drilling method used and model number of rig
- Ground surface elevation (if known)
- Diameter and depth of borehole
- Depth of well bottom
- Depth of top and bottom of screened interval
- Depth of top and bottom of filter pack
- Depth of top and bottom of secondary filter pack (if used)
- Depth of top and bottom of annular seal
- Depth of top and bottom of grout seal
- Type, diameter, length, and screen slot size of well screen
- Type, diameter and length of riser
- Type, diameter, and length of casing (if used)
- Type, gradation, and volume/mass of filter pack
- Type and volume/mass of secondary filter pack (if used)
- Method used for filter pack placement

- Well lock type (i.e., padlock) and key number
- Type and volume of bentonite or other material used for annular seal
- Method used for annular seal placement
- Type, volume, and mix percentages of grout used
- Method used for grout placement
- Source of water used
- Type and length of protective casing
- Type and dimensions of well vault
- Type, number and array of protective posts (if used)
- Type and dimensions of surface completion/seal
- Measurement of "stickup" above or below ground
- Initial depth to groundwater
- Other pertinent observations
- Measurement equipment used
- Decontamination procedures used

6.0 REFERENCES

ASTM. 2004. *Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers*, ASTM Standard D 5092, ASTM, West Conshohocken, PA 2004, pp. 20.

EPA. 1987. *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, US EPA. August 1987.

Nielsen, D.M. and Ronald Schalla. 2006. *Design and Installation of Ground-Water Monitoring Wells*. In Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring. Second Edition. David M. Nielsen ed. CRC Press. Boca Raton, FL. pp. 339 – 805.

7.0 SOP REVISION HISTORY

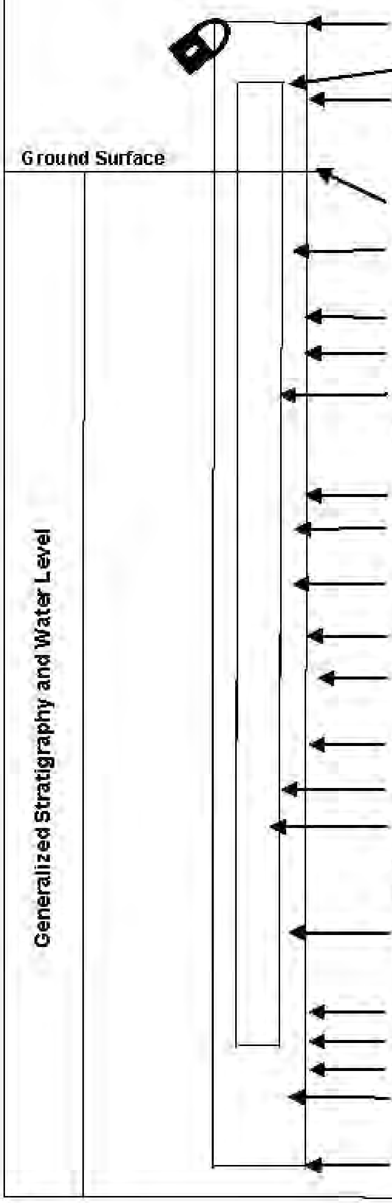
REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	JANUARY 2014	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

ATTACHMENT A
EXAMPLE MONITORING WELL INSTALLATION FORMS

Monitoring Well Construction Summary

TRC — Well ID.

Project: ____________ No.: ____________ Depth to Ground Water: ____________
Client: ____________ Date Completed: ____________ Development Date: ____________
Location: ____________ Development Method: ____________
Boring Contractor: ____________ Method: ____________ Notes:
TRC Geologist: ____________



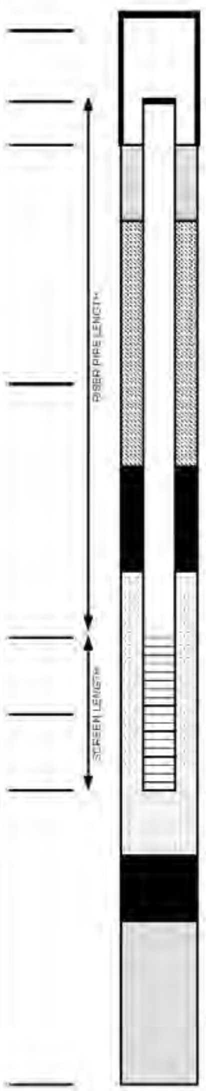
	Height/Depth ( )	Elevation ( )
Top of protective casing:	______	______
Top of riser pipe:	______	______
I.D. of protective casing: ______		
Type of protective casing: ______		
Ground Surface Elevation:	______	______
Type/thickness of surface seal: ______		
Bottom of protective casing	______	______
Borehole diameter: ______		
Riser pipe I.D.: ______		
Type of riser pipe: ______		
Top of grout:	______	______
Type of grout/backfill: ______		
Method of grout/backfill: ______		
Top of seal:	______	______
Type and thickness of seal: ______		
Top of filter pack:	______	______
Elevation/Depth top of screen:	______	______
Type of screen: ______		
Slot size: ______		
I.D. of screen: ______		
Type of filter/sand pack: ______		
Bottom of screen:	______	______
Bottom of well:	______	______
Bottom of filter pack:	______	______
Type of backfill below monitoring well: ______		
Bottom of borehole:	______	______

AF-374 November 2013

WELL CONSTRUCTION DIAGRAM (FLUSH-MOUNT)

PROJ. NAME:		WELL ID:
PROJ. NO:	DATE INSTALLED: INSTALLED BY:	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH /HEIGHT RELATIVE TO GROUND SURFACE (FEET)



0.0 GROUND SURFACE

TOP OF CASING

SURFACE SEAL MATERIAL

SURFACE SEAL

GROUT/BACKFILL MATERIAL

GROUT/BACKFILL METHOD

GROUT

BENTONITE SEAL MATERIAL

BENTONITE SEAL

TOP OF SCREEN

FILTER PACK MATERIAL

BOTTOM OF SCREEN

BOTTOM OF FILTER PACK

BENTONITE PLUG

BACKFILL MATERIAL

HOLE BOTTOM

NOTES:

CASING AND SCREEN DETAILS

TYPE OF RISER: ____

PIPE SCHEDULE: ____

PIPE JOINTS: ____

SCREEN TYPE: ____

SCR. SLOT SIZE: ____

BOREHOLE DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

SURF. CASING DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

WELL DEVELOPMENT

DEVELOPMENT METHOD: ____

TIME DEVELOPING: ____ HOURS

WATER REMOVED: ____ GALLONS

WATER ADDED: ____ GALLONS

WATER CLARITY BEFORE / AFTER DEVELOPMENT

CLARITY BEFORE: ____

COLOR BEFORE: ____

CLARITY AFTER: ____

COLOR AFTER: ____

ODOR (IF PRESENT): ____

WATER LEVEL SUMMARY

MEASUREMENT (FEET)			DATE	TIME
DTB BEFORE DEVELOPING:		T/PVC		
DTB AFTER DEVELOPING:		T/PVC		
SWL BEFORE DEVELOPING:		T/PVC		
SWL AFTER DEVELOPING:		T/PVC		
OTHER SWL:		T/PVC		
OTHER SWL:		T/PVC		

PROTECTIVE CASING DETAILS

PERMANENT, LEGIBLE WELL LABEL ADDED? ☐ YES ☐ NO

PROTECTIVE COVER AND LOCK INSTALLED? ☐ YES ☐ NO

LOCK KEY NUMBER: ____

REVISED 11/2013

TRC WELL CONSTRUCTION DIAGRAM (ABOVE-GRADE)

PROJ. NAME:			WELL ID:
PROJ. NO:	DATE INSTALLED:	INSTALLED BY:	CHECKED BY:

ELEVATION (BENCHMARK: USGS)	DEPTH /HEIGHT RELATIVE TO GROUND SURFACE (FEET)

- ____ TOP OF CASING
- 0.0 GROUND SURFACE
- SURFACE SEAL MATERIAL ____________
- ____ SURFACE SEAL
- GROUT/BACKFILL MATERIAL ____________
- GROUT/BACKFILL METHOD ____________
- ____ GROUT
- BENTONITE SEAL MATERIAL ____________
- ____ BENTONITE SEAL
- ____ TOP OF SCREEN
- FILTER PACK MATERIAL ____________
- ____ BOTTOM OF SCREEN
- ____ BOTTOM OF FILTER PACK
- ____ BENTONITE PLUG
- BACKFILL MATERIAL ____________
- ____ HOLE BOTTOM

NOTES:

CASING AND SCREEN DETAILS

TYPE OF RISER: ____________

PIPE SCHEDULE: ____________

PIPE JOINTS: ____________

SCREEN TYPE: ____________

SCR. SLOT SIZE: ____________

BOREHOLE DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

SURF. CASING DIAMETER: ____ IN. FROM ____ TO ____ FT.
____ IN. FROM ____ TO ____ FT.

WELL DEVELOPMENT

DEVELOPMENT METHOD: ____________

TIME DEVELOPING: ____ HOURS

WATER REMOVED: ____ GALLONS

WATER ADDED: ____ GALLONS

WATER CLARITY BEFORE / AFTER DEVELOPMENT

CLARITY BEFORE: ____________

COLOR BEFORE: ____________

CLARITY AFTER: ____________

COLOR AFTER: ____________

ODOR (IF PRESENT): ____________

WATER LEVEL SUMMARY

MEASUREMENT (FEET)			DATE	TIME
DTB BEFORE DEVELOPING:		T/PVC		
DTB AFTER DEVELOPING:		T/PVC		
SWL BEFORE DEVELOPING:		T/PVC		
SWL AFTER DEVELOPING:		T/PVC		
OTHER SWL:		T/PVC		
OTHER SWL:		T/PVC		

PROTECTIVE CASING DETAILS

PERMANENT, LEGIBLE WELL LABEL ADDED? ☐ YES ☐ NO

PROTECTIVE COVER AND LOCK INSTALLED? ☐ YES ☐ NO

LOCK KEY NUMBER: ____________

REVISED 11/2013

ATTACHMENT B
SOP FACT SHEET

GROUNDWATER MONITORING WELL INSTALLATION

PURPOSE AND OBJECTIVE

The objective of a groundwater monitoring well is to provide for the collection of representative groundwater samples and hydrologic data at the target saturated zone. These objectives require that the well be installed and developed (well development is presented in ECR SOP 006) using suitable materials, equipment, and procedures that will best represent the actual hydraulic conditions.

WHAT TO BRING

- Personal protection equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator
- Weighted tape measure
- Equipment decontamination supplies

OFFICE PREPARATION

The TRC field representative is responsible for coordinating the following items with the drilling subcontractor personnel:

- Providing and reviewing a copy of the project-specific work plan and HASP.
- Verifying that buried utility clearance notifications/approvals have been completed. Obtain notification date and number.
- Verifying that all required permits have been obtained prior to the start of work.
- Copies of any permits and notification forms must be obtained by TRC.

ON-SITE PREPARATION

- Conduct daily Health & Safety tailgate meetings, as appropriate.
- Verify that underground utilities have been marked out and that the mark outs are clear. Identify if any overhead obstructions or limited access areas exist near proposed borings.
- Verify that appropriate PPE is worn by all personnel and work area is safe (e.g., utilize traffic cones; minimize interference with on-site activities etc.).

GENERAL MONITORING WELL INSTALLATION PROCEDURES

Monitoring wells shall be installed by a drilling subcontractor under the direction of a qualified TRC geologist, environmental scientist, or engineer. The TRC representative should prepare a written record of the monitoring well installation. Monitoring wells will be installed using the general procedures presented in the SOP and any site-specific work plan which may be dependent on the site- or location-specific requirements. A summary of various acceptable well construction materials is presented in the SOP. The following summarizes several key aspects of monitoring well installation procedures.

- All well materials shall be inspected to ensure that they are new and clean prior to installation.
- Once the well is completed, the well cap should have a hole drilled in the top for venting, if possible.
- The thickness of each layer of well materials placed in the well annulus should be measured with a weighted measurement tape and recorded to the nearest 0.10 foot.
- The appropriate type of bentonite seal should be selected to suit the objectives of the installation program.
- The bentonite seal material should be poured slowly into the annular well space to minimize bridging, with periodic tamping. The volume of the annular space should be calculated and compared to the volume of bentonite used as a check to make sure bridging in the annular space has not occurred. If a tremie pipe is used for installation of the annular seal, either coated pellets or slurry should be used because bridging may occur as the bentonite swells.
- Grout mixtures may vary based on applicable regulatory requirements or site-specific subsurface conditions. Depending on the depth of the well and water table, the grout may be tremied into the desired location from the bottom up. Grout requires 8 to 48 hours to set, but it does not become rigid like cement.
- The ground or pad around the well head should be sloped away from the well to promote drainage away from the surface completion.

GROUNDWATER MONITORING WELL INSTALLATION

- Flush-mount wells should be located outside of areas that accumulate ponded water or areas of runoff, if at all possible, or constructed to minimize the potential for well damage by freeze/thaw conditions or for surface water to flow into the completed well.
- Completed wells should be permanently marked with the well identification number either on the cover or an appropriate place (i.e., in concrete pad) that will not be easily damaged and/or vandalized. Keyed-alike weatherproof brass padlocks should be installed on each well casing.
- All information concerning well installation details should be recorded on a Monitoring Well Installation Form (examples provided in Attachment A of SOP).

WASTE DISPOSAL

There are minimal wastes other than general refuse and PPE that are generated during well installation. Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

DATA MANAGEMENT AND RECORDS MANAGEMENT

Record well installation measurements on field forms or in a field book. See Attachment A of the SOP for an example of a Monitoring Well Installation Form.

DOS AND DO NOTS OF MONITORING WELL INSTALLATION

DOs:

- DO have the following items when going into the field:
  - Site-specific work plan
  - Site-specific HASP
  - PPE (e.g., steel-toed safety boots, hard hat, gloves)
  - Field book and indelible black ink, ball-point pens or markers
- DO review existing soil boring logs, groundwater contour maps, or geologic cross sections, if available.
- DO have the telephone numbers for the driller, testing laboratory, vehicle rental and equipment rental providers readily available while in the field.
- DO call the Project Manager or field team leader if unexpected conditions are encountered or at least daily to update them.
- DO check well construction materials to ensure the materials conform with the work plan and project specifications.
- DO inspect all well materials to ensure that they are new and clean prior to installation.
- DO document the manufacturer, type, weight, and number of bags or other containers of each type of well sand, cement, bentonite, and any other well materials used.
- DO make sure that the wells are permanently marked with a well identification number.
- DO make sure the completed well cover is securely locked.
- DO mark the location on the top of the well casing from which water level measurements are obtained following well completion.

DO NOTs:

- DO NOT sign anything in the field unless authorized in writing by client. This includes waste disposal documentation, statements, etc; call the Project Manager if there is an issue.
-

Title: **Groundwater Sampling**	Procedure Number: **ECR 009**
	Revision Number: **3**
	Effective Date: **January 2020**

Authorization Signatures

Technical Reviewer	Date	Environmental Sector Quality Director	Date
Darby Litz	1/1/20	Elizabeth Denly	1/1/20

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Page No.

ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to provide TRC personnel with general guidance in performing groundwater sampling activities. This SOP details equipment and sampling procedures for low-flow sampling, multi-volume purge sampling and passive diffusion bag sampling from monitoring wells. Various regulatory agencies and project-specific work plans may have specific requirements (e.g., equipment/instrument, flow rate, etc.) that may be applicable and take precedence, depending on the program.

The objective of groundwater sampling is to obtain a representative sample of water from a saturated zone or groundwater-bearing unit (i.e., aquifer) with minimal disturbance of groundwater chemistry. This requires that the sample being collected is representative of groundwater within the formation surrounding the well bore as opposed to stagnant water within the well casing or within the filter pack immediately surrounding the well casing.

1.2 Summary of Method

There are three general approaches to groundwater purging/sampling that can be used to obtain a representative groundwater sample for analysis: 1) the low-flow or micropurge method where the mixing of the stagnant water is minimized using low-flow pumping rates during the collection of the groundwater sample; 2) the multiple well volume removal approach in which the stagnant water is removed from the well and the filter pack prior to sample collection; and 3) the passive sampler procedure where water quality equilibration with the surroundings is achieved through deployment of the passive sampler for a sufficient amount of time prior to sampling.

For low-flow and multiple well volume removal, there are various types of equipment available to perform groundwater sampling. The most common of these are the submersible pump, peristaltic pump, and bailer. However, the equipment selected and the purge method used, if any, will depend on project goals, data quality objectives (DQOs), hydrogeologic conditions, and regulatory requirements. Care should be taken when choosing the sampling procedures and device(s), as some procedures have the potential to affect the representativeness of the sample more than others. For repeated monitoring events, the sampling methodology and operating equipment employed should be consistent to minimize potential variability due to sampling procedures. The type of sampling method utilized is dependent upon site-specific conditions and it is not within the scope of this document to recommend a specific methodology. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment D for further details. Information on applicability of sampling methods can be found on Interstate Technology & Regulatory Council (ITRC) and United States Environmental Protection Agency (EPA) websites.

1.3 Equipment

The following equipment is commonly used to collect groundwater samples from a monitoring well. Site-specific conditions may warrant the use of additional equipment or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)
- Electronic water level indicator capable of measuring to 0.01 foot accuracy
- Oil/water interface probe
- Extra batteries for water level/interface probe
- Submersible pump with low-flow capabilities (less than 1 liter/min) constructed of inert materials (e.g., stainless steel and Teflon®), such as a bladder pump (with sufficient quantity of bladders, o-rings, grab plates, etc.)
- Peristaltic pump
- Source of power for use with submersible or peristaltic pump (e.g., 12-volt battery, compressor, generator, compressed gas tanks, etc.)
- Flow controller for use with submersible pump (varies depending on type of pump used)
- Bottom-filling bailer constructed of inert materials (i.e., polyethylene, polyvinyl chloride [PVC], stainless steel or Teflon®)
- Bailer cord or wire (recommended Teflon®-coated, stainless steel cable; bailer wire; or contaminant-free rope with a Teflon®-coated stainless steel leader to connect bailer and rope)
- Tubing (Teflon®, Teflon®–lined polyethylene, or high density polyethylene [HDPE], type dependent upon project objectives)
- Silicone tubing (only used for peristaltic pump head and/or flow-through cell connections)
- Water quality meter(s) capable of measuring parameters, such as pH, temperature, specific conductivity, oxidation-reduction potential (ORP), and dissolved oxygen (DO)
- Flow-through cell
- T-connector
- Turbidity meter
- Passive sampling device (and any device-specific accessories)
    - Passive diffusion bags (PDBs)
    - Tether (stainless steel cable or marine-grade polyethylene rope), well cap, and weights, unless already installed
    - Funnel (Fill kit)
    - PVC cable ties
    - Tool to cut cable ties
    - PVC discharge tubes
    - Tether reel
- Well lock keys
- Bolt cutters

- Appropriate tools for equipment and to open well box (e.g., socket wrench, pry bar, etc.)
- Containers with lids for purge water (i.e., 5-gallon buckets, drums, etc.)
- Stopwatch or timer
- Graduated measuring container appropriately sized to measure flow rate
- Sample bottle labels
- Laboratory-grade water (can request from lab – for equipment blanks)
- Chain-of-custody (COC) forms
- Sample cooler(s)
- Photoionization detector (PID) or flame ionization detector (FID) for well head monitoring
- Sample containers (may be supplied by the laboratory depending upon the regulatory program): The proper containers should be determined in conjunction with the analytical laboratory in the planning stages of the project. If not included in sample containers provided by laboratory, sample preservatives will need to be kept with sample containers, and added to sample containers prior to sample collection.
- Field book and/or Groundwater Field Data Record (multiple copies)
- Filtration equipment
- In-line filter (0.45 micron [µm]) or as otherwise required by the project-specific work plan.
- Bubble wrap/Bubble wrap bags
- Lint-free, non-abrasive, disposable towels (e.g., Kimwipes®)
- Indelible marking pens
- Plastic bags (e.g., Ziploc®)
- Ice
- Teflon® tape
- Plastic sheeting or large trash bags which can be cut open
- Umbrella, tent, or equivalent for shading equipment (particularly the flow-through cell) from sunlight or blocking rain
- Equipment decontamination supplies
- Container for bailing water out of water-logged road boxes or well vaults
- Map of well locations and well construction data
- Copy of field notes from previous sampling event for reference
- Project-specific work plan

1.4 Definitions

Bailer — A cylindrical device suspended from a rope or cable, which is used to remove water, non-aqueous phase liquid (NAPL), sediment or other materials from a well or open borehole. Usually equipped with some type of check valve at the base to allow water, NAPL, and/or sediment to enter the bailer and be retained as it is lifted to the surface. A bailer may be made in varying diameters; however a bailer that fits in a two-inch well is the most common. In some instances a < 1-inch diameter bailer (a.k.a. pencil bailer) is used for small diameter wells.

Borehole — A hole drilled into the soil or bedrock using a drill rig or similar equipment.

Dense Non-aqueous Phase Liquid (DNAPL) — Separate-phase product that is denser than water and, therefore, sinks to the bottom of the water column.

Depth To Water (DTW) — The distance to the groundwater surface from an established measuring point.

Drawdown — The response to purging/pumping a well resulting in the lowering of groundwater within the water column in the well or in a water-bearing zone.

FID — An instrument that uses a flame to break down volatile organic compounds (VOCs) into ions that can be measured.

Flow-Through Cell — The container used to immerse the multi-parameter probes in well purge water during pre-sampling well purging. The flow-through cell is usually made of transparent acrylic and is connected to the end of the discharge tubing creating an in-line, sealed container in which purge water circulates around the measurement probes. The discharge from the pump prior to the flow-through cell may be fitted with a check valve or T-connector for collection of water for turbidity measurement.

Flush Mount — The type of well completion where the riser terminates at or below grade. Flush-mounted wells are typically completed with a “curb box” which is an “at-grade” enclosure designed to protect the well riser.

Light Non-aqueous Phase Liquid (LNAPL) — Separate-phase product that is less dense than water and therefore floats on the surface of the water.

Monitoring Well	A well made from a PVC pipe, or other appropriate material, with slotted screen installed across or within a saturated zone. A monitoring well is typically constructed with a PVC or stainless steel pipe in unconsolidated deposits and with steel casing in bedrock.
PID	An instrument that uses an ultraviolet light source to break down VOCs into ions that can be measured.
Piezometer	A well made from PVC or metal with a slotted screen installed across or within a saturated zone. Piezometers are primarily installed to monitor changes in the potentiometric surface elevation.
Potentiometric Surface	A surface representing the hydraulic head of groundwater.
Protective Casing	The pipe installed around the well riser that sticks up from the ground (above-grade completions) or is flush with the ground (at-grade completions, e.g., curb box) in order to protect the well integrity. Protective casings are typically constructed of steel or aluminum and usually closeable with a locking cover/hasp to maintain well integrity between sampling events.
Recharge Rate	The rate at which groundwater returns to the water column in the well.
Separate-Phase Product	A liquid that does not easily dissolve in water. Separate-phase product can be more dense (i.e., DNAPL) or less dense (i.e., LNAPL) than water and, therefore, can be found at different depths in the water column.
Static Water Level	Level at which water resides in a well when the water level is at equilibrium with atmospheric pressure.
Well Cover	The cap or lid constructed at the end of the protective casing (above-grade completions) or flush-mounted curb box (ground surface completions) to secure access to the well. Well covers for stick-up wells are often equipped with a hasp to accommodate a padlock. Well covers for flush-mounted road boxes or vaults are opened and closed using a threaded bolt.
Well Filter Pack	A material composed of clean silica sand or sand and gravel of selected grain size and gradation that is placed in the annulus between the screened interval and the borehole wall in a well for the purpose of retaining and stabilizing the formation material.

Well Plug/Expansion Plug	The plug fashioned into a cap placed into the top of the well riser (e.g., J-Plug). Well plugs are usually designed with an expandable gasket that is activated by turning a locking wing nut or removable key latch, closing a snap cap or engaging a magnetic clutch cap to seal the well riser.
Well Riser	Sections of blank (non-slotted) pipe that extend from the well screen to or above the ground surface.
Well Screen	Pipe (typically PVC or stainless steel) used to retain the formation or filter pack materials outside of the well. The pipe has openings/slots of a uniform width, orientation, and spacing. The openings/slots can vary based on formation and filter pack material specifications.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

The well head should be pre-screened using a PID/FID to avoid inhalation of contaminants venting from the well. If monitoring results indicate sustained elevated concentrations of organic contaminants, the level of PPE may need to be increased in accordance with the HASP or work could be conducted upwind of the well.

When present, special care should be taken to avoid contact with LNAPL or DNAPL. The use of an air monitoring program, as well as the proper PPE designated by the site-specific HASP, can identify and/or mitigate potential health hazards.

Implementing this SOP may require the use of reagents and/or compressed gases for the calibration and operation of field equipment. These substances may be hazardous and TRC personnel must appropriately handle, store, and dispose of them at all times. Skin contact with liquid from preserved sample bottles must be avoided as they may contain strong acids or bases. When filling bottles pre-preserved with acid (e.g., hydrochloric acid, nitric acid, sulfuric acid), vapors may be released and should not be inhaled. Do not allow bottles with acid to be exposed to elevated atmospheric temperatures or sunlight as this will facilitate fumes from the acids.

1.6 Cautions and Potential Problems

The following sections highlight issues that may be encountered and should be discussed with the Project Manager prior to mobilization into the field. Special care should be taken when sampling for PFAS. Please refer to Attachment D for details.

1.6.1 Pre-Sampling Issues

(a) Selection of equipment for groundwater sampling should consider multiple factors, including: DTW, well specifications (e.g., depth and length of well screen intervals), desired flow rate, possible weather conditions, type and concentration of contaminant(s), and remoteness/accessibility to the site. The benefits and limits of each type of groundwater sampling equipment should be fully reviewed during project planning or prior to mobilization if the project-specific work plan does not identify the required equipment. For example, peristaltic pumps are incapable of withdrawing water in wells in which the depth to water is greater than approximately 20-25 feet below ground surface (bgs).

(b) If the screen or open borehole is greater than 10 feet in length, consult the project-specific work plans for the target sampling interval. Generally, pumps are either placed in the middle of the saturated zone if the water level is below the top of the screen or in the middle of the screen interval if the water level is above the top of the screen.

(c) The need for redevelopment of the monitoring wells should be evaluated periodically in accordance with the project-specific requirements. This is assessed by comparing the measured total depth of the well with the constructed depth. If the measured depth is less than the constructed depth, this may indicate siltation of the well and/or the presence of an obstruction in the well. If it is determined that redevelopment is necessary, it should be performed in accordance with ECR SOP 006, *Well Development.* The time necessary for a well to restabilize after redevelopment will be determined on a project-specific basis and may depend on regulatory requirements.

(d) During the total well depth measurement, there is the potential for sediment, if present at the bottom of the well, to be disturbed, thereby increasing the turbidity of the groundwater. Therefore, the total well depth measurement should be collected the day prior to collecting groundwater samples, if possible.

(e) Use caution if using compressed gas cylinders (e.g., nitrogen, carbon dioxide) for purging/sampling of groundwater. Check for leaks around regulator connections by spraying soapy water on the connections. If a leak is discovered, the connection to the regulator should be disassembled, wrapped with Teflon® tape, and reconnected to the cylinder. If the leak continues, the regulator should be replaced. It should be noted that Department of Transportation (DOT) regulations apply to the transportation and handling of compressed gas cylinders (see 49 Code of Federal Regulations [CFR] 171). Never transport cylinders with the regulator attached. Replace the cylinder valve cover on the compressed gas cylinder before transport.

(f) All field personnel must be made aware of the water level measurement reference point being used for each well at a site (i.e., must be clearly marked) in order to ensure collection of comparable data between events.

(g) Bolt cutters may be necessary to remove rusted locks. Dipping rusted locks in a soapy solution may help with opening difficult locks. Oils and other products containing VOCs (e.g., WD-40) should not be used on locks as these compounds may cause contamination of water samples collected at the well. Replace cut locks and note in the field book.

(h) Prior to accessing the well, physical conditions around the well head should be assessed for situations that might result in cross-contamination or the introduction of foreign material/debris into the well. For example, flush-mounted wells may have water or road sand/salt/debris inside the curb box. Rodents and insects (e.g., bees, wasps) have been known to construct nests within the protective casing of a well. If bees, wasps, or other insects are encountered, insecticides should be used with caution as the chemicals may cause contamination of water samples collected at the well. If water or foreign material is introduced into the well, the Project Manager should be immediately notified.

1.6.2 General Purging and Sampling Issues

(a) Prior to installation of a submersible pump into a well, ensure that the tubing is properly sealed to the pump to avoid losing the pump down the well and to prevent escape of air or water from the pump, which could result in poor pump performance and the aeration of the well water. Do not do this by tugging on tubing. Never lower pumps into the well using only tubing; instead a security line attached to the pump is required to prevent potentially losing the pump down the well.

(b) A submersible pump should not be lowered to the bottom of the well to avoid stirring up any sediment at the bottom of the well and prevent getting the pump stuck (fine sediment accumulation in the bottom of the well can create a strong suction with a flat bottom pump such as a bladder pump, which may require jetting to retrieve the pump).

(c) Start with the lowest pumping rate possible and increase until a sustainable rate is reached. Avoid high pumping rates (> 1 liter/min), as this could lead to damage of the well filter pack, if present. Where practical and/or possible, refer to previous sampling events to establish consistent flow rates.

(d) Some regulatory agencies may have concern about the use of peristaltic pumps when sampling for VOCs due to the potential for loss of VOCs during sampling and alteration of other water quality parameters such as pH and alkalinity. Samplers should review the requirements in the project-specific work plan and/or regulatory guidelines prior to performing the work. Explicit approval to use a peristaltic pump for the collection of VOCs may be required by the governing regulatory agency. An option may be to use the "soda straw" method to collect the VOC sample which does not allow the water to go through the pump head:

  (1) After purging the well with the peristaltic pump, collect all fractions except VOCs from the outlet side of the pump (i.e., VOCs will be collected last instead of first).
  (2) Turn the pump off.
  (3) Change into clean gloves.
  (4) Disconnect the tubing coming out of the well from the inlet side of the pump and immediately put a finger over the end of this tubing to prevent water from draining out of the tubing.
  (5) Retrieve tubing from the well, coiling it in one hand as it is being retrieved (maintain finger over end of tubing).
  (6) Open VOC vials. Briefly remove finger from end of tubing to allow water to flow into vial. Replace finger on end of tubing to stop flow. Do this for remaining VOC vials.

(e) In the event that a well cannot be purged and sampled with a pump, the alternative to pumping may be the use of a bottom-filling bailer. The applicable regulatory agency requirements and the Project Manager should be consulted if in doubt about the appropriateness of using a bailer at a site or during a particular sampling event.

(f) During purging and sampling, the tubing should remain filled with water to minimize possible changes in water chemistry due to contact with the atmosphere. All flow-through cells should be shaded from direct sunlight to minimize the potential for off-gassing and temperature fluctuations.

(g) Ensure monitoring instruments (i.e., multi-parameter water quality instrument, turbidity meter, water level measuring device) are maintained in good condition and properly calibrated to ensure accurate readings. Be sure to have appropriate-sized extra batteries on hand.

(h) Adverse weather conditions may present challenges that need to be dealt with on a case-by-case basis. For example, air temperatures below 32°F may cause ice formation in the tubing, flow-through cell, and on the sampling equipment, or heavy rain could cause standing water issues with flush-mounted wells. Heavy rain can also impact electronic sampling equipment; preventative measures should be taken to keep electronic equipment dry.

(i) Observe and avoid any uncontrolled ambient/surrounding air conditions that could affect analytical results (e.g., truck/vehicle exhaust nearby, industrial building vents). Always ensure that vehicles are turned off during sampling to avoid introducing vehicle exhaust into the sample. If uncontrolled ambient/surrounding air conditions cannot be avoided, contact the Project Manager for further instruction; collection of a field blank sample may be warranted in this situation.

(j) Procedures should be established to minimize potential cross-contamination. For example:

- Wrap monitoring and sampling equipment with protective material (e.g., aluminum foil, polyethylene sheeting, Ziploc® bags) after decontamination and between sampling locations to minimize the potential for cross-contamination between well purging events at different locations.
- Use dedicated or disposable sampling equipment or new tubing at each sampling point when appropriate to minimize the need for decontamination.
- Protect sampling equipment and/or the open well head from blowing soil and dust by covering with plastic sheeting as needed.
- If a bailer and rope are used to purge and/or sample the well, then there is the possibility of contamination from the rope used to lower the bailer. New or dedicated rope should be used when appropriate. Alternatively, a decontaminated, Teflon®-coated stainless steel leader can be attached between the rope and the bailer. The leader acts as an extension to the rope and allows for the top of the bailer to enter the water column without immediately placing the rope into the water. It is important to keep the rope clean and not allow contact with the ground surface during bailing.

(k) Disposal of the groundwater collected during purging must be performed in accordance with all applicable regulations and the project-specific work plan.

(l) Clear tape should not be used to cover labels on containers used for certain analyses (e.g., 40-mL vials for VOC analysis) due to potential interference with analytical equipment.

(m) In cases where it is difficult to obtain sufficient sample volume for multiple analytical fractions as well as required quality control (QC) analyses (*e.g.*, field duplicates, matrix spike/matrix spike duplicate [MS/MSD] analyses), discuss this situation with the Project Manager and laboratory prior to sample collection. Laboratories can often "make do" with less volume, especially for inorganic parameters, or increase the reporting limit proportional to the sample volume obtained.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

Procedures for collecting groundwater samples from monitoring wells are described below. The project-specific work plan should also be consulted for specific details regarding sampling.

Sampling should always begin at the monitoring well with the least contaminated groundwater and systematically proceed to the well with the most contaminated groundwater, if possible.

2.1 Pre-sampling Activities

(a) It should be determined if there is the requirement to determine static water level measurements on all wells at the site prior to sampling, regardless if the well is being sampled.

(b) Prior to field activities, review historical groundwater sampling logs (if available) to maintain consistency for the current sampling event (e.g., equipment type, pump intake depth setting, flow rate, etc.)

(c) Organize monitoring, purging, and sampling equipment taking care not to allow cross-contamination. This can be accomplished by laying new polyethylene sheeting near the well or using new buckets, etc.

(d) Calibrate (or perform a calibration check on) all field monitoring equipment on the same day before collecting groundwater samples. Refer to TRC SOPs and manufacturer's equipment calibration instructions. A calibration check may also be required during or at the end of each sampling day. Consult the project-specific work plan.

(e) Unlock the well cover on the well.

(f) Record the sample location, time, and date in the field book and/or on the Groundwater Field Data Record.

(g) On the Groundwater Field Data Record, note the physical condition of the well, including damage, deterioration, and signs of tampering, if any. Collect photographic documentation of serious damage to present to the Project Manager.

(h) Open the well cap and expansion plug, and stay upwind of and not directly over the well. Note any unusual odors, sounds, or difficulties in opening the well and, if required, measure the organic vapor reading at the rim of the well with a suitable organic vapor screening device (e.g., PID or FID), and record the reading in the field book and/or on the Groundwater Field Data Record. If pressure or vacuum is noted or suspected in the well, allow sufficient time for the water level elevation in the well to equilibrate.

(i) Gently lower a clean, decontaminated water level measuring device into the well to determine the static water level. If appropriate for site conditions, check for the presence of LNAPL or DNAPL using an oil/water interface probe (refer to ECR SOP 004, *Water Level and Product Measurements*). If LNAPL or DNAPL is detected, contact the Project Manager before proceeding with purging and sampling activities. Record the information on depth to groundwater to the nearest 0.01 feet, depth to LNAPL or DNAPL, and/or thickness of NAPL in the field book and/or the Groundwater Field Data Record. Refer to ECR SOP 004, *Water Level and Product Measurements*, for proper procedures in performing these measurements.

(j) If required in the project-specific work plan, measure the depth to the bottom of the well to assist in calculating the well volume of the well. If possible, avoid making total well depth measurements on the same day as sampling due to the tendency to disturb sediment during this measurement. If NAPL is suspected, use a decontaminated oil/water interface probe. If the measured depth is less than the constructed depth, this may indicate that the well needs to be redeveloped (see ECR SOP 006, *Well Development*). Consult the project-specific work plan or Project Manager for further instructions.

2.2 Groundwater Purging Activities

Purging is conducted to ensure that representative groundwater is obtained from the water-bearing unit for analysis. The multiple-volume or low-flow purging approach may be used to remove water from the well and monitor the water in order to determine when a well has been adequately purged (i.e., stabilized); at a minimum, the pH, specific conductance and temperature of the groundwater removed during purging should be monitored and recorded in the field notes. Other parameters may be required in some regulatory jurisdictions (e.g., turbidity). Additionally, the purge volume should be monitored and recorded. In some instances, such as when monitoring at solid waste disposal facilities, simply removing an adequate volume of water (e.g., three well volumes) may be suitable for adequate purging, and sampling can commence. Check with the project-specific work plan and appropriate regulatory guidance to determine any specific purging requirements.

If the well has been previously sampled consistent with this SOP, then the prior purging strategy (e.g., method, pump intake depth and the flow rates) should be followed during subsequent sampling events to maintain consistency and minimize potential variability due to the sampling procedure.

2.2.1 Multiple-Volume Purging Approach

The multiple-volume purging approach is typically performed using bailers or submersible or peristaltic pumps. In the multiple-volume purging approach, there are two measurements used to determine adequate purge volume removal prior to sample collection: 1) purge volume and 2) field parameter stabilization. The field parameters should be recorded at regular volumetric intervals. There are no set criteria for establishing how many total sets of measurements are adequate to document stability of parameters. If the calculated purge volume is small, the measurements should be taken frequently enough (e.g., every 3 to 5 minutes) to provide a sufficient number of measurements to evaluate stability. If the purge volume is large, measurements taken every 15 minutes may be sufficient.

<u>Purge Volume</u>
Prior to purging a well, the amount of water inside the well riser and well screen (i.e., water column) should be determined, if possible. To do this, the diameter of the well should be determined and the water level and total depth of the well should be measured and recorded. The specific methodology for obtaining these measurements is included in ECR SOP 004 *Water Level and Product Measurements.*

Once this information is known, the well volume can be calculated using Equation 1:

Well Volume (V) = πr^2 h (cf) **Equation 1**

where:
π = pi (3.14)
r = radius of well in feet (ft)
h = height of the water column in ft. [This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
cf = conversion factor in gallons per cubic foot (gal/ft^3) = 7.48 gal/ft^3.

The volume in gallons/linear foot (gal/ft) and liters/linear foot (L/ft) for common-size wells are as follows:

Well Inside Diameter (inches)	Volume (gal/ft)	Volume (L/ft)
1	0.0408	0.1529
2	0.1631	0.6174
3	0.3670	1.3892
4	0.6524	2.4696
6	1.4680	5.5570

If the volumes for the common-size wells above are utilized, Equation 1 is modified as follows:

Well volume = (h)(f) **Equation 2**

where:
h = height of water column (feet)
f = the volume in gal/ft or L/ft

For volumetric purging, an adequate purge is typically achieved when 3 to 5 well volumes have been removed. The field notes should reflect the single-well volume calculations or determinations according to one of the above methods and a reference to the appropriate multiplication of that volume, (i.e., a minimum of 3 well volumes) clearly identified as a purge volume goal.

For volumetric purging, it is suggested that field readings are collected every ½ well/well screen volume after an initial 1 to ½ well volumes are purged. The volume removed between readings can be adjusted as well-specific information is developed.

If removing a specified volume of water (e.g., 3 well volumes) has been determined to be suitable for purging, sampling can commence immediately upon achieving the required purge volume. In other cases, where specified in the project-specific work plan, stabilization of field parameters must be documented prior to sample collection. If, after 3 well volumes have been removed, the field parameters have not stabilized (see discussion in Section 2.2.3), additional well volumes (up to a total of 5 well volumes), should be removed. If the parameters have not stabilized within five well volumes, it is at the discretion of the Project Manager whether or not to collect a sample or to continue purging. If, after 5 well volumes, pH and conductivity have stabilized and the turbidity is still decreasing and approaching an acceptable level, additional purging should be considered to obtain the best sample possible with respect to turbidity. The conditions of sampling should be noted in the field book.

2.2.2 Low-flow Purging Approach

The low-flow purging approach is typically performed using peristaltic pumps or submersible pumps. Low-flow purging (also referred to as low-stress purging, low-volume purging, or Micropurging®) is a method of well purging/sampling that minimizes the volume of water withdrawn from a well in obtaining a representative sample. The term low-flow refers to the low velocity with which water enters the pump intake during purging and sampling. The objective is to draw representative saturated zone water through the well screen to the pump intake while avoiding disturbance of the stagnant water above the well screen through minimizing drawdown of the water column in the well. To achieve this, the flow rate should be adjusted to less than 1 L/min (usually, this will be a rate less than 500 ml/min and may be as low as 100 ml/min). Once drawdown stabilizes, the sampled water is isolated from the stagnant water in the well casing, thus eliminating the need for its removal. This sampling method is based on the principle that water within the screened zone passes through continuously and does not mix with water above the screen. Water entering the pump can be considered representative of water in the formation after drawdown and indicator parameters have stabilized.

When performing low-flow purging and sampling, it is recommended that the pump intake be set in the center of the well screen interval (or center of the water column within the well screen if the water level is below the top of the well screen) to help prevent disturbance of any sediment at the bottom of the well. If known, the pump can be placed adjacent to the areas with the highest hydraulic conductivity or highest level of contaminants. Dedicated pumps can be utilized to minimize disturbance of the water column. Subsequent sampling events should duplicate as closely as possible the pump intake depth and the stabilized flow rate from the previous events.

To begin purging, the pump should be started at the lowest pressure/power flow rate setting (e.g., 100 mL/min) and then slowly increased until water begins discharging. Monitor the water level and slowly adjust the pump speed until there is little or no drawdown or drawdown has stabilized. The pump pressure/power may need to be increased for discharge to occur.

The stabilization of drawdown should be documented. Measure and record the flow rate and water level every 3 to 5 minutes during purging. The flow rate should be reduced if drawdown is greater than 0.3 feet over three consecutive 3 to 5 minute interval readings. Note any flow rate adjustments on the Groundwater Field Data Record. Once an appropriate purge rate has been achieved, record this information, continue purging until water quality indicator parameters have stabilized (see Section 2.2.3), and then sample the well.

Attempts should be made to avoid pumping a well dry. If drawdown cannot be maintained at less than 0.3 feet and the falling water level is approaching the top of the screened interval (or the top of the pump for sampling that began with the water level below the top of the screen), perform the following steps:

1. Reduce the flow rate, or turn the pump off and allow for recovery. (The pump must have a check valve to prevent backflow if it is shut off).
2. Begin pumping again at a lower flow rate.
3. If water draws down to the top of the screened interval again (or the top of the pump for sampling that began with the water level below the top of the screen), turn the pump off and allow for recovery.
4. If two tubing volumes (including volume of water in the pump and flow-through cell) have been removed during purging, sampling can proceed the next time the pump is turned on without waiting for indicator field parameters to stabilize. The project-specific work plan or Project Manager should be consulted for guidance.
5. If this procedure is used, this should be recorded in the field book and/or on the Groundwater Field Data Record.

2.2.3 Field Parameter Stabilization During Purging

Stabilization criteria may depend on project objectives or regulatory-specific requirements. Refer to Appendix A for some of the regulatory-specific requirements for field parameter stabilization. Generally, an adequate purge with respect to the ground water chemistry is achieved when, stability for at least three consecutive measurements is as follows:

- pH ± 0.1 standard unit (SU)
- specific conductance within 3%
- turbidity within 10% for values greater than 5 nephelometric turbidity units (NTUs). If three turbidity readings are less than 5 NTUs, the values are considered as stabilized

Other parameters, such as DO, may also be used as a stabilization parameter. Typical stabilization goals for DO are within 0.2 mg/L or 10% saturation, whichever is greater. DO measurements should be conducted using either a flow-through cell or an over-topping cell to minimize or reduce potential oxygenation of the sample.

Because groundwater temperature is generally not very sensitive in distinguishing between stagnant casing water and formation water and is subject to rapid changes during purging, its usefulness is subject to question for the purpose of determining parameter stability. Even if temperature is not used to determine stability during well purging, it is still advisable to record the sample temperature, along with the other groundwater chemistry parameters, during well purging, as it may be needed to interpret other parameter results.

ORP is not always used as a stabilization parameter since it may also be subject to rapid changes during the purging process; however, it may be measured and recorded during well purging.

2.2.4 Special Considerations During Purging

Wells Purged Dry/Purge Adequacy

For wells with slow groundwater recovery, attempts should be made to avoid purging the well dry. This may be accomplished by slowing the purge rate. As water enters a well that has been purged dry, the water may cascade down the sand pack and/or the well screen, potentially stripping VOCs that may be present and/or potentially mobilizing soil fines into the re-accumulating water column.

However, even with slower purge rates, in some situations, a well may be pumped or bailed dry (evacuated) during the purging process. In these situations, evacuation generally constitutes an adequate purge and the well may be sampled following sufficient recovery (enough volume to allow filling of all sample containers). **It is not necessary that the well be evacuated three times before it is sampled.** Purging parameters should be measured and recorded during sample collection to serve as the measurements of record for the sampling event.

It is particularly important that wells be sampled as soon as possible after purging to maintain sample representativeness. If adequate volume is available upon completion of purging, the well should be sampled immediately. If not, sampling should occur as soon as adequate volume has recovered. If possible, sampling of wells that have a slow recovery should be scheduled so that they can be purged and sampled in the same day after adequate volume has recovered. Wells of this type should, unless it is unavoidable, not be purged at the end of one day and sampled the following day.

Temporary Monitoring Wells

Procedures used to purge temporary groundwater monitoring wells may differ from permanent wells, because temporary wells are installed with different DQOs for immediate sample acquisition. Wells of this type may include standard well screens and risers placed in boreholes created by hand augering, power augering, or by drilling. Alternatively, they may consist of a rigid rod and screen that is pushed, driven, or hammered into place to the desired sampling interval, such as a direct push Wellpoint®, a Geoprobe® Screen Point 15/16 sampler, or a Hydropunch® sampler.

Purging to address stagnant water may not necessarily apply to temporary wells, because stagnant water is not typically present. It is important to note, however, that the longer a temporary well is in place and not sampled, the more stagnant the water column may become, and the more appropriate it may be to apply, to the extent possible, standard permanent monitoring well purging criteria.

In cases where the temporary well is to be sampled immediately after installation, purging is conducted primarily to mitigate the impacts of installation. In most cases, temporary well installation procedures disturb the existing saturated conditions, resulting primarily in increased turbidity. Therefore, the goal of purging, if conducted, may be to reduce the turbidity and remove the volume of water in the area directly impacted by the installation procedure. Low turbidity conditions in these types of wells that are completed within the limit of suction are typically and routinely achieved by the use of low-flow/low-stress purging techniques using variable-speed peristaltic pumps.

2.2.5 Equipment Considerations for Purging

Monitoring well purging is accomplished by using in-place plumbing and dedicated pumps or by using portable pumps/equipment when dedicated systems are not present. The pump of choice is usually a function of the purging approach (e.g., multiple-volume vs. low-flow), well diameter, the DTW, the total depth of the well, the amount of water that is to be removed during purging, the specific analytical testing program for the well, and the equipment previously used during purging and sampling of the well. A peristaltic pump is appropriate for purging whenever the head difference between the sampling location and the water level is less than the limit of suction (approximately 25' to 30') and the volume to be removed is reasonably small. For wells where the water level is below the limit of suction, and/or where there is a large volume of water to be purged, the variable-speed electric submersible pump or adjustable-rate bladder pumps would be appropriate. Bailers may also be used for purging in appropriate situations (e.g., shallow wells with small purge volumes); bailers are not suitable for low-flow purging.

The following subsections describe well evacuation devices that are most commonly used. Other devices are available but are not discussed in this SOP due to their limited use. Site-specific operating procedures should be developed in the case that an uncommon purge device is used.

2.2.5.1 Purging with a Suction Pump

There are many different types of suction pumps. They commonly include: centrifugal, peristaltic and diaphragm. Diaphragm pumps can be used for well evacuation at a fast pumping rate and sampling at a low pumping rate. The peristaltic pump is a low-volume pump that incorporates a roller to squeeze flexible tubing, thereby creating suction. This tubing can be dedicated to a well for re-use or discarded. It is recommended that 1/4 inch or 3/8 inch (inner diameter) tubing be used to help ensure that the sample tubing remains filled with water and to prevent water from being aerated as it flows through the tubing. Purging procedures are as follows.

(a) Determine the volume of water to be purged as described in Section 2.2.1 or follow the low-flow approach described in Section 2.2.2 (applicable to peristaltic pumps only).
(b) Take necessary precautions (e.g., laying plastic sheeting around the well) to prevent contamination of pumps, tubing or other purging/sampling equipment with foreign materials.
(c) Assemble the pump, tubing and power source, if necessary, in accordance with manufacturer's specifications.
(d) Ensure that the pump tubing is set at the pre-determined pump intake depth.
(e) Connect the discharge line from the pump to the flow-through cell for parameter measurements. Use a T-connection or valve prior to the flow-through cell to allow for collection of water for turbidity measurements. Direct the discharge line from the flow-through cell to a 5-gallon bucket (or equivalent) to contain the purge water for proper

disposal. Verify the end of the tubing is not submerged in the purge bucket. Manage purge water as specified in the project-specific work plan.

(f) Do not allow the pump to run dry. If the pumping rate exceeds the well recharge rate, adjust the rate accordingly or, if consistent with the purging and sampling objectives, lower the tubing further into the well and continue pumping.

(g) Using the water quality meter, take an initial reading of the required indicator parameters. All measurements, except turbidity, must be obtained using a transparent flow-through cell unless an unforeseen situation makes this impractical or inadvisable. Initially, turbidity may be elevated. Once turbidity has decreased to a measurable range, begin monitoring indicator parameters at approximately every 3-5 minutes, or as appropriate. Please note that flow-through cell size should be taken into account in conjunction with the flow rate to determine the length of time between water quality parameter readings. At least one flow-through cell volume should be turned over between readings. For example, if the flow through cell size is 500 mL and the flow rate is 100 mL/min, then it would be appropriate to measure water quality parameters every 5 minutes.

(h) Record the readings on the Groundwater Field Data Record. The monitoring probes must be submerged in water at all times. Record the indicator parameters, along with the water level, as described in Step (g) above. If removing a specified volume of water (e.g., 3-5 well volumes) has been determined to be suitable for purging, sampling can commence immediately upon achieving the required purge volume. In other cases, where specified in the project-specific work plan, stabilization of field parameters must be documented prior to sample collection. Stabilization criteria are discussed in Section 2.2.3.

Particulate build-up in the flow-through cell may impact indicator parameters. If the cell must be cleaned during pumping operations, continue pumping and disconnect the cell for cleaning, then reconnect and continue monitoring. Record the start and stop times, and describe the cleaning steps in the field book.

If indicator parameter stabilization is required and parameters have not stabilized after 2-hours of purging (or other pre-determined length of time), one of three options may be taken after consultation with the Project Manager:

1) continue purging until stabilization is achieved;
2) discontinue purging, do not collect any samples, and record in the field book and/or on the Groundwater Field Data Record the stabilization conditions and steps taken to attempt to achieve stabilization; or,
3) discontinue purging, collect samples and document attempts to achieve stabilization.

NOTE: If parameters do not stabilize, or turbidity remains greater than 5 NTU within the project-determined time range (EPA recommends up to 2 hours), contact the Project Manager to develop a modified sampling approach.

(i) Record the volume of water purged on the Groundwater Field Data Record. Record the disposal method used for purge water in the field book.

(j) Once the required volume of water is removed (typically 3 to 5 well volumes) from the well and/or parameters are stabilized to the satisfaction of the project-specific work plan, proceed to Section 2.3, Post-purging Groundwater Sample Collection.

2.2.5.2 Purging with a Submersible Pump

Submersible pumps generally use one of two types of power supplies, either electric or compressed gas. Electric pumps can be powered by a 12-volt DC rechargeable battery, or a 110- or 220-volt AC power supply. Those units powered by compressed gas (e.g., bladder pump) normally use a small electric controller that also needs a 12-volt DC battery or 110-volt AC power. They may also utilize compressed gas from bottles. Pumps differ according to the depth and diameter of the monitoring wells and the height of the potentiometric surface/water table (e.g., pressure head). It is recommended that 1/4-inch or 3/8-inch (inner diameter) tubing be used to help ensure that the sample tubing remains filled with water and to prevent water from being aerated as it flows through the tubing. Purging procedures are as follows.

(a) Determine the volume of water to be purged as described in Section 2.2.1 or follow the low-flow approach described in Section 2.2.2.

(b) Take necessary precautions (e.g., laying plastic sheeting around the well) to prevent contamination of pumps, tubing or other purging/sampling equipment with foreign materials.

(c) Assemble the pump, tubing and power source, if necessary, in accordance with manufacturer’s specifications. If the pump itself is being lowered into the well, ensure a safety line is attached.

(d) Non-dedicated purge/sampling vs. dedicated purge/sampling systems.

<u>Dedicated systems:</u> Pump has already been installed. Refer to historical monitoring well information, and record the depth of the pump intake in the field book and/or on the Groundwater Field Data Record.

<u>Non-dedicated systems:</u> Determine the target depth of the pump intake. Note that this may be a historical intake depth; see well construction data or the project-specific work plan. If there is not an established intake depth, the center of the screened interval should be targeted. If the measured water level is lower than the top of the well screen, position the pump intake at the midpoint of the water column. The intake should be generally 1 to 2 feet above the bottom of the well to minimize potential mobilization of any settled sediment, the risk of the pumping suction being broken, or the entrainment of air in the pump tubing and resulting sample. Slowly lower the pump, safety line, and tubing into the well to the pre-determined pump intake depth. The tubing should be cut to the desired length to assist in installing the pump. Measure the depth of the pump intake while lowering the tubing/pump into location. Record the pump intake depth in the field book and/or on the Groundwater Field Data Record. For deeper wells and large diameter wells, two staff members may be necessary to accomplish this task.

(e) Connect the discharge line from the pump to the flow-through cell for parameter measurements. Use a T-connection or valve prior to the flow-through cell to allow for collection of water for turbidity measurements. Direct the discharge line from the flow-through cell to a 5-gallon bucket (or equivalent) to contain the purge water for proper disposal. Verify the end of the tubing is not submerged in the purge bucket. Manage purge water as specified in the project-specific work plan.

(f) Measure the flow rate of the pump with a graduated container and stop watch. The pump pressure may need to be increased for discharge to occur. Record the volume of water collected for a period of 1 minute and calculate the flow rate as follows.

$$Flowrate\,(mL\,/\,min) = \frac{volume\ collected\ (mL)}{1\,minute}$$

(g) Measure the water level and record the flow rate and the water level. This should be performed every 3 to 5 minutes during purging. For low-flow purging, the flow rate should be adjusted to result in a rate between 100 to 500 mL/min; however, if drawdown of the well is observed, a slower flow rate may be necessary. If using a bladder pump, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL volatile organic analysis (VOA) vial, if possible.

(h) Prior to recording the water quality indicator parameters, a minimum of one tubing volume should be purged. Note that this includes the volume of the flow-through cell.

(i) Proceed to steps (g) through (j) in Section 2.2.5.1.

2.2.5.3 Purging with a Bailer

(a) Determine the volume of water to be purged as described in Section 2.2.1.

(b) Take necessary precautions (e.g., laying plastic sheeting around the well) to prevent contamination of tubing or other purging/sampling equipment with foreign materials.

(c) Use a well-dedicated bailer (i.e., used exclusively for that well only), a decontaminated bailer or an unused, disposable bailer.

(d) Attach an appropriate length of (a) bailing line, (b) Teflon®-coated bailing wire or (c) rope with Teflon®-coated stainless steel leader to reach the bottom of the well. Secure a knot or series of knots to the top of the bailer. Be sure to have additional length of line to facilitate handling of the bailer at the surface (typically 10 ft).

(e) Lower the bailer gently into the well until it reaches the water column and fills with water from the bottom. Note: It is recommended that the bailer be lowered into the water to a depth that prevents the water from entering the top of the bailer. This is done to prevent excess turbulence caused by filling from the bottom and the top simultaneously. Controlling the line attached to the bailer as it is lowered into the well is also important to prevent degassing of the water as the bailer impacts the water. In shallow wells, controlling the line is not too difficult; however, for wells of greater depths it is common to utilize a hand-over-hand (windmill) approach using both hands to control longer lengths of line and prevent the loops in the line from tangling with one another. This procedure is simple to learn and saves a good deal of time by preventing tangles. Do not allow the bailing line or rope to become contaminated by surface soil.

(f) Once the bailer is full of water, gently withdraw the bailer from the well until it comes out of the top of the well. Be sure to control excess line in your hands to prevent the rope and bailer from touching the ground, and then grasp the bailer as it appears at the top of the well.

(g) Immediately pour the water into a vessel for water quality measurements, and record the measurements in the field book or on the Groundwater Field Data Record (at the project-required frequency). Otherwise, pour water into a 5-gallon bucket or other vessel to track the volume purged. As a general rule, standard 2-inch bailers are able to hold about 1 liter of water when full. This process will have to be repeated several times to complete adequate purging of the well (e.g., three to five well volumes).

(h) Record the volume of water purged on the Groundwater Field Data Record. Record the disposal method used for purge water in the field book.

(i) Once the required volume of water is removed (typically 3 to 5 well volumes) from the well and/or parameters are stabilized to the satisfaction of the project-specific work plan, proceed to Section 2.3, Post-purging Groundwater Sample Collection.

2.3 Post-purging Groundwater Sample Collection

(a) New, disposable gloves should be donned immediately prior to sample collection and should be changed at any point that their cleanliness becomes compromised during sample collection.

(b) If using a submersible or peristaltic pump, maintain the same flow rate as used during purging. Disconnect the pump tubing from the flow-through cell or sample from the T-connector, if used. Samples must be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. This is critically important to avoid cross-contamination between wells.

(c) If using bottom-filling bailers,

- Slowly lower the bailer into the well until it is submerged to the point where water does not enter the top (i.e., bottom-filling).
- Retrieve the bailer. The first bailer recovered after well purging must be used for sample collection.

2.3.1 Sample Collection Order

Fractions of the groundwater sample should be collected in the following order (i.e., decreasing volatility) unless otherwise specified in the project-specific work plan:

1. VOCs;
2. Semivolatile organic compounds (SVOCs);
3. Other organic parameters;
4. Unfiltered inorganic constituents (e.g., total metals);
5. Filtered inorganic constituents (e.g., dissolved metals); and
6. Other constituents.

During sample collection, allow the water to flow directly down the side of the sample container without allowing the tubing to touch the inside of the sample container or lid in order to minimize aeration and turbulence and maintain sample integrity. The tubing should remain filled with water.

2.3.2 VOC Sample Collection

<u>Collection of VOCs/Volatile Petroleum Hydrocarbons (VPH):</u> Samples for VOCs will be collected first unless they are being collected by the “straw” method described in Section 1.6.2 (d), and the sample vial must be filled so a meniscus forms over the mouth of the vial. This ensures no air bubbles or headspace will be formed after it has been capped. Ensure the lack of air bubbles and headspace by turning the vial upside down and tapping it lightly. If any bubbles are observed, the vial should be topped off using a minimal amount of sample to re-establish the

meniscus. Care should be taken to not flush any preservative out of the vial when topping off. If, after topping off and capping the vial, bubbles are still present, a new vial should be obtained and the sample re-collected. Note: Extra VOC vials should be obtained prior to the sampling event in case this situation occurs.

Note: When using a bladder pump, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 ml VOA vial, if possible.

When acid preservation is used for the collection of VOCs, the acid must be added to the vials before sample collection. However, in most cases 40-ml VOA vials come pre-preserved. If a pre-preserved vial effervesces upon the addition of sample, the acid preservative can be rinsed out of the vial with sample water and then used to collect the sample. The laboratory should be made aware that the affected sample will not be acid-preserved as this may affect the sample holding time. Note effervescence in the field book for future reference.

2.3.3 Non-VOC Sample Collection

Completely fill the remaining sample containers for all non-VOC analyses.

Preserve the non-VOC samples in accordance with method and project-specific requirements following sample collection if the sample containers are not pre-preserved. (**NOTE:** Pre-preserved vials may be supplied by the laboratory, depending on the program).

2.3.4 Field Filtering

Depending upon project requirements, field filtering may be performed for non-VOC analyses. An in-line filter should be fitted at the end of the discharge tubing and the sample should be collected after the filter. Pre-rinse the in-line filter by allowing a minimum of 0.5 to 1 liter of groundwater from the well to pass through the filter prior to sampling. Ensure the filter is free of air bubbles prior to collecting samples. Preserve the filtered water sample immediately or directly fill pre-preserved containers (if provided). Clearly note “filtered” or “dissolved” on sample label and COC document.

2.4 Groundwater Sample Collection Without Purging (Passive Sampling)

Passive sampling can be defined as the free flow of contaminants from the media being sampled to a receiving phase in a sampling device. Depending upon the sampler, the receiving phase can be a solvent (e.g., water), chemical reagent, or porous adsorbent (e.g., activated carbon). While there are many different types of passive samplers, most have a barrier between the medium being sampled and the receiving phase. The barrier determines the sampling rate that contaminants are collected at a given concentration and can be used to selectively permit or restrict various classes of chemicals from entering the receiving phase.

There are three generic forms of passive (no purge) samplers: thief (grab) samplers, diffusion (equilibrium) samplers, and integrating (kinetic) samplers. However, this SOP focuses on the more commonly used diffusion (equilibrium) samplers.

Passive samplers are deployed down a well to the desired depth within the screened interval or open borehole to obtain a discrete sample without using pumping or a purging technique. Most samplers are able to be stacked to obtain samples at multiple depths. Some samplers can also be used to measure contaminants in groundwater as it enters a surface water body.

Diffusion, or equilibrium, samplers are devices that rely on diffusion of the analytes to reach equilibrium between the sampler fluid and the well water. Samples are time-weighted toward conditions at the sampling point during the latter portion of the deployment period. The degree of weighting depends on analyte and device-specific diffusion rates. Typically, conditions during only the last few days of sampler deployment are represented. Depending upon the contaminant of concern, equilibration times range from a few days to several weeks. Diffusion samplers are less versatile than grab samplers as they are not generally effective for all chemical classes.

Both the diffusion and integrating samplers depend upon permeation or diffusion through barriers that hold the receiving phase. This diffusion process is chemical and barrier specific. Diffusion samplers are commonly known as PDBs or rigid porous polyethylene (RPP) samplers. PDBs may be used to sample for VOCs, and RPPs may be used to sample for various organic and inorganic constituents. PDBs must be allowed to remain in the well for a sufficient period of time to allow the deionized water in the sampler to come into equilibrium with the constituents in the ambient groundwater.

Some regulatory agencies allow groundwater samples to be collected without purging the well. This may be accomplished by suspending a passive sampler in the well for a period of time appropriate for the type of passive sampler being used. It is important to confirm that the chosen sampler is compatible with the contaminants of concern including all VOCs of interest at the site.

Diffusion passive samplers are used most commonly and the procedure for their use is as follows:

(a) Passive samplers are deployed at a predetermined depth across the well screen. Typically, the initial sampling event may deploy multiple passive samplers across 5-foot intervals of saturated well screen to observe any potential stratification. Long-term sampling depths typically target a zone of higher concentration, if present.

(b) New passive samplers are attached via PVC cable ties to a tether (a pre-made marine-grade polyethylene rope or stainless steel cable with a weight at the bottom) that is then suspended within the well. There should be sufficient well screen saturation within the well to completely cover the passive sampler. For VOCs, it is recommended that there should be several feet of groundwater above the top of the PDB.

(c) The passive sampler should be allowed to equilibrate with groundwater for an appropriate period of time (e.g., at least 2 weeks for PDB samplers). Longer equilibration times may be necessary in lower permeability formations. Once sufficient time for equilibration has passed, the PDB samplers can be retrieved when convenient.

(d) Raise the passive sampler to the surface using a tether reel. Examine the surface of the passive sampler for evidence of algae, iron, or other coatings, and for tears to the membrane. Note observations in the field book. If tears are present and water is leaking out, the sample is not considered viable. Contact the Project Manager.

(e) Detach the passive sampler from the tether.

(f) Remove excess beaded water from the passive sampler with a clean gloved hand, running top to bottom; this is to minimize the contact of beaded water with water in the passive sampler.

(g) Use a small diameter discharge tube (<0.15 inch diameter to reduce volatilization) and pierce near the bottom, allowing water to smoothly flow into the VOA vial. Tilting the passive sampler will control the flow rate. The VOA vials must be filled within the first several minutes of passive sampler retrieval. (Note that sample vials should be prepared and opened on a stable surface or holding device such as a foam pack. Decanting sample from passive samplers into containers requires techniques that may require some practice and patience.) Refer to Section 2.3.2 for special circumstances regarding the filling of VOA vials.

(h) A small amount of water may remain within the passive sampler after filling the VOA vials and can be used for field parameter measurements if required.

(i) Dispose of the passive sampler after use.

2.5 Post-sampling Activities

(a) Cease pumping and, if system is non-dedicated, disassemble and decontaminate the purging and sampling equipment. Verify the end of the tubing is not submerged in the purge bucket prior to turning off the pump.

(b) Dispose of the bailer (if disposable) and/or rope and/or other disposable equipment in accordance with the project-specific work plan, or store the bailer in a plastic bag for transport to the site decontamination area.

(c) Dispose of the empty passive sampler and/or rope and/or other disposable equipment in accordance with the project-specific work plan, or store the empty passive sampler in a plastic bag for transport to the site decontamination area

(d) Replace the well cap and well cover on the well and lock the outer casing (if present).

(e) Label each sample. If the labels are covered with clear tape, ensure this is not performed for VOA vials.

(f) Place all samples in a cooler with ice.

(g) Ensure samples are delivered to the laboratory well before the required holding time expires.

(h) Consult the project-specific work plan to determine if a calibration check is required at the end of the day for the water quality parameters.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The collection of QC samples is dependent upon the DQOs. Project-specific work plans should be consulted to determine the required frequency of QC sample collection.

4.1 Field Duplicates

The following procedures should be used for collecting field duplicates of groundwater samples:

(a) For QC purposes, each duplicate sample will be typically submitted to the laboratory as a "blind" duplicate sample, in that a unique sample identification not tied to the primary sample identification will be assigned to the duplicate (e.g., DUP-01). Standard labeling procedures used for groundwater sampling will be employed. However, a sample collection time will not be included on the sample label or the COC form. The actual source of the duplicate sample will be recorded in the field book and/or on the Groundwater Field Data Record.

(b) Each duplicate sample will be collected simultaneously with the actual sample by alternately filling sample and duplicate bottles. Following the order of collection specified for each set of containers (VOCs, SVOCs, other organic parameters, unfiltered inorganic constituents, and filtered inorganic constituents), the duplicate sample containers will be alternately filled with groundwater for each parameter.

(c) All collection and preservation procedures outlined for groundwater sampling will be followed for each duplicate sample.

4.2 Equipment Blanks

Equipment blanks include reagent water that is run through the bailer (if not disposable), rope, leader line, decontaminated pump, a representative section of the pump's tubing, or any other piece of sampling equipment that may have come in contact with the sample. The equipment blanks are collected and preserved in the same sample containers as field samples. If dedicated or disposable systems are used, equipment blanks are not required, although an initial blank could be performed to demonstrate that the dedicated equipment is clean prior to use. If only dedicated tubing is used, the equipment blank will include only the pump in subsequent sampling events. A passive sampler is considered a dedicated device and no equipment blank is required.

Ideally, the reagent water should come from the laboratory and be certified clean. If not certified and/or if not from the laboratory performing the analyses, a separate water blank that has not run through the sampling equipment should be sent to the laboratory for analysis.

4.3 Trip Blanks

Trip blanks will be used to check for potential contamination of VOCs via migration during storage and shipping. Trip blanks typically consist of two to three 40 mL VOA vials filled with analyte-free water and preserved with hydrochloric acid (HCl) to pH <2 SU. Trip blank containers are usually supplied pre-filled by the laboratory. Trip blanks are typically submitted to the laboratory at a frequency of one per cooler for coolers that contain samples for VOC and/or VPH analysis. Trip blanks are analyzed by the laboratory for VOCs and/or VPH, depending on field sample analyses.

4.4 Field Blanks

Field blanks consists of analyte free water exposed to the atmosphere during field sample collection. The water is containerized in an appropriate bottle and preservative for the analytical suite and shipped to the laboratory with the other field samples. The results are used to assess whether or ambient/surrounding air conditions may have influenced analytical results.

4.5 MS/MSDs and MS/Duplicates

MSs are an additional analysis of a sample spiked by the laboratory with a subset or all of the target analytes and are used to demonstrate the accuracy of analytical methods for a given matrix. MSDs are an additional analysis of a sample spiked with a subset or all of the target analytes and are also used to demonstrate the accuracy of analytical methods for a given matrix. MS/MSDs also provide a measure of analytical precision for a given matrix. Duplicates are an additional analysis of a sample and are used to demonstrate the precision of analytical methods for a given matrix.

Triplicate volumes of a field sample must be collected in order for the laboratory to have enough volume to perform the MS/MSD analyses for organic parameters. Duplicate volumes of a field sample must be collected in order for the laboratory to have enough volume to perform MS/Duplicate analyses for inorganic parameters. The sample designated for MS/MSD or MS/Duplicate analyses should be noted in the Comments column of the COC document.

4.6 Temperature Blanks

Temperature blanks consist of a sample container filled with non-preserved water (potable or distilled) and typically are included in all coolers that contain samples that require temperature preservation. These may be added to the coolers by the field team if not provided by the laboratory. Temperature blanks must remain inside the coolers on ice during the sampling process.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

Record the sample location, sample identification, and date and time of collection in the field book and/or the Groundwater Field Data Record. The Groundwater Field Data Record (Attachment B) should be used to record the following information:

- Volume of each sample

- Sample identification number
- Sample location (sketch of the sample point)
- Time and date sample was collected
- Personnel performing the task
- Volume of water removed
- Purging time
- Flow rate during purging and sampling
- Weather conditions during sampling
- Field parameters such as water level, pH, temperature, conductivity, turbidity, ORP, and DO
- Sample collection equipment and method used
- Decontamination procedures
- Analytical parameters
- Preservation method and amount of preservative

All sample numbers must be documented on the COC form that accompanies the samples during shipment. Any deviations from the records management procedures specified in the project-specific work plan must be approved by the Project Manager and documented in the field book.

6.0 REFERENCES

Interstate Technology Regulatory Council (ITRC). March 2006. *Technology Overview of Passive Sampler Technologies.*

USEPA. November 1992. *RCRA Ground-Water Monitoring: Draft Technical Guidance*. EPA/530-R-93-001. USEPA Office of Solid Waste.

USEPA. April 1996. *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*. EPA Ground Water Issue. EPA/540-S-95-504. USEPA Office of Solid Waste and Emergency Response.

USEPA. May 2002. *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers*. EPA/542-S-02-001. USEPA Office of Solid Waste and Emergency Response.

USEPA. September 2004. Field Sampling Guidance Document #1220: Groundwater Well Sampling. USEPA Region 9 Laboratory Richmond, California.

USEPA, January 19, 2010. *Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells*. USEPA Region 1, Rev. 3.

USEPA. March 6, 2013. *Groundwater Sampling.* SESDPROC-301-R3. USEPA Region 4, Science and Ecosystem Support Division. Athens, Georgia.

USEPA. April 22, 2014. Passive (No Purge) Samples. http://www.clu-in.org/characterization/technologies/default.focus/sec/Passive_%28no%20purge%29_Samplers/cat/Overview/

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	AUGUST 2014	NOT APPLICABLE
1	JULY 2016	ADDED ATTACHMENT D TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFCS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	NOVEMBER 2016	ADDED ADDITIONAL INFORMATION REGARDING PFAS.
3	JANUARY 2020	TRC RE-BRANDING; ADDED FIELD BLANKS TO SECTION 4

Attachment A:

Groundwater Field Parameter Stabilization Criteria for Selected Jurisdictions

Jurisdiction	Information Source	Applicable Stabilization Criteria
USEPA Region 1	Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells; U.S. Environmental Protection Agency Region 1, January 19, 2010. http://www.epa.gov/region1/lab/qa/pdfs/EQASOP-GW001.pdf (for low flow PDF) http://www.epa.gov/region1/lab/qa/qualsys.html (for EPA's Quality System Documents)	pH: ±0.1 unit Specific Conductance: ±3% Temperature: ±3% Turbidity: ±10% if >5 NTUs; if three Turbidity values are <5 NTU, consider the values as stabilized Dissolved Oxygen: ±10% if >0.5 mg/L, if three Dissolved Oxygen values are <0.5 mg/L, consider the values as stabilized Oxidation/Reduction Potential: ±10 millivolts
USEPA Region 2	Groundwater Sampling Procedure: Low Stress (Low Flow) Purging and Sampling, SOP # SST-7, Revision No. 1, November 2010.	Same as above
USEPA Region 4	USEPA Region 4 SOPs: http://www.epa.gov/region4/sesd/fbqstp/index.html See Chemical Parameter Stabilization Criteria (section 3.2.1.1.2 of Groundwater Sampling SOP, revision 3/6/2013: http://www.epa.gov/region4/sesd/fbqstp/Groundwater-Sampling.pdf	pH: ±0.1 unit Specific Conductance: ±5% Temperature: Not used Turbidity: "Stabilized" (no criteria specified) if >10 NTUs ; if three Turbidity values are <10 NTUs, consider the values as stabilized Dissolved Oxygen (optional parameter): ±0.2 mg/L or ±10% of saturation, whichever is greater Oxidation/Reduction Potential: Not used
USEPA Region 5	Ground Water Forum Issue Paper (May 2002, Yeskis and Zavala) http://www.epa.gov/superfund/remedytech/tsp/download/gw_sampling_guide.pdf A minimum set of parameters would include pH, conductivity, and turbidity or DO. Puls and Barcelona, 1996 (pH, specific conductance, ORP, turbidity) Wilde et al., 1998 (pH, turbidity, DO)	pH: ±0.1 unit Specific Conductance: ±3% Temperature: Not used Turbidity: ±10% if >10 NTUs Dissolved Oxygen: ±0.3 mg/L Oxidation/Reduction Potential: ±10 millivolts
USEPA Region 9	See USEPA Region 1 (above)	
USEPA Region 10	See USEPA Region 5 (above)	
Alabama	Alabama Environmental Investigation and Remediation Guidance (section C.3.1) http://www.adem.state.al.us/MoreInfo/pubs/AEIRGInvestigation.pdf	pH: ±0.1 unit Specific Conductance: ±10% Temperature: "Constant" (no criteria specified) Turbidity: Stabilized (no criteria specified), or <10 NTUs Dissolved Oxygen: No criteria specified Oxidation/Reduction Potential: No criteria specified

Jurisdiction	Information Source	Applicable Stabilization Criteria
Indiana	Indiana Department of Environmental Management The Micro-Purge Sampling Option http://www.in.gov/idem/files/remediation_tech_guidance_micro-purge.pdf The parameters normally measured for stability (listed in increasing order of sensitivity) are pH, temperature, specific conductivity, oxidation-reduction potential, DO and turbidity. At least one of the last three listed must be used.	pH: ±0.1 unit Specific Conductance: ±3% Temperature: ±3% Turbidity: ±10% Dissolved Oxygen: ±10% Oxidation/Reduction Potential: ±10 millivolts (document says microvolts, but that may be an error)
Michigan	MDEQ Part 201 Op Memo 2, Attachment 5 http://www.michigan.gov/documents/deq/deq-rrd-OpMemo_2_Attachment5_249853_7.pdf	No specific values to determine stabilization are listed, but the Op Memo lists several other groundwater sampling guidance documents. If a valid reference exists, then it can be used to justify a sampling approach and stabilization parameters.
New Jersey	New Jersey Department of Environmental Protection http://www.state.nj.us/dep/srp/guidance/fspm/	pH: ± 0.1 unit Specific Conductance: ± 3% Temperature: ± 3% Dissolved Oxygen: ± 10% Turbidity: ± 10% for values greater than 1 NTU ORP/Eh: ± 10 millivolts
Ohio	Ohio EPA SOPs: http://www.epa.state.oh.us/portals/30/rules/FSOPs.pdf See Purging Stabilization Criteria (SOP 2.2.4, dated January 2, 2007, review in progress)	pH: ±0.1 unit Specific Conductance: ±3% Temperature: No criteria specified Turbidity: Below 10 NTUs ideal; ±10% if greater than 10 NTUs Dissolved Oxygen: ±0.3 mg/L Oxidation/Reduction Potential: ±10 millivolts
This table was last updated in July 2014.		

Attachment B:

Example Groundwater Field Data Records

TRC Groundwater Field Data Record

Project: Project No.: Date/Time: Sheet ___ of ___

TRC Personnel: Well ID:

WELL INTEGRITY

	YES	NO
Protect. Casing Secure	☐	☐
Concrete Collar Intact	☐	☐
PVC Stick-up Intact	☐	☐
Well Cap Present	☐	☐
Security Lock Present	☐	☐

Sampling Equipment:

Flow-thru Cell Volume:

PID SCREENING MEAS.

Background	
Well Mouth	

Protective Casing Stick-up ______ ft. (from ground)

Riser Stick-up (from ground) ______ ft.

WELL DIAMETER ☐ 2 inch ☐ 4 inch ☐ 6 inch
Other: ______

WELL MATERIAL
☐ PVC ☐ SS
Other: ______

Well Depth ______ ft. ☐ top of riser ☐ top of casing ☐ ______ ☐ measured ☐ historical

Water Depth ______ ft.
LNAPL/DNAPL Depth = ____
NAPL Thickness = ______
Well Volume______

Depth of pump intake:
Static water level after pump put into well:
Initial purge Rate/ Water Level (100-400 ml/min):
Adjusted purge Rates/time/WL(record changes)
Flow rate at time of sampling:
Total volume of water purged:

FIELD WATER QUALITY MEASUREMENTS (record at appropriate intervals)

Time									
Temp. (°C)									
Conduct. (µmhos/cm)									
DO (mg/L)									
pH (su)									
ORP (millivolts)									
Turbidity (NTU)									
Flow (ml/min)									
Depth To Water (ft)									
Cumulative Purge Vol. (gal or L)									

Time						
Temp. (°C)						
Conduct. (µmhos/cm)						
DO (mg/L)						
pH (Std. Units)						
Eh/ORP (millivolts)						
Turbidity (NTU)						
Flow (ml/min)						
Depth To Water (ft)						
Cumulative Purge Vol. (gal or L)						

Stabilization Criteria*
(3 consecutive readings)
- Temperature: ± 3 %
- Conduct. (µmhos/cm): ± 3 %
- DO (mg/L): ± 10 % (for values >0.5 mg/L)
- pH (Std. Units): ± 0.1 SU
- ORP (millivolts): ± 10 mV
- Turbidity (NTU): +/- 10 % (for values >5.0 NTUs)
- Drawdown: < 0.3 ft (can be greater as long as water level stabilizes above well screen)

	Purge	Sample
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bladder Pump	☐	☐
Bailer	☐	☐
Other: ______	☐	☐

Comments:

Analytical Parameter	Filtered (Y/N)	Preservation	# Bottles	Size/Type Bottles	Time Collected	QC	Sample #

* Consult the applicable regulatory guidance for the specific criteria.

Signed: ______________________

Rev: April 2014

PAGE ______ OF ______

WATER SAMPLE LOG

PROJECT NAME:	PREPARED		CHECKED	
PROJECT NUMBER:	BY:	DATE:	BY:	DATE:

SAMPLE ID: WELL DIAMETER: ☐ 2" ☐ 4" ☐ 6" ☐ OTHER ____________

WELL MATERIAL: ☐ PVC ☐ SS ☐ IRON ☐ GALVANIZED STEEL ☐ OTHER ____________

SAMPLE TYPE: ☑ GW ☐ WW ☐ SW ☐ DI ☐ LEACHATE ☐ OTHER ____________

PURGING TIME: DATE:

PURGE METHOD: ☐ PUMP ____________ ☐ BAILER ____________

DEPTH TO WATER: ________ T/ PVC

DEPTH TO BOTTOM: ________ T/ PVC

PUMP INTAKE DEPTH: ________ T/ PVC

FLOW-THRU CELL VOLUME ________ LITERS

WELL VOLUME: ________ ☐ LITERS ☐ GALLONS

VOLUME REMOVED: ________ ☐ LITERS ☐ GALLONS

COLOR: ____________ ODOR: ____________

TURBIDITY

☐ NONE ☐ SLIGHT ☐ MODERATE ☐ VERY

DISPOSAL METHOD: ☐ GROUND ☐ DRUM ☐ OTHER

SAMPLE TIME: DATE:

PH: ________ SU CONDUCTIVITY: ________ umhos/cm

ORP: ________ mV DO: ________ mg/L

TURBIDITY: ________ NTU

☐ NONE ☐ SLIGHT ☐ MODERATE ☐ VERY

TEMPERATURE: ________ °C OTHER: ____________

COLOR: ____________ ODOR: ____________

FILTRATE (0.45 um) ☐ YES ☐ NO

FILTRATE COLOR: ____________ FILTRATE ODOR: ____________

QC SAMPLE: ☐ MS/MSD ☐ DUP: ________

COMMENTS:

TIME	PURGE RATE (ML/MIN)	PH (SU)	CONDUCTIVITY (umhos/cm)	ORP (mV)	D.O. (mg/L)	TURBIDITY (NTU)	TEMPERATURE (°C)	WATER LEVEL (FEET)	CUMULATIVE PURGE VOLUME (GAL OR L)
									INITIAL

NOTE: STABILIZATION TEST IS COMPLETE WHEN 3 SUCCESSIVE READINGS ARE WITHIN THE FOLLOWING LIMITS:

pH: +/- **10 %** COND.: +/- **10 %** ORP: +/- **10 %** D.O.: +/- **10 %** TURB: +/- **10 %** or </= **5** TEMP.: +/- **0.5°C**

BOTTLES FILLED PRESERVATIVE CODES A - NONE B - HNO3 C - H2SO4 D - NaOH E - HCL F - ______

NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED	NUMBER	SIZE	TYPE	PRESERVATIVE	FILTERED
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N
				☐ Y ☐ N					☐ Y ☐ N

SHIPPING METHOD: ____________	DATE SHIPPED: ____________	AIRBILL NUMBER: ____________
COC NUMBER: ____________	SIGNATURE: ____________	DATE SIGNED: ____________

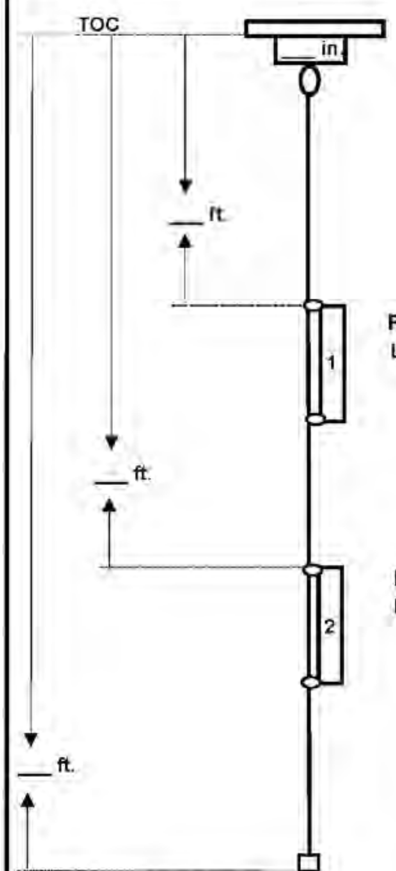
REVISED 06/2011

TRC Groundwater Sampling Record for Organics (For Wells with Passive Diffusion Bags)

Project Name/No:

Well ID:

Installation of PDBs:	Sampling of PDBs:
TRC Personnel: ____________	TRC Personnel: ____________
Date: ____________	Date: ____________
Time: ____________	DTW (ft): ____________
DTW (ft): ____________	



PDB #1
Length: ___ in.

Sample ID: ____________
Sample Time: ____________
Evidence of algae, iron or other coatings?: ____________

PDB #2
Length: ___ in.

Sample ID: ____________
Sample Time: ____________
Evidence of algae, iron or other coatings?: ____________

Measured well depth during tether installation: ___ ft.

Field Notes:

Rev: April 2014

Attachment C: SOP Fact Sheet

GROUNDWATER SAMPLING

PURPOSE AND OBJECTIVE

The objective of groundwater sampling is to obtain a representative sample of water from a saturated zone or groundwater-bearing unit (i.e., aquifer) with minimal disturbance of groundwater chemistry. This requires that the sample being collected is representative of groundwater within the formation surrounding the well bore as opposed to stagnant water within the well casing or within the filter pack immediately surrounding the well casing.

There are three general approaches to groundwater purging/sampling that can be used to obtain a representative groundwater sample for analysis: 1) the low-flow or micropurge method where the mixing of the stagnant water is minimized using low-flow pumping rates during the collection of the groundwater sample; 2) the multiple well volume removal approach in which the stagnant water is removed from the well and the filter pack prior to sample collection; and 3) the passive sampler procedure where water quality equilibration with the surroundings is achieved through deployment of the passive sampler for a sufficient amount of time prior to sampling. All three approaches are summarized in this document.

WHAT TO BRING

- Site-specific HASP and field book
- Project-specific work plan
- Figure or site map showing well locations and table showing well construction details
- Field data sheets from previous sampling event
- Well wrenches, ratchet set, and turkey baster to remove standing water from flushmount manholes
- Bolt cutters, padlocks and keys
- Water level meter of sufficient length
- Decontaminated pump, control box, power source (i.e., battery, generator, etc.)
- Tubing (Teflon®, Teflon®–lined polyethylene, or HDPE, type dependent upon project objectives)
- Multi-parameter instrument and flow-through cell (typically should include: pH, temperature, conductivity, ORP, and DO)
- Turbidity meter
- Equipment decontamination supplies (refer to ECR SOP 010, *Equipment Decontamination*)
- Appropriate PPE
- Field book
- Sample bottleware, labeled cooler, ice, temperature blank and blank COC forms; may also need field blank bottles and reagent-grade water
- Zip-loc® plastic bags
- Groundwater field data records
- Graduated cylinder and stop-watch
- Rope for tying off pump at desired intake
- Indelible marking pens
- Bubble wrap
- 5-gallon bucket(s)

<u>As Needed:</u>

- Calibrated PID or FID for well mouth readings
- Oil/water interface probe of sufficient length
- Drums for purge water, grease pen and adhesive drum labels; appropriate crescent or socket wrench
- Filtration equipment, if required (0.45 micron filters, or as otherwise required for the project)
- Other non-routine PPE such as Tyvek coveralls or respirators
- Traffic cones
- Field calibration sheets and calibration solutions

OFFICE

- Prepare/update the site-specific HASP; make sure the field team is familiar with the most recent version.
- Review the project-specific work plan with the Project Manager and/or the field team leader. Discuss the following:
  - Communication procedures;
  - Sampling order and designation;
  - Collection and sample method;
  - Analytical parameters, holding times and turn-around times;
  - Laboratory (contact/shipping info, COC, billing references);
  - Purge water management (Drums? Discharge to ground?);
  - QC sample collection; and
  - Decontamination procedures.
- Verify that monitoring wells will be accessible and/or coordinate to have a site contact available to assist.
- Make sure that monitoring well sample designations and QC sample designations/frequency are understood.
- Confirm that all necessary equipment is available in-house or has been ordered. Rental equipment is typically delivered the day before fieldwork is scheduled. Prior to departure or mobilization to site, test equipment and make sure it is in proper working order. Have rental equipment supplier contact information available for use in field.
- Review sample bottle order for accuracy and completeness and damaged bottles.
- Discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

ON-SITE

GROUNDWATER SAMPLING

- Review the HASP with all field personnel, sign acknowledgement form and conduct Health & Safety tailgate meeting. Check in security, site contact, or designated person per project-specific work plan or Project Manager.
- Make sure appropriate PPE is worn by all personnel and work area is safe (i.e., utilize traffic cones; minimize interference with on-site activities and pedestrian traffic, etc.)
- Calibrate equipment (if applicable) and record all rental equipment serial numbers in the field book.
- Open wells to allow equilibration and collect full round of water level gauging before sampling is started (unless otherwise noted in project-specific work plan). Record the following:
  - Well mouth PID/FID reading (if necessary);
  - Depth to product and water;
  - Total well depth (not required if free product is measured unless otherwise noted in project-specific work plan); and
  - Condition of wells (i.e., lid broken, pad cracked, rusted lock) and collect photographs if site allows camera use.

SAMPLING PROCEDURES: PRE-PURGE

- Decontaminate pump.
- Take water level measurements prior to pump installation.
- Connect sampling tubing to pump outlet and lower to sample depth; **ALWAYS USE ROPE TO SECURE PUMP TO SURFACE.**
- The pump intake depth(s) for each well should be specified in the project-specific work plan (either specific depth or mid-point of saturated well screen).
- For wells with screened or open borehole intervals greater than 10 feet in length, sampling of multiple intervals may be required.
- If samples are to be collected from multiple depths from an individual well, always collect a sample from the shallowest depth first and leave enough extra tubing coiled at the surface so the pump can be lowered to the next interval; always try to cover excess tubing present at the surface to prevent the air temperature from influencing the measurements and exposure to contaminants on the ground;
- Be careful not to let the pump hit the bottom of the well.
- If using Teflon®-lined tubing, be sure that the lining does not bunch up around the connection. This will restrict water flow and make the pump work harder than it has to.
- Calibrate (or perform a calibration check on) all field monitoring equipment on the same day before collecting groundwater samples. Refer to TRC SOPs and manufacturer's equipment calibration instructions. A calibration check may also be required during or at the end of each sampling day. Consult the project-specific work plan.

SAMPLING PROCEDURES: MULTIPLE-VOLUME PURGING

- The multiple-volume purging approach is typically performed using bailers or submersible or peristaltic pumps. In the multiple-volume purging approach, there are two measurements used to determine adequate purge volume removal prior to sample collection: 1) purge volume and 2) field parameter stabilization.
- The field parameters should be recorded at regular volumetric intervals. There are no set criteria for establishing how many total sets of measurements are adequate to document stability of parameters.
- Prior to purging a well, the amount of water inside the well riser and well screen (i.e., water column) should be determined, if possible. Once this information is known, the well volume can be calculated using the following equation:

$$\text{Well Volume (V)} = \pi r2\ h$$

- For volumetric purging, an adequate purge is typically achieved when 3 to 5 well volumes have been removed.
- For volumetric purging, it is suggested that field readings are collected every ½ well/well screen volume after an initial 1 to ½ well volumes are purged. The volume removed between readings can be adjusted as well-specific information is developed.
- If removing a specified volume of water (e.g., 3 well volumes) has been determined to be suitable for purging, sampling can commence immediately upon achieving the required purge volume.
- In other cases, where specified in the project-specific work plan, stabilization of field parameters must be documented prior to sample collection.
- If, after 3 well volumes have been removed, the field parameters have not stabilized, additional well volumes (up to a total of 5 well volumes), should be removed.
- If the parameters have not stabilized within five well volumes, it is at the discretion of the Project Manager whether or not to collect a sample or to continue purging.

SAMPLING PROCEDURES: LOW-FLOW PURGING

- The low-flow purging approach is typically performed using peristaltic pumps or submersible pumps. Low-flow purging (also referred to as low-stress purging, low-volume purging, or Micropurging®) is a method of well purging/sampling that minimizes the volume of water withdrawn from a well in obtaining a representative sample.
- When performing low-flow purging and sampling, it is recommended that the pump intake be set in the center of the well screen interval to help prevent disturbance of any sediment at the bottom of the well.

GROUNDWATER SAMPLING

- To begin purging, the pump should be started at the lowest pressure/power flow rate setting (e.g., 100 mL/min) and then slowly increased until water begins discharging. Monitor the water level and slowly adjust the pump speed until there is little or no drawdown or drawdown has stabilized. The pump pressure/power may need to be increased for discharge to occur.
- The stabilization of drawdown should be documented. Measure and record the flow rate and water level every 3 to 5 minutes during purging. The flow rate should be reduced if drawdown is greater than 0.3 feet over three consecutive 3 to 5 minute interval readings.
- Attempts should be made to avoid pumping a well dry.

Field Parameter Stabilization During Purging

- Generally, an adequate purge with respect to the groundwater chemistry is achieved when stability for at least three consecutive measurements is achieved. See stability requirements in Appendix A of this SOP.

POST-PURGE GROUNDWATER SAMPLE COLLECTION

- New, disposable gloves should be donned immediately prior to sample collection and should be changed at any point that their cleanliness becomes compromised during sample collection.
- If using a submersible or peristaltic pump, maintain the same flow rate as used during purging. Disconnect the pump tubing from the flow-through cell. Samples must be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. This is critically important to avoid cross-contamination between wells.
- If using bottom-filling bailers, slowly lower the bailer into the well until it is submerged to the point where water does not enter the top (i.e., bottom-filling). Retrieve the bailer. The first bailer recovered after well purging must be used for sample collection.
- Collect groundwater samples in the following order:
  - VOCs;
  - SVOCs;
  - Other organic parameters;
  - Unfiltered inorganic constituents; and
  - Filtered inorganic constituents.
- Note that sample vials for VOCs must be filled so a meniscus forms over the mouth of the vial. This ensures no air bubbles or headspace will be formed after it has been capped. Ensure the lack of air bubbles and headspace by turning the vial upside down and tapping it lightly. If any bubbles are observed, see Section 2.3.2 of this SOP.
- Preserve the non-VOC samples in pre-preserved vials supplied by the laboratory or if the sample containers are not pre-preserved, preserve the non-VOC samples in accordance with method and project-specific requirements.
- Depending upon project requirements, filtering may be performed. See procedures listed in Section 2.3.4 of this SOP. Clearly note "filtered" on the sample label and the COC.
- Make sure all sample bottles are appropriately labeled.
- Package the samples with bubble wrap and/or organic absorbent, as necessary. Place into shipping container and cool to 4°C and complete the COC.
- Decontaminate non-disposable sampling equipment between uses.

PASSIVE SAMPLING

- There are three generic forms of passive (no purge) samplers: thief (grab) samplers, diffusion (equilibrium) samplers, and integrating (kinetic) samplers. However, this SOP focuses on the more commonly used diffusion (equilibrium) samplers. Be aware of sample holding times, and arrange for samples to be in the laboratory's possession accordingly.
- Passive samplers are deployed at a predetermined depth across the well screen. Typically, the initial sampling event may deploy multiple passive samplers across 5-foot intervals of saturated well screen to observe any potential stratification. Long-term sampling depths typically target a zone of higher concentration, if present.
- New passive samplers are attached via PVC cable ties to a tether (pre-made marine-grade polyethylene rope or stainless steel cable with a weight at the bottom) that is then suspended within the well.
- The passive sampler should be allowed to equilibrate with groundwater for an appropriate period of time (e.g., at least 2 weeks for PDB samplers).
- Raise the passive sampler to the surface using a tether reel. Examine the surface of the passive sampler for evidence of algae, iron, or other coatings, and for tears to the membrane. Note observations in the field book. If tears are present and water is leaking out, the sample is not considered viable. Contact the Project Manager.
- Detach the passive sampler from the tether.
- Remove excess beaded water from the passive sampler with a clean gloved hand, running top to bottom; this is to minimize the contact of beaded water with water in the passive sampler.

GROUNDWATER SAMPLING

- Use a small diameter discharge tube (<0.15 inch diameter to reduce volatilization) and pierce near the bottom, allowing water to smoothly flow into the VOA vial. The VOA vials must be filled within the first several minutes of passive sampler retrieval.
- A small amount of water may remain within the passive sampler after filling the VOA vials and can be used for field parameter measurements if required.
- Dispose of the passive sampler after use.
- Note that sample vials for VOCs must be filled so a meniscus forms over the mouth of the vial. This ensures no air bubbles or headspace will be formed after it has been capped. Ensure the lack of air bubbles and headspace by turning the vial upside down and tapping it lightly. If any bubbles are observed, see Section 2.3.2 of this SOP.
- Make sure all sample bottles are appropriately labeled.
- Package the samples with bubble wrap and/or organic absorbent, as necessary. Place into shipping container and cool to 4°C and complete the COC.

DOs AND DO NOTs OF GROUNDWATER PURGING AND SAMPLING

DOs:

- DO have the following items when going into the field: site-specific work plan; site-Specific HASP; appropriate PPE (steel-toed boots, safety glasses, etc.) as required by the Site-Specific HASP; field book and a water-proof ball-point pen; business cards; nitrile gloves; well keys; copies of well installation forms and field data forms from previous sampling event.
- DO make sure that the equipment is set up properly and the bottleware is nearby and ready to be filled. There is little time between taking parameters.
- DO look at the water quality parameters from the previous round of sampling. If there is a large deviation from the previous round's measurements, make sure the meters are properly calibrated and the parameter units are the same. Otherwise, consult the Project Manager or field team leader.
- DO fill sample bottles slowly to make sure that they are not overfilled and that preservative does not become diluted. If collecting filtered samples, fill all non-filtered first, then fill filtered samples - if water is very silty, more than one filter might be required to fill sample bottles.
- DO record the time that purging begins and ends. "Purge Stop" and sample start time are the same.
- DO call your Project Manager or field team leader if unexpected conditions are encountered or at least daily to update them. It is also recommended to call when sampling is winding down for the day to make sure that the project-specific work plan has been fully implemented and there are no additional tasks to complete. Provide shipping tracking numbers to the Project Manager and laboratory contact.
- DO have the numbers for laboratory, vehicle rental and equipment rental providers readily available while in the field.
- DO record sample locations and parameters in the field book and the Groundwater Field Data Records as you purge.
- DO check on the purging setup frequently to make sure proper equipment function is maintained.
- DO bring ice to the site in the morning so that samples are kept cool throughout the entire event. Storing samples in a warm cooler can invalidate sample results and may result in re-sampling on your own time.

DO NOTs:

- DO NOT sign anything in the field. This includes disposal documentation, statements, etc.; call the Project Manager if this is an issue.
- DO NOT allow the pump or sampling equipment to hit the bottom of the well - If the pump hits the bottom of the well, it can stir up mud. Remember, the goal of low-flow sampling is to collect non-turbid samples.
- DO NOT use non-indelible ink to label samples or record field notes – if the field book gets wet, notes become illegible.
- DO NOT leave air bubbles in VOA vials.
- DO NOT pour any extracted water back down into the well.
- DO NOT lean over wells with pens, keys, cell phones, tools, etc. in your pocket.
- DO NOT use clear tape to cover labels on certain analyses (e.g., 40-mL vials for VOC analysis) due to potential interference with analytical equipment.

Attachment D: SOP Modifications for PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Do not use equipment utilizing Teflon® or low density polyethylene (LDPE)[1] during sample handling or mobilization/demobilization. This includes bailers, tubing, bladders, bailer cord/wire, waterproof/resistant paper products, certain personal protective equipment (PPE) (see below), and Teflon® tape. High density polyethylene (HDPE) or silicone tubing should be used in lieu of Teflon® or Teflon®-lined tubing. • Passive diffusion bags (PDBs) should not be used due to the presence of LDPE material in PDBs. • Blue Ice® (chemical ice packs) must not be used to cool samples or be used in sample coolers. Regular ice in Ziploc® bags can be used. • Do not use LDPE or glass sample containers or containers with Teflon-lined lids. HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable. • Do not use aluminum foil. • Field notes should be recorded on loose paper field forms maintained in aluminum or Masonite clipboards. Waterproof field books, plastic clipboards and spiral bound notebooks should not be used. • Do not use Post-It Notes during sample handling or mobilization/demobilization. • Refer to TRC's SOP ECR-010 Equipment Decontamination for PFAS-specific decontamination protocols. Ensure that PFAS-free water is used during the decontamination procedure.
1.5	Always consult the Site Specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to field preparation during PFAS sampling: • Tyvek® suits should not be worn during PFAS sampling events. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Stain resistant clothing should not be worn. • Food and drink should not be allowed within the exclusion area. Pre-wrapped food or snacks should not be in the possession of sampling personnel during sampling. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only.

PFAS Sampling Protocols	
SOP Section Number	**Modifications to SOP**
	• Personnel involved with sample collection and handling should wear nitrile gloves at all times while collecting and handling samples or sampling equipment. Avoid handling unnecessary items with nitrile gloves. A new pair of gloves must be donned prior to collecting each sample. • Wash hands with Alconox or Liquinox and deionized water after leaving vehicle before setting up to sample a well.
1.6.1	• Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended 6 washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering on the day of sampling. • Avoid using sunscreens or insect repellants that are not natural or chemical free.
2.2.5	Tubing used to purge and sample groundwater for PFAS must not be LDPE or Teflon®. HDPE and silicone are acceptable.
2.3 and 2.3.3	LDPE and/or glass containers should not be used for sampling. Teflon®-lined caps should also not be used during sample collection. Instead, HDPE or polypropylene containers are acceptable for sample storage. HDPE or polypropylene caps are acceptable.
2.4	Due to LDPE material in PDBs, PDBs cannot be used for PFAS sampling.
2.5 (e)	Avoid using waterproof labels for sample bottles. The use of paper labels covered with clear tape or placed in Ziploc® bags to avoid moisture on the sample label is acceptable.
2.5 (f)	Samples for PFAS analysis must be shipped at <10°C. Standard coolers are acceptable.
4.3	Due to low reporting limit requirements for PFAS, trip blanks for PFAS analysis should be included in sample coolers if PFAS are being analyzed for in the associated groundwater samples.

Notes:

[1] – PFAS have been used as an additive in the manufacturing of LDPE to smooth rough surfaces and, in the case of LDPE tubing, to allow for less turbulent flow along the surface of the tubing.

Title: **Equipment Decontamination**	Procedure Number: **ECR 010**
	Revision Number: **2**
	Effective Date: **January 2020**

Authorization Signatures

Technical Reviewer	Date	Environmental Sector Quality Director	Date
James Peronto	1/1/20	Elizabeth Denly	1/1/20

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ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the procedures needed for decontamination of equipment used in the field during environmental investigations (e.g., sediment, soil, groundwater investigations). Other state or federal requirements may be above and beyond the scope of this SOP and will be followed, if applicable. In all instances, the actual procedures used should be documented and described in the field notes. Preventing or minimizing potential cross-contamination of samples is important for the collection of representative samples, avoiding the possible introduction of sampling error into sample results, and for protecting the health and safety of site personnel.

Removing or neutralizing potential contaminants that may have accumulated on equipment and vehicles ensures protection of personnel, reduces or eliminates potential transfer of contaminants to clean areas, and minimizes the likelihood of sample cross-contamination.

The use of dedicated, disposable, new sampling equipment (e.g., disposable liners, plastic spoons, plastic or aluminum bowls) should be considered as an alternative to equipment decontamination and the subsequent generation of decontamination fluids.

1.2 Summary of Method

Equipment decontamination is used to remove potential contaminants from a sampling device or piece of field equipment prior to and between the collection of samples and is also used to limit personnel exposure to residual contamination that may be present on used field equipment.

Contaminants can be physically removed from equipment or deactivated by sterilization or disinfection. Gross contamination of equipment requires physical decontamination, including abrasive and nonabrasive methods. These include the use of brushes, air and wet blasting, and high-pressure water, followed by a wash/rinse process using appropriate cleaning solutions. A solvent rinse may be required when organic contamination is present, and an acid rinse may be required when metals are parameters of interest. Equipment decontamination procedures can vary depending on the media being sampled and the type of sampling equipment being used. Disposal of decontamination fluids will be handled on a project-specific basis and will be in accordance with all applicable regulations.

1.3 Equipment

The following equipment may be utilized when decontaminating equipment. Project-specific conditions or requirements may warrant the use of additional equipment or deletion of items from this list. For specialized sampling programs involving per- and polyfluorinated alkyl substances (PFAS), refer to Attachment B for further details.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)

- Alconox®, Liquinox® or other nonphosphate concentrated laboratory-grade soap
- Simple Green® or other nontoxic biodegradable cleaner
- Deionized, distilled, or organic-free water, as appropriate (may be supplied by the laboratory or purchased from commercial vendors depending on project requirements)
- Pump sprayer
- Pressure sprayer
- Squeeze bottle filled with pesticide-grade hexane (option for organic analyses)
- Squeeze bottle filled with pesticide-grade methanol (option for organic analyses)
- Squeeze bottle filled with pesticide-grade isopropanol (option for organic analyses)
- Squeeze bottle filled with 10 percent nitric acid (option for metals analyses and stainless-steel equipment)
- Squeeze bottle filled with 1 percent nitric acid (option for metals analyses)
- Container (squeeze bottle to 5-gallon bucket) filled with potable water and a nonphosphate, laboratory-grade soap (approximately 1 tablespoon of soap to 5 gallons of water)
- Extra quantities of above listed liquids
- Potable water
- Containers, such as buckets or wash basins (the type and number of containers is dependent on the procedure)
- Scrub brushes
- Small wire brush
- Aluminum foil
- Polyethylene sheeting
- A container for decontamination of pumps and associated tubing.

1.4 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

Samples containing chemical contaminants may be handled during implementation of this SOP. Certain decontamination fluids, including solvents and/or acids, are considered hazardous materials, and TRC employees will appropriately handle and store them at all times. Appropriately manage chemicals that pose specific toxicity or safety concerns, and follow any other relevant requirements as appropriate. Hazardous substances may be incompatible or may react to produce heat, chemical reactions, or toxic products. Some hazardous substances may be incompatible with clothing or equipment and can permeate or degrade protective clothing or equipment. Also, hazardous substances may pose a direct health hazard to workers through inhalation or skin contact or if exposed to heat/flame and they combust. Safety data sheets for chemicals handled by TRC personnel should be maintained in a designated location at the project site.

1.5 Cautions and Potential Problems

Special care should be taken when decontaminating equipment used for sampling for PFAS. Please refer to Attachment B for details.

- The use of deionized, distilled or organic-free water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment provided that it has been certified by the vendor as analyte-free and/or meets the project-specific requirements.

- Alconox®, Liquinox®, or other nonphosphate, concentrated, laboratory-grade soap may contain trace quantities of perchlorate.

- Avoid using an excessive amount of soap during decontamination procedures, as this could result in difficulty rinsing the soap residue off of the equipment. Typically the soap solution is prepared using 1 tablespoon of soap to 5 gallons of water.

- Use sufficient amount of decontamination fluid (e.g., acid or solvent rinses) so that the fluid flows over the equipment and runs off. Spraying the equipment with a minimal amount of decontamination fluid that does not run off is ineffective.

- Spent decontamination solutions are considered investigation-derived waste (IDW) and must be managed as directed by the site-specific field program. Project and regulatory requirements, chemical compatibility, ambient conditions and professional judgment should be used to determine the appropriate decontamination process with respect to combining and/or segregating decontamination fluids. Section 3 of this SOP provides more guidance on the disposal procedures.

- Several procedures can be established to minimize the potential for cross-contamination or analytical interference by decontamination fluids. For example:

  - The use of methanol in the decontamination procedure may not be appropriate if methanol is a contaminant of concern.

  - Isopropanol may be used as a substitute for methanol but may not be appropriate when collecting samples for volatile organic compound (VOC) analyses. Residual isopropanol on the equipment may cause substantial interferences in subsequent VOC analyses and may result in unnecessary dilutions and/or false positive results if isopropanol is not removed in subsequent decontamination steps. It should also be noted that the application of isopropanol to hot metal surfaces (e.g., a steam-cleaned split spoon) may cause oxidation of the isopropanol to acetone.

- If hexane is used in the decontamination procedure, caution should be used to ensure that the hexane is completely volatilized and the equipment is subsequently rinsed when samples are to be analyzed for VOCs and volatile petroleum hydrocarbons (VPH). Residual hexane on equipment could interfere with the VOC and VPH analyses and may result in unnecessary dilutions and/or false positive results.

- Cover monitoring and sampling equipment with protective material (i.e., aluminum foil, polyethylene sheeting, or Ziploc® bags) to minimize potential re-contamination after decontamination.

- Use disposable sampling equipment when appropriate to minimize the need for decontamination. Although disposable sampling tools are encouraged in order to minimize the generation of decontamination fluids, it should be noted that plastic tools may not be appropriate for collection of samples to be analyzed for semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs). Potential phthalate contamination may cause significant interferences in the subsequent analyses and may result in unnecessary dilutions and/or false positive results.

- After decontamination, equipment should be handled only by personnel wearing clean disposable powder-free nitrile gloves to prevent recontamination.
- If equipment decontamination is performed in the field, the equipment should be moved away (preferably upwind) from the decontamination area to prevent recontamination.
- Equipment that is not decontaminated properly may result in potentially high biased results in field samples. **Note:** Equipment blank collection may be appropriate after decontamination of equipment used to collect highly contaminated samples.

1.6 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

Refer to the site-specific sampling plan and/or Quality Assurance Project Plan (QAPP), if applicable, for site-specific procedures. Other state or federal requirements may be above and beyond the scope of this SOP and will be followed if applicable. In all instances, the actual procedures used should be documented and described in the field notes.

2.1 General

All personnel, sample containers, and equipment leaving the contaminated area of a site must be decontaminated. Various decontamination methods will either physically remove contaminants by abrasive and/or washing actions, inactivate contaminants by disinfection or sterilization, or both. Decontamination procedures should be documented in the field book.

2.2 Physical Decontamination Procedures

In many cases, gross contamination can be removed by physical means. The physical decontamination techniques appropriate for equipment decontamination can be grouped into two categories: abrasive methods and nonabrasive methods. In general, heavy equipment decontamination is conducted by drilling and construction subcontractors and not by TRC personnel. However, TRC personnel will typically need to document such decontamination efforts as part of project work.

ABRASIVE CLEANING METHODS APPROPRIATE FOR DRILLING EQUIPMENT (DRILLING RIGS, ETC.)

Abrasive cleaning methods involve rubbing and wearing away the top layer of the surface containing the contaminant. The following abrasive methods are available but are not commonly used:

- *Mechanical:* Mechanical cleaning methods use brushes of metal or nylon. The amount and type of contaminants removed will vary with the hardness of bristles, length of brushing time, and degree of brush contact.

- *Air Blasting:* Air blasting is used for cleaning large equipment, such as bulldozers, drilling rigs, or auger bits. The equipment used in air blasting employs compressed air to force abrasive material through a nozzle at high velocities. The distance between the nozzle and the surface cleaned, as well as the pressure of air, the time of application, and the angle at which the abrasive material strikes the surface, determines cleaning efficiency. Air blasting has several disadvantages, including it is unable to control the amount of materials removed, it can aerate contaminants, and it generates large amounts of waste.

- *Wet Blasting:* Wet blasting, also used to clean large equipment, involves use of a suspended fine abrasive delivered by compressed air to the contaminated area. The amount of materials removed can be carefully controlled by using very fine abrasives. One disadvantage of this method is the generation of a large amount of waste.

NONABRASIVE CLEANING METHODS APPROPRIATE FOR FIELD EQUIPMENT (DRILLING AUGERS AND RIGS, ETC.)

Nonabrasive cleaning methods involve forcing the contaminant off of a surface with pressure. In general, less of the equipment surface is removed using nonabrasive methods. Special care should be taken during decontamination procedures following sampling for PFAS. Please refer to Attachment B for details. The following non-abrasive methods are available:

- *High-pressure Potable Water:* This method consists of a high-pressure pump, an operator-controlled directional nozzle, and a high-pressure hose. Flow rates typically range from 20 to 140 liters per minute.

  This procedure is used the majority of the time and is more appropriate for equipment with painted surfaces.

- *Ultrahigh-Pressure Potable Water:* This system produces a pressurized water jet. The ultrahigh-pressure spray removes tightly adhered surface film. The water velocity ranges from 500 meters per second (m/sec) to 900 m/sec. Additives can enhance the method. This method is not applicable for hand-held sampling equipment.

  This procedure is not commonly used but would be appropriate for carbon steel drilling rods and augers.

2.3 Procedure for Sampling Equipment

Sampling equipment, such as split-spoon samplers, shovels, hand augers, trowels, spoons, spatulas, bailers, tethers, dippers, and pumps, will be cleaned using the following procedure. Special care should be taken during decontamination procedures following sampling for PFAS. Please refer to Attachment B for details. **Note:** The overall number of containers needed for collection of decontamination fluids may vary depending on chemical compatibilities, project and regulatory requirements, and ultimate disposal methods for these fluids.

1. Lay out sufficient polyethylene sheeting on the ground or floor to allow placement of the necessary number of containers (e.g., plastic wash basins or buckets) and an air drying area. The number of decontamination steps and designated containers should be determined prior to field sampling based on the site-specific sampling plan. At a minimum, one container should be designated for the detergent wash. A second container should be designated for water rinsing. A third container may be designated for nonwater rinsing. If more than one, the nonwater rinsate fluids may need to be separated. Nonwater rinsate fluids should not be combined with the detergent wash during decontamination. Place the containers on the polyethylene sheeting. The decontamination line should progress from "dirty" to "clean".

   Note: In instances where acid or solvent rinses are required, additional containers may be needed to manage collection and subsequent disposal of the spent decontamination fluids.

2. Fill the first container with potable water. Add sufficient nonphosphate concentrated laboratory-grade soap to cause suds to form in the container. Do not use an excessive amount of the soap (approximately 1 tablespoon of soap to 5 gallons of water), or rinsing the soap residue off of the equipment will be difficult.

3. Brush any visible dirt off of the sampling equipment into a designated area before getting equipment wet.

4. Using a clean, coarse scrub brush, submerge and wash the sampling equipment in the soap solution in the first container, removing all dirt or visible hydrocarbons. Allow excess soap to drain off the equipment into the container when finished. If cleaning a pump that is not completely disassembled, run the submerged pump in the container long enough to allow sufficient contact time with the internal components of the pump.

5. Rinse the equipment with potable water over an appropriate container, using a coarse scrub brush or pressure sprayer to aid in the rinse if necessary. If an additional acid or solvent rinse is not required, proceed to Step 8.

6. ******If sampling for metals and if required by the project, rinse the equipment with nitric acid over an appropriate container. Consider using a container dedicated to acidic solutions to minimize the volume of liquid that needs to be neutralized later. A 10 percent nitric acid solution is used on stainless steel equipment. A 1 percent nitric acid solution is used on all other equipment. If not required, this step may be omitted.

   Rinse the equipment over an appropriate container using deionized, distilled or organic-free water. If cleaning a pump that is not completely disassembled, run the submerged pump in the container long enough to allow sufficient contact time with the internal components of the pump.

7. ******If sampling for organic parameters and if required by the project, rinse the equipment over an appropriate container using pesticide-grade methanol or isopropanol (see Cautions and Potential Problems). If oily, a pesticide-grade hexane rinse should follow the methanol/isopropanol rinse, or as an alternative, Simple Green® can be used if approved by the Project Manager. Consider using an appropriate container dedicated to volatile solvents to minimize the volume of liquid that subsequently needs to be managed as IDW. If not required, this step may be omitted.

   Allow the equipment to completely air dry prior to proceeding to the next step.

   **** Steps 6 and 7 are optional and may be used on a site-specific basis. The site-specific sampling plan or QAPP, if available, should be consulted. In the absence of a sampling plan or QAPP, the Project Manager will decide upon the necessity of these steps.**

8. Rinse the equipment over an appropriate container using deionized, distilled or organic-free water. If cleaning a pump that is not completely disassembled, run the submerged pump in the container long enough to allow sufficient contact time with the internal components of the pump.

9. Allow the equipment to completely air dry on a clean surface (e.g., polyethylene sheeting or a clean container) (See*NOTE).

   ***NOTE** that if temperature or humidity conditions preclude air drying equipment, sufficient spares, if possible, should be available so that no item of sampling equipment need be used more than once. If an ample amount of spare equipment is not available and the equipment will not completely air dry, additional rinses with deionized, distilled or organic-free water should be used. The inability of equipment to air dry and the usage of additional rinses should be recorded in the field book or on the appropriate form.

10. Reassemble equipment, if necessary, and wrap completely in clean, unused, protective material. Reuse of equipment on the same day without wrapping in protective material is acceptable.

11. Spent decontamination fluids are considered IDW and must be managed as directed by the site-specific field program.

12. Record the decontamination procedure in the field book or on the appropriate form.

2.4 Procedure for Measuring Equipment

Measuring equipment, such as pressure transducers, water level indicators, oil/water interface probes, and soil moisture/pH meters will be cleaned using the following procedure, unless it conflicts with the manufacturer's recommendations. Special care should be taken during decontamination procedures following sampling for PFAS. Please refer to Attachment B for details.

1. Fill two clean containers (e.g., plastic wash basins or buckets) with potable water.

2. Add sufficient nonphosphate concentrated laboratory-grade soap to one container to form a thin layer of soap suds. If oily residues are apparent, the use of Simple Green® may be required.

3. Brush any visible dirt off of the measuring equipment before getting the equipment wet.

4. Either spray rinse the device with the soap solution over the first container, or for heavily soiled equipment, immerse the device in the container containing soap and gently agitate. Scrub device if it is soiled. Do not submerse any electrical controls or take-up reels. Submerse only that portion of the device that came in contact with potential contaminants.

5. Immerse the device in the container containing the potable water and gently agitate. Do not submerse any electrical connectors or take-up reels. Submerse only that portion of the device that came in contact with potential contaminants.

6. Spray rinse equipment with deionized, distilled, or organic-free water over the last container used.

7. Allow the equipment to air dry if time allows.

8. Record the decontamination procedure in the field book or on the appropriate form.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for IDW disposal with the Project Manager.

Each project must consider IDW disposal methods and have a plan in place prior to performing the field work. Provisions must be in place regarding what will be done with IDW. If IDW cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

One type of quality control sample specific to the field decontamination process is the equipment blank. The equipment blank provides information about the effectiveness of the decontamination process employed in the field. An equipment blank can detect contamination that may arise from potentially contaminated equipment or equipment that has not been decontaminated effectively.

Equipment blanks consist of a sample of analyte-free (i.e., deionized, distilled, organic-free) water that is poured over and through a decontaminated sampling device and placed in a clean sample container. Ideally, the reagent water should come from the laboratory and be certified as clean. If the blank water is not certified as clean and/or not supplied by the laboratory performing the analyses, a separate water blank that has not run through the sampling equipment should also be sent to the laboratory for analysis.

Equipment blanks are typically collected for all parameters of interest at a minimum rate of 1 per 20 samples for each parameter. The frequency of equipment blank collection will vary from project to project, depending upon the data quality objectives, and will be specified in either the site-specific sampling plan or QAPP. Equipment blanks are typically not required if dedicated sampling equipment is used.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

All reagents used must be documented in the field book or on the appropriate form. Any deviations from the decontamination procedures specified in the sampling plan or QAPP must be approved by the Quality Assurance (QA) Officer and Project Manager and documented in the field book. The lot number and vendor of each reagent used should be documented in the field book. Refer to ECR SOP 001 for field documentation procedures.

6.0 REFERENCES

USEPA. December 1987. *A Compendium of Superfund Field Operations Methods*. EPA/540/P-87/001.

USEPA. January 1991. *Compendium of ERT Groundwater Sampling Procedures*. OSWER Directive 9360.4-06. PB91-9211275.

USEPA. November 1992. *RCRA Ground-Water Monitoring: Draft Technical Guidance*. EPA/530-R-93-001. USEPA Office of Solid Waste.

USEPA. January 1999. *Compendium of ERT Groundwater Sampling Procedures*. EPA/540/P-91/007. OSWER Directive 9360.4-06. PB91-921275.

USEPA. December 20, 2011. *Field Equipment Cleaning and Decontamination*. SESDPROC-205-R2. Region 4. Science and Ecosystems Support Division. Athens, Georgia.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
1	DECEMBER 2016	ADDED ATTACHMENT B TO ACCOMMODATE SOP MODIFICATIONS REQUIRED WHEN SAMPLING FOR PFAS; CHANGED NAMING CONVENTION FOR SOP FROM RMD TO ECR.
2	JANUARY 2020	TRC RE-BRANDING

Attachment A: SOP Fact Sheet

EQUIPMENT DECONTAMINATION

PURPOSE AND OBJECTIVE

Removing or neutralizing potential contaminants that may have accumulated on equipment and vehicles ensures protection of personnel, reduces or eliminates potential transfer of contaminants to clean areas, and minimizes the likelihood of sample cross-contamination. Preventing or minimizing potential cross-contamination of samples is important for the collection of representative samples, avoiding the possible introduction of sampling error into sample results, and for protecting the health and safety of site personnel.

WHAT TO BRING

- Field book
- Appropriate PPE
- Site-specific HASP
- Alconox®, Liquinox® or other nonphosphate concentrated laboratory-grade soap
- Simple Green® or other nontoxic biodegradable cleaner
- Deionized, distilled, or organic-free water, as appropriate
- Potable water (or water containers if potable water source on site or nearby)
- Pump or pressure sprayer
- Squeeze bottles filled with appropriate decontamination chemicals (e.g., organic solvents, nitric acid)
- Containers, such as buckets or wash basins (type and number is dependent on the procedure)
- Scrub brushes
- Aluminum foil
- Polyethylene sheeting

OFFICE

- Prepare/update the site-specific HASP; make sure the field team is familiar with the latest version.
- Review site-specific sampling plan/QAPP for decontamination procedures and procedures for management of investigation-derived waste (IDW) (e.g., used decontamination solutions).
- Confirm all required decontamination supplies are in stock or order as needed.

ON-SITE

- Verify project HASP including safety data sheets for decontamination chemicals used on site.
- Conduct daily Health & Safety tailgate meetings, as appropriate.
- Establish a designated equipment and personnel decontamination area.
- Provide for the proper collection and management of all IDW.
- Verify that appropriate PPE is worn by all site personnel (including subcontractors) and the work area is safe.

SAMPLING EQUIPMENT DECONTAMINATION - PROCEDURES

Sampling equipment, such as split-spoon samplers, shovels, hand augers, trowels, spoons, spatulas, bailers, tethers, dippers, and pumps, will be cleaned using the following procedure. **A more simplified procedure for decontamination of measuring equipment is presented in the SOP.** Note: The overall number of containers needed for collection of decontamination fluids may vary depending on chemical compatibilities, project and regulatory requirements, and ultimate disposal methods for these fluids.

1. Lay out sufficient polyethylene sheeting on the ground or floor and the necessary number of containers (e.g., plastic wash basins or buckets) and an air drying area. At a minimum, one container should be designated for the detergent wash. A second container should be designated for water rinsing. A third container may be designated for nonwater rinsing. Nonwater rinsate fluids should not be combined with the detergent wash during decontamination. The decontamination line should progress from "dirty" to "clean".
   Note: In instances where acid or solvent rinses are required, additional containers may be needed to manage collection and subsequent disposal of the spent decontamination fluids.
2. Fill the first container with potable water. Add sufficient nonphosphate concentrated laboratory-grade soap to cause suds to form in the container.
3. Brush any visible dirt off of the sampling equipment before getting equipment wet.
4. Using a clean, coarse scrub brush, submerge and wash the sampling equipment in the soap solution in the first container.

EQUIPMENT DECONTAMINATION

5. Rinse the equipment with potable water over an appropriate container. If an additional acid or solvent rinse is not required, proceed to Step 8.
6. **If sampling for metals and if required by the project, rinse the equipment with nitric acid over an appropriate container. Consider using a container dedicated to acidic solutions to minimize the volume of liquid that needs to be neutralized later. A 10 percent nitric acid solution is used on stainless steel equipment. A 1 percent nitric acid solution is used on all other equipment. If not required, this step may be omitted.
7. **If sampling for organic parameters and if required by the project, rinse the equipment over an appropriate container using pesticide-grade methanol or isopropanol (see Caution and Potential Problems). If oily, a pesticide-grade hexane rinse should follow the methanol/isopropanol rinse, or as an alternative, Simple Green® can be used if approved by the Project Manager. Consider using an appropriate container dedicated to volatile solvents to minimize the volume of liquid that subsequently needs to be managed as IDW. If not required, this step may be omitted.
   Allow the equipment to completely air dry prior to proceeding to the next step.
   ** Steps 6 and 7 are optional and may be used on a site-specific basis. The site-specific sampling plan or QAPP, if available, should be consulted. In the absence of a sampling plan or QAPP, the Project Manager will decide upon the necessity of these steps.
8. Rinse the equipment over an appropriate container using deionized, distilled or organic-free water.
9. Allow the equipment to completely air dry on a clean surface (e.g., polyethylene sheeting or a clean container).
   *NOTE that if temperature or humidity conditions preclude air drying equipment, sufficient spares, if possible, should be available so that no item of sampling equipment need be used more than once. If an ample amount of spare equipment is not available and the equipment will not completely air dry, additional rinses with deionized, distilled or organic-free water should be used. The inability of equipment to air dry and the usage of additional rinses should be recorded in the field logbook or on the appropriate form.
10. Reassemble equipment, if necessary, and wrap completely in clean, unused, protective material. Reuse of equipment on the same day without wrapping in protective material is acceptable.
11. Spent decontamination fluids are considered IDW and must be managed as directed by the site-specific field program.

INVESTIGATION DERIVED WASTE (IDW) DISPOSAL

Field personnel should review the project work plan and ensure project-specific IDW management documentation and containerization requirements are specified or discussed with the Project Manager before going to the project site.

DATA MANAGEMENT AND RECORDS MANAGEMENT

All reagents used must be documented in the field book or an appropriate field form. Any deviations from the decontamination procedures specified in the work plan, sampling plan or QAPP must be approved by the Quality Assurance (QA) Officer and Project Manager and documented in the field book. The lot number and vendor of each reagent used should be documented in the field logbook. Refer to ECR SOP 001 for field documentation procedures.

DOs AND DO NOTs OF EQUIPMENT DECONTAMINATION

DOs:

- DO call the Project Manager or field team leader if unexpected conditions are encountered or at least daily to update them on site work.
- DO manage and collect IDW in accordance with project requirements.
- DO use deionized, distilled or analyte free water that is provided by the laboratory, is certified analyte-free, and/or meets project requirements.
- DO use sufficient amount of decontamination fluids so that the fluid flows over the equipment and runs off.
- DO use new wrapped disposable dedicated sampling equipment when appropriate to minimize the need for decontamination.

DO NOTs:

- DO NOT use an excessive amount of soap during decontamination.
- DO NOT sign anything in the field unless authorized in writing by client. This includes waste disposal documentation, statements, etc.; call PM if this issue arises.

Attachment B: SOP Modifications for PFAS

Due to the pervasive nature of PFAS in various substances routinely used during sampling and the need to mitigate potential cross-contamination or sampling bias to ensure representative data are collected, special care should be taken when sampling for PFAS. The following table highlights the required modifications to this SOP when sampling for PFAS.

PFAS Equipment Decontamination Protocols	
SOP Section Number	**Modifications to SOP**
1.3	• Use only Alconox® or Liquinox® soap; do not use Decon 90. • Use new plastic buckets for wash and rinse water. • Ensure that PFAS-free water is used during the decontamination procedure. • Do not use aluminum foil.
1.5	Always consult the Site-specific Health and Safety Plan prior to conducting field work. The following considerations should be made with regards to decontamination procedures: • Tyvek® suits should not be worn. Cotton coveralls may be worn. • Boots and other field clothing containing Gore-Tex™ or other waterproof/resistant material should not be worn. This includes rain gear. Boots made with polyurethane and polyvinyl chloride (PVC) are acceptable. • Food and drink should not be allowed within the decontamination area. Bottled water and hydration drinks (e.g., Gatorade®) may be consumed in the staging area only. • Personnel involved with decontamination should wear a new pair of nitrile gloves after each decontamination procedure when handling equipment to avoid re-contamination. Avoid handling unnecessary items with nitrile gloves. • Do not store on or cover equipment with aluminum foil after decontamination. Use of polyethylene sheeting is acceptable. • Avoid wearing clothing laundered with fabric softeners. • Avoid wearing new clothing (recommended six washings since purchase). Clothing made of cotton is preferred. • Avoid using cosmetics, moisturizers, hand creams, or other related products as part of cleaning/showering the morning of sampling and decontamination field work.
2.2	• New nylon or metal bristle brushes should be used for mechanical cleaning methods. • If high-pressure water is used, it must be tested prior to use for presence of PFAS.
2.3	• Ensure that PFAS-free water is used during the decontamination procedure.
2.4	• Ensure that PFAS-free water is used during the decontamination procedure.

Title:	Procedure Number:
Calibration of Field Instruments for Water Quality Parameters	**ECR 011**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures

Technical Review	Date	Environmental Sector Quality Director	Date
Darby Litz	1/1/20	Elizabeth Denly	1/1/20

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LIST OF ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope and Applicability

The purpose of this standard operating procedure (SOP) is to provide a framework for calibrating field instruments used to measure water quality parameters for ground water and surface water. Water quality instruments addressed in this SOP include those that measure temperature, pH, dissolved oxygen (DO), conductivity/specific conductance, oxidation-reduction potential (ORP), and turbidity.

1.2 Summary of Method

All monitoring instruments must be calibrated before they are used to measure environmental samples. This SOP outlines the general methods for field instrument calibration, calibration documentation requirements, and corrective action procedures that will be implemented during field activities. Calibration procedures are different for each field instrument used and these procedures should be provided by the instrument manufacturer. The manufacturer's instruction manual (including the instrument specifications) should accompany the instrument into the field.

At a minimum, calibration and/or a calibration check must be performed at the beginning of each day prior to use. Site-specific work plans should be consulted for required calibration frequency. Note: The initial calibration may be performed in the office prior to the field event or by the equipment supplier; however, calibration checks should be performed on site prior to use on the day of the fieldwork.

1.3 Equipment

The following equipment may be utilized when calibrating water quality parameter measuring equipment. Project-specific conditions or laboratory requirements may warrant the addition or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE), as specified in the site-specific Health and Safety Plan (HASP).
- Water quality meter capable of measuring one or more of the following based on project scope: pH, temperature, DO, specific conductivity, and ORP (e.g., YSI 600XL, Horiba U-50, Hydrolab Quanta/QED MP-20, or equivalent)
- Turbidity meter (e.g., LaMotte Model 2020e, Hach 2100P, or equivalent)
- Deionized water
- Flow-through cell
- Ring stand with clamp
- Paper towels
- Soft tissue (e.g., Kimwipes®)
- Cuvettes

- Buffer solutions at pH 4, 7 and 10 standard units (SU)*. Commercially available solutions that have been validated by comparison to National Institute of Standards and Technology (NIST) standards are recommended for routine use.
- Conductivity solution (potassium chloride, typically 1,413 micromhos/centimeter [μmhos/cm])*
- ORP calibration solution (e.g., Zobell)*
- Turbidity standards (0, 1, 10 nephelometric turbidity units [NTUs] or StablCal Kit)*
- Zero DO solution (0.0 milligrams per liter [mg/L])*
- DO membrane kit (electrolyte solution, membranes)
- NIST thermometer (0.2ºC accuracy)*
- Small glass or polyethylene jars to hold the calibration standards (4-8 oz.)
- Field book
- Field instrument calibration logs
- Cup or spray bottle for the deionized water

*Dependent on the project-specific requirements and the instrument manufacturer

1.4 Definitions

Not applicable

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

Implementing this SOP will require the use of calibration solutions. The following health and safety precautions must be taken with the pH, conductivity, turbidity, zero DO and ORP solutions: Avoid inhalation, skin and eye contact, and ingestion.

Maintenance of the instruments will require the use of liquid cleaners. Although these substances are not hazardous materials, TRC will appropriately handle and store them at all times in accordance with manufacturer’s instructions.

1.6 Cautions and Potential Problems

General cautions and potential problems are discussed below. Specific issues for individual parameters are discussed in Section 2.

- Prior to calibration, all instrument probes must be cleaned according to the manufacturer’s instructions. Failure to perform this step (proper maintenance) can lead to erroneous measurements. Rental instruments are routinely maintained by the vendor but should be checked for residues upon receipt.

- Prior to using calibration standards, check and record all expiration dates and lot numbers for the solutions on the field instrument calibration log. Discard any calibration standards that are past their expiration date.

- Avoid storing calibration solutions in extremely hot or cold temperatures to maintain solution integrity and prevent calibration errors.

- The volume of the calibration solutions must be sufficient to cover both the probe being calibrated and the temperature sensor (see manufacturer's instructions for additional information).

- Pre-rinse the sensor and calibration cup with a small amount of calibration solution to minimize dilution or cross-contamination.

- If desired, use a ring stand and clamp to secure the sonde in an upright position. This will prevent the sonde from falling over and damaging the probes.

- While calibrating or performing sample measurements, make sure there are no air bubbles lodged between the probe and the probe guard.

- Do not immerse the sensors in sea water or other highly saline water, alcohol or organic solvents.

- Problems during calibration may indicate the need to clean or replace sensors, electrodes or membranes or replace the calibration solutions.

- Have several clean absorbent paper towels or cotton cloths available to dry the probe between rinses and calibration solutions. Shake excess water off of the probes and dry off the outside of the probe sensors.

- All meters may have different relative accuracy, which will be specified in the instrument manual. Confirm that the meter being used meets the project's accuracy requirements.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project- and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- OSHA 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training

2.0 PROCEDURES

Prior to use, instruments that will be used during field activities will be inspected to ensure they are clean, checked for possible malfunctions, and calibrated in accordance with manufacturer's procedures. Often, equipment provided by a rental company is calibrated prior to shipment, and a calibration certificate is provided with the equipment. Review the calibration certificate provided by the equipment supplier.

Calibration checks (or verifying that instrument readings fall within an acceptable range of a standard without running through the full instrument calibration steps) will be performed on field instruments prior to their initial use, at least once daily, or whenever indications of faulty readings or instrument malfunction occurs. Some instruments or certain project scopes may require more frequent calibration checks depending on project quality objectives. In general, instrument selection and calibration will include the following steps:

- Determine which instruments are needed for the specific field tasks. Record the make, model number, and serial number of the instrument on the field instrument calibration log or in the field book.
- Obtain the necessary instruments and standard solutions for calibration. Check expiration dates on standard solutions and replace if out of date. Record the manufacturer, true value, lot number and expiration date of the standard solutions on the field instrument calibration log or in the field book.
- Assemble the instrument and turn it on allowing the instrument to warm up.
- Check battery charge, and charge or replace if necessary.
- Clean instrument (if necessary).
- If applicable, program the multi-probe instrument so that the applicable parameters to be measured will be displayed.
- Calibrate the instrument prior to field use in accordance with manufacturer's procedures. (Note: If applicable, calibrate DO and conductivity first, because these parameters may affect the other calibrations).
- Document all calibration activities and results on the field instrument calibration log or in the field book.
- If the instrument malfunctions and cannot be corrected, obtain a replacement.
- Clean and decontaminate the instrument after use and before storage.
- Conduct calibration checks at least once per day or as needed.

The subsections that follow provide additional details and guidance regarding calibration for specific parameters; however, since every field instrument is different, refer to the specific instrument's manual for appropriate operating and calibration procedures.

2.1 Temperature

Most instrument manuals state that calibration of the temperature sensor is not required, but this SOP recommends that the temperature sensor be checked to verify its accuracy. This accuracy check should be performed at least once per year and the accuracy check date/information should be kept with the instrument. If the accuracy check date/information is not included with the instrument or the last check was performed over a year prior to the date of use, it is recommended that the temperature sensor accuracy be checked at the beginning of the sampling event. If the instrument contains multiple temperature sensors, each sensor should be checked. Accuracy checks may be performed by the manufacturer/equipment supplier or in the field. Review the calibration certificate provided by the equipment supplier.

In the event of suspect temperature readings, the following verification procedure can be performed.

FIELD VERIFICATION PROCEDURE

1. Record the manufacturer, model number, and the certification number of the NIST thermometer being used to check the instrument's temperature sensor on the field instrument calibration log or in the field book. Allow a container filled with water to equilibrate to ambient temperature.

2. Place an NIST thermometer and the instrument's temperature sensor into the water, and wait approximately 2 to 3 minutes for both temperature readings to stabilize.

3. Record the temperature displayed by the thermometer and the temperature sensor on the field instrument calibration log or in the field book.

4. Compare the two measurements. The instrument's temperature sensor must agree with the NIST thermometer measurement within the accuracy of the sensor (typically $\pm$0.15ºC). If the measurements do not agree, determine the correction factor to be applied to any subsequent temperature measurements made with this instrument. This correction factor must be applied to all readings made with the temperature sensor of this instrument.

   Correction Factor = NIST thermometer value – temperature sensor value

5. Record the date the temperature sensor check was performed and the correction factor that was determined, if applicable, on the field instrument calibration log or in the field book.

2.2 Dissolved Oxygen

DO is the volume of oxygen that is dissolved in water and is typically measured using an electrochemical membrane sensor.

CAUTIONS AND POTENTIAL PROBLEMS WITH DO MEASUREMENTS

- The DO probe's membrane and electrolyte solution should be checked prior to the sampling period and replaced if needed. If wrinkles or air bubbles are present under the membrane, if the membrane is torn or dirty, or if the electrolyte solution looks contaminated, replace both the membrane and electrolyte solution prior to calibration. Failure to perform this step may lead to erratic or erroneous measurements.
- Rental instruments are routinely maintained by the vendor, but the membrane should be checked for signs of wear upon receipt.
- If the probe reading shows the error message, "value out of range", the instrument probe must be recalibrated at a minimum. If the error persists, replace the sensor membrane and recalibrate.
- Most meters will allow you to calibrate the meter in air or against a wet sponge, which gives a "saturated air" calibration. Like pH, conductivity, and ORP, DO is heavily dependent on temperature. DO is also dependent upon barometric pressure. Typically DO is calibrated by entering the barometric pressure (usually in mm of mercury). Barometric pressure is dependent upon elevation, so be aware of substantial differences in elevation between your sampling location and the location from which you are

obtaining the barometric pressure reading. Use the Oxygen Solubility at Indicated Pressure chart in Attachment A for comparison to your calibrated reading.

- Barometric pressure should be corrected to local altitude for DO calibration:

  True BP (mm Hg) = [Corrected BP (mm Hg)] – [2.5 * Local Altitude (ft. above sea level)/100]

- If the calibration cup is used for DO, ensure the cup is loose to allow for pressure equilibration.
- Wait 3 to 5 minutes for the air in the cup to saturate with water during DO calibration.
- If calibrating in air, remove water droplets from the membrane by shaking the probe prior to inserting it into the calibration environment.
- Allow the temperature to stabilize completely in the calibration environment.
- Always keep the sensor clean of biofouling, such as bacteria or algae growth which may generate or consume oxygen resulting in erroneous readings.
- Keep the sensor free of oil, which could clog the membrane and prevent oxygen from diffusing to the sensor.
- Store the probe in a moist environment to keep the membrane from drying out, but do not store it in water which could encourage algae growth on the probe.

CALIBRATION PROCEDURE

1. Gently dry the temperature sensor according to manufacturer's instructions.

2. Place a wet sponge, a wet paper towel, or 1/8 inch of water on the bottom of the DO calibration container that comes with the instrument. (The protective cover of the probe assembly also serves as the container used for the DO calibration.)

3. Place the DO probe in the container without the probe coming in contact with the wet sponge or paper towel. The probe must fit loosely in the container to ensure it is vented to the atmosphere.

4. Allow the confined air to become saturated with water vapor (saturation occurs in approximately 3 to 5 minutes as temperature becomes stable). During this time, turn on the instrument to allow the DO probe to warm up (may require at least 10-20 minutes warm-up time).

5. Record the barometric pressure (usually in mm of mercury) from the instrument's onboard sensor, if available. If the instrument does not have an onboard barometer, this measurement can also be determined from an on-site barometer if a weather station is on site and manually entered into the meter. It is recommended that the barometric pressure not be obtained from the local weather service unless the pressure is corrected for the elevation of the sampling location and this is the only source of barometric data. [**Note:** inches of mercury times 25.4 mm/inch mercury equals mm of mercury].

6. Record the DO reading in mg/L and percent and compare this reading to the Oxygen Solubility at Indicated Pressure chart in Attachment A. For example, if the barometric

pressure is 750 mm Hg and the temperature inside the calibration cup is 25°C, the DO in mg/L reading should be 8.13 mg/L. Record this value on the field instrument calibration log.

7. If the values recorded on the field instrument calibration log for DO in mg/L do not agree with the published values from Attachment A and are not within the accuracy of the instrument (such as ± 0.2 mg/L and ± 2%, depending on the reading), repeat calibration. If this does not work, change the membrane and electrolyte solution and repeat calibration.

8. Remove the probe from the container, rinse it with deionized water, pat it dry with a towel, and place it into a zero (0.0 mg/L) DO standard if being used as part of the calibration. Fill the protective cup with the fresh zero DO standard. Pour the zero DO standard into the protective cup; the standard should be close enough to the top, so that the DO probe fits tightly into the container (no headspace). Check and record the unit's temperature reading.

9. Wait until the "mg/L DO" readings have stabilized. The instrument should read between -0.5 and +0.5 mg/L or to the accuracy of the instrument (usually ± 0.2 mg/L) within 3 minutes. Record this value on the field instrument calibration log. If the instrument does not reach this value, it may be necessary to clean the probe and change the membrane and electrolyte solution. Repeat the zero DO step if the value obtained is not acceptable. If this does not work, prepare a new 0.0 mg/L standard. If these procedures do not work, consult the equipment vendor for troubleshooting or equipment replacement.

   NOTE: For Zero DO checks: The solution used for this check contains sodium meta-bisulfite or sodium sulfite, which are harmful to the sensor and membrane. It is common practice to recalibrate the meter to 100% saturation after conducting a zero DO check to confirm that the sensor is still operating correctly. A zero DO check is not performed every day the instrument is in use for this reason, but a check should be performed at a minimum of once per sampling event. If conducting this check, be sure to record the manufacturer, true value, lot number, and expiration date of the solution on the field instrument calibration log.

2.3 pH

The pH is the measure of the degree of the acidity or alkalinity of a solution as measured on a scale of 0 to 14 SU. The pH of a sample is determined electrometrically using a glass electrode. All pH measurements are in SU.

CAUTIONS AND POTENTIAL PROBLEMS WITH PH MEASUREMENTS

- Choose the appropriate buffered standards that will bracket the expected values at the sampling locations. For ground water, the pH will usually be close to 7 SU. A minimum of two standards are typically needed for the calibration: one close to 7 SU, one at least two pH units below 7 SU or at least two pH units above 7 SU. The instrument will need to be re-calibrated if the water sample's pH is outside the range defined by the two standards used in the initial calibration, either by adding a third calibration point (if the meter will allow) or by selecting two new pH standards that bracket the water sample's pH.
- Regardless if performing a two- or three-point calibration, always calibrate with pH 7 buffer first.

CALIBRATION PROCEDURE

1. Allow the buffered standards to equilibrate to the ambient temperature.

2. Fill calibration containers with the buffered standards to ensure the pH probe and temperature sensor are completely submerged.

3. Remove the cover of the probe, rinse the probe in a cup filled with deionized water or use a spray bottle, and blot the probe dry with a soft tissue.

4. Enter the value of the first pH buffer solution (e.g., pH 7), immerse the probe in the standard, and allow at least 1 minute for temperature equilibration before proceeding. Record the temperature on the field instrument calibration log.

5. Enter the buffered solution value (7) into the pH calibration menu of the instrument. Allow the pH reading to stabilize for approximately 30 seconds, and if the reading does not change, finish the calibration and record the calibrated value on the field instrument calibration log. The calibration values after adjustment shall be within the accuracy of the instrument, or as required by the project. For example, if the accuracy of the meter is ±0.1 SU, then the calibration values after adjustment shall be between 6.9 and 7.1 SU. If the calibration values after adjustment are outside of this range, recalibrate. If readings continue to fluctuate or readings do not stabilize after recalibration, consult the equipment vendor for troubleshooting or equipment replacement (e.g., may need a new pH electrode).

6. Remove probe from the initial buffer solution, rinse in a cup filled with deionized water or use a spray bottle, and blot dry with soft tissue. Dispose of the used buffer solution.

7. Immerse probe into the second buffer solution (e.g., pH 4). Repeat step #5, substituting “4” into the pH calibration menu instead of “7”.

8. Remove probe from the second buffer solution, rinse in a cup filled with deionized water or use a spray bottle, and blot dry with soft tissue. Dispose of the used buffer solution.

9. Immerse probe in third buffer solution (e.g., pH 10) or continue to step #11 if only a two-point calibration is being performed. Repeat step #5, substituting “10” into the pH calibration menu instead of “7”.

10. Remove probe from the third buffer solution, rinse in a cup filled with deionized water or use a spray bottle, and blot dry with soft tissue. Dispose of the used buffer solution.

11. To perform the instrument pH check, select monitoring/run mode, (ensure that the initial buffer solution temperature [pH 7] has not changed), and immerse the probe into the buffer solution. Wait for the reading to stabilize. The instrument should read the initial standard value (7 SU) within the accuracy of the instrument, or as required by the project. Record the pH 7 check reading on the field instrument calibration log. If the reading is not within the acceptance criteria, then re-calibrate the instrument. If re-calibration does not correct the instrument reading, then the calibration range may be too wide. Reducing the calibration range by using standards that are closer together may improve the instrument’s accuracy.

2.4 Specific Conductance

Conductivity is used to measure the ability of an aqueous solution to conduct an electrical current. Specific conductance is the conductivity value corrected to 25ºC. Calibrating an instrument for specific conductance automatically calibrates the instrument for conductivity and vice-versa.

CAUTIONS AND POTENTIAL PROBLEMS WITH SPECIFIC CONDUCTANCE MEASUREMENTS

- Most instruments are calibrated against a single standard that is near the specific conductance of the environmental samples. A second standard that is above the environmental sample specific conductance can be used to check the linearity of the instrument in the range of measurements. However, a single-point calibration standard is adequate to assess the accuracy and operation of the sensor.
- Calibrate the conductivity with a standard near the anticipated conductivity of the water. For fresh water, a 1 mS/cm standard is appropriate.
- For some meters, it is important that the top vent hole of the conductivity sensor be immersed during the calibration. Review the instrument manual to determine if this is required.
- Specific conductance/conductivity can have different units (e.g., mmho/cm, mS/cm, µmho/cm, µS/cm), especially on auto-ranging instruments. Note: mhos/cm = Siemens/cm. Check with the Project Manager or database manager to determine if field measurements should be restricted to a consistent unit (e.g., µmhos/cm or µS/cm, not mmhos/cm or mS/cm) so that conversion is not necessary when importing data into a database.
- Be aware of meters which autocorrect for temperature and how to enter the calibration value per the procedures in the instrument's manual. To calibrate instruments that autocorrect for temperature, enter the calibration value of the solution (µmhos/cm at 25°C). For instruments without automatic temperature compensation, the solution's conductivity value must be corrected for the temperature that the sensor is reading before entering the value into the meter. In some cases, you may be able to adjust the temperature of the calibration solution to near 25°C, such that the standard calibration value is applicable; otherwise an adjustment for temperature needs to be accounted for. Additionally, if calibrating for conductivity instead of specific conductance, the solution's conductivity value must be corrected for the temperature that the sensor is reading.

CALIBRATION PROCEDURE

1. Allow the calibration standard to equilibrate to the ambient temperature.

2. Remove probe from its storage container, rinse the probe with a small amount of deionized water, and pat dry the sensor with a soft tissue.

3. Lower the sensor into the conductivity standard. Gently move the probe up and down in the solution to remove any air bubbles from the sensor if present. Allow the probe to sit in the solution for at least 30 seconds to allow values to equilibrate before proceeding.

4. Enter the calibration value of the solution (e.g., 1,413 µmhos/cm at 25°C). Record the temperature of the solution on the field instrument calibration log, and allow the specific conductance reading to stabilize for approximately 30 seconds. Record the calibrated value after stabilization on the field instrument calibration log. The reading should be within ±5% of the true value. If the reading is not within this range, recalibrate. If readings continue to fluctuate significantly after a recalibration, consult the equipment vendor for troubleshooting or equipment replacement.

5. Remove probe from the standard, rinse the probe with deionized water, and replace the protective cover over the sensors.

2.5 Oxidation-Reduction Potential (ORP)

The oxidation-reduction potential is the electrometric difference measured in a solution between an inert indicator electrode and a suitable reference electrode. The electrometric difference is measured in millivolts and is temperature dependent.

CAUTIONS AND POTENTIAL PROBLEMS WITH ORP MEASUREMENTS

- Note that ORP is not usually the same as Eh. Eh is ORP measured relative to a standard hydrogen electrode (SHE). Typical ORP reference electrodes used in the field are Ag/AgCl electrodes, not SHEs. The difference is that Eh would be approximately 200mV higher than ORP measured against a Ag/AgCl reference electrode. See Standard Methods 2580B and YSI Tech Note (2005) for more details.
- Some meters allow you to calibrate ORP, but many do not allow calibration. Testing solutions are available to verify your ORP reading but they are not accurate enough to be used as calibration standards.
- ORP is temperature dependent. Look up the millivolt (mV) calibration value at the measured temperature from the millivolt versus temperature correction table usually found on the standard bottle or on the standard instruction sheet. It may be necessary to interpolate millivolt values between temperatures.

CALIBRATION OR VERIFICATION PROCEDURE

1. Allow the calibration standard (e.g., a Zobell solution) to equilibrate to ambient temperature.

2. Remove the cover of the probe, and place it into the standard.

3. While stirring the standard, wait for the probe temperature to stabilize, and then read the temperature.

4. Look up the millivolt (mV) value at this temperature from the millivolt versus temperature correction table usually found on the standard bottle or on the standard instruction sheet. It may be necessary to interpolate millivolt values between temperatures. Enter the temperature-corrected ORP value, and calibrate the instrument. Record the values on the field instrument calibration log.

5. The reading should remain unchanged within manufacturer's specifications. If it changes, re-calibrate. If readings continue to change after calibration, consult the manufacturer.

6. If the instrument instruction manual states the instrument is factory calibrated, then verify the factory calibration against the standard. If the reading does not agree with the standard within the accuracy of the instrument, the instrument will need to be re-calibrated by the manufacturer.

2.6 Turbidity

Turbidity refers to how clear the water is and is a measure of relative sample clarity. The greater the amount of total suspended solids in the water, the higher the measured turbidity. The turbidity method is based upon a comparison of intensity of light scattered by a sample under defined conditions with the intensity of light scattered by a standard reference suspension. A turbidity meter is a nephelometer with a visible light source for illuminating the sample and one or more photo-electric detectors placed 90 degrees to the path of the light source. Turbidity values are recorded in NTUs.

CAUTIONS AND POTENTIAL PROBLEMS WITH TURBIDITY MEASUREMENTS

- Some instruments will only accept one standard. For these instruments, the standards will serve as check points.
- Some regulatory agencies will not allow turbidity measurements through a flow-through cell, and require a stand alone turbidity meter. Verify that the selected meter will meet project objectives prior to use.
- For the greatest accuracy during the calibration procedure, ensure that after the meter is blanked and the blank is scanned as a sample, the reading is 0.00 NTU. If not, re-zero the meter and scan the blank again until it reads 0.00 NTU. When scanning the calibration standards as the sample, scan the calibration standard three times removing the tube from the chamber after each scan. The readings should be consistent. Use the last consistent reading to calibrate the meter. If the readings are not consistent, avoid using an aberrant reading to calibrate the meter.
- The meter should be placed on a surface that is free from vibrations. Vibrations can cause high readings.
- Gently mix the sample by inverting before taking a reading, but avoid introducing air bubbles.
- Scratches, fingerprints, and water droplets on the outside of the cuvettes can cause additional light scatter, leading to inaccurate readings. If necessary, wipe the outside of the cuvette with a soft tissue. If the cuvette is scratched or dirty, discard.
- Ensure that the cuvette is always placed in the chamber in the same orientation, as differences in orientation can cause differences in results. Proper cuvette orientation may be indicated by a mark or arrow on both the cuvette and the instrument.

CALIBRATION PROCEDURES – STAND ALONE TURBIDITY METER

NOTE: Sometimes standards are provided in the cuvette with the meter.

1. Rinse a cuvette with deionized water. Shake the cuvette to remove as much water as possible. Do not wipe the inside of the cuvette, because lint from the wipe may remain in the cuvette. Add the standard to the cuvette.

2. Place the 0.0 NTU standard into the instrument and scan the sample (measure the standard). Record the reading on the field instrument calibration log. The 10.0 NTU standard can be measured after the 0.0 NTU standard is scanned.

3. Select the 10.0 NTU standard and scan the sample (measure the standard). The reading should be within $\underline{+}$10% of the true value. Record the reading on the field instrument calibration log. If the reading is within the acceptance criteria, then move on to step # 5. If not, calibrate the instrument to 10.0 NTU. Record the reading and any significant changes on the field instrument calibration log.

4. After adjusting the calibration, re-read the 10.0 NTU standard to ensure it is now meeting accuracy requirements. If not, repeat step #3. Otherwise, continue to step #5.

5. Repeat step #3, if needed, for the 1.0 NTU standard.

6. After adjusting the calibration, re-read the 1.0 NTU standard to ensure it is now meeting accuracy requirements ($\underline{+}$10% of the true value). If not, repeat step #3. Otherwise, continue to step #7.

7. As a final check of the instrument, scan the blank (0.0 NTU standard). The unit display should read very close to zero. Record the reading on the field instrument calibration log.

   NOTE: If during the calibration procedure, you find the value of the standard is >50% from the expected value (e.g., 0.49 NTU for the 1.0 NTU standard), scrolling to the true value (e.g., 1.0 NTU) and attempting to calibrate will result in an error code, because the value to which you have changed it is >50% of the expected value of the standard. In this case, it is necessary to re-calibrate the unit from the beginning starting with a blank. If this fails to produce adjustable and reproducible values for the 1.0 and 10.0 NTU standards, re-calibrate using new standards and discard the current standards. If the meter still fails to calibrate following repeated attempts at calibration, consult the equipment vendor for troubleshooting or equipment replacement.

   NOTE: If only performing a two-point calibration (depending on project requirements), the 0.0 NTU and 10 NTU (or comparable NTU level) standards should be used.

CALIBRATION PROCEDURES – MULTI-PARAMETER METER WITH FLOW-THROUGH CELL

This is a two point calibration with a standard and turbidity free water. The standard can be formazin, polymer beads, or a meter-specific quick calibration solution. Turbidity free water can be obtained by filtering distilled or deionized water through a 0.1, 0.3, or 0.45 micron filter.

1. Rinse the calibration cup and sensors with the turbidity free water. Fill the cup with enough water so that the turbidity sensor is covered (sensors pointed down).

2. Scan the sample (measure the standard). After the reading has stabilized, enter the zero turbidity value into the meter in accordance with manufacturer directions and record the reading on the field instrument calibration log.

3. Rinse the calibration cup and sensors with the standard solution. Fill the cup with enough standard solution so that the turbidity sensor is covered (sensors pointed down).

4. Scan the sample (measure the standard). After the reading has stabilized, enter the standard solution turbidity value into the meter in accordance with manufacturer directions and record the reading on the field instrument calibration log. If the reading is within the acceptance criteria, calibration is complete. If not, recalibrate the instrument. Record the reading and any significant changes on the field instrument calibration log.

   NOTE: If during the calibration procedure, you find the value of the standard is outside of the range acceptable by the meter and attempting to calibrate results in an error code, it is necessary to re-calibrate the unit from the beginning starting with a blank/turbidity free water. If this fails to produce acceptable and reproducible values for the standards, re-calibrate using new standards and discard the current standards. If the meter still fails to calibrate following repeated attempts at calibration, consult the equipment vendor for troubleshooting or equipment replacement.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste disposal with the Project Manager.

Each project must consider investigation-derived waste disposal methods and have a plan in place prior to performing the field work. Provisions must be in place as to what will be done with investigation-derived waste. If investigation-derived waste cannot be returned to the site, consider material containment, such as a composite drum or roll-off bin, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

In addition to checking the calibration of instruments prior to measurements, calibration checks may also be required at other times of the day. If there are significant temperature fluctuations or erroneous readings, a calibration check may be required. Some programs require a post-calibration check at the conclusion of the day to ensure that instrument drift has not occurred. Refer to the site-specific work plan for calibration frequency.

Comparing current values with historical values at the same measuring location can be helpful in assessing instrument and calibration reliability.

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

All work must be dated and signed by the analyst. Any changes should be crossed out with a single line, initialed, and dated.

Prior to calibrating, the field equipment and calibration standard information should be recorded on a field instrument calibration log and/or in the field book. For field equipment, the information recorded should include the make, model number, and the serial number of the instrument. Each instrument can be assigned an identification number that can be referenced in future field notes or when filling out the field instrument calibration log.

For calibration standards, the information recorded should include the manufacturer, expiration date, true value, and any other description, such as lot number. Each calibration standard can also be assigned an identification number that can be referenced in future field notes or when filling out the field instrument calibration log. If standards are not supplied with an expiration date, the standards should be initialed and dated when received and when opened (not applicable for standards supplied with the rental equipment).

The calibration records provided by the equipment vendor and the certificates of analysis for each standard will be maintained in the project files.

All calibration measurements must be documented in the field book or on a separate field instrument calibration log. Example field instrument calibration logs are presented in Attachment B. At a minimum, the field instrument calibration log must include the instrument information described above, calibration standard information described above, calibration date, and the instrument calibration results.

6.0 REFERENCES

USEPA. January 19, 2010. *Standard Operating Procedure, Calibration of Field Instruments*, Revision No. 2. USEPA Region I.

American Public Health Association, American Water Works Association, and Water Environment Federation. January 2012. *Standard Methods for the Examination of Water and Wastewater*, 22nd Edition.

YSI Environmental. 2005. *Measuring ORP on YSI 6-Series Sondes: Tips, Cautions and Limitations*. YSI Environmental Tech Note. http://www.ysi.com/media/pdfs/T608-Measuring-ORP-on-YSI-6-Series-Sondes-Tips-Cautions-and-Limitations.pdf.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	NOVEMBER 2014	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

Attachment A

Oxygen Solubility at Indicated Pressure

Attachment A (page 1 of 2)

Oxygen Solubility at Indicated Pressure

Temp.	Pressure (Hg)							
	760	755	750	745	740	735	730	mm
°C	29.92	29.72	29.53	29.33	29.13	28.94	28.74	in
0	14.57	14.47	14.38	14.28	14.18	14.09	13.99	mg/l
1	14.17	14.08	13.98	13.89	13.79	13.70	13.61	
2	13.79	13.70	13.61	13.52	13.42	13.33	13.24	
3	13.43	13.34	13.25	13.16	13.07	12-98	12.90	
4	13.08	12.99	12.91	12.82	12.73	12.65	12.56	
5	12.74	12.66	12.57	12.49	12.40	12.32	12.23	
6	12.42	12.34	12.26	12.17	12.09	12.01	11.93	
7	12.11	12.03	11.95	11.87	11.79	11.71	11.63	
8	11.81	11.73	11.65	11.57	11.50	11.42	11.34	
9	11.53	11.45	11.38	11.30	11.22	11.15	11.07	
10	11.28	11.19	11.11	11.04	10.96	10.89	10.81	
11	10.99	10.92	10.84	10.77	10.70	10.62	10.55	
12	10.74	10.67	10.60	10.53	10.45	10.38	10.31	
13	10.50	10.43	10.36	10.29	10.22	10.15	10.08	
14	10.27	10.20	10.13	10.06	10.00	9.93	9.86	
15	10.05	9.98	9.92	9.85	9.78	9.71	9.65	
16	9.83	9.76	9.70	9.63	9.57	9.50	9.43	
17	9.63	9.57	9.50	9.44	9.37	9.31	9.24	
18	9.43	9.37	9.30	9.24	9.18	9.11	9.05	
19	9.24	9.18	9.12	9.05	8.99	8.93	8.87	
20	9.06	9.00	8.94	8.88	8.82	8.75	8.69	
21	8.88	8.82	8.76	8.70	8.64	8.58	8.52	
22	8.71	8.65	8.59	8.53	8.47	8.42	8.36	
23	8.55	8.49	8.43	8.38	8.32	8.26	8.20	
24	8.39	8.33	8.28	8.22	8.16	8.11	8.05	
25	8.24	8.18	8.13	8.07	8.02	7.96	7.90	
26	8.09	8.03	7.98	7.92	7.87	7.81	7.76	
27	7.95	7.90	7.84	7.79	7.73	7.68	7.62	
28	7.81	7.76	7.70	7.65	7.60	7.54	7.49	
29	7.68	7.63	7.57	7.52	7.47	7.42	7.36	
30	7.55	7.50	7.45	7.39	7.34	7.29	7.24	
31	7.42	7.37	7.32	7.27	7.22	7.16	7.11	
32	7.30	7.25	7.20	7.15	7.10	7.05	7.00	
33	7.08	7.13	7.08	7.03	6.98	6.93	6.88	
34	7.07	7.02	6.97	6.92	6.87	6.82	6.78	
35	6.95	6.90	6.85	6.80	6.76	6.71	6.66	
36	6.84	6.79	6.76	6.70	6.65	6.60	6.55	
37	6.73	6.68	6.64	6.59	6.54	6.49	6.45	
38	6.63	6.58	6.54	6.49	6.44	6.40	6.35	
39	6.52	6.47	6.43	6.38	6.35	6.29	6.24	
40	6.42	6.37	6.33	6.28	6.24	6.19	6.15	
41	6.32	6.27	6.23	6.18	6.14	6.09	6.05	
42	6.22	6.18	6.13	6.09	6.04	6.00	5.95	
43	6.13	6.09	6.04	6.00	5.95	5.91	5.87	
44	6.03	5.99	5.94	5.90	5.86	5.81	5.77	
45	5.94	5.90	5.85	5.81	5.77	5.72	5.68	

(Continued)

Table taken from EPA Region I SOP, Calibration of Field Instruments, January 10, 2010.

Attachment A (Page 2 of 2)

Oxygen Solubility at Indicated Pressure (continued)

Temp.	Pressure (Hg)								
	725	720	715	710	705	700	695	690	mm
°C	28.54	28.35	28.15	27.95	27.76	27.56	27.36	27.17	in
0	13.89	13.80	13.70	13.61	13.51	13.41	13.32	13.22	mg/l
1	13.51	13.42	13.33	13.23	13.14	13.04	12.95	12.86	
2	13.15	13.06	12.07	12.88	12.79	12.69	12.60	12.51	
3	12.81	12.72	12.63	12.54	12.45	12.36	12.27	12.18	
4	12.47	12.39	12.30	12.21	12.13	12.04	11.95	11.87	
5	12.15	12.06	11.98	11.89	11.81	11.73	11.64	11.56	
6	11.84	11.73	11.68	11.60	11.51	11.43	11.35	11.27	
7	11.55	11.47	11.39	11.31	11.22	11.14	11.06	10.98	
8	11.26	11.18	11.10	11.02	10.95	10.87	10.79	10.71	
9	10.99	10.92	10.84	10.76	10.69	10.61	10.53	10.46	
10	10.74	10.66	10.59	10.51	10.44	10.36	10.29	10.21	
11	10.48	10.40	10.33	10.28	10.18	10.11	10.04	9.96	
12	10.24	10.17	10.10	10.02	9.95	9.88	9.81	9.46	
13	10.01	9.94	9.87	9.80	9.73	9.66	9.59	9.52	
14	9.79	9.72	9.65	9.68	9.51	9.45	9.38	9.31	
15	9.58	9.51	9.44	9.58	9.31	9.24	9.18	9.11	
16	9.37	9.30	9.24	9.17	9.11	9.04	8.97	8.91	
17	9.18	9.11	9.05	8.98	8.92	8.85	8.79	8.73	
18	8.99	8.92	8.86	8.80	8.73	8.67	8.61	8.54	
19	8.81	8.74	8.68	8.62	8.56	8.49	8.43	8.37	
20	8.63	8.57	8.51	8.45	8.39	8.33	8.27	8.21	
21	8.46	8.40	8.34	8.28	8.22	8.16	8.10	8.04	
22	8.30	8.24	8.18	8.12	8.06	8.00	7.95	7.89	
23	8.15	8.09	8.03	7.97	7.91	7.86	7.80	7.74	
24	7.99	7.94	7.88	7.82	7.76	7.71	7.65	7.59	
25	7.85	7.79	7.74	7.68	7.60	7.57	7.51	7.46	
26	7.70	7.65	7.59	7.54	7.48	7.43	7.37	7.32	
27	7.57	7.52	7.46	7.41	7.35	7.30	7.25	7.19	
28	7.44	7.38	7.33	7.28	7.22	7.17	7.12	7.06	
29	7.31	7.26	7.21	7.15	7.10	7.05	7.00	6.94	
30	7.19	7.14	7.08	7.03	6.98	6.93	6.88	6.82	
31	7.06	7.01	6.96	6.91	6.86	6.81	6.76	6.70	
32	6.95	6.90	6.85	6.80	6.70	6.70	6.64	6.59	
33	6.83	6.78	6.73	6.68	6.83	6.58	6.53	6.48	
34	6.73	6.68	6.63	6.58	6.53	6.48	6.43	6.38	
35	6.61	6.56	6.51	6.47	6.42	6.37	6.36	6.27	
36	6.51	6.46	6.41	6.36	6.31	6.27	6.22	6.17	
37	6.40	6.35	6.31	6.26	6.21	6.16	6.12	6.07	
38	6.30	6.26	6.21	6.16	6.12	6.07	6.02	5.98	
39	6.26	6.15	6.11	6.06	6.01	5.97	5.92	5.87	
40	6.10	6.06	6.01	5.96	5.92	5.86	5.83	5.78	
41	6.00	5.96	5.91	5.87	5.82	5.78	5.73	5.69	
42	5.91	5.86	5.82	5.77	5.73	5.69	5.64	5.60	
43	5.82	5.78	5.73	5.69	5.65	5.60	5.56	5.51	
44	5.72	5.68	5.64	5.59	5.55	5.51	5.46	5.42	
45	5.64	5.59	5.55	5.51	5.47	5.42	5.38	5.34	

Table taken from EPA Region I SOP, Calibration of Field Instruments, January 10, 2010.

Attachment B

Example Field Instrument Calibration Logs

TRC Field Instrument Calibration Log

Date:____________________ Site Name:____________________

Water Quality Instrument Type / ID:____

Turbidity Instrument Type / ID:____

Date of Last Temperature Probe Check:____________

Dissolved Oxygen (DO)

Time	Barometric Pressure (mm Hg)	Temperature (°Celsius)	Oxygen Solubility at Indicated Pressure (mg/L) (On Instrument)	Actual Oxygen Solubility at Indicated Pressure (mg/L) (Refer to Attachment A)	Zero DO Check (mg/L)	Comments	Initials

pH

Time	Solution Temperature (°Celsius)	pH 7	pH 4	pH 10	pH 7 Check	Comments	Initials

Specific Conductance

Time	Specific Conductance Reading (umhos/cm3)	Comments	Initials

Oxidation Reduction Potential (ORP)

Time	Solution Temperature (°Celsius)	ORP Reading (mV) (Refer to std instruction sheet)	Actual ORP Reading (mV) (On Instrument)	Comments	Initials

Turbidity

Time	Zero Standard	Standard #1 (___ NTUs)	Standard #2 (___ NTUs)	Comments	Initials

Calibration Fluid ID / Expiration Date:

Zero DO ______________ Specific Conductance______________

pH 4 ______________ pH 7______________ pH 10______________

ORP ______________

Zero Turbidity ______________ Turbidity Std # 1 ______________ Turbidity Std # 2 ______________

Signed____________________________________

revised November 2014

PAGE ______ OF ______

WATER QUALITY METER CALIBRATION LOG

PROJECT NAME: 0	MODEL:	SAMPLER: SN	
PROJECT NO.: 0.00	SERIAL #:	DATE:	

PH CALIBRATION CHECK

pH 7 (LOT #): (EXP. DATE): POST-CAL READING / STANDARD	pH 4 / 10 (LOT #): (EXP. DATE): POST-CAL READING / STANDARD	CAL. RANGE	TIME
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	

SPECIFIC CONDUCTIVITY CALIBRATION CHECK

CAL. READING (LOT #): (EXP. DATE): POST-CAL READING / STANDARD	TEMPERATURE (°CELSIUS)	CAL. RANGE	TIME
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	

ORP CALIBRATION CHECK

CAL. READING (LOT #): (EXP. DATE): POST-CAL READING / STANDARD	TEMPERATURE (°CELSIUS)	CAL. RANGE	TIME
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	

D.O. CALIBRATION CHECK

CAL. READING POST CAL READING / SATURATED AIR	TEMPERATURE (°CELSIUS)	CAL. RANGE	TIME
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	
/		☐ WITHIN RANGE	

TURBIDITY CALIBRATION CHECK

CALIBRATION READING (NTU) (LOT #): (EXP. DATE): POST-CAL READING / STANDARD	(LOT #): (EXP. DATE): POST-CAL READING / STANDARD	CAL. RANGE	TIME
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	
/	/	☐ WITHIN RANGE	

COMMENTS

☐ AUTOCAL SOLUTION (LOT #): (EXP. DATE):	☐ STANDARD SOLUTION (S) LIST LOT NUMBERS AND EXPIRATION DATES UNDER CALIBRATION CHECK
CALIBRATED PARAMETERS	CALIBRATION RANGES [1]
☐ pH	pH: +/- 0.2 S.U.
☐ COND	COND: +/- 1% OF CAL. STANDARD
☐ ORP	ORP: +/- 25 mV
☐ D.O.	D.O.: VARIES
☐ TURB	TURB: +/- 5% OF CAL. STANDARD
☐ ______	[1] CALIBRATION RANGES ARE SPECIFIC TO THE MODEL OF THE WATER QUALITY METER
☐ ______	

NOTES

PROBLEMS ENCOUNTERED	CORRECTIVE ACTIONS

SIGNED ______ DATE ______ CHECKED BY ______ DATE ______

REVISED 06/2011

Attachment C

SOP Fact Sheet

WATER QUALITY PARAMETER INSTRUMENT CALIBRATION

PURPOSE AND OBJECTIVE

Before a meter is utilized in the field, it will be calibrated and checked in accordance with this SOP to ensure proper operation. Water quality instruments addressed in this SOP include those that measure temperature, pH, dissolved oxygen (DO), conductivity/specific conductance, oxidation-reduction potential (ORP), and turbidity for the purposes of field screening and field measurements.

WHAT TO BRING

- Appropriate Level of PPE
- Field book
- Field instrument calibration logs
- Water quality meter capable of measuring one or more of the following based on project scope: pH, temperature, DO, specific conductivity, and ORP (e.g., YSI 600XL, Horiba U-50, Hydrolab Quanta/QED MP-20, or equivalent)
- Deionized water
- Flow-through cell
- Ring stand with clamp
- Paper towels
- Soft tissue (e.g., Kimwipes®)
- Cuvettes
- Buffer solutions at pH 4, 7 and 10 standard units (SU)*
- Conductivity solution (potassium chloride, typically 1,413 μhos/cm)*
- ORP calibration solution (e.g., Zobell)*
- Turbidity standards (0, 1, 10 nephelometric turbidity units [NTUs] or StablCal Kit)*
- Zero DO solution (0.0 mg/L)*
- DO membrane kit (electrolyte solution, membranes)
- NIST thermometer (0.2°C accuracy)*
- Small glass or polyethylene jars to hold the calibration standards (4-8 oz.)
- Cup or spray bottle for the deionized water

*Dependent on the project-specific requirements and the instrument manufacturer

OFFICE

- Review project work plan and confirm what field measurements are required based on the scope of work.
- Confirm that all necessary equipment (including necessary calibration solutions) are available in-house or order if necessary.
- All meters may have different relative accuracy, which will be specified in the instrument manual. Confirm that the meter being used meets the project's accuracy requirements.
- Confirm that a copy of the manufacturer's instruction manual is available to accompany the instrument into the field.
- Properly clean/decontaminate the instrument before storage or returning equipment to rental vendor.

CALIBRATION PROCEDURES

- Prior to use, inspect instruments to ensure instruments are clean, check for possible malfunctions, and calibrate in accordance with manufacturer's procedures. Note: The initial calibration may be performed in the office prior to the field event or by the equipment supplier; however, calibration checks should be performed on site prior to use on the day of the fieldwork.
- Calibration checks (or verifying that instrument readings fall within an acceptable range of a standard without running through the full instrument calibration steps) will be performed on field instruments prior to their initial use, at least once daily, or whenever indications of faulty readings or instrument malfunction occurs. Some instruments or certain project scopes may require more frequent calibration checks depending on project quality objectives.
- In general, instrument selection and calibration will include the following steps:
  1. Determine which instruments are needed for the specific field tasks. Record the make, model number, and serial number of the instrument on the field instrument calibration log or in the field book.
  2. Obtain the necessary instruments and standard solutions for calibration. Check expiration dates on standard solutions and replace if out of date. Record the manufacturer, true value, lot number and expiration date of the standard solutions on the field instrument calibration log or in the field book.
  3. Assemble the instrument and turn it on allowing the instrument to warm up.
  4. Check battery charge, and charge or replace if necessary.
  5. Clean instrument (if necessary).
  6. If applicable, program the multi-probe instrument so that the applicable parameters to be measured will be displayed.
  7. Calibrate the instrument prior to field use in accordance with manufacturer's procedures. (Note: If applicable, calibrate DO and conductivity first, because these parameters may affect the other calibrations).
  8. Document all calibration activities and results in the field instrument calibration log or field book.
  9. If the instrument malfunctions and cannot be corrected, document the issues, qualify any erroneous data, and obtain a replacement.
  10. Clean and decontaminate the instrument after use and before storage.

11. Conduct calibration checks at least once per day or additionally as needed.

INVESTIGATION-DERIVED WASTE (IDW) DISPOSAL

Field personnel should review the project work plan and ensure project-specific IDW management documentation and containerization requirements are specified or discussed with the Project Manager before going to the project site.

DATA MANAGEMENT AND RECORDS MANAGEMENT

- Prior to calibrating, the field equipment and calibration standard information should be recorded on a field instrument calibration log and/or in a field book. For field equipment, the information recorded should include the make, model number, and the serial number of the instrument. Each instrument can be assigned an identification number that can be referenced in future field notes or when filling out the field instrument calibration log.
- For calibration standards, the information recorded should include the manufacturer, expiration date, true value, and any other description, such as lot number.
- The calibration records provided by the equipment vendor and the certificates of analysis for each standard will be maintained in the project files.
- All calibration measurements must be documented in a field logbook or on a separate field instrument calibration log. At a minimum, the field instrument calibration log must include the instrument information described above, calibration standard information described above, calibration date, and the instrument calibration results.

DOs AND DO NOTs OF WATER QUALITY PARAMETER INSTRUMENT CALIBRATION

DOs

- DO wear appropriate PPE (i.e., chemical resistant gloves and safety glasses) when cleaning and calibrating water quality instruments.
- DO confirm what field measurements are required, and what accuracy is required based on the scope of work.
- DO ensure you have the instrument instruction manual available if needed, as well as contact information for the manufacturer or rental company for troubleshooting questions.
- DO properly document calibration procedures and calibration checks performed.
- DO note when erroneous readings/equipment malfunctions are observed and any troubleshooting and/or corrective measures taken.
- DO conduct calibration checks at least once per day or additionally as needed.
- DO properly store the calibration standard solutions. Avoid extreme hot/cold temperatures. Frozen solution is useless and extreme temperatures can make calibration difficult and/or calibration may not work at all.

DO NOTs

- DO NOT use expired calibration solutions.
- DO NOT immerse the sensors in sea water or other highly saline water, alcohol, or organic solvents.
- DO NOT forget to clean and decontaminate the instrument after use and before storage.
- DO NOT store the sensors improperly (e.g., avoid storing in extreme hot or cold temperatures, make sure appropriate storage solutions are being used per manufacturer's recommendations).

Title: **Headspace Field Screening Procedure**		Procedure Number: **ECR 014**
		Revision Number: **1**
		Effective Date: **January 2020**

Authorization Signatures	
Jamie Stapleton (signature)	*Elizabeth Denly* (signature)
Technical Reviewer / Jamie Stapleton — Date 1/1/20	Environmental Sector Quality Director / Elizabeth Denly — Date 1/1/20

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ATTACHMENTS

1.0 INTRODUCTION

1.1 Scope & Applicability

This Standard Operating Procedure (SOP) was prepared to direct TRC personnel in the methods for conducting headspace field screening measurements of solid and aqueous samples during field investigations. This SOP does not cover screening for health & safety purposes or well mouth and tank headspace.

1.2 Summary of Method

The objective of headspace field screening is to obtain organic vapor/gas measurements of solid or aqueous media encountered during solid or aqueous sampling. The procedure involves collecting solid or aqueous samples, sealing them in airtight containers, and analyzing the Total Organic Vapors (TOVs) that form within the container using a portable vapor/gas detector.

Headspace field screening data can be used to pre-screen field samples or as a guide to direct subsequent investigations. Data collected using these methods are considered qualitative and specific compounds cannot be distinguished.

1.3 Equipment

The following list of equipment may be utilized when conducting headspace field screening measurements. Project-specific conditions or requirements may warrant the use of additional equipment or deletion of items from this list.

- Appropriate level of personal protective equipment (PPE) as specified in the site-specific Health and Safety Plan (HASP)
- Photoionization detector (PID) with appropriate electron volt (eV) lamp source (see Section 1.6.2 for selection of proper lamp source) or flame ionization detector (FID)
- Aluminum foil
- 500 ml clean jars or larger (for solid samples) - jars less than 8 oz. capacity should not be used
- One quart or one gallon resealable plastic bags (for solid samples)
- 40 ml to 1,000 ml clean jars (for aqueous samples)
- Field book
- Charcoal filter (for FID only, if methane present)
- Moisture filter/external water trap (for PID only)
- Tedlar bag(s)
- Isobutylene (100 parts per million by volume [ppmV], at a minimum): compressed gas cylinder (for PID)
- Methane (100 ppmV, at a minimum): compressed gas cylinder (for FID)

- Zero air: compressed gas cylinder or carbon filter with ambient air
- Sharpie pen

1.4 Definitions

FID	An instrument that uses a flame to break down volatile organic compounds (VOCs) into ions that can be measured by the detector.
Headspace	The area/space between the sample media and the top of the airtight container holding the sample. Organic vapors, if present, will collect in this area/space and can be measured.
PID	An instrument that uses an ultraviolet light source to break down VOCs into ions that can be measured by the detector.
VOCs	Any chemical compound based on carbon chains or rings with a vapor pressure greater than 2 mm of mercury.

1.5 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. Therefore, TRC personnel shall follow the site-specific HASP. TRC personnel will use the appropriate level of PPE as defined in the HASP.

Implementing this SOP will require the use of compressed gases for portable meter calibration. These gases may be hazardous materials and TRC will appropriately transport, handle and store them at all times.

1.6 Cautions and Potential Problems

1.6.1 Environmental Factors

Environmental factors may influence the performance of these methods. These factors include:

1. High moisture in soil or sediment. High moisture levels in soil/sediment can limit the amount of contaminants that volatilize into the container headspace. High moisture levels affect PID readings more than FID readings and may cause a positive or negative bias or inconsistent and non-comparable readings. For this reason, headspace field screening readings of aqueous samples using a PID may not be appropriate. A water trap or filter should be used with a PID to reduce these impacts.

2. A slowly increasing response on a PID may result from moisture levels interfering with instrument measurements. Instrumentation with digital (LED/LCD) displays may not be able to discern maximum headspace response unless equipped with a maximum hold feature or strip-chart recorder.

3. High organic levels in soil or sediment and organic matter in aqueous samples. Contaminants can sorb onto organic matter (i.e., leaves, peat), which can limit the amount of contaminants that volatilize into the container headspace and may cause inconsistent or non-comparable readings. The presence of organic matter in aqueous samples (i.e., microbial populations) can

reduce volatilization of contaminants. High levels of organics in soil/sediment and aqueous samples may also produce methane, a natural gas that is included in the TOV readings from FIDs, but not recorded by PIDs. A charcoal filter may be used with an FID to remove the methane from the vapor sample.

4. Limited pore space due to fines (e.g., clay or silt). It may be difficult to generate headspace measurements in a tight clay matrix.
5. Meteorological variations, especially humidity and ambient temperature. Normal ambient temperature variations could affect the amount of vapors that form in the headspace. Very cold temperatures will limit volatilization of VOCs. Increasing ambient temperature as the day progresses will result in more volatilization and higher readings, an effect that needs to be considered when using the data to make decisions. PIDs may not be able to operate in heavy rain so the Project Manager should be consulted if inclement weather is expected.
6. Background ambient levels of VOCs. Before beginning a headspace field screening program, identify background ambient levels of VOCs. Taking these levels into account when interpreting headspace field screening measurements will minimize the potential for false measurements. Data may be corrected for background measurements; however, the use of this procedure will be determined on a site-specific basis by the Project Manager.
7. Be aware of where the headspace readings are being obtained. Locations near potential sources of VOCs, such as operating vehicles, operating generators, or air handling equipment at a site, may contribute to transient volatile conditions and be a source of bias.
8. Certain instruments have multiple operating ranges. If the sample yields headspace field screening results higher than the upper limit of calibration, recalibration to accommodate a higher range may be necessary.

1.6.2 Ionization Potentials of Contaminants of Concern

The ionization potential of the contaminant is the energy required to completely remove an electron from its atom. In general, the ultraviolet lamp in the PID will either be 10.6 eV or 11.7 eV. When selecting the proper lamp, the ionization potential of the contaminant(s) of concern must be less than the ionization potential of the lamp. For example, if a PID is equipped with a 10.6 eV lamp, it will generally detect compounds with ionization potentials less than or equal to 10.6 eV. For most compounds, a 10.6 eV lamp is sufficient. Refer to Attachment B for a list of compounds and their ionization potentials. Two examples of proper lamp selection are provided below:

Example 1: Trichloroethene: Ionization potential = 9.47 eV.
Since the ionization potential is less than 10.6 eV, either the 10.6 eV or the 11.7 eV lamp could be used.

Example 2: 1,1,1-Trichloroethane: Ionization potential = 11 eV
Since the ionization potential is greater than 10.6 eV but is less than 11.7 eV, only the 11.7 eV lamp could be used.

It should also be noted that the life of an 11.7 eV lamp is considerably shorter (i.e., 1-3 months) than that of a 10.6 eV lamp (i.e., up to 3 years).

1.6.3 High Levels of Methane

If samples are suspected of containing high levels of methane (e.g., high levels of decaying organics or sites undergoing natural or enhanced degradation), representative readings of non-methane hydrocarbon vapors may be inhibited when using an FID. To avoid methane interference, a PID should be used or if an FID is used, it should be equipped with a charcoal filter on the inlet which will filter out all compounds except methane and ethane; the heavier organic compounds are adsorbed onto the charcoal filter. Measurements can be taken with and without the charcoal filter to determine the levels of methane/ethane in the sample and TOVs, respectively. The use of a PID and one FID (without a filter) or two FIDs (one with a charcoal filter and one without a charcoal filter) may be considered in order to obtain simultaneous readings.

- Measurement without charcoal filter = TOV Concentration (including methane and ethane)
- Measurement with charcoal filter = Methane and Ethane Concentration
- Measurement without charcoal filter – Measurement with charcoal filter = Total Non-Methane/Ethane Hydrocarbons provided that the sample only contains hydrocarbons and no other VOCs that would be detected by the FID.

NOTE: The loading capacity (amount of hydrocarbons which can be adsorbed on the charcoal filter before breakthrough will occur) and lifetime of the charcoal filter must be verified with the vendor prior to use. Depending on project needs, it may be advisable to have a supply of charcoal on hand to replace spent filter material.

1.6.4 Use of Headspace Field Screening Data

It is important to note that measurements obtained using portable vapor/gas detectors such as a PID or FID are considered qualitative and semi-quantitative. This type of data is sufficient for demonstrating the relative presence of contamination, determining "hot spots," and using as a guide to direct subsequent investigations. This type of field screening data cannot be used to identify specific contaminants and should not be used to determine whether a sample is "clean."

1.6.5 Use of Thermal Enhancement for Headspace Measurements

Certain compounds (e.g., xylenes and other high molecular weight VOCs) yield a better response when the headspace screening is performed with thermal enhancement. Thermal enhancement of a sample can be performed using direct sunlight, a heated vehicle, a heated building, a hot water bath, or a hot lamp. Refer to site-specific plans to determine the need for thermal enhancement. Thermal enhancement may also be useful for headspace screening in cold weather situations.

1.7 Personnel Qualifications

Since this SOP will be implemented at sites or in work areas that entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project work plan. These requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers
- 8-hour annual HAZWOPER refresher training.

2.0 PROCEDURES

Refer to the site-specific work plan and/or Quality Assurance Project Plan (QAPP), if applicable, for any site-specific procedures. Other state or federal requirements may be above and beyond the scope of this SOP and will be followed if applicable. In all instances, the actual procedures used should be documented and described in the field notes. Attachment B lists the ionization potentials of specific compounds. Refer to Section 1.6.2 for instruction on selecting a PID with an appropriate lamp.

2.1 Calibration Procedures

PID and FID field instruments shall be operated and calibrated to yield TOVs in ppm volume/volume (v/v) as isobutylene for the PID and methane for the FID. In certain instances, other gases may be appropriate for calibration. Correction of results using response factors may be appropriate; refer to the instrument manufacturer's manuals for the proper procedure. Batteries of the PID and FID should be checked prior to the beginning of the field event. Following calibration, response checks should periodically be performed throughout the day to demonstrate the responsiveness of the instrument. These checks can be performed by exposing the PID or FID to the tip of a Sharpie pen; the performance of this check and the presence of instrument response must be documented in the field notes. General calibration procedures are as follows:

PID AND FID

1. Turn the instrument on and allow it to warm up for at least 10 minutes.
2. Fill a separate tedlar bag ¼ full with zero air; depress the bag completely to expel any miscellaneous gases trapped in the bag. Fill the bag full with zero air. Alternatively, clean ambient air can be used instead of a tedlar bag filled with zero air.
3. Set the PID or FID to the appropriate zero gas Calibration Mode.
4. Attach the probe to the tedlar bag, open the bag valve, and begin the calibration mode on the instrument. Keep the bag attached until the meter finishes the calibration. Alternatively, expose the probe to clean ambient air until the meter finishes the calibration.
5. Fill a tedlar bag ¼ full with the isobutylene standard for the PID or the methane standard for the FID. Depress the bag completely to expel any miscellaneous gases trapped in the bag. Fill the bag full with the isobutylene standard (PID) or methane standard (FID). Alternatively, the instrument can be connected directly to the compressed gas standard cylinder.
6. Set the instrument to the appropriate span gas Calibration Mode. Enter the appropriate calibration gas concentration in the meter.
7. Attach the probe to the tedlar bag, open the bag valve, and begin the calibration mode on the instrument. Keep the bag attached until the meter finishes the calibration. Alternatively, attach the probe directly to the compressed gas standard cylinder, open the cylinder valve, and begin the calibration mode on the instrument; keep the cylinder attached until the meter finishes the calibration.
8. Calibration should be performed in accordance with the site-specific work plan, at least at the beginning of the day. Calibration checks should be performed as necessary. Calibration

should be checked if there is a substantial change in weather, if you have moved from an indoor location to an outdoor location (or vice versa), or if inconsistent or non-comparable readings are observed. The calibration check is performed using the compressed gas standard followed by the zero air check. The measured value of the standard must be within ±10% of the true value. The zero air check should not yield a reading above background. All calibration measurements must be recorded in the field book or on a field data form (see Attachment A).

2.2 Field Screening Procedures

The following procedures should be followed for headspace field screening measurements of solid and aqueous samples. For solid samples, a re-sealable plastic bag may be substituted for clean jars; however, this depends on site-specific requirements and must be verified with the Project Manager. Soil samples collected for field screening should not be used for laboratory chemical analysis due to potential loss of volatile contaminants in the sample from sample handling. Sample collection for headspace field screening and laboratory analysis of VOCs should occur as soon as possible (i.e., preferably within minutes) after the sample is exposed to air to minimize loss of TOVs due to volatilization.

1. Put on chemical-resistant gloves.

2. Fill a clean container one-third to one-half full with the sample to be analyzed. The type and size of the container, as well as the amount of sample collected, should be consistent for all samples collected at a site. See Section 1.3 for appropriate size containers for each matrix.

3. Quickly cover the open container top with one sheet of clean aluminum foil and apply the screw cap to tightly seal the jar. Plastic bags filled with soil should be sealed.

4. Vigorously shake the jar or bag for approximately 15 seconds. Be sure that all samples are shaken for approximately the same period of time.

5. Allow headspace development to occur for at least 10 minutes. The time allowed for headspace development should be approximately the same for all samples; differences should be noted. Where ambient temperatures are near or below 32ºF (0ºC), thermal enhancement of the sample may be considered and modified via direct sunlight, a heated vehicle or building, a hot water bath, a hot lamp, or similar. Site-specific conditions (e.g., sunlight, wind) may impact the actual temperature. Otherwise, headspace development can occur at ambient temperatures. Headspace development should not be allowed to occur so long that condensation forms in the container.

6. Determine the background ambient level of TOVs. Record this value in the field book.

7. Vigorously shake jar for approximately 15 seconds after the headspace development period. Be sure that all samples are shaken for approximately the same period of time.

8. Subsequent to headspace development, unscrew and remove lid to expose aluminum foil seal. Be sure to hold edge of foil during the removal of the lid to ensure the foil seal remains in place. Quickly puncture aluminum foil seal with instrument sampling probe, and insert probe to a point about one-half of the headspace depth. Alternatively, for solid samples in a re-sealable bag, partially open the seal, insert the probe into the bag, and re-seal the zipper

around the probe. Exercise care to avoid uptake of water droplets or soil particulates into the instrument.

9. Following probe insertion through the aluminum foil seal or into the plastic bag, record the highest meter response as the headspace concentration. Using the aluminum foil seal/probe insertion method, maximum response should occur between 2 and 5 seconds.

10. The headspace screening data should be recorded in the field book and/or on a field data form (see Attachment A).

11. All headspace screening waste should be returned to the original source site location or disposed of in accordance with Section 3.0.

3.0 INVESTIGATION-DERIVED WASTE DISPOSAL

Field personnel should discuss specific documentation and containerization requirements for investigation-derived waste (IDW) disposal with the Project Manager.

Each project must consider IDW disposal methods and have a plan in place prior to performing the field work. Provisions must be in place regarding what will be done with IDW. If IDW cannot be returned to the site, consider material containment, such as a composite drum, proper labeling, on-site storage by the client, testing for disposal approval of the materials, and ultimately the pickup and disposal of the materials by appropriately licensed vendors.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following procedures should be used for collecting headspace field screening measurements:

1. Operate and calibrate field instruments according to the manufacturer's manuals.

2. Headspace measurements should be performed in duplicate on one sample each day, at a minimum. This requires collection of two separate aliquots of sample. All procedures, including the amount of time allowed for headspace development and the number of seconds the containers are shaken, should be the same for each container. Ensure that both of the containers are in the same environment during headspace development (e.g., both jars are in the sun, both jars are in a heated car).

3. The results of duplicate samples should be compared; generally, the relative percent differences (RPDs) of the replicate values should be $\leq$20 when readings are greater than 10 ppmV. RPDs may be higher when readings are less than or equal to 10 ppmV. If the RPD of the replicate values is not within these criteria, make sure that the cautions and potential problems listed in Section 1.6 were not encountered during the headspace measurements. If none of these factors were encountered, perform a calibration check to ensure the instrument is working properly. Document the test results as well as any performance or calibration checks in the field book. RPD is calculated using the following equation:

$$\text{RPD} = \frac{\text{Reading 1} - \text{Reading 2}}{(\text{Reading 1} + \text{Reading 2})/2} \text{X } 100$$

5.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

All procedures and field screening results must be documented in the field book and/or on an appropriate field data form. Refer to Attachment A for an example of headspace field screening results documentation. Correction of headspace measurements for background values may be performed; the use of this procedure will be determined on a site-specific basis by the Project Manager. Any deviations from the headspace field screening procedures specified in this SOP, a site-specific work plan, or a site-specific QAPP must be approved by the Project Manager as well as documented in the field book. In such cases, compelling technical justification must be presented and documented for the methodology employed. Refer to ECR SOP 001 for field documentation procedures.

6.0 REFERENCES

Compendium of Superfund Field Operations Methods. EPA/540/P-87/001. December 1987.

Expedited Site Assessment Tools For Underground Storage Tank Sites. EPA 510/B-97/001. March 1997.

Attachment 11, Interim Remediation Waste Management Policy for Petroleum Contaminated Soils. MassDEP WSC-94-400. April 1994.

Commonwealth of Massachusetts Underground Storage Tank Closure Assessment Manual. MassDEP WSC-402-96. April 9, 1996.

RAE Systems, Inc. Technical Note TN-106, *A Guideline for PID Instrument Response*, 07/16.

7.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	APRIL 2015	NOT APPLICABLE
1	JANUARY 2020	TRC RE-BRANDING AND SOP RE-NUMBERING

Attachment A

Example Documentation for Headspace Field Screening Results

Headspace Field Screening Log

Site Name ___________________________
Site Location _________________________
TRC Personnel_________________________

Instrument Used (make/model)___________________
Calibration Gas Used/Concentration________________
Matrix/Sampling Method__________________________

Sample ID	Location	Depth	Date/Time	Background Reading (ppmV)	Screening Results (ppmv)			Comments	Instrument/Lamp Used
					Reading 1	Reading 2	RPD		
Soil Boring – 01, 2-4'			*8/5/03-0700*	*2*	*24.6*	*25.3*	*2.8*	*South side of excavation*	*PID / 10.2 eV*
Soil Boring – 02, 0-2'			*8/5/03-0815*	*2*	*1.5*	*1.2*	*22*	*North side of excavation*	*PID / 10.2 eV*

ppmV = parts per million by volume
RPD = relative percent difference

Attachment B

Photoionization Characteristics of Selected Compounds

NR – No Response
IE – Ionization Energy
C – Confirmed values (correction factors) indicated by "+" in this column; all others are preliminary or estimated values and are subject to change
ne – Not Established ACGIH 8-hr. TWA
C## - Ceiling value, given where 8-hr. TWA is not available
TWA – Time-weighted average

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Acetaldehyde		75-07-0	C_2H_4O	NR	+	6	+	3.3	+	10.23	C25
Acetic acid	Ethanoic Acid	64-19-7	$C_2H_4O_2$	NR	+	22	+	2.6	+	10.66	10
Acetic anhydride	Ethanoic Acid Anhydride	108-24-7	$C_4H_6O_3$	NR	+	6.1	+	2.0	+	10.14	5
Acetone	2-Propanone	67-64-1	C_3H_6O	1.2	+	0.9	+	1.4	+	9.71	500
Acetone cyanohydrin	2-Hydroxyisobutyronitrile	75-86-5	C_4H_7NO					4	+	11.1	C5
Acetonitrile	Methyl cyanide, Cyanomethane	75-05-8	C_2H_3N					100		12.19	40
Acetylene	Ethyne	74-86-2	C_2H_2					2.1	+	11.40	ne
Acrolein	Propenal	107-02-8	C_3H_4O	42	+	3.9	+	1.4	+	10.10	0.1
Acrylic acid	Propenoic Acid	79-10-7	$C_3H_4O_2$			12	+	2.0	+	10.60	2
Acrylonitrile	Propenenitrile	107-13-1	C_3H_3N			NR	+	1.2	+	10.91	2
Allyl alcohol		107-18-6	C_3H_6O	4.5	+	2.4	+	1.6	+	9.67	2
Allyl chloride	3-Chloropropene	107-05-1	C_3H_5Cl			4.3		0.7		9.9	1
Ammonia		7664-41-7	NH_3	NR	+	10.9	+	5.7	+	10.16	25
Amyl acetate	mix of n-Pentyl acetate & 2-Methylbutyl acetate	628-63-7	$C_7H_{14}O_2$	11	+	2.3	+	0.95	+	<9.9	100
Amyl alcohol	1-Pentanol	75-85-4	$C_5H_{12}O$			5				10.00	ne
Aniline	Aminobenzene	62-53-3	C_6H_7N	0.50	+	0.48	+	0.47	+	7.72	2
Anisole	Methoxybenzene	100-66-3	C_7H_8O	0.89	+	0.58	+	0.56	+	8.21	ne
Arsine	Arsenic trihydride	7784-42-1	AsH_3			1.9	+			9.89	0.05
Benzaldehyde		100-52-7	C_7H_6O					1		9.49	ne
Benzene		71-43-2	C_6H_6	0.55	+	0.47	+	0.6	+	9.25	0.5
Benzonitrile	Cyanobenzene	100-47-0	C_7H_5N			1.6				9.62	ne
Benzyl alcohol	α-Hydroxytoluene, Hydroxymethylbenzene, Benzenemethanol	100-51-6	C_7H_8O	1.4	+	1.1	+	0.9	+	8.26	ne
Benzyl chloride	α-Chlorotoluene, Chloromethylbenzene	100-44-7	C_7H_7Cl	0.7	+	0.6	+	0.5	+	9.14	1
Benzyl formate	Formic acid benzyl ester	104-57-4	$C_8H_8O_2$	0.9	+	0.73	+	0.66	+		ne
Boron trifluoride		7637-07-2	BF_3	NR		NR		NR		15.5	C1
Bromine		7726-95-6	Br_2	NR	+	1.30	+	0.74	+	10.51	0.1
Bromobenzene		108-86-1	C_6H_5Br			0.6		0.5		8.98	ne
2-Bromoethyl methyl ether		6482-24-2	C_3H_7OBr			0.84	+			~10	ne
Bromoform	Tribromomethane	75-25-2	$CHBr_3$	NR	+	2.7	+	0.5	+	10.48	0.5
Bromopropane,1-	n-Propyl bromide	106-94-5	C_3H_7Br	150	+	1.5	+	0.6	+	10.18	ne
Butadiene	1,3-Butadiene, Vinyl ethylene	106-99-0	C_4H_6	0.8		0.6	+	1.1		9.07	2
Butadiene diepoxide, 1,3-	1,2,3,4-Diepoxybutane	298-18-0	$C_4H_6O_2$	25	+	3.5	+	1.2		~10	ne
Butane		106-97-8	C_4H_{10}			67	+	1.2		10.53	800
Butanol, 1-	Butyl alcohol, n-Butanol	71-36-3	$C_4H_{10}O$	70	+	4.7	+	1.4	+	9.99	20
Butanol, t-	tert-Butanol, t-Butyl alcohol	75-65-0	$C_4H_{10}O$	6.9	+	2.9	+			9.90	100
Butene, 1-	1-Butylene	106-98-9	C_4H_8			0.9				9.58	ne
Butoxyethanol, 2-	Butyl Cellosolve, Ethylene glycol monobutyl ether	111-76-2	$C_6H_{14}O_2$	1.8	+	1.2	+	0.6	+	<10	25
Butoxyethyl Acetate, 2-	2-Butoxyethyl acetate; 2-Butoxyethanol acetate; Butyl Cellosolve acetate; Butyl glycol acetate; EGBEA; Ektasolve EB acetate	112-07-2	$C_8H_{16}O_3$			1.27	+				20
Butyl acetate, n-		123-86-4	$C_6H_{12}O_2$			2.6	+			10	150
Butyl acrylate, n-	Butyl 2-propenoate, Acrylic acid butyl ester	141-32-2	$C_7H_{12}O_2$			1.6	+	0.6	+		10
Butylamine, n-		109-73-9	$C_4H_{11}N$	1.1	+	1.1	+	0.7	+	8.71	C5
Butyl cellosolve see 2-Butoxyethanol		111-76-2									
Butyl hydroperoxide, t-		75-91-2	$C_4H_{10}O_2$	2.0	+	1.6	+			<10	1

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Butyl mercaptan	1-Butanethiol	109-79-5	$C_4H_{10}S$	0.55	+	0.52	+			9.14	0.5
Butyraldehyde	Butanal	123-72-8	C_4H_8O			1.87	+			9.82	20
Camelinal HRJ						1.1	+	0.32	+		
Camelinal HRJ/JP-8 50/50						0.89	+	0.41	+		
CamelinalHRJ						1.15	+				
CamelinalHRJ/JP-8						1.07	+				
Carbon disulfide		75-15-0	CS_2	4	+	1.2	+	0.44		10.07	10
Carbon tetrachloride	Tetrachloromethane	56-23-5	CCl_4	NR	+	NR	+	1.7	+	11.47	5
Carbonyl sulfide	Carbon oxysulfide	463-58-1	COS							11.18	
Cellosolve see 2-Ethoxyethanol											
CFC-14 see Tetrafluoromethane											
CFC-113 see 1,1,2-Trichloro-1,2,2-trifluoroethane											
Chlorine		7782-50-5	Cl_2					1.0	+	11.48	0.5
Chlorine dioxide		10049-04-4	ClO_2	NR	+	NR	+	NR	+	10.57	0.1
Chlorobenzene	Monochlorobenzene	108-90-7	C_6H_5Cl	0.44	+	0.55	+	0.39	+	9.06	10
Chlorobenzotrifluoride, 4-	PCBTF, OXSOL 100 p-Chlorobenzotrifluoride	98-56-6	$C_7H_4ClF_3$	0.74	+	0.63	+	0.55	+	<9.6	
Chloro-1,3-butadiene, 2-	Chloroprene	126-99-8	C_4H_5Cl			3					10
Chloro-1,1-difluoroethane, 1-	HCFC-142B, R-142B	75-68-3	$C_2H_3ClF_2$	NR		NR		NR		12.0	ne
Chlorodifluoromethane	HCFC-22, R-22	75-45-6	$CHClF_2$	NR		NR		NR		12.2	1000
Chloroethane	Ethyl chloride	75-00-3	C_2H_5Cl	NR	+	NR	+	1.1	+	10.97	100
Chloroethanol	Ethylene chlrohydrin	107-07-3	C_2H_5ClO							10.52	C1
Chloroethanol, 2-	2-Chloroethanol; 2-Chloroethyl alcohol; Ethylene chlorhydrin	107-07-3	C_2H_5ClO			2.88	+			10.5	5
Chloroethyl ether, 2-	bis (2-chloroethyl) ether	111-44-4	$C_4H_8Cl_2O$	8.6	+	3.0	+				5
Chloroethyl methyl ether, 2-	Methyl 2-chloroethyl ether	627-42-9	C_3H_7ClO			3					ne
Chloroform	Trichloromethane	67-66-3	$CHCl_3$	NR	+	NR	+	3.5	+	11.37	10
Chloro-2-methylpropene, 3-	Methallyl chloride, Isobutenyl chloride	563-47-3	C_4H_7Cl	1.4	+	1.2	+	0.63	+	9.76	ne
Chloropicrin		76-06-2	CCl_3NO_2	NR	+	~400	+	7	+		0.1
Chlorotoluene, o-	o-Chloromethylbenzene	95-49-8	C_7H_7Cl			0.5		0.6		8.83	50
Chlorotoluene, p-	p-Chloromethylbenzene	106-43-4	C_7H_7Cl					0.6		8.69	ne
Chlorotrifluoroethene	CTFE, Chlorotrifluoroethylene Genetron 1113	79-38-9	C_2ClF_3	6.7	+	3.9	+	1.2	+	9.76	5
Chlorotrimethylsilane		75-77-4	C_3H_9ClSi	NR		NR		0.82	+	10.83	ne
Cresol, m-	m-Hydroxytoluene, 3-Methylphenol	108-39-4	C_7H_8O	0.57	+	0.50	+	0.57	+	8.29	5
Cresol, o-	ortho-Cresol; 2-Cresol; o-Cresylic acid; 1-Hydroxy-2-methylbenzene; 2-Hydroxytoluene; 2-Methyl phenol	95-48-7	C_7H_8O			1	+			8.14	5
Cresol, p-	para-Cresol; 4-Cresol; p-Cresylic acid; 1-Hydroxy-4-methylbenzene; 4-Hydroxytoluene; 4-Methyl phenol	106-44-5	C_7H_8O			1.4	+			8.34	5
Crotonaldehyde	trans-2-Butenal	123-73-9 4170-30-3	C_4H_6O	1.5	+	1.1	+	1.0	+	9.73	2
Cumene	Isopropylbenzene	98-82-8	C_9H_{12}	0.58	+	0.54	+	0.4	+	8.73	50
Cyanogen bromide		506-68-3	CNBr	NR		NR		NR		11.84	ne
Cyanogen chloride		506-77-4	CNCl	NR		NR		NR		12.34	C0.3
Cyclohexane		110-82-7	C_6H_{12}	3.3	+	1.4	+	0.64	+	9.86	300
Cyclohexanol	Cyclohexyl alcohol	108-93-0	$C_6H_{12}O$	1.5	+	0.9	+	1.1	+	9.75	50
Cyclohexanone		108-94-1	$C_6H_{10}O$	1.0	+	0.9	+	0.7	+	9.14	25

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Cyclohexene		110-83-8	C_6H_{10}			0.8	+			8.95	300
Cyclohexylamine		108-91-8	$C_6H_{13}N$			1.2				8.62	10
Cyclopentane 85% 2,2-dimethylbutane 15%		287-92-3	C_5H_{10}	NR	+	15	+	1.1		10.33	600
Cyclopropylamine	Aminocyclpropane	765-30-0	C_3H_7N	1.1	+	0.9	+	0.9	+		ne
Decamethylcyclopentasiloxane		541-02-6	$C_{10}H_{30}O_5Si_5$	0.16	+	0.13	+	0.12	+		ne
Decamethyltetrasiloxane		141-62-8	$C_{10}H_{30}O_3Si_4$	0.17	+	0.13	+	0.12	+	<10.2	ne
Decane		124-18-5	$C_{10}H_{22}$	4.0	+	1.4	+	0.35	+	9.65	ne
Diacetone alcohol	4-Methyl-4-hydroxy-2-pentanone	123-42-2	$C_6H_{12}O_2$			0.7					50
Dibromochloromethane	Chlorodibromomethane	124-48-1	$CHBr_2Cl$	NR	+	5.2	+	0.7	+	10.59	ne
Dibromo-3-chloropropane, 1,2-	DBCP	96-12-8	$C_3H_5Br_2Cl$	NR	+	1.7	+	0.43	+		0.001
Dibromoethane, 1,2-	EDB, Ethylene dibromide, Ethylene bromide	106-93-4	$C_2H_4Br_2$	NR	+	1.7	+	0.6	+	10.37	ne
Dichlorobenzene, o-	1,2-Dichlorobenzene	95-50-1	$C_6H_4Cl_2$	0.54	+	0.64	+	0.38	+	9.08	25
Dichlorodifluoromethane	CFC-12	75-71-8	CCl_2F_2			NR	+	NR	+	11.75	1000
Dichlorodimethylsilane		75-78-5	$C_2H_6Cl_2Si$	NR		NR		1.1	+	>10.7	ne
Dichloroethane, 1,2-	EDC, 1,2-DCA, Ethylene dichloride	107-06-2	$C_2H_4Cl_2$			NR	+	0.6	+	11.04	10
Dichloroethene, 1,1-	1,1-DCE, Vinylidene chloride	75-35-4	$C_2H_2Cl_2$			0.82	+	0.8	+	9.79	5
Dichloroethene, c-1,2-	c-1,2-DCE, *cis*-Dichloroethylene	156-59-2	$C_2H_2Cl_2$			0.8				9.66	200
Dichloroethene, t-1,2-	t-1,2-DCE, *trans*-Dichloroethylene	156-60-5	$C_2H_2Cl_2$			0.45	+	0.34	+	9.65	200
Dichloro-1-fluoroethane, 1,1-	R-141B	1717-00-6	$C_2H_3Cl_2F$	NR	+	NR	+	2.0	+		ne
Dichloromethane see Methylene chloride											
Dichloropentafluoropropane	AK-225, mix of ~45% 3,3-dichloro-1,1,1,2,2-pentafluoro-propane (HCFC-225ca) & ~55% 1,3-Dichloro-1,1,2,2,3-penta-fluoropropane (HCFC-225cb)	442-56-0 507-55-1	$C_3HCl_2F_5$	NR	+	NR	+	25	+		ne
Dichloropropane, 1,2-		78-87-5	$C_3H_6Cl_2$					0.7		10.87	75
Dichloro-1-propene, 1,3-		542-75-6	$C_3H_4Cl_2$	1.3	+	0.96	+			<10	1
Dichloro-1-propene, 2,3-		78-88-6	$C_3H_4Cl_2$	1.9	+	1.3	+	0.7	+	<10	ne
Dichloro-1,1,1- trifluoroethane, 2,2-	R-123	306-83-2	$C_2HCl_2F_3$	NR	+	NR	+	10.1	+	11.5	ne
Dichloro-2,4,6- trifluoropyridine, 3,5-	DCTFP	1737-93-5	$C_5Cl_2F_3N$	1.1	+	0.9	+	0.8	+		ne
Dichlorvos**	Vapona; O,O-dimethyl O-dichlorovinyl phosphate	62-73-7	$C_4H_7Cl_2O_4P$			0.9	+			<9.4	0.1
Dicyclopentadiene	DCPD, Cyclopentadiene dimer	77-73-6	$C_{10}H_{12}$	0.57	+	0.48	+	0.43	+	8.8	5
Diesel Fuel**		68334-30-5	m.w. 226			0.9	+				11
Diesel Fuel #2 (Automotive)**		68334-30-5	m.w. 216	1.3		0.7	+	0.4	+		11
Diethylamine		109-89-7	$C_4H_{11}N$			1	+			8.01	5
Diethylaminopropylamine, 3-		104-78-9	$C_7H_{18}N_2$			1.3					ne
Diethylbenzene see Dowtherm J											
Diethyl ether	Diethyl ether; Diethyl oxide; Ethyl oxide; Ether; Solvent ether	60-29-7	$C_4H_{10}O$			1.74	+			9.51	400
Diethylene glycol butyl ether	2-(2-Butoxyethoxy)ethanol, BDG, Butyldiglycol, DB Solvent	112-34-5	$C_8H_{18}O_3$			4.6	+				5
Diethylene glycol monobutyl ether acetate	Butyldiglycol acetate, DB Acetate, Diethylene glycol monobutyl ether acetate	124-17-4	$C_{10}H_{20}O_4$			5.62	+				ne
Diethylmaleate		141-05-9	$C_8H_{12}O_4$			4					ne
Diethyl sulfide see Ethyl sulfide											
Diglyme see Methoxyethyl ether		111-96-6	$C_6H_{14}O_3$								

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Diisobutyl ketone	DIBK, 2,2-dimethyl-4-heptanone	108-83-8	$C_9H_{18}O$	0.71	+	0.61	+	0.35	+	9.04	25
Diisopropylamine		108-18-9	$C_6H_{15}N$	0.84	+	0.74	+	0.5	+	7.73	5
Diisopropylcarbodiimide,N,N'-	DIPC	693-13-0	$C_7H_{14}N_2$			0.42	+				ne
Diisopropylethylamine	'Hünig's base', *N*-Ethyldiisopropylamine, DIPEA, Ethyldiisopropylamine	7087-68-5	$C_8H_{19}N$			0.7	+				ne
Diketene	Ketene dimer	674-82-8	$C_4H_4O_2$	2.6	+	2.0	+	1.4	+	9.6	0.5
Dimethylacetamide, N,N-	DMA	127-19-5	C_4H_9NO	0.87	+	0.8	+	0.8	+	8.81	10
Dimethylamine		124-40-3	C_2H_7N			1.5				8.23	5
Dimethyl carbonate	Carbonic acid dimethyl ester	616-38-6	$C_3H_6O_3$	NR	+	~70	+	1.7	+	~10.5	ne
Dimethyl disulfide	DMDS	624-92-0	$C_2H_6S_2$	0.2	+	0.20	+	0.21	+	7.4	ne
Dimethyl ether see Methyl ether											
Dimethylethylamine	DMEA	598-56-1	$C_4H_{11}N$	1.1	+	1.0	+	0.9	+	7.74	~3
Dimethylformamide, N,N-	DMF	68-12-2	C_3H_7NO	0.7	+	0.7	+	0.8	+	9.13	10
Dimethylhydrazine, 1,1-	UDMH	57-14-7	$C_2H_8N_2$			0.8	+	0.8	+	7.28	0.01
Dimethyl methylphosphonate	DMMP, methyl phosphonic acid dimethyl ester	756-79-6	$C_3H_9O_3P$	NR	+	4.3	+	0.74	+	10.0	ne
Dimethyl sulfate		77-78-1	$C_2H_6O_4S$	~23		~20	+	2.3	+		0.1
Dimethyl sulfide see Methyl sulfide											
Dimethyl sulfoxide	DMSO, Methyl sulfoxide	67-68-5	C_2H_6OS			1.4	+			9.10	ne
Dioxane, 1,4-		123-91-1	$C_4H_8O_2$			1.3				9.19	25
Dioxolane, 1,3-	Ethylene glycol formal	646-06-0	$C_3H_6O_2$	4.0	+	2.3	+	1.6	+	9.9	20
Dowtherm A see Therminol®**											
Dowtherm J (97% Diethylbenzene)**		25340-17-4	$C_{10}H_{14}$			0.5					
DS-108F Wipe Solvent	Ethyl lactate/Isopar H/ Propoxypropanol ~7:2:1	97-64-3 64742-48-9 1569-01-3	m.w. 118	3.3	+	1.6	+	0.7	+		ne
Epichlorohydrin	ECH Chloromethyloxirane, 1-chloro2,3-epoxypropane	106-89-8	C_2H_5ClO	~200	+	8.5	+	1.4	+	10.2	0.5
Ethane		74-84-0	C_2H_6			NR	+	15	+	11.52	ne
Ethanol	Ethyl alcohol	64-17-5	C_2H_6O			9.6	+	3.1	+	10.47	1000
Ethanolamine**	MEA, Monoethanolamine	141-43-5	C_2H_7NO	5.6	+	1.6	+			8.96	3
Ethene	Ethylene	74-85-1	C_2H_4			9	+	4.5	+	10.51	ne
Ethoxyethanol, 2-	Ethyl cellosolve, Ethylene glycol monoethyl ether	110-80-5	$C_4H_{10}O_2$			1.3				9.6	5
Ethyl acetate	Acetic ester; Acetic ether; Ethyl ester of acetic acid; Ethyl ethanoate	141-78-6	$C_4H_8O_2$			3.8	+			10.01	400
Ethyl acetoacetate		141-97-9	$C_6H_{10}O_3$	1.4	+	1.2	+	1.0	+	<10	ne
Ethyl acrylate		140-88-5	$C_5H_8O_2$			2.4	+	1.0	+	<10.3	5
Ethylactate	Acetic ester; Acetic ether; Ethyl ester of acetic acid; Ethyl ethanoate	141-78-6	$C_4H_8O_2$					2.18	+	10.01	400
Ethylamine		75-04-7	C_2H_7N			0.8				8.86	5
Ethylbenzene		100-41-4	C_8H_{10}	0.52	+	0.65	+	0.51	+	8.77	100
Ethyl caprylate	Ethyl octanoate	106-32-1	$C_{10}H_{20}O_2$		+	0.52	+	0.51	+		
Ethylenediamine	1,2-Ethanediamine; 1,2-Diaminoethane	107-15-3	$C_2H_8N_2$	0.9	+	0.8	+	1.0	+	8.6	10
(Ethylenedioxy)diethanethiol, 2,2'-	1,2-Bis(2-mercaptoethoxy)ethane, 3,6-Dioxa-1,8-octane-dithiol	14970-87-7	$C_6H_{14}O_2S_2$			1.3	+				ne
Ethylene glycol**	1,2-Ethanediol	107-21-1	$C_2H_6O_2$			16	+	6	+	10.16	C100
Ethylene glycol, Acrylate**	2-hydroxyethyl Acrylate	818-61-1	$C_5H_8O_3$			8.2				≤10.6	
Ethylene glycol dimethyl ether	1,2-Dimethoxyethane, Monoglyme	110-71-4	$C_4H_{10}O_2$	1.1		1.1		0.7		9.2	ne

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Ethylene glycol monobutyl ether acetate	1,2-Dimethoxyethane, Monoglyme	110-71-4	$C_4H_{10}O_2$	1.1		1.1		0.7		9.2	ne
Ethylene glycol, monothio		60-24-2	C_2H_6OS			1.5				9.65	
Ethylene oxide	Oxirane, Epoxyethane	75-21-8	C_2H_4O			13	+	3.5	+	10.57	1
Ethyl ether	Diethyl ether	60-29-7	$C_4H_{10}O$			1.1	+			9.51	400
Ethyl 3-ethoxypropionate	EEP	763-69-9	$C_7H_{14}O_3$	1.2	+	0.75	+				ne
Ethyl formate		109-94-4	$C_3H_6O_2$					1.9		10.61	100
Ethyl-1-hexanol, 2-	Isooctyl alcohol	104-76-7	$C_8H_{18}O$			1.9	+				ne
Ethyl hexyl acrylate, 2-	Acrylic acid 2-ethylhexyl ester	103-11-7	$C_{11}H_{20}O_2$			1.1	+	0.5	+		ne
Ethylidenenorbornene	5-Ethylidene bicyclo(2,2,1) hept-2-ene	16219-75-3	C_9H_{12}	0.4	+	0.39	+	0.34	+	≤8.8	ne
Ethyl (S)-(-)-lactate see also DS-108F	Ethyl lactate, Ethyl (S)-(-)-hydroxypropionate	687-47-8 97-64-3	$C_5H_{10}O_3$	13	+	3.2	+	1.6	+	~10	ne
Ethyl mercaptan	Ethanethiol	75-08-1	C_2H_6S	0.60	+	0.56	+			9.29	0.5
Ethyl sulfide	Diethyl sulfide	352-93-2	$C_4H_{10}S$			0.5	+			8.43	ne
Formaldehyde	Formalin	50-00-0	CH_2O	NR	+	NR	+	1.6	+	10.87	C0.3
Formamide		75-12-7	CH_3NO			6.9	+	4		10.16	10
Formic acid		64-18-6	CH_2O_2	NR	+	NR	+	9	+	11.33	5
Furfural	2-Furaldehyde	98-01-1	$C_5H_4O_2$			0.92	+	0.8	+	9.21	2
Furfuryl alcohol		98-00-0	$C_5H_6O_2$			0.80	+			<9.5	10
Gasoline #1		8006-61-9	m.w. 72			0.9	+				300
Gasoline #2, 92 octane		8006-61-9	m.w. 93	1.3	+	1.0	+	0.5	+		300
Glutaraldehyde	1,5-Pentanedial, Glutaric dialdehyde	111-30-8	$C_5H_8O_2$	1.1	+	0.8	+	0.6	+		C0.05
Glycidyl methacrylate	2,3-Epoxypropyl methacrylate	106-91-2	$C_7H_{10}O_3$	2.6	+	1.2	+	0.9	+		0.5
Halothane	2-Bromo-2-chloro-1,1,1-trifluoroethane	151-67-7	$C_2HBrClF_3$					0.6		11.0	50
HCFC-22 see Chlorodifluoromethane											
HCFC-123 see 2,2-Dichloro-1,1,1-trifluoroethane											
HCFC-141B see 1,1-Dichloro-1-fluoroethane											
HCFC-142B see 1-Chloro-1,1-difluoroethane											
HCFC-134A see 1,1,1,2-Tetrafluoroethane											
HCFC-225 see Dichloropentafluoropropane											
Heptane, n-		142-82-5	C_7H_{16}	45	+	2.8	+	0.60	+	9.92	400
Heptanol, 4-	Dipropylcarbinol	589-55-9	$C_7H_{16}O$	1.8	+	1.3	+	0.5	+	9.61	ne
Hexamethyldisilazane, 1,1,1,3,3,3-**	HMDS	999-97-3	$C_6H_{19}NSi_2$			0.2	+	0.2	+	~8.6	ne
Hexamethyldisiloxane	HMDSx	107-46-0	$C_6H_{18}OSi_2$	0.33	+	0.27	+	0.25	+	9.64	ne
Hexane, n-		110-54-3	C_6H_{14}	350	+	4.3	+	0.54	+	10.13	50
Hexanol, 1-	Hexyl alcohol	111-27-3	$C_6H_{14}O$	9	+	2.5	+	0.55	+	9.89	ne
Hexene, 1-		592-41-6	C_6H_{12}			0.8				9.44	30
HFE-7100 see Methyl nonafluorobutyl ether											
Histoclear (Histo-Clear)	Limonene/corn oil reagent		m.w. ~136	0.5	+	0.4	+	0.3	+		ne
Hydrazine**		302-01-2	H_4N_2	>8	+	2.6	+	2.1	+	8.1	0.01
Hydrazoic acid	Hydrogen azide		HN_3							10.7	
Hydrogen	Synthesis gas	1333-74-0	H_2	NR	+	NR	+	NR	+	15.43	ne
Hydrogen cyanide	Hydrocyanic acid	74-90-8	HCN	NR	+	NR	+	NR	+	13.6	C4.7
Hydrogen iodide**	Hydriodic acid	10034-85-2	HI			~0.6				10.39	
Hydrogen peroxide		7722-84-1	H_2O_2	NR	+	NR	+	NR	+	10.54	1
Hydrogen sulfide		7783-06-4	H_2S	NR	+	3.3	+	1.5	+	10.45	10
Hydroxyethyl acrylate, 2-	Ethylene glycol monoacrylate	818-61-1	$C_5H_8O_3$			8.2	+				ne

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Hydroxypropyl methacrylate		27813-02-1 923-26-2	$C_7H_{12}O_3$	9.9	+	2.3	+	1.1	+		ne
Iodine**		7553-56-2	I_2	0.1	+	0.1	+	0.1	+	9.40	C0.1
Iodomethane	Methyl iodide	74-88-4	CH_3I	0.21	+	0.22	+	0.26	+	9.54	2
Isoamyl acetate	Isopentyl acetate	123-92-2	$C_7H_{14}O_2$	10.1		2.1		1.0		<10	100
Isobutane	2-Methylpropane	75-28-5	C_4H_{10}			100	+	1.2	+	10.57	ne
Isobutanol	2-Methyl-1-propanol	78-83-1	$C_4H_{10}O$	19	+	3.8	+	1.5		10.02	50
Isobutene	Isobutylene, Methyl butene	115-11-7	C_4H_8	1.00	+	1.00	+	1.00	+	9.24	ne
Isobutyl acetate	2-methylpropyl ethanoate, β-methylpropyl acetate	110-19-0	$C_6H_{12}O_2$			2.1	+			9.97	150
Isobutyl acrylate	Isobutyl 2-propenoate, Acrylic acid Isobutyl ester	106-63-8	$C_7H_{12}O_2$			1.5	+	0.60	+		ne
Isoflurane	1-Chloro-2,2,2-trifluoroethyl difluoromethyl ether, forane	26675-46-7	$C_3H_2ClF_5O$	NR	+	NR	+	48	+	~11.7	ne
Isooctane	2,2,4-Trimethylpentane	540-84-1	C_8H_{18}			1.2				9.86	ne
Isopar E Solvent	Isoparaffinic hydrocarbons	64741-66-8	m.w. 121	1.7	+	0.8	+				ne
Isopar G Solvent	Photocopier diluent	64742-48-9	m.w. 148			0.8	+				ne
Isopar K Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 156	0.9	+	0.5	+	0.27	+		ne
Isopar L Solvent	Isoparaffinic hydrocarbons	64742-48-9	m.w. 163	0.9	+	0.5	+	0.28	+		ne
Isopar M Solvent	Isoparaffinic hydrocarbons	64742-47-8	m.w. 191			0.7	+	0.4	+		ne
Isopentane	2-Methylbutane	78-78-4	C_5H_{12}			8.2					ne
Isophorone		78-59-1	$C_9H_{14}O$					3		9.07	C5
Isoprene	2-Methyl-1,3-butadiene	78-79-5	C_5H_8	0.69	+	0.63	+	0.60	+	8.85	ne
Isopropanol	Isopropyl alcohol, 2-propanol, IPA	67-63-0	C_3H_8O	500	+	4.6	+	2.7		10.12	200
Isopropyl acetate		108-21-4	$C_5H_{10}O_2$			2.6				9.99	100
Isopropyl ether	Diisopropyl ether	108-20-3	$C_6H_{14}O$			0.8				9.20	250
Jet fuel JP-4	Jet B, Turbo B, F-40 Wide cut type aviation fuel	8008-20-6 + 64741-42-0	m.w. 115			1.0	+	0.4	+		ne
Jet fuel JP-5	Jet 5, F-44, Kerosene type aviation fuel	8008-20-6 + 64747-77-1	m.w. 167			0.6	+	0.5	+		29
Jet fuel JP-8	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 165			0.94	+	0.3	+		30
Jet fuel A-1	F-34, Kerosene type aviation fuel	8008-20-6 + 64741-77-1	m.w. 145			0.67					34
Jet Fuel TS	Thermally Stable Jet Fuel, Hydrotreated kerosene fuel	8008-20-6 + 64742-47-8	m.w. 165	0.9	+	0.6	+	0.3	+		30
JP-10						0.7	+	0.5	+		
JP5, Petroleum/camelinal						1.05	+				
JP5/Petroleum						0.98	+				
Limonene, D-	(R)-(+)-Limonene	5989-27-5	$C_{10}H_{16}$			0.33	+			~8.2	ne
Kerosene C10-C16 petro.distillate	see Jet Fuels	8008-20-6									
MDI see 4,4'-Methylenebis (phenylisocyanate)											
Maleic anhydride	2,5-Furandione	108-31-6	$C_4H_2O_3$							~10.8	0.1
Mercapto-2-ethanol	β-Mercaptoethanol, 2-Hydroxyethylmercaptan, BME, Thioethylene glycol	60-24-2	C_2H_6OS			1.5	+			9.65	0.2
Mesitylene	1,3,5-Trimethylbenzene	108-67-8	C_9H_{12}	0.36	+	0.35	+	0.3	+	8.41	25
Methallyl chloride see 3-Chloro-2-methylpropene											
Methane	Natural gas	74-82-8	CH_4	NR	+	NR	+	NR	+	12.61	ne
Methanol	Methyl alcohol, carbinol	67-56-1	CH_4O	NR	+	NR	+	2.5	+	10.85	200
Methoxyethanol, 2-	Methyl cellosolve, Ethylene glycol monomethyl ether	109-86-4	$C_3H_8O_2$	4.8	+	2.4	+	1.4	+	10.1	5

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Methoxyethoxyethanol, 2-	2-(2-Methoxyethoxy)ethanol Diethylene glycol monomethyl ether	111-77-3	$C_7H_{16}O$	2.3	+	1.2	+	0.9	+	<10	ne
Methoxyethyl ether, 2-	bis(2-Methoxyethyl) ether, Diethylene glycol dimethyl ether, Diglyme	111-96-6	$C_6H_{14}O_3$	0.64	+	0.54	+	0.44	+	<9.8	ne
Methyl acetate		79-20-9	$C_3H_6O_2$	NR	+	6.6	+	1.4	+	10.27	200
Methyl acrylate	Methyl 2-propenoate, Acrylic acid methyl ester	96-33-3	$C_4H_6O_2$			3.7	+	1.2	+	(9.9)	2
Methylamine	Aminomethane	74-89-5	CH_5N			1.2				8.97	5
Methyl amyl ketone	MAK, 2-Heptanone, Methyl pentyl ketone	110-43-0	$C_7H_{14}O$	0.9	+	0.85	+	0.5	+	9.30	50
Methylaniline, N-	MA; (Methylamino) benzene; N-Methyl aniline; Methylphenylamine; N-Phenylmethylamin	100-61-8	C_7H_9N			0.68	+			7.32	2
Methyl bromide	Bromomethane	74-83-9	CH_3Br	110	+	1.7	+	1.3	+	10.54	1
Methyl-2-butanol, 2-	*tert*-Amyl alcohol, *tert*-Pentyl alcohol	75-85-4	$C_5H_{12}O$			1.62	+			10.16	100
Methyl t-butyl ether	MTBE, tert-Butyl methyl ether	1634-04-4	$C_5H_{12}O$			0.9	+			9.24	40
Methyl cellosolve see 2-Methoxyethanol											
Methyl chloride	Chloromethane	74-87-3	CH_3Cl	NR	+	NR	+	0.74	+	11.22	50
Methylcyclohexane		107-87-2	C_7H_{14}	1.6	+	0.97	+	0.53	+	9.64	400
Methylene bis (phenyl-isocyanate), 4,4'-**	MDI, Mondur M		$C_{15}H_{10}N_2O_2$	Very slow ppb level response							0.005
Methylene chloride	Dichloromethane	75-09-2	CH_2Cl_2	NR	+	NR	+	0.89	+	11.32	25
Methyl ether	Dimethyl ether	115-10-6	C_2H_6O	4.8	+	3.1	+	2.5	+	10.03	ne
Methyl ethyl ketone	MEK, 2-Butanone	78-93-3	C_4H_8O	0.86	+	1.0	+	1.1	+	9.51	200
Methylhydrazine	Monomethylhydrazine, Hydrazomethane	60-34-4	$C_2H_6N_2$	1.4	+	1.2	+	1.3	+	7.7	0.01
Methyl isoamyl ketone	MIAK, 5-Methyl-2-hexanone	110-12-3	$C_7H_{14}O$	0.8	+	0.76	+	0.5	+	9.28	50
Methyl isobutyl ketone	MIBK, 4-Methyl-2-pentanone	108-10-1	$C_6H_{12}O$	0.9	+	0.8	+	0.6	+	9.30	50
Methyl isocyanate		624-83-9	C_2H_3NO	NR	+	4.6	+	1.5		10.67	0.02
Methyl isothiocyanate		551-61-6	C_2H_3NS	0.5	+	0.45	+	0.4	+	9.25	ne
Methyl mercaptan	Methanethiol	74-93-1	CH_4S	0.65		0.54		0.66		9.44	0.5
Methyl methacrylate		80-62-6	$C_5H_8O_2$	2.7	+	1.5	+	1.2	+	9.7	100
Methyl nonafluorobutyl ether	HFE-7100DL	163702-08-7, 163702-07-6	$C_5H_3F_9O$			NR	+	~35	+		ne
Methyl-1,5-pentanediamine, 2- (coats lamp)**	Dytek-A amine, 2-Methyl pentamethylenediamine	15520-10-2	$C_6H_{16}N_2$			~0.6	+			<9.0	ne
Methyl propyl ketone	MPK, 2-Pentanone	107-87-9	$C_5H_{12}O$			0.93	+	0.79	+	9.38	200
Methyl-2-pyrrolidinone, N-	NMP, N-Methylpyrrolidone, 1-Methyl-2-pyrrolidinone, 1-Methyl-2-pyrrolidone	872-50-4	C_5H_9NO	1.0	+	0.8	+	0.9	+	9.17	ne
Methyl salicylate**	Methyl 2-hydroxybenzoate	119-36-8	$C_8H_8O_3$	1.3	+	0.9	+	0.9	+	~9	ne
Methylstyrene, α-	2-Propenylbenzene	98-83-9	C_9H_{10}			0.5				8.18	50
Methyl sulfide	DMS, Dimethyl sulfide	75-18-3	C_2H_6S	0.49	+	0.44	+	0.46	+	8.69	ne
Methyl tertiary-butyl ether	MTBE, Methyl *tert*-butyl ether	1634-04-4	$C_5H_{12}O$			1.43	+			9.24	50
Methyl vinyl ketone	MVK, 3-Buten-2-one	78-94-4	C_4H_6O			0.93	+			9.65	ne
Methyltetrahydrofuran	2-MeTHF, Tetrahydro-2-methylfuran, Tetrahydrosilvan	96-47-9	$C_5H_{10}O$			2.44	+			9.22	ne
Mineral spirits	Stoddard Solvent, Varsol 1, White Spirits	8020-83-5 8052-41-3 68551-17-7	m.w. 144	1.0		0.69	+	0.38	+		100
Mineral Spirits	Viscor 120B Calibration Fluid, b.p. 156-207°C	8052-41-3	m.w. 142	1.0	+	0.7	+	0.3	+		100

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Monoethanolamine see Ethanolamine											
Mustard	HD, Bis (2-chloroethyl) sulfide	505-60-2 39472-40-7 68157-62-0	$C_4H_8Cl_2S$			0.6					0.0005
Naphtha see VM & P Naphtha											
Naphthalene	Mothballs	91-20-3	$C_{10}H_8$	0.45	+	0.42	+	0.40	+	8.13	10
Nickel carbonyl (in CO)	Nickel tetracarbonyl	13463-39-3	C_4NiO_4			0.18				<8.8	0.001
Nicotine	3-(1-Methyl-2-pyrrolidyl)pyridine	54-11-5	$C_{10}H_{14}N_2$			1.98	+				ne
Nitric oxide		10102-43-9	NO	~6		5.2	+	2.8	+	9.26	25
Nitrobenzene		98-95-3	$C_6H_5NO_2$	2.6	+	1.9	+	1.6	+	9.81	1
Nitroethane		79-24-3	$C_2H_5NO_2$					3		10.88	100
Nitrogen dioxide		10102-44-0	NO_2	23	+	16	+	6	+	9.75	3
Nitrogen trifluoride		7783-54-2	NF_3	NR		NR		NR		13.0	10
Nitromethane		75-52-5	CH_3NO_2					4		11.02	20
Nitropropane, 2-		79-46-9	$C_3H_7NO_2$					2.6		10.71	10
Nonane		111-84-2	C_9H_{20}			1.4				9.72	200
Norpar 12	n-Paraffins, mostly C_{10}-C_{13}	64771-72-8	m.w. 161	3.2	+	1.1	+	0.28	+		ne
Norpar 13	n-Paraffins, mostly C_{13}-C_{14}	64771-72-8	m.w. 189	2.7	+	1.0	+	0.3	+		ne
Octamethylcyclotetrasiloxane		556-67-2	$C_8H_{24}O_4Si_4$	0.21	+	0.17	+	0.14	+		ne
Octamethyltrisiloxane		107-51-7	$C_8H_{24}O_2Si_3$	0.23	+	0.18	+	0.17	+	<10.0	ne
Octane, n-		111-65-9	C_8H_{18}	13	+	1.8	+			9.82	300
Octene, 1-		111-66-0	C_8H_{16}	0.9	+	0.75	+	0.4	+	9.43	75
Pentachloropropane	1,1,1,3,3-pentachloropropane	23153-23-3	$C_3H_3Cl_5$					1.25	+		0.1
Pentane		109-66-0	C_5H_{12}	80	+	8.4	+	0.7	+	10.35	600
Peracetic acid**	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	$C_2H_4O_3$	NR	+	NR	+	2.3	+		ne
Peracetic/Acetic acid mix**	Peroxyacetic acid, Acetyl hydroperoxide	79-21-0	$C_2H_4O_3$			50	+	2.5	+		ne
Perchloroethene	PCE, Perchloroethylene, Tetrachloroethylene	127-18-4	C_2Cl_4	0.69	+	0.57	+	0.31	+	9.32	25
Propylene glycol methyl ether, 1-Methoxy-2-propanol	PGME	107-98-2	$C_6H_{12}O_3$	2.4	+	1.5	+	1.1	+		100
Propylene glycol methyl ether acetate, 1-Methoxy-2-acetoxypropane, 1-Methoxy-2-propanol acetate	PGMEA	108-65-6	$C_6H_{12}O_3$	1.65	+	1.0	+	0.8	+		ne
Phenol	Hydroxybenzene	108-95-2	C_6H_6O	1.0	+	1.0	+	0.9	+	8.51	5
Phosgene	Dichlorocarbonyl	75-44-5	CCl_2O	NR	+	NR	+	8.5	+	11.2	0.1
Phosgene in Nitrogen	Dichlorocarbonyl	75-44-5	CCl_2O	NR	+	NR	+	6.8	+	11.2	0.1
Phosphine (coats lamp)		7803-51-2	PH_3	28		3.9	+	1.1	+	9.87	0.3
Photocopier Toner	Isoparaffin mix					0.5	+	0.3	+		ne
Picoline, 3-	3-Methylpyridine	108-99-6	C_6H_7N			0.9				9.04	ne
Pinene, α-		2437-95-8	$C_{10}H_{16}$			0.31	+	0.47		8.07	ne
Pinene, β-		18172-67-3	$C_{10}H_{16}$	0.38	+	0.37	+	0.37	+	~8	100
Piperylene, isomer mix	1,3-Pentadiene	504-60-9	C_5H_8	0.76	+	0.69	+	0.64	+	8.6	100
Propane		74-98-6	C_3H_8			NR	+	1.8	+	10.95	2500
Propanol, n-	Propyl alcohol	71-23-8	C_3H_8O			5.5		1.7		10.22	200
Propene	Propylene	115-07-1	C_3H_6	1.5	+	1.4	+	1.6	+	9.73	ne
Propionaldehyde	Propanal	123-38-6	C_3H_6O			1.9				9.95	ne
Propyl acetate, n-		109-60-4	$C_5H_{10}O_2$			3.5				10.04	200
Propyl acetate	Propylacetate; n-Propyl ester of acetic acid	109-60-4	$C_5H_{10}O_2$			2.27	+			10.04	200

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Propylamine, n-	1-Propylamine, 1-Aminopropane	107-10-8	C_3H_9N	1.1	+	1.1	+	0.9	+	8.78	ne
Propylene carbonate**		108-32-7	$C_4H_6O_3$			62	+	1	+	10.5	ne
Propylene glycol	1,2-Propanediol	57-55-6	$C_3H_8O_2$	18		4.2	+	1.6	+	<10.2	ne
Propylene glycol propyl ether	1-Propoxy-2-propanol	1569-01-3	$C_6H_{14}O_2$	1.3	+	1.0	+	1.6	+		ne
Propylene oxide	Methyloxirane	75-56-9 16088-62-3 15448-47-2	C_3H_6O	~240		6.6	+	2.9	+	10.22	20
Propyleneimine	2-Methylaziridine	75-55-8	C_3H_7N	1.5	+	1.3	+	1.0	+	9.0	2
Propyl mercaptan, 2-	2-Propanethiol, Isopropyl mercaptan	75-33-2	C_3H_8S	0.64	+	0.66	+			9.15	ne
Pyridine		110-86-1	C_5H_5N	0.78	+	0.7	+	0.7	+	9.25	5
Pyrrolidine (coats lamp)	Azacyclohexane	123-75-1	C_4H_9N	2.1	+	1.3	+	1.6	+	~8.0	ne
RR7300 (PGME/PGMEA)	70:30 PGME:PGMEA (1-Methoxy-2-propanol: 1-Methoxy-2-acetoxypropane)	107-98-2	$C_4H_{10}O_2$/ $C_6H_{12}O_3$			1.4	+	1.0	+		ne
Sarin	GB, Isopropyl methylphosphonofluoridate	107-44-8 50642-23-4	$C_4H_{10}FO_2P$			~3					
Shell SPK						1.26	+				
Shell SPK						1.29	+	0.4	+		
Shell SPK 50/50						1.02	+	0.41	+		
Shell SPK/JP-8						1.11	+				
Stoddard Solvent see Mineral Spirits		8020-83-5									
Styrene		100-42-5	C_8H_8	0.45	+	0.43	+	0.4	+	8.43	20
Sulfur dioxide		7446-09-5	SO_2	NR		NR	+	NR	+	12.32	2
Sulfur hexafluoride		2551-62-4	SF_6	NR		NR		NR		15.3	1000
Sulfuryl fluoride	Vikane	2699-79-8	SO_2F_2	NR		NR		NR		13.0	5
Tabun**	Ethyl N, N-dimethylphosphoramidocyanidate	77-81-6	$C_5H_{11}N_2O_2P$			0.8					15ppt
Tallow HRJ						1.09	+				
Tallow HRJ						0.95	+	0.36	+		
Tallow HRJ/JP-8						1.14	+				
Tallow HRJ/JP-8 50/50						0.9	+	0.39	+		
Tetrachloroethane, 1,1,1,2-		630-20-6	$C_2H_2Cl_4$					1.3		~11.1	ne
Tetrachloroethane, 1,1,2,2-		79-34-5	$C_2H_2Cl_4$	NR	+	NR	+	0.60	+	~11.1	1
Tetrachlorosilane		10023-04-7	$SiCl_4$	NR		NR		15	+	11.79	ne
Tetraethyllead	TEL	78-00-2	$C_8H_{20}Pb$	0.4		0.3		0.2		~11.1	0.008
Tetraethyl orthosilicate	Ethyl silicate, TEOS	78-10-4	$C_8H_{20}O_4Si$			0.7	+	0.2	+	~9.8	10
Tetrafluoroethane, 1,1,1,2-	HFC-134A	811-97-2	$C_2H_2F_4$			NR		NR			ne
Tetrafluoroethene	TFE, Tetrafluoroethylene, Perfluoroethylene	116-14-3	C_2F_4			~15				10.12	ne
Tetrafluoromethane	CFC-14, Carbon tetrafluoride	75-73-0	CF_4			NR	+	NR	+	>15.3	ne
Tetrahydrofuran	THF	109-99-9	C_4H_8O	1.9	+	1.7	+	1.0	+	9.41	200
Tetramethyl orthosilicate	Methyl silicate, TMOS	681-84-5	$C_4H_{12}O_4Si$	10	+	1.9	+			~10	1
Therminol® D-12**	Hydrotreated heavy naphtha	64742-48-9	m.w. 160	0.8	+	0.51	+	0.33	+		ne
Therminol® VP-1**	Dowtherm A, 3:1 Diphenyl oxide: Biphenyl	101-84-8 92-52-4	$C_{12}H_{10}O$ $C_{12}H_{10}$			0.4	+				1
Toluene	Methylbenzene	108-88-3	C_7H_8	0.54	+	0.45	+	0.51	+	8.82	50
Tolylene-2,4-diisocyanate	TDI, 4-Methyl-1,3-phenylene-2,4-diisocyanate	584-84-9	$C_9H_6N_2O_2$	1.4	+	1.4	+	2.0	+		0.002
Trichlorobenzene, 1,2,4-	1,2,4-TCB	120-82-1	$C_6H_3Cl_3$	0.7	+	0.9	+			9.04	C5
Trichloroethane, 1,1,1-	1,1,1-TCA, Methyl chloroform	71-55-6	$C_2H_3Cl_3$			NR	+	1	+	11	350

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Compound Name	Synonym/Abbreviation	CAS No.	Formula	9.8	C	10.6	C	11.7	C	IE (eV)	TWA
Trichloroethane, 1,1,2-	1,1,2-TCA	79-00-5	$C_2H_3Cl_3$	NR	+	NR	+	0.9	+	11.0	10
Trichloroethene	TCE, Trichoroethylene	79-01-6	C_2HCl_3	0.62	+	0.54	+	0.43	+	9.47	50
Trichloromethylsilane	Methyltrichlorosilane	75-79-6	CH_3Cl_3Si	NR		NR		1.8	+	11.36	ne
Trichlorotrifluoroethane, 1,1,2-	CFC-113	76-13-1	$C_2Cl_3F_3$			NR		NR		11.99	1000
Triethylamine	TEA	121-44-8	$C_6H_{15}N$	0.95	+	0.9	+	0.65	+	7.3	1
Triethyl borate	TEB; Boric acid triethyl ester, Boron ethoxide	150-46-9	$C_6H_{15}O_3B$			2.2	+	1.1	+	~10	ne
Triethyl phosphate	Ethyl phosphate	78-40-0	$C_6H_{15}O_4P$	~50	+	3.1	+	0.60	+	9.79	ne
Trifluoroethane, 1,1,2-		430-66-0	$C_2H_3F_3$					34		12.9	ne
Trimethylamine		75-50-3	C_3H_9N			0.9				7.82	5
Trimethylbenzene, 1,3,5- see Mesitylene		108-67-8									25
Trimethyl borate	TMB; Boric acid trimethyl ester, Boron methoxide	121-43-7	$C_3H_9O_3B$			5.1	+	1.2	+	10.1	ne
Trimethyl phosphate	Methyl phosphate	512-56-1	$C_3H_9O_4P$			8.0	+	1.3	+	9.99	ne
Trimethyl phosphite	Methyl phosphite	121-45-9	$C_3H_9O_3P$			1.1	+		+	8.5	2
Turpentine	Pinenes (85%) + other diisoprenes	8006-64-2	$C_{10}H_{16}$	0.37	+	0.4	+	0.29	+	~8	20
Undecane		1120-21-4	$C_{11}H_{24}$			2				9.56	ne
Varsol see Mineral Spirits											
Vinyl actetate		108-05-4	$C_4H_6O_2$	1.5	+	1.2	+	1.0	+	9.19	10
Vinyl bromide	Bromoethylene	593-60-2	C_2H_3Br			0.4				9.80	5
Vinyl chloride	Chloroethylene, VCM	75-01-4	C_2H_3Cl			2.0	+	0.6	+	9.99	5
Vinyl-1-cyclohexene, 4-	Butadiene dimer, 4-Ethenylcyclohexene	100-40-3	C_8H_{12}	0.6	+	0.56	+			9.83	0.1
Vinylidene chloride see 1,1-Dicholorethene											
Vinyl-2-pyrrolidinone, 1-	NVP, N-vinylpyrrolidone, 1-ethenyl-2-pyrrolidinone	88-12-0	C_6H_9NO	1.0	+	0.8	+	0.9	+		ne
Viscor 120B see Mineral Spirits—Viscor 120B Calibration Fluid											
V. M. & P. Naphtha	Ligroin; Solvent naphtha; Varnish maker's & painter's naphtha	64742-89-8	m.w. 111 (C_8-C_9)	1.7	+	0.97	+				300
Xylene, m-	1,3-Dimethylbenzene	108-38-3	C_8H_{10}	0.50	+	0.44	+	0.40	+	8.56	100
Xylene, o-	1,2-Dimethylbenzene	95-47-6	C_8H_{10}	0.56	+	0.45	+	0.43		8.56	100
Xylene, p-	1,4-Dimethylbenzene	106-42-3	C_8H_{10}	0.48	+	0.39	+	0.38	+	8.44	100

* The term "ionization energy" is more scientifically correct and replaces the old term "ionization potential." High-boiling ("heavy") compounds may not vaporize enough to give a response even when their ionization energies are below the lamp photon energy. Some inorganic compounds like H_2O_2 and NO_2 give weak response even when their ionization energies are well below the lamp photon energy.

** Compounds indicated in green can be detected using a MiniRAE 3000, UltraRAE 3000 or ppbRAE 3000 with slow response, but may be lost by adsorption on a MultiRAE, EntryRAE and AreaRAE. Response on multi-gas meters can give an indication of relative concentrations, but may not be quantitative and for some chemicals no response is observed.

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Attachment C:

SOP Fact Sheet

HEADSPACE FIELD SCREENING PROCEDURE

PURPOSE AND OBJECTIVE

Headspace field screening measurements of soil and aqueous samples are conducted in order to obtain organic vapor/gas measurements during field investigations. Headspace field screening can be used as a guide to direct the collection of samples for laboratory testing, to look for evidence of contamination, and to direct subsequent investigations. Data collected during these methods are considered qualitative and specific compounds cannot be distinguished. The procedure involves collecting solid or aqueous samples, sealing them in an airtight container, and analyzing the organic vapors that form within the container using a portable vapor/gas detector.

WHAT TO BRING

- Site-specific HASP
- Appropriate PPE
- PID with appropriate electron volt lamp source, or FID
- Field book
- Aluminum foil for enclosing jars
- 500 ml clean jars or 1-quart or larger resealable plastic bags for solid samples
- 40 ml to 1,000 ml clean jars for aqueous samples
- Charcoal filter (for FID, if methane is present)
- Moisture filter/external water trap (for PID)
- Tedlar bags
- Isobutylene compressed gas cylinder (for PID; 100 ppmV)
- Methane compressed gas cylinder (for FID; 100 ppmV)
- Zero air compressed gas cylinder or carbon filter
- Sharpie

OFFICE

- Prepare/update the site-specific HASP.
- Review the site-specific work plan.
- Set up procedures for management of IDW (e.g., soils used in screening).
- Confirm all required equipment is available.

ON-SITE

- Verify project HASP is available on site.
- Conduct daily Health & Safety tailgate meetings, as appropriate.
- Establish a designated work area.
- Compressed gases used for calibration are hazardous materials and must be appropriately be transported, handled, and stored.
- Provide for the proper collection and management of all IDW.
- Verify that appropriate PPE is worn by all site personnel (including subcontractors) and the work area is safe.

HEADSPACE FIELD SCREENING PROCEDURES

1. Allow the instrument to warm up at least 10 minutes. Calibrate using zero air or ambient air. Record the results. Properly calibrate the PID or FID using the appropriate calibration gas. Calibrate at the beginning of the day and if conditions change during the day or if results become inconsistent.
2. Depending on site-specific requirements, a resealable plastic bag or container can be used for solid samples.
3. Use chemical-resistant gloves and PPE per the HASP.
4. Fill the screening container ⅓ to ½ full of the sample. Seal the bag, or if a jar is used, quickly cover the top with aluminum foil and screw on the cap.
5. Vigorously shake the bag or jar for 15 seconds. Shake each sample container consistently for a similar time.
6. Allow headspace development to occur for at least 10 minutes. The time allowed should be approximately the same for all samples. For ambient temperatures below 32°F, thermal enhancement of the sample may be considered using a heated vehicle or building, sunlight, hot lamp, etc. Headspace development should not be allowed to occur so long that condensation forms in the container.
7. Vigorously shake the container for approximately 15 seconds after headspace development, using approximately the same time period for all samples.

HEADSPACE FIELD SCREENING

8. Unscrew the lid of the jar to expose the aluminum foil seal. Quickly puncture the seal with the instrument probe, and insert the probe to about ½ of the headspace depth. For a resealable bag, partially open the seal, insert the probe, and re-seal the bag around the probe. Avoid contacting the probe with water droplets or soil particles.
9. Following probe insertion, record the highest meter response as the headspace concentration. Maximum response should be between 2 to 5 seconds.
10. A slowly increasing response on a PID may be due to high moisture levels. Repeat analysis may be needed taking care to avoid condensation or contact with moisture.
11. If the sample yields headspace readings higher than the upper limit of calibration, recalibration to a higher level may be necessary.
12. Record the headspace screening data in the field book and/or on a field data form.
13. Return the sample to the original source site location, or dispose of the sample in accordance with the IDW plan.

INVESTIGATION DERIVED WASTE (IDW) DISPOSAL

Field personnel should review the site-specific work plan and ensure project-specific IDW management documentation and containerization requirements are specified or discussed with the Project Manager before going to the project site. Containerize, label, or manage all IDW as specified in the plan.

QA/QC, DATA MANAGEMENT AND RECORDS MANAGEMENT

1. Headspace measurements should be performed in duplicate on one sample per day, at a minimum.
2. Procedures followed for sample preparation should be the same for all samples.
3. Operate and calibrate the instruments according to the manufacturer's manual.
4. Record the model name and number of the instrument in the field book.
5. All procedures and results must be documented in the field book and/or field forms. Correct values for background, if appropriate.
6. Document any deviations from the procedures specified in the work plan or QAPP in the field book. Any deviations must be approved by the Project Manager.

DOS AND DON'TS OF HEADSPACE FIELD SCREENING

DOs:

- DO call the Project Manager or field team leader if unexpected conditions are encountered, or at least daily to update them on site work.
- DO use properly trained staff.
- DO check the instrument batteries before each day.
- DO manage IDW in accordance with project requirements.
- DO properly calibrate the instrument using the compressed gas standard. Perform periodic response checks throughout the day. Record the results in the field notes.
- DO consider environmental factors such as high moisture and high organic content in the sample. High moisture may make using a PID inappropriate. A water trap or filter should be used to reduce moisture impacts. High organic matter can also affect results.
- DO use thermal enhancement such as a heated vehicle or building, or sunlight, to warm the samples to achieve a better response in cold conditions.
- DO use the proper lamp source in the PID based on the ionization potential of the contaminant of concern.
- DO collect samples for headspace or laboratory analysis within minutes of being exposed to air to minimize loss due to volatilization.

DON'Ts:

- DON'T perform headspace screening near potential sources of VOCs such as operating vehicles, generators, or air handling equipment.
- DON'T use samples collected for headspace screening for laboratory analysis.
- DON'T sign anything in the field unless authorized in writing by client. This includes waste disposal documentation, statements, etc.; call the PM if this issue arises.

Title: **Slug Test Procedures**	Procedure Number: **ECR 029**
	Revision Number: **1**
	Effective Date: **January 2020**

Authorization Signatures

Jeff Hansen Principal Author	Date 1/1/20	David Hay Contributing Author	Date 1/1/20
Nidal Rabah Technical Reviewer	Date 1/1/20	Environmental Sector Quality Director Elizabeth Denly	Date 1/1/20

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1.0 INTRODUCTION

1.1 Scope and Applicability

The objective of this Standard Operating Procedure (SOP) is to specify the methodologies and techniques for performing slug tests to estimate local aquifer properties. The parameters obtained from a slug test analysis represent the saturated medium in the immediate vicinity of the well screen due to the limited volume of the displaced groundwater and the heterogeneity of geologic media.

1.2 Summary of Method

Slug tests are performed by near-instantaneous raising or lowering the water level in a well, then measuring the change in water level with time as it rebounds to the static water level. The most common and preferred method for initiating a slug test is to rapidly introduce or remove a solid object to/from the well. In low permeability media, it is possible to measure the change in water level using an electronic water level indicator. However, it is preferable to use a pressure transducer and a data logger during slug tests for frequent water level measurements, particularly during the early part of the test when the rate of water level rebound is greatest. These early time data are essential for differentiating filter pack drainage effects from aquifer response (*i.e.*, groundwater flow from or to the aquifer), which is required to calculate hydraulic conductivity.

Recorded measurements of transient water level rebound are analyzed for aquifer parameters using analytical solutions that account for well geometry (*i.e.*, well casing radius, borehole radius, and length of screen or open borehole), hydrogeologic boundary conditions (*e.g.*, aquitard thickness for leaky aquifers and block thickness/diameter in bedrock aquifers), and other hydrogeologic information (*e.g.*, water level displacement, initial static water column height, depth to the top of the screen below the top of the aquifer, and aquifer thickness). The solutions vary depending on the type of aquifer (confined or unconfined), boundary conditions, partial or full aquifer penetration, and the potential occurrence of wellbore skin and inertial effects. *The Design, Performance, and Analysis of Slug Tests* (Butler, 1998) is an essential reference for project managers, field personnel, and data analysts.

1.3 Equipment

The following equipment is generally needed for performing slug tests:

- Well keys and/or gate box key
- Hand tools, including socket set and safety knife
- Three- to five-inch long bolt to hang slug from the well head
- Health and safety monitoring equipment – consult health and safety plan (HASP)
- Trash bags
- Buckets (5-gallon capacity)
- Electronic water level meter and/or oil/water interface probe
- Gauge/Vented transducer and data logger. If a non-vented (absolute pressure) transducer is used, a barometer should be deployed during testing to assess barometric pressure effects.

Applying barometric pressure corrections prior to data analysis is especially important for slow rebounding water levels in low permeability media.

- Polyvinyl chloride (PVC) slugs (two different displacement volumes varying by a factor of two or more), or, for very high hydraulic conductivity media, an air-tight pneumatic well-head apparatus with compressed air or nitrogen gas supply, regulator, and appropriate fittings. Pneumatic well-head apparatus configurations may vary by manufacturer. The user should check with the manufacturer to determine specific types and diameters of fittings needed to connect the compressed gas supply to the well-head apparatus and to secure the apparatus to the well casing.
- If slug test is conducted by water removal
    - A bailer or a pump (and hoses, pipes, or tubes with necessary fittings)
    - Containers and check valves and gages
- Compressed air or nitrogen
- Duct tape
- 1/8-inch nylon rope or similar
- Polyethylene sheeting
- Laptop computer or tablet with appropriate software for downloading data
- Site documents: HASP, Field Sampling Plan (FSP), SOP, site plan, access agreements, etc.
- Test well construction data including diameter, depth, screen interval, etc.
- Field logbook, pen, permanent marker, data sheets, etc.
- Personal Protective Equipment (PPE) - see site-specific HASP
- Air monitoring equipment as required by the HASP (*e.g.*, photoionization detector (PID), flame ionization detector (FID), multi-gas meter, dust meter, etc.)
- Traffic control/warning equipment (cone, tape, etc.)
- Decontamination equipment (*e.g.*, Alconox®, Liquinox®, or equivalent, distilled water, paper towels, spray bottles, and brushes, as needed).

1.4 Definitions

Falling Head Test – A slug test which rapidly raises the water level in a well, followed by recording the transient water levels and times since initiation of the test until the level rebounds to or closely approaches the static water level.

Hydraulic Conductivity – A property of porous or fractured media that defines the rate of fluid flow through the media. In the English System of measurement, the typical units of hydraulic conductivity are gallons per day per square foot (gal/day/ft^2), or feet per day (ft/day). In the International System (SI), the units are meters per day (m/day) or centimeters per second (cm/sec).

Rising Head Test – A slug test which rapidly lowers the water level in a well, followed by recording the transient water levels and times since initiation of the test until the level rebounds to or closely approaches the static water level.

Slug – A solid object, volume of water, or pressurized air or nitrogen that induces a sudden change of head in a well. The change in water level may be induced by adding a known volume of water to a well (usually with a drop tube) or removing water using a bailer or pump, although techniques involving addition or removal of water should be avoided (Butler, 1998).

When a solid object is used to initiate the water level displacement, a slug is commonly a cylindrical object that can be submerged in the well water or withdrawn from the water to generate the displacement. The advantage of using a solid slug is the capability of properly conducting slug testing by performing a series of alternating rising and falling head tests. The solid slug is commonly constructed with an appropriate diameter and length of PVC pipe that is filled with clean sand and securely capped and sealed at both ends. An eye bolt is fastened to the top of the slug for attaching cotton twine or a rope (nylon or polypropylene) to enable lowering or raising the slug in the well. Natural fiber ropes may be treated with oil and should not be used. A slug should have the capability of generating an initial displacement of the water column in the test well ranging between 0.5 foot and 3 feet, depending upon the permeability of the medium (Cunningham, 2010). Water level displacements at the lower end of this range are preferable in low permeability media to minimize the rebound time, especially for conducting multiple tests in a well and testing multiple wells. Displacements toward the upper end of the range are generally better suited for higher permeability media, in which the rebound time is faster.

Well Skin – A finite thickness zone of altered natural permeability near the wellbore, which is classified as positive or negative according to whether the skin has lower or higher permeability than the natural medium. In the case of a positive skin, the medium near the wellbore has a decreased permeability, which may be the product of many factors, including drilling mud infiltration, fine sediments distributed along the borehole wall during drilling, or mineral precipitation. A negative skin occurs when the permeability immediately adjacent to the wellbore is enhanced by processes such as washing out natural fractures or solution cavities near the wellbore, hydraulic fracturing, or acid treatment during well development or rehabilitation.

2.0 PERSONNEL QUALIFICATIONS

Since this SOP will be implemented at sites or in work areas that may entail potential exposure to toxic chemicals or hazardous environments, all TRC personnel must be adequately trained. Project and client-specific training requirements for samplers and other personnel on site should be developed in project planning documents, such as the sampling plan or project-specific work plan. These requirements may include:

- Occupational Safety and Health Administration (OSHA) 40-hour Health and Safety Training for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers and 8-hour annual HAZWOPER refresher training.
- OSHA 10-hour Construction Industry Outreach Training.
- Site-specific safety training.

2.1 Health & Safety Considerations

TRC personnel will be on site when implementing this SOP. TRC personnel will use appropriate PPE. The Project Manager, Office Safety Coordinator (OSC), TRC ECR Safety Manager, or TRC National Safety Director can address questions or safety concerns. Project-specific safety considerations should be documented in the project-specific work plan (or equivalent).

If the HASP indicates that groundwater in the wells may contain measurable levels of volatile organic compounds (VOCs), the wellheads should be screened using a PID or FID to assess the VOC vapor level and identify the necessary procedures. If monitoring results indicate elevated VOC concentrations in the well, the level of PPE may need to be increased in accordance with the HASP. Contact with non-aqueous phase liquid (NAPL), if present, should be avoided.

For safety and avoidance of error associated with fatigue, a work shift should be no longer than 12 hours. A minimum break time of 8 hours following a work shift is recommended.

3.0 PLANNING FOR SLUG TESTING

The planning stage for slug testing includes compiling well construction data (*i.e.*, well diameter, borehole diameter, screen length, total well depth) and hydrogeologic information (water levels and a description of the media screened by the wells). These data will be used to select and/or implement the appropriate equipment, including the transducer, the slug type and size, and the rope length for a solid slug. An initial estimate of the magnitude of hydraulic conductivity will assist in the choice of slug type and size based on expected duration of rebound and number of wells.

Information on well development and the age of the well should be reviewed to determine if additional development is warranted prior to testing. Well development is typically minimal at monitoring wells (Butler, 1998). If new wells are being installed, consider designing them to minimize the thickness of the filter pack annulus to limit filter pack drainage and the length of screen for efficiency of well development.

3.1 Cautions & Potential Problems

(a) Slug tests in wells constructed with 1) large annulus filter packs relative to the radius of the well casing and 2) filter packs extending several feet above the top of the well screen may produce water level rebound data that are significantly compromised by filter pack drainage. Careful evaluation of slug test data generated from these wells should be performed by a hydrogeologist or engineer experienced in slug test analysis to determine if the resulting aquifer parameters are consistent with the geologic medium.

(b) Transducers are rated for a range of pressures. When using a transducer, verify that the transducer is rated for the pressure head that will be encountered in the well during the test. For example, a transducer rated at 30 psi would be appropriate for use at depths of up to 69 feet below the static water level ([2.31 feet of water column/1 psi] * 30 psi = 69 feet). Note that when conducting slug tests, transducers need not be installed at depths greater than 10 feet below the base of the slug when fully immersed. Therefore, transducers rated for pressures of 10 to 20 psi are adequate.

(c) Prior to initiating the test, the transducer should be set a minimum of one foot above the bottom of the well, and the transducer cable shall be secured at the top of the well to prevent vertical movement of the transducer during the test. The transducer must also be located sufficiently below the bottom of the fully immersed solid slug, several feet if possible, to avoid producing dynamic pressure effects in the data.

(d) When using transducers and data loggers, data should be collected at an appropriate rate. A rapid rate is important in high permeability media, where water level rebound is rapid and filter pack drainage must be distinguished from aquifer discharge during data analysis.

(e) Solid slugs should have a diameter that does not impede the flow of water along the slug or into or out of the well.

(f) If a solid slug is used to initiate a test, ensure there is sufficient space for the slug and the transducer cable to avoid disturbing the transducer during insertion or withdrawal of the slug.

(g) Although not a recommended method of slug testing, if rising head tests are performed with a bailer, the bailer should be completely removed from the well.

(h) In order to obtain accurate aquifer parameters, wells must be adequately developed to remove drilling debris along the borehole wall and drilling additives (if used) that may form a low permeability "skin". In wells screened across the water table, some development of the unsaturated filter pack is desirable to ensure that aquifer response data collected during falling head tests are representative of the aquifer. In cases where the extent of well development is questionable, redevelopment of the well prior to slug testing should be considered.[1]

(i) A minimum of three slug tests should be performed at each well. The magnitude of the initial displacement should be varied by at least a factor of two, and the first and last tests of the series should have the same initial displacement. The direction of slug-induced flow should be varied during the series of tests to identify a skin-related directional dependence. The flow direction in the majority of tests should be from the medium into the well (rising head test). Flow from the well into the medium (falling head test) can lead to a progressive decrease in near-well hydraulic conductivity as a result of mobilized fine material being lodged deeper into the medium. Data from slug tests with two different slug sizes and different flow directions can be used to assess the occurrence of a well skin.

(j) A good approach to slug testing is to initiate the series of tests with a rising head test. Slowly submerge the slug, then wait for the water level to return to static. Perform at least the following tests: the initial rising head test, followed by a falling head test, and finishing with a rising head test.

(k) An ideal test series consists of the initial rising head test followed by a pair of falling head and rising head tests with a larger slug and finishing with a pair of falling and rising head tests with the smaller slug.

[1] It may be appropriate to perform slug tests on a well before redevelopment to assess the need for redevelopment. For example, if a change in hydraulic conductivity from baseline conditions is suspected, that would be related to injection of remedial amendments.

4.0 PROCEDURES FOR SLUG TESTING

4.1 Slug Tests Using Solid Slugs and Bailers

The following procedure is recommended for slug testing:

(a) Prior to conducting slug tests, the expected initial water level displacement (H_0*) in the well should be calculated for each slug and recorded on a field form or in a field book. Water level displacement by solid slugs and bailers is calculated with the following equations:

$$V_s = p * r_s^2 * h_s = V_{sw} = p * r_c^2 * h_c$$

or

$$h_c = (r_s^2 * h_s)/r_c^2 = H_0*$$

Where:

V_s = volume of the slug (L^3),
p = 3.1416,
r_s = radius of the slug (L),
h_s = length of the slug (L),
V_{sw} = volume of water displaced by the slug (L3),
r_c = radius of the casing/screen (L), and
h_c = water level displacement in casing/screen (L).

The actual water level displacement (H_0) is less than H_0* because the slug does not displace the water in the casing/screen instantaneously, and drainage from the filter pack begins before the slug is completely withdrawn (rising head test), or some of the displaced water enters the unsaturated filter pack before the slug is fully submerged (falling head test). H_0* can be bounded at the lower end by accounting for the filter pack porosity and assuming no flow to or from the medium:

$$V_{sw} = p * r_s^2 * h_s = p * r_c^2 * H_{0L*} + (p * r_w^2 * H_{0L*} - p * r_c^2 * H_{0L*}) * f_{fp},$$

or

$$H_{0L*} = r_s^2 * h_s / [r_c^2 + f_{fp} * (r_w^2 - r_c^2)]$$

Where:

H_{0L*} = minimum expected initial water level displacement (L),
r_w = radius of the well (L),
f_{fp} = porosity of the filter pack.

H_0 typically exceeds H_{0L*}, unless the slug is raised or lowered very slowly, which would invalidate the test.

(b) Open the well.

(c) Perform headspace screening of the well in accordance with the requirements of the work plan and/or HASP.

(d) Don a clean pair of nitrile gloves and measure the static water level using a decontaminated electronic water level meter. If NAPL occurs at the site, verify the absence of NAPL in the well using an oil/water interface probe. Do not conduct a slug test in a well containing NAPL.

(e) If the well was capped with an expansion plug and was not vented, wait for water level stabilization. For the purpose of slug testing, consider stabilization attained when the water level does not vary by more than 0.1 foot over a period of 15 minutes for granular media and a period of 1 hour for fine-grained media.

(f) Record the well designation and location, static water level, and the date and time of the observation in the field logbook.

(g) Determine the depth of deployment of a pressure-sensitive transducer/data logger, which should be a minimum of one foot off the bottom of the well. With the intended depth of deployment from the top of the well casing, measure the corresponding length of transducer cable from the transducer using a tape, and mark the cable where it will be secured at the top of casing. This procedure ensures the initial head of water above the transducer (depth of transducer minus depth of static water level) is known for analysis of the data.

(h) Secure the transducer cable at the wellhead to prevent the transducer from sliding down the well during the slug test.

(i) Confirm the static water level in the well using the electronic water level meter.

(j) Program the data logger/transducer in accordance with the manufacturer's instructions. When using In-Situ® data loggers, the data type should be "water level", the reference should be the top of casing (static water level = depth to water from top of casing), and the time scale (frequency of data collection) may be logarithmic or linear. The data collection frequency should be set to logarithmic for tests in sand and gravel. For tests in fine-grained sediments, a reduced frequency of data collection may be appropriate. The frequency of data collection should be determined with concurrence of the Project Manager/hydrogeologist prior to entering the field. When programming the data logger for each test, the input data must include the well designation, the type of test being performed (*i.e.*, RH – rising head or FH – falling head), and a numeric value corresponding to the sequence of the test for multiple tests on a well.

(k) After programming the data logger/transducer, verify that the water level (head) and/or pressure (2.31 feet/psi) read by the transducer is consistent with the length of the water column above the transducer determined in (g). Most data loggers generate real time water level/head and/or pressure data for viewing on a computer. Consult the manufacturer's instrument manual for the transducer data logger being used.

(l) Raise the transducer by a minimum of six inches measured along the cable with a tape to verify on the computer that the transducer registered the change in head or pressure within the error limits of the transducer. If the change was accurately recorded by the transducer, proceed to step (n) below.

(m) If the change is not accurate within the error limits of the transducer, remove the transducer from service and repeat steps (g) through (l) with a backup transducer.

(n) When performing tests in areas where potential background variations in water level affect the data (*i.e.*, tidal, river stage, or anthropogenic influence), monitor the aquifer with the pressure transducer for an appropriate duration before beginning the test and after complete rebound to determine potential ambient water level trends and adjustments to the data prior to analysis. Pre- and post-test monitoring may also be necessary for tests in a low hydraulic conductivity medium, requiring long rebound periods in which barometric pressure affects water levels.

(o) To perform a rising head test with a slug or a bailer, the slug/bailer is slowly lowered into the well until submerged just below the water surface. Prior to lowering the slug or bailer in the well, the necessary length of the rope attached to the slug/bailer must be measured according to the depth to water and marked to ensure that the top of the slug/bailer will be no more than 6 inches below the static water level. If a solid slug will be used with the intent of conducting a subsequent falling head test, the rope must also be marked so that the bottom of the slug will be no more than 1 foot above the static water level prior to lowering the slug.

(p) Before pulling the slug for the initial rising head test, measure the depth to water to ensure the level has returned to static. Activate the data logger/transducer and in a smooth, rapid motion, withdraw the slug/bailer from the well. Monitor water level rebound using the data logger. When the water level has rebounded (*i.e.*, the difference between the water level and the static water level is less than 5% of the initial displacement), stop the data logger and save the data for the first test.

(q) Before introducing a solid slug for the subsequent falling head test, be sure that the transducer/data logger has been re-programmed with the appropriate information. If a longer slug is used for the falling head test, measure the rope and slug length to mark the rope so that the bottom of the slug will be no more than 1 foot above the static water level prior to lowering the slug. Activate the data logger and lower the slug below the static water level in a smooth, rapid motion to the mark on the rope for complete submergence that was measured for the rising head test. In anticipation of suspending the solid slug, a good practice to avoid disturbing the water during rebound is to affix a 3- to 5-inch long bolt to the rope, depending on casing diameter, at the mark of complete submergence prior to lowering the slug. Monitor water level rebound.

(r) Note that for test initiation, the slugs/bailers should be withdrawn and introduced (solid slug) as quickly as practicable without disturbing the transducer and generating oscillations of the water in the well. Splashing with introduction of the solid slug can be avoided by first slowly lowering the slug a known distance to within a couple of inches of the water, then rapidly lowering it. Good skills in test initiation are acquired through practice, and the necessary rapidity is different for low permeability and high permeability media.

(s) Prior to performing each repeat slug test, measure the water level using the water level meter, record the water level, date, and time of the observation in the field logbook, and re-program the transducer in accordance with (j). Also, record the type of test (RH or FH) and sequence number of the test in the field notebook.

4.2 Pneumatic Slug Tests

Pneumatic slug tests should be considered, if the medium is anticipated to be highly permeable. The pneumatic approach can only be applied to wells with screens that are fully submerged because the procedure requires pressurizing the air column or developing a vacuum in a sealed well. Pressurization is accomplished with compressed air or nitrogen gas, which depresses the water level. A rising head test is initiated, after the air column is rapidly depressurized. Applying a vacuum to the air column raises the water level, and breaking the vacuum initiates a falling head test. Alternatively, a pair of falling- and rising-head tests can be performed in tandem, if both the pressurization (falling-head) and depressurization (rising-head) are conducted very rapidly with respect to the response of the water level.

The pressure required to perform a successful test is not more than 1 to 2 psi. Pneumatic pressurization slug tests should only be performed on wells with screens submerged at least 3.5 feet below the static water level. Otherwise, the pressurization must be carefully performed and monitored to avoid depressing the water level below the top of the well screen. Typical pneumatic displacements range from 10 to 100 cm (0.33 to 3.3 ft), corresponding to 0.14 to 1.4 psi. However, Zurbuchen et al. (2002) present data suggesting the displacement in high permeability media should be limited to 0.87 to 1.5 ft (0.38 to 0.65 psi). Procedures for conducting pneumatic pressurization slug tests are outlined below. Similar steps are applicable to pneumatic vacuum tests. Consult Butler (1998) for additional information and precautions in performing pneumatic slug tests.

a) Perform steps (b) through (n) as described in Section 4.1.

b) Using the static water level (L_s) and well completion log, calculate the length of water column (L_w) from the static water level to the top of the well screen using the following equation:

$$L_w = D_{ws} - L_s$$

Where: D_{ws} = Depth to top of well screen below ground surface (feet);

Note: Static water level must be in feet below ground surface. Measurements made from the top of casing must be adjusted, as appropriate, if the casing is above or below ground surface.

c) Calculate the maximum theoretical pressure (P_{max}) that can be applied during pressurization of the well casing at which the water level is depressed to the top of the well screen:

$$P_{max} = L_w/2.3067 \text{ ft/psi}.$$

The actual air or gas pressure applied to the casing should be less than P_{max}. An applied air pressure of P_{max} less approximately 0.25 to 0.5 psi should maintain the water level between approximately 0.5 and 1 foot above the top of the screen.

d) Verify that the transducer is at least 2 feet below the depth of the intended depressed water level.

e) Attach the pneumatic well-head apparatus to the well casing.

f) Connect the pressurized air or gas supply to the pneumatic well-head apparatus and verify that the bleeder valve on the assembly is closed.

g) Program the data logger and record the hydraulic head or pressure measured with the transducer in a field book or on an appropriate field form. Be sure the data collection frequency is programed to logarithmic.

h) Slowly pressurize the well casing, and check for leaks along the joint between the well-head apparatus and the well casing using a solution of Alconox® and distilled water (or equivalent). As necessary, tighten or re-seat the well-head apparatus, and repeat this step until leaks are eliminated.

i) After leaks are eliminated, pressurize the well to the planned pressure. Record the applied pressure in the field log book or on the appropriate field form.

j) When the transducer has the same reading as the initial reading prior to pressurization, activate the data logger and release the pressure by opening the pressure-release valve on the pneumatic well-head apparatus.

k) After the water level has rebounded, save the test data and re-program the data logger for the next test.

l) After this initial pressurization procedure for a rising head test, a pair of falling- and rising-head tests could be performed in tandem, if the water level response is monitored during pressurization as well as after the pressure is released. The pressurization (falling-head) and depressurization (rising-head) must be conducted very rapidly with respect to the response of the water level. The falling-head test terminates when the pressure in the well reaches equilibrium (the transducer has the same reading as the initial reading prior to pressurization).

m) Multiple tests should be performed at different displacements in accordance with recommendations in Section 3.1.

5.0 DECONTAMINATION

Reusable equipment, including water level meters, measuring tapes, transducers, and slugs will be thoroughly decontaminated using a solution of Alconox™ and/or Liquinox™ followed by a rinse with distilled water prior to and following uses at different wells to avoid cross-contamination.

Equipment that cannot be readily decontaminated (*e.g.*, slugs that are heavily contaminated) will be discarded after each use and managed as investigation-derived waste (IDW).

6.0 INVESTIGATION-DERIVED WASTE DISPOSAL

IDW generated during slug tests includes expendable equipment (*i.e.*, unusable slugs, rope, and PPE) and decontamination residuals and supplies. These materials will be managed as IDW in accordance with the project FSP.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

Upon completing each test, the data should be reviewed on a field laptop computer. For wells exhibiting a moderate to high rate of rebound, a plot of the water level rebound versus time should exhibit an asymptotic trend. Wells exhibiting a low rate of rebound will typically exhibit a linear response, unless monitoring is continued for an extended duration. Deviations from this response pattern may indicate problems, and the test may be repeated when the water level has rebounded to static conditions.

It is good practice to perform multiple (*e.g.*, 2 to 3 rising and 2 falling head) tests in each well with two different water level displacements (*i.e.*, using two different slug sizes) to assess the validity of the hydraulic conductivity estimates (*i.e.*, not affected by poor well development).

8.0 DATA MANAGEMENT AND RECORDS MANAGEMENT

At the end of each day, or more frequently as necessary, data will be downloaded to a laptop computer and emailed to the data manager for retention in the project file pending analysis. The data should also be saved to a flash drive to prevent inadvertent data loss.

The field logbook should be used to record the following information, at a minimum:

- Weather conditions at the time of testing;
- The make, model, pressure rating, accuracy rating, and serial number of the pressure transducer used to record water level data;
- Well designation and location;
- The static depth to water and total depth of the tested well;
- The depth of the transducer in the tested well below its measurement point;
- Reference point from which all measurements are made;
- The type of test (RH or FH);
- The expected displacement, or the pneumatic pressure and displacement; and
- Time that the test is started and stopped.

Any deviations from the record management procedures specified in the FSP or Quality Assurance Project Plan, if applicable, must be approved by the QA Officer and Project Manager and documented in the field logbook.

9.0 REFERENCES

Butler, J.J., 1998. *The Design, Performance, and Analysis of Slug Tests.* Lewis Publishers, Boca Raton, Florida.

Cunningham, W.L., 2010. *Conducting an Instantaneous Change in Head (Slug) Test with a Mechanical Slug and Submersible Pressure Transducer*, United States Geological Survey.

Zurbuchen, B.R., V.A. Zlotnik, and J.J. Butler, 2002. *Dynamic interpretation of slug tests in highly permeable aquifers*. Water Resources Research, v. 38, no. 3, p. 7-1 to 7-18.

10.0 SOP REVISION HISTORY

REVISION NUMBER	REVISION DATE	REASON FOR REVISION
0	FEBRUARY 2019	NOT APPLICABLE.
1	JANUARY 2020	TRC RE-BRANDING

Attachment 2: Sample Chain-of-Custody Form

CHAIN-OF-CUSTODY Analytical Request Document

Pace Analytical

Chain-of-Custody is a LEGAL DOCUMENT - Complete all relevent fields

LAB USE ONLY- Affix Workorder/Login Label Here or List Pace Workorder Number or MTJL Log-in Number Here

ALL SHADED AREAS are for LAB USE ONLY

Company:

Billing Information:

Address:

Report To:

Email To:

Copy To:

Site Collection Info/Address:

Customer Project Name/Number:

State: / County/City:

Time Zone Collected: [ ] PT [ ] MT [ ] CT [ ] ET

Phone:
Email:

Site/Facility ID #:

Compliance Monitoring? [ ] Yes [ ] No

Collected By (print):

Purchase Order #:
Quote #:

DW PWS ID #:
DW Location Code:

Collected By (signature):

Turnaround Date Required:

Immediately Packed on Ice: [ ] Yes [ ] No

Sample Disposal:
[ ] Dispose as appropriate [ ] Return
[ ] Archive: _______________
[ ] Hold: _______________

Rush:
[ ] Same Day [ ] Next Day
[ ] 2 Day [ ] 3 Day [ ] 4 Day [ ] 5 Day
(Expedite Charges Apply)

Field Filtered (if applicable): [ ] Yes [ ] No

Analysis: ____________________

Container Preservative Type **

Lab Project Manager:

** Preservative Types: (1) nitric acid, (2) sulfuric acid, (3) hydrochloric acid, (4) sodium hydroxide, (5) zinc acetate, (6) methanol, (7) sodium bisulfate, (8) sodium thiosulfate, (9) hexane, (A) ascorbic acid, (B) ammonium sulfate, (C) ammonium hydroxide, (D) TSP, (U) Unpreserved, (O) Other _____________

Analyses

Lab Profile/Line:

Lab Sample Receipt Checklist:

Custody Seals Present/Intact	Y N NA
Custody Signatures Present	Y N NA
Collector Signature Present	Y N NA
Bottles Intact	Y N NA
Correct Bottles	Y N NA
Sufficient Volume	Y N NA
Samples Received on Ice	Y N NA
VOA - Headspace Acceptable	Y N NA
USDA Regulated Soils	Y N NA
Samples in Holding Time	Y N NA
Residual Chlorine Present	Y N NA
Cl Strips: ____________________	
Sample pH Acceptable	Y N NA
pH Strips: ____________________	
Sulfide Present	Y N NA
Lead Acetate Strips: ___________	

LAB USE ONLY:
Lab Sample # / Comments:

* Matrix Codes (Insert in Matrix box below): Drinking Water (DW), Ground Water (GW), Wastewater (WW), Product (P), Soil/Solid (SL), Oil (OL), Wipe (WP), Air (AR), Tissue (TS), Bioassay (B), Vapor (V), Other (OT)

Customer Sample ID	Matrix *	Comp / Grab	Collected (or Composite Start)		Composite End		Res Cl	# of Ctns
			Date	Time	Date	Time		

Customer Remarks / Special Conditions / Possible Hazards:

Type of Ice Used: Wet Blue Dry None

SHORT HOLDS PRESENT (<72 hours): Y N N/A

Packing Material Used:

Lab Tracking #:

Radchem sample(s) screened (<500 cpm): Y N NA

Samples received via:
FEDEX UPS Client Courier Pace Courier

Lab Sample Temperature Info:
Temp Blank Received: Y N NA
Therm ID#: _______________
Cooler 1 Temp Upon Receipt: _____oC
Cooler 1 Therm Corr. Factor: ______oC
Cooler 1 Corrected Temp: ________oC
Comments:

Relinquished by/Company: (Signature)	Date/Time:	Received by/Company: (Signature)	Date/Time:
Relinquished by/Company: (Signature)	Date/Time:	Received by/Company: (Signature)	Date/Time:
Relinquished by/Company: (Signature)	Date/Time:	Received by/Company: (Signature)	Date/Time:

MTJL LAB USE ONLY
Table #:
Acctnum:
Template:
Prelogin:
PM:
PB:

Trip Blank Received: Y N NA
HCL MeOH TSP Other

Non Conformance(s): YES / NO

Page: _______
of: _______

Appendix B

Health & Safety Plan

SITE SPECIFIC HEALTH & SAFETY PLAN

Supplemental Remedial Investigation

BNSF Glacier Park East Site

Intersection of U.S. Highway 2 and Chumstick Highway
Leavenworth, Washington

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TABLES

ATTACHMENTS

1.0 INTRODUCTION

The purpose of this Health & Safety Plan (HASP) is to establish responsibilities, procedures and contingencies for the protection of TRC employees, contractors, visitors and the public while performing activities at the BNSF Glacier Park East (GPE) site. This site-specific HASP is to be implemented in conjunction with TRC's Health and Safety Management System.

The use of proper health and safety procedures in accordance with applicable OSHA regulations shall be required during site work. The procedures presented in this HASP are intended to serve as guidelines. They are not a substitute for sound judgment by site personnel.

1.1 Key Companies Involved in Project

CUSTOMER OR CLIENT:	BNSF
DESIGN ENGINEER:	TRC
CONTRACTOR:	TRC
SUBCONTRACTOR:	TBD

1.2 Scope of Work

The proposed work will be performed by TRC and their contractors/subcontractors and will include but may not be limited to the following activities as part of the Supplemental Remedial Investigation:

- Collect depth-discrete groundwater samples from existing wells.
- Install soil borings and conduct soil samples.
- Install and develop additional shallow piezometer.
- Downloading data from previously-installed transducers.
- Slug testing.
- Gauging and sampling of all groundwater monitoring wells quarterly for one year.
- Inspect asphalt cap and perform necessary maintenance (remove weeds, etc.).
- Site clean-up.

2.0 SITE INFORMATION

This HASP considers the physical, chemical, and biological hazards that may be encountered during work activities at the site. Operations associated with this HASP will be conducted in accordance with the scope of work and approved design drawings/specifications.

Summary information for this project is provided in the following table:

Table 1: Site Information

Anticipated Work Period:	❑ Collect depth-discrete groundwater samples from existing wells (Summer 2020). ❑ Install soil borings and conduct soil samples (late Summer 2020) ❑ Install and develop additional shallow piezometer (late Summer 2020) ❑ Downloading data from previously-installed transducers (August 2020). ❑ Slug testing (later Summer 2020) ❑ Gauging and sampling of all groundwater monitoring wells quarterly for one year (2020-2021) ❑ Inspect asphalt cap and perform necessary maintenance (remove weeds, etc.) (2020-2021)
Site description (see **Attachment A** for site location map):	A former bulk fuel storage facility. Currently, the facility is vacant with an asphalt cap overlying petroleum-impacted soil.
Approximate depth to groundwater:	Approximately 56 to 76 feet below ground surface.
Contaminants of concern (COCs) (see Attachment B)	COCs for soil are diesel-range organics (DRO), oil-range organics (ORO), gasoline-range organics (GRO), benzene, toluene, ethylbenzene, and total xylenes (BTEX), and naphthalene. COCs for groundwater are DRO, ORO, GRO, and benzene.

3.0 ROLES & RESPONSIBILITIES

Contact information and names of key project personnel are listed below. A description of their responsibilities follows.

Table 2: Key Project Personnel and Contact Information

Role	Name	Contact Information
TRC Project Manager/Supervisor	Keith Woodburne	Cell: (415) 497-1947
TRC Field Manager	Mathieu Piovesan	Cell: (425) 219-2221
TRC Site Safety Officer (SSO)	Eric Stata	Cell: (425) 273-7681
TRC Assistant Site Safety Officer (Assistant SSO)	Mathieu Piovesan	Cell: (425) 219-2221
BNSF Project Representative	Scott MacDonald	Office: (253) 591-2678
TRC Site Safety Officer or Assistant Safety Officer must report all site incidents immediately to the TRC Project Manager		
Contractor/Subcontractor Personnel		☐ NA
☐ Contractor / ☐ Subcontractor Company Name: **TBD**		
Site Safety Officer (SSO)	TBD	
Assistant Site Safety Officer (SSO)	TBD	
TRC PM/Supervisor must report all incidents INVOLVING PERSONAL INJURY immediately to:		
TRC Human Resources Manager	Suzanne Micallef	Office: (978) 656-3628
TRC PM/Supervisor must report all incidents NOT INVOLVING PERSONAL INJURY within 24 hours to:		
TRC National Safety Director	Mike Glenn	Office: (949)727-7347 Cell: (949) 697-7418
TRC ECR Safety Coordinator	Dave Sullivan	Office: (978) 656-3565 Cell: (978) 758-2809

3.1 TRC Project Manager/Supervisor (and assistant)

- ❑ Overall responsibility for development of a complete and accurate HASP. The HASP shall account for all foreseeable hazards.
- ❑ Responsible for the management and technical direction of all aspects of the project.
- ❑ Ensure the completion of periodic site inspections.
- ❑ Conduct incident investigations.
- ❑ Delegate responsibility for field implementation of the HASP to TRC Site Safety Officer.

3.2 Site Safety Officers (SSO) – TRC & Contractor Personnel

- ❑ Responsible for the daily implementation of the HASP.
- ❑ Ensures HASP is available onsite and that the plan is understood and signed by all personnel entering the site. (See **Attachment F** "Safety Compliance Agreement").
- ❑ Conducts (or coordinates the completion of) Tailgate Safety Meetings and ensures documentation of these meeting is available for review.

- Uses JSAs to emphasize hazards and protective measures discussed in the HASP.
- Communicates any revisions to the scope of work or HASP to affected personnel and Project Manager/Supervisor.
- Implements emergency response procedures.

3.3 Assistant Site Safety Officer (Asst SSO) – TRC & Contractor Personnel

- In the event the SSO is not on site, the Assistant SSO will assume the responsibilities of the SSO.
- It is TRC's intent to have a TRC SSO or Assistant SSO available onsite during work activities. On the occasion neither person is physically onsite, they will be available by phone or pager. See "Table 2: Key Project Personnel and Contact Information".

3.4 TRC Employees

- Responsible for understanding and complying with this HASP, including the JSAs.
- Are required to participate in daily Tailgate Safety Meetings prior to commencement of site work.
- Each employee must acknowledge an understanding of the HASP by signing the "Safety Compliance Agreement" (See **Attachment F**) on a daily basis.

3.5 Visitors / Regulatory Agents

- Visitors / regulatory agents will be provided an overview of the basic site safety information. A copy of this HASP will be made available for review.
- All visitors are required to sign-in on "Safety Compliance Agreement" (See **Attachment F**) each time they enter the project site.
- Visitors / regulatory agents should be escorted by a TRC or designated contractor employee and should not be allowed to move about the site alone.

4.0 COMMUNICATION

Communication is an important aspect of project safety and this HASP. There are several processes incorporated in this HASP to ensure communication of health and safety hazards.

- Pre-job project planning meetings to discuss the scope of work and potential hazards
- Site walk downs with the TRC workgroup, subcontractors and the customer/client.
- Development of site-specific HASP and JSAs.
- Communication and acknowledgement of understanding of HASP & JSAs by signing the "Safety Compliance Agreement" (See **Attachment F**) at the start of each day. Additional communication is needed if conditions change or when changing tasks.
- Daily tailgate meetings emphasizing that hazard assessment is a continuous process, and any potentially unsafe actions or condition are to be communicated immediately to the SSO.
- Near misses are to be communicated to the onsite staff and Project Manager by the SSO and reported on the near miss form (**Attachment I**). The near misses will be discussed during the next tailgate meeting to ensure all onsite staff are aware of the near miss.
- Communicating results of field observations/audits. Visual observations are to be conducted daily by the SSO. Periodic field observations will also be recorded on the TRC Site Safety Observation Form (**Attachment G**). Results from either observation will be communicated during Tailgate Safety Meetings.

5.0 REVISIONS TO HASP

If a situation arises where the HASP requires revision, the following options are available:

- Except in the case of emergency situations, no deviations from the HASP may be implemented without the prior notification and approval of the TRC Site Safety Officer (SSO) and the Project Manager/Supervisor.

- If HASP revisions are minor (i.e. not involving significant changes to the scope of work, associated hazards or PPE requirements), the TRC Site Safety Officer (SSO) can make hand-written revisions to the HASP in the field. HASP Revisions must then be communicated to affected personnel and the Project Manager/Supervisor.
- If HASP revisions are substantial (i.e. involving significant changes to the scope of work, associated hazards or PPE requirements), the TRC Site Safety Officer (SSO) must consult with the Project Manager/Supervisor before making revisions. The TRC Site Safety Officer (SSO) can make hand-written revisions to the HASP in the field. HASP Revisions must then be communicated to affected personnel and the Project Manager/Supervisor. It is up to the discretion of the Project Manager/Supervisor whether a revised HASP will be reissued to replace the original HASP on the work site.

6.0 HAZARD ASSESSMENT

Hazard assessment is essential for establishing hazard prevention measures. Below is a list of potential physical, chemical and biological hazards associated with various TRC project sites. Not all hazards apply to this site-specific HASP. In addition, the list is not all-inclusive and may require additional hazards associated with a particular project/site to be added.

Please check, or add applicable hazards or hazardous tasks, hazards associated with the scope of work described in this HASP (Section 1.2). A JSA shall be developed to address each of the indicated hazards or hazardous tasks. JSAs are included in **Attachment E** of this HASP.

6.1 Physical Hazards

☐ Excavation & trenching (where personnel will be entering the excavation)

☐ Heavy equipment (not drilling related)

☒ Drilling

☒ Overhead lines

☐ Working within a high voltage area

☒ Underground utilities

☐ Energy control – lock out / tag out

☐ Flammable atmospheres (> 10% LEL)

☒ Traffic - vehicular and pedestrian

☒ Trips, slips & falls

☒ Head, foot, eye, and back injuries

☐ Falling objects

☐ Working from elevated surface (greater than 6 feet); fall protection / fall arrest

☐ Ladders use

☒ Sharp objects

☐ Welding hazards

☐ Confined spaces

Equipment

☒ Electrical equipment (including powered hand tools)

☒ Hydraulic equipment

☒ Pneumatic equipment

Non-Powered Hand Tools

☒ Cutting equipment (non-powered)

☒ Hammers, shovels, screwdrivers

☐ _________________ (Additional equipment)

6.2 Chemical Hazards

☒ Refined Petroleum products / waste oil
☐ Asbestos
☐ Serpentine Soils
☐ PCE, TCE (in groundwater)
☐ Ozone
☐ Hydrogen Sulfide
☐ Heavy metals
☐ Landfill Gases
☒ Environmental samples, soil cuttings, decontamination water, dust (nuisance, silica)
☐ Industrial chemicals

6.3 Biological Hazards

☒ Noise Exposure
☒ Heat Stress
☒ Cold Stress
☒ Weather - heat, cold, rain, fog
☐ Poisonous Plants
☒ Animals/Insects
☐ Misc. Pathogens

7.0 GENERAL SAFETY RULES

This section presents general safety rules for all persons working at the project site. Failure to follow safety protocols and/or continued negligence of health and safety policies will result in expulsion of a worker or firm from the site and may result in termination of employment.

1. Horseplay, fighting, gambling or the possession of firearms is not permitted.
2. Work shall be well planned and supervised to prevent injuries. Supervisors shall assure that employees observe and obey safety rules and regulations.
3. An employee reporting for work who, in the opinion of his supervisor, is unable to perform his assigned duties in a safe and reasonable manner shall not be allowed on the job.
4. No employee shall be assigned a task without first having been instructed on proper methods, including safety training, of carrying out the task. Any employee who feels they have not received proper instruction shall notify their supervisor prior to carrying out the task.
5. Injuries and accidents shall be reported immediately to the immediate supervisor, who will then report it to the SSO.
6. There shall be no consumption of food or drink in operational areas of the site. Hands should be thoroughly cleansed prior to eating.
7. Smoking is not permitted on the site.
8. When personnel are conducting hazardous operations, there shall be at least one other person (buddy system) on duty in the immediate area as a backup in case of emergency.
9. Wear required personal protective equipment (PPE) in the workplace when appropriate and/or when specified in the site-specific health & safety plan. Loose clothing and jewelry should not be worn when operating machinery.
10. Do not operate any machinery if you are not authorized or qualified to do so. If unsure how to operate a machine or perform any assigned task, ask the Project Manager/Supervisor before proceeding.

11. Do not operate motorized equipment until proper training and certification has been provided (e.g. forklifts, etc.)
12. No one shall knowingly be permitted or required to work while the employee's ability or alertness is so impaired by fatigue, illness or other causes that it might unnecessarily expose the employee or others to injury.
13. Alcohol and drugs are strictly prohibited on any TRC premises, customer property, and/or in Company vehicles. Employees shall not report to work under the influence of drugs or alcohol. Employees are prohibited from possessing, using, manufacturing, distributing, dispensing, selling or purchasing illegal drugs or other controlled substances (as defined under federal and state law).

8.0 BNSF-SPECIFIC SAFETY REQUIREMENTS

Site activities must be performed in accordance with client-specific requirements and procedures. Details are provided in the following subsections.

8.1 BNSF Contractor Safety Action Plan

Prior to mobilizing to the site to begin work, TRC shall complete and submit BNSF's Contractor Safety Action Plan found at contractororientation.com. The completed safety action plan shall be sent to the BNSF project representative and a copy maintained on-site by the Project Manager and SSHO.

8.2 Job Safety Briefing

Before beginning any task, a complete job safety briefing will be conducted with all individuals involved with the task, and again if the task changes. If the Task is within 25 feet of any track, the job briefing must include the BNSF flagman. All TRC, subcontractor, and lower-tier subcontractor employees will receive safety instruction from TRC's SSO or a qualified representative prior to the start of any project. TRC and its subcontractor supervisor will review the safety guidelines contained in **Attachment K** to familiarize their employees with safety issues that exist when working in a railroad environment.

Quick Reference Guides (QRGs) are available in **Attachment K** for BNSF specific requirements and applicable industry and federal standards. This should be reviewed at least weekly, and immediately with any new employee(s) coming on the job. It is the responsibility of the SSHO to instruct employees on these guidelines and to require their compliance. The primary exposures and life-saving processes will be discussed during the job safety briefing. These include:

- Line of Fire
- Pinch Points
- Ascending/Descending
- Walking/Path of Travel
- Life-Saving Processes
    - 4444
    - AED/First Aid
    - Evacuation Route

8.3 Personal Protective Equipment

All personnel working at the Glacier Park East site will be required to wear OSHA approved safety glasses with side shields, hard hats, reflective traffic safety vests (ANSI Class II or higher and orange), and above the ankle, lace-up, safety toed boots with a defined heel. Office employees restricted to office work will not be required to comply.

8.4 Fouling Tracks

Train or equipment movement should be expected on any track, in any direction, at any time. Work will not be performed at less than 25 feet from the centerline of any track without a BNSF representative present to provide track protection, unless the track is protected by other approved means and work has been authorized by the BNSF Railroad representative in charge of the project.

Do not walk between rails or foul track, except when duties require, and proper protection is provided. When necessary to cross tracks, look in both directions and keep a minimum of 25 feet from the nearest end of stationary rail equipment. Do not crawl under or between rail cars. Under certain conditions, trains and equipment can approach without being heard. Proper attention and protection are essential to personal safety when working near railroad tracks.

8.5 Blue Signal Protection

Proper Blue Signal Protection is vital for the safety of mechanical employees making repairs to rail equipment. Clear understanding and absolute compliance to the rules is the only certain way to insure your safety.

Blue Signal Protection provides for the protection of railroad workers while inspecting, testing, repairing, or servicing rolling equipment. Without proper protection, workers would be exposed to potential serious injury or death from moving equipment.

Make sure you know the proper Blue Signal Protection procedures for the type of equipment you are working on and the location of the equipment. Obviously, we cannot cover every situation in this briefing. However, always keep in mind the following key points:

8.5.1 *On Main Track*

- A blue signal must be displayed at each end of the rolling equipment.

8.5.2 *On Other than Main Track*

- Protection must be provided by switches or derails lined against movement onto the track and secured with an effective locking device. In addition, a blue signal must be displayed at or near each switch or derail.
- Where derails are used, they must be positioned at least 150 feet from the rolling equipment to be protected.
- Derails may be positioned no closer than 50 feet from the end of rolling equipment on designated engine servicing tracks or car shop repair tracks where the speed is limited to no more than 5 mph.
- Protection also may be provided by remote control switches as long as the proper procedures are followed.

8.5.3 *Blue Signal Protection Visible to Engineer*

In addition to providing the protection listed above, the following also must be in place:

- A blue signal must be attached to the controlling engine.
- A blue signal must be visible to the engineer or employee controlling the engine.
- The engine must not be moved.

8.6 Work Protection

If work protection is provided, every employee must know:

- Who the BNSF qualified flagman is, and how to contact him/her;
- Limits of the work protection;
- The method of communication to stop and resume work;
- Entry into work limits when designated.

When track protection is required, a Daily Job Briefing Field Documentation Card (**Attachment K**) will be completed daily by the entire field crew including subcontractors. All field crew must understand the track protection that is being provided.

Note: Individuals or equipment entering work limits that were not previously job briefed must notify the flagman immediately and be given a job briefing if working less than 25 feet from the centerline of the track.

8.7 Riding on Equipment

Riding on rail equipment is prohibited unless authorized by the BNSF Railroad representative in charge of the project.

8.8 Underground Utilities/Excavation

TRC must obtain the specific approval of the responsible BNSF Project Representative prior to excavating. See **Attachment K** for the specific Quick Reference Guide (QRG) for Clearing Underground Utilities. It is TRC's responsibility to contact a one-call service at least 48 hours prior to work and provide appropriate notification to other companies who may have underground utilities in an area to be excavated. The BNSF Project Representative will work with TRC to make sure that appropriate personnel, including BNSF Signal, Telecommunications, Structures, and Track employees, are contacted at (800) 533-2891 to determine whether there are any underground communication lines, electrical lines, or pipes in an area to be excavated. Work within 25 feet of track will require a pre-excavation meeting with BNSF Signals and Telecommunications. The form entitled *Underground Cable Location & Acknowledgement* (**Attachment N**) must be completed by TRC prior to initiating excavation work. This does not preclude the calling of the "One Call" system.

Work is NOT to proceed where there is doubt regarding the location of underground obstructions, including utilities. TRC shall facilitate a meeting with BNSF facility personnel who may have knowledge of unmapped utilities, previous underground excavations, or provide utility maps from onsite archives. Prior to any boring work on Railroad property, TRC shall initiate a privately contracted utility locate service before conducting any intrusive work. The private utility locate service is used to review and confirm the presence/absence of utilities as well as be escorted by TRC to perform physical survey of area to visually identify above surface structures or "signs" of utilities. All utilities located must be flagged with appropriate colors (see Table 4 below). Virtual maps or photographs housed on electronic devices are not considered appropriate substitutes for clearly marked and preserved locations in the field. Geophysical methods shall be used to verify marked utilities and potentially identify unmarked or unmapped utilities. If any excavation extent shall come within 3 feet of a marked utility, a manual excavation shall be performed, or all attempts to relocate the proposed location shall be made.

Table 4: Utility Coloring per ANSI Z535.1

Utility/Service	Color	Type of Lines or Materials
Survey Markings or Excavation Extent	Pink or White	• Known extents of construction or survey. White to be used to identify extent of excavations for visually showing utility services where digging will commence.
Electrical	Red	• Electrical power line (above and below ground), cables, conduit, lighting cables in PVC or shielded lines
Gas	Yellow	• Natural Gas, Petroleum Gas & Liquids, Steam in Steel or Fiberglass
Communications	Orange	• Phone, Internet, Cables, Conduit, Low voltage relay lines in PVC or shielded lines
Potable Water	Blue	• Residential or Industrial in PVC, Steel, Iron lines
Reclaimed Water	Purple	• Non-Potable Water in PVC, Steel, Iron lines
Sewage	Green	• Raw sewage or stormwater in Steel, Iron Ductile, Concrete

TRC shall explore the proposed location for such work with air-knife/hydro-knife and vacuum equipment, or hand tools to a depth of at least five (5) feet below the surface of the ground to determine whether pipeline or other structures exist below the surface, provided; however, that in lieu of the foregoing, TRC shall have the right to use suitable detection equipment or other generally accepted industry practice (e.g., consulting with the Underground Services Association) to determine the existence or location of pipelines and other subsurface structures prior to drilling or excavating with mechanized equipment.

Should TRC request, by giving thirty (30) working days in advance of requested entry, Railroad will provide TRC any information that it has in its possession concerning the existence and approximate location of underground utilities and pipelines in the proposed location of such work and, prior to any such boring, TRC will review all such material to preclude TRC's fouling any existing pipelines or structures.

Railroad does not warrant the accuracy of information relating to subsurface conditions and TRC's operations will be subject at all times to the liability provisions of the contract. Should an underground line, pipe, or other obstruction be unexpectedly encountered, immediately discontinue excavation activities and contact the responsible BNSF Project Representative and TRC incident reporting line. Where the obstruction is a utility, and the owner of the utility is known, then the owner of the utility will be immediately notified, as well.

8.9 Heavy Equipment

All heavy equipment must be equipped with roll-over protection and contain lockable battery disconnects. Do not leave unattended equipment within 25 feet of the track centerline, unless obtaining specific approval from the responsible BNSF Project Representative. Under no circumstances is equipment to be left where it is within 8' 6" of the track centerline or otherwise it could be struck by a train or on-track equipment.

8.10 Damage to BNSF Railroad Property

Any damage to BNSF Railroad property will be reported immediately to the BNSF representative in charge of the project. Any vehicle or machine contact with a track, signal equipment or structure (bridge) that could result in derailment will be reported by the quickest means possible to the BNSF Railroad representative in charge of the project or the respective System or Network Operations Center. Emergency numbers are to be obtained from the BNSF Railroad representative in charge of the project, prior to the start of any work, and posted at the job site for the duration of the project.

8.11 Passing Trains

When a train is approaching, personnel or equipment working less than 25 feet from the centerline of the track will stop work and move as far away from the track as practical, until the ENTIRE train has passed. This assures the train engineer that the train has been seen and it is safe to proceed. Failure to do this could result in the engineer placing the train into an emergency that could result in damage to the train and delay to railroad traffic. After notification by the BNSF Railroad flagman that no other trains are within the working limits, work may then resume. If a train is stopped on a track, work can only be performed that is beyond 8 feet of the nearest rail of the track the train is on. No work within 8 feet of the nearest rail can be performed. In passing around the ends of standing cars, engines, roadway machines, or work equipment, leave at least 20 feet between yourself and the end of the equipment. Do not go between pieces of equipment if the opening is less than one railcar length (50 feet).

NOTE: Some projects may require a different procedure. In these cases, the BNSF Railroad representative in charge of the project will advise TRC of the proper work procedure adjacent to passing trains.

Violent arm, flag, or flashlight movement while trains are passing indicates an emergency (requires trains to stop) and must not be done unless an emergency exists. NEVER stand with your back to a moving train. Metal banding and other components sometimes break during shipment and can swing out several feet from the train.

8.12 Stepping or Sitting on Rails

Stepping, walking, or sitting on the top of rail is prohibited. The railhead becomes very slick from oil buildup and presents a slipping hazard.

8.13 Confined Space Entry

BNSF does not allow the downgrading of the following permit-required confined spaces:

- Permit-required spaces associated with environmental treatment systems, including sanitary sewer systems, and above ground storage tank.

- Permit-required confined spaces that are entered vertically with workers subsequently moving significant distances horizontally, in a direction away from the entry point, for example below grade pipe tunnels.

In addition to the Pre-Entry/Entry Requirements specifically required by applicable OSHA standards, which includes applicable training and certification. BNSF has the below listed specific requirements. TRC will:

- Obtain from the responsible BNSF Project Representative a *Confined Space Identification Form* specific to each permit-required confined space that is to be entered during the course of a project. This form lists the known or suspected hazards of the permit-required confined space.
- Use a Confined Space Entry Permit system.
- Coordinate entry operations with affected BNSF personnel where appropriate.
- Provide and use its own air monitoring and rescue equipment.
- Determine that outside emergency responders are available and equipped to handle rescues that may require entry into a confined space.
- Provide the responsible BNSF Project Representative with copies of closed-out permits.
- Advise the responsible BNSF Project Representative of any hazards encountered or created that were not listed on the space specific *Confined Space Identification Form*.

8.14 Fall Protection

BNSF requires fall protection equipment to be worn when on railroad bridges where the distance to the top of the deck to the ground or water surface below is 12 feet or more. While this is the cited FRA Bridge Worker Safety Standard, this policy is less restrictive than both the OSHA and TRC fall protection requirements of six feet. As a result, all TRC personnel will don a personal fall protection system when exposed to unprotected falls of six feet or more.

8.15 Games, Reading or Electronic Devices

While on duty, do not:

- Play games.
- Read magazines, newspapers, or other literature not related to duties.
- Use cellular or mobile telephones, or similar hand-held electronic devices for voice communications, emailing, performing any electronic text retrieval or entry, or accessing a web page when:
  - On the ground within four feet of the nearest rail of a track; and
  - On, under, or while involved with the operation or movement of equipment or machinery (e.g. cranes, loaders, forklifts, intermodal hostlers, etc.).
  - Exception – Mechanical employees not involved with the operation or movement of equipment or machinery and within 4 feet of the nearest rail of a track may use cellular phones for business-related voice communications when Blue Signal Protection is established on that track.
  - Use personal electronic devices (cellular telephones, notebook computers, laptops, e-books, etc.) for other than business purposes, except when located in a predetermined place of safety during break periods and not performing duties.

While driving a BNSF-owned or rented vehicle (off rail), do not:

- Use cellular or mobile telephones, or similar hand-held electronic devices for voice communications in other than hands-free mode. Manually enter or read text from cellular or mobile telephones, or similar hand-held electronic devices (e.g., e-mailing, performing any electronic text retrieval or entry, accessing a web page, etc.).
- Dial or answer cellular or mobile telephones by pressing more than a single button when operating a commercial motor vehicle.
- Use notebook computers, laptops, or similar devices. The display screen of such devices must be closed or off.

Employees must be aware of and comply with any local, state, or federal laws governing use of wireless equipment while driving (e.g., laws banning use of wireless phone while driving).

While occupying the control compartment of on-track equipment including Hy-Rails (on rail), do not:

- Use cellular or mobile telephones, or similar hand-held electronic devices when the equipment is in motion.
- Use the instant messaging feature of Smart Mobile Client (SMC) when the equipment is in motion.

While occupying the controlling cab of a moving train or engine:

- Employees' and/or supervisors' cellular telephones must be turned off and ear pieces removed from the ear.
- Exception - Cellular telephones may be used for mechanical or technical evaluations of locomotives or locomotive systems on a moving train; prior to using the device, a job safety briefing must be held with all assigned members of the train crew and all must agree how communications can safely take place.
- Cellular telephones may be used when the train or engine is stopped. Prior to using the device, a job safety briefing must be held with all assigned members of the train crew and all must agree how the use of the device can safely take place.
- Other electronic devices (not capable of voice communication) may be used only as duties require. Prior to using such device, a job safety briefing must be held with all assigned members of the train crew and all must agree how the use of the device can safely take place.

9.0 PERSONAL PROTECTIVE EQUIPMENT

TRC and contractor personnel are required to wear PPE appropriate for the task and potential physical, chemical and biological exposures. Selection of PPE is based on hazard assessment (i.e. JSAs) and air monitoring.

8.1 PPE required by all personnel at all times on the site:

☒ Hard Hat

☒ Safety Shoes/Boots

☒ Safety Vest (Orange)

☒ Eye Protection - ☒ glasses ☐ goggles ☐ face shield

☐ Hand Protection - ☐Kevlar ☐ nitrile ☐ other _______

☐ Hearing Protection

☐ Respiratory Protection - ☐ APR Particulate ☐ APR Chemical cartridge ☐ other ______

☐ Protective Clothing - ☐ Tyvex ☐ Nomex ☐ Coveralls ☐ other ______

8.2 PPE which should be available at all times on the site:

☐ Hard Hat

☐ Safety Shoes/Boots

☐ Safety Vest

☐ Eye Protection - ☐ glasses ☐ goggles ☐ face shield

☒ Hand Protection - ☒ Kevlar ☒ nitrile ☐ other _______

☒ Hearing Protection

☒ Respiratory Protection - ☐ APR Particulate ☐ APR Chemical cartridge ☒ Face Mask (Pandemic/Covid-19)

☐ Protective Clothing - ☐ Tyvex ☐ Nomex ☐ Coveralls ☐ other ______

10.0 RESPIRATORY PROTECTION

For operations that require the use of a respirator, the TRC and Contractor SSOs must verify that field personnel are medically approved to use respiratory equipment, fit tested, and trained in the proper use of respirators. Only respirators that are NIOSH/MSHA approved are to be used.

Respiratory protection is mandatory if workers are required to complete tasks within a hazardous atmosphere. According to OSHA, a hazardous atmosphere is defined as:

- Flammable gas, vapor, or mist in excess of 10% of LEL.
- Atmospheric oxygen is below 19.5% or above 23.5%.
- When concentration of a known contaminant is greater than the permissible exposure limit (PEL).
- Airborne combustible dust exceeds its LEL (approximated when dust obscures vision at a distance of 5 feet or less).

If conditions warrant, air monitoring may be required to verify the presence or absence of a hazardous atmosphere. Air monitoring is to be conducted whenever a situation or condition arises that could reasonably result in a hazardous atmosphere.

10.1 Air-Purifying Particulate Respirators

Employees involved in construction and earthmoving operations that result in nuisance dust and particulates may use air-purifying respirators. These are commonly referred to as “dust masks” and do not require fit testing. Particulate respirators can to be used in situations where nuisance dust and particulates are the only contaminants posing an inhalation hazard. Particulate respirators are not to be used in oxygen deficient atmosphere or if hazardous levels of gas/vapor contaminants are also present.

A high efficiency particulate air (HEPA), P100 respirator should be used in place of commercially available “dust masks”.

10.2 Air-Purifying Gas/Vapor Respirators

TRC employees and Contractors are required to wear half-face, air-purifying respirators with the appropriate chemical cartridge under the following circumstances:

- When concentration of a known contaminant continuously exceeds permissible exposure limit (PEL) time-weighted average or the threshold limit value (TLV) time-weighted average.
- When volatile organic compound (VOC) vapors in the work area continuously exceed the threshold limit value- time-weighted average (TLV-TWA) for gasoline (300 parts per million [ppm]) or other chemicals of concern as shown in **Attachment B**.
- When, at any time, VOC vapors in the work area exceed the threshold limit value - short-term exposure limit (TLV-STEL) for gasoline (500 ppm) or other chemicals of concern shown in **Attachment B**.

See **Attachment B** for additional information and regulatory exposure limits for chemicals of concern at this site.

Air purifying respirators (APRs) with chemical cartridges can be used under the following conditions:

- If the oxygen concentration is between 19.5% and 23.5%.
- If chemical contaminants have been identified.
- The toxic concentrations are known and the respirator cartridges are effective in removing the contaminants.
- The respirator and cartridges are NIOSH/MSHA approved.
- The contaminants have noticeable warning qualities such as odor and visibility characteristics including color.

In the event workers are required to wear air purifying respirators (APRs) with chemical cartridges, the following requirements must be met:

- The TRC or Contractor SSO must verify that workers are:
  - Medically approved (within one year) to use respiratory protection.
  - Fit-tested for the specific respirator to be used.
  - Trained in the proper use and limitations of the respirator to be used.
- Contractors must provide proof of the above to the TRC SSO, upon request.

- If an employee or contractor has not cleared by the SSO to use a respirator, they will not be assigned tasks that may potentially expose them to contaminants.
- Personnel with interfering facial hair are not permitted to wear respirators and shall not be permitted in areas where respiratory protection is required.

10.3 Air-Supplied Respirators

Air-supplied respirators, such as SCBA or airline, full-face respiratory protection, are not anticipated to be required at the site. This level of respiratory protection is utilized in oxygen deficient atmospheres or atmospheres considered to be at or above immediately dangerous to life and health (IDLH) levels. These conditions will only occur in rare, if any, circumstances such as confined space entry or emergency situations. The use of air-supplied respiratory protection is not permitted without approval and guidance from the Project Manager.

11.0 AIR MONITORING

Air monitoring may be required to verify the presence or absence of a hazardous gas/vapor atmosphere whenever a situation or condition arises that could reasonably result in a hazardous atmosphere.

Based on OSHA's definition of a hazardous atmosphere, there are 4 different hazards that require monitoring. The table below describes the type of hazard, what air monitoring equipment to use and what levels constitute a hazard. The information provided in the table does not take into consideration all the possible variations of hazardous atmosphere; however, it will provide guidance when determining the presence of a hazardous atmosphere. Any questions or concerns should be directed to the SSO before work begins.

Table 3: Air Monitoring Guidance

Hazard	Appropriate Air Monitoring Equipment	Hazardous Levels	Comments
Flammability	Combustible gas indicators (CGI) are direct-reading instruments; measures % LEL and oxygen.	>25% of the LEL during cold work >10% of the LEL during hot work	Since many flammable vapors are heavier than air, be sure to take readings at ground level. Work be suspended if CGI readings exceed 10% of LEL.
Oxygen deficiency or abundance	Same as above or an Oxygen Meter	<19.5% and >23.5%	Concentrations >23.5% may present an increased flammability hazard.
Exceeding permissible exposure limit (PEL)	Photoionization detector (PID) can detect organic and inorganic vapors/gases	Varies depending on chemical. See Attachment B for hazardous levels of common chemicals	It is impossible to differentiate the different chemicals using a PID meter. However, the PID will indicate whether chemicals are present and at what levels. Measurements taken within worker's breathing zone will be used to determine respiratory protection requirements.

Airborne combustible dust is not anticipated at the work site.

When conducting, air monitoring the following actions should be considered:

- Be familiar with the proper use and limitations of the air monitoring equipment to be used.
- Ensure air-monitoring equipment (TRC's or otherwise) is in working order and has been properly calibrated. The TRC SSO is to document verification of calibration (i.e. in a field logbook).
- Clearly document the results of air monitoring, including:
  - Equipment name / type and calibration data
  - Date, time and site location of air monitoring (use a site map to clarify the locations of readings.

  - Indication of what is being measured (LEL, oxygen, or ppm)
  - Results of the air monitoring

- ❑ Measurements for volatile organics should be taken at low point where vapors could accumulate.
- ❑ Measurements taken to determine the need for respiratory protection should be taken within the worker's "breathing zone", keeping in mind the worker's closest proximity to the hazard source.
- ❑ An individual should never enter a confined area or excavation in order to conduct initial air monitoring. Instead, actions should be taken to lower the air monitoring equipment into the area to indicate the presence (or absence) of a hazardous atmosphere. Most air monitoring equipment has audible alarms.
- ❑ In the event that CGI readings on the site exceed 10 percent of the LEL, work will be suspended until the source can be eliminated or controlled.

12.0 SITE CONTROL

The primary objective of site control is to minimize the exposure to potentially hazardous substances and/or situations. Supervision and controlling access to the work site is necessary to protect site personnel, visitors and the public.

For this site, the following areas will be designated as hot, warm and cold zones:

Hot Zones: Within 5 feet of the monitoring well

Warm Zone: ☒ NA

Cold Zone: Outside the hot zone

For the purposes of this HASP, site control will be discussed under two circumstances: (1) work involving physical hazards and (2) work involving chemical hazards.

In either case, site control areas are to be clearly identified and communicated by the SSO. The hot zone must be clearly identified and should be isolated with cones, barricades, or high visibility caution tape. In addition, sufficient area also must be available to conduct operations while providing a protective buffer for persons and property outside the controlled areas.

☒ Work involving Physical Hazards

Work does *not* involve direct contact with hazardous substances. However, if the scope of work primarily involves physical hazards (i.e. vehicular traffic, heavy equipment operation, etc.), the establishment of a warm zone is not necessary. Instead, a hot zone must be established to surround all the physical hazards. The hot zone area shall provide enough room and buffer to protect both workers and the public. A cold zone is established outside the hot zone to allow "support" activities to be conducted in a safe location.

☒ Work involving Chemical Hazards

The concept of site control and the establishment of hot/warm/cold work zones are intended for work involving the exposure (or potential exposure) to hazardous chemical concentrations. Under these circumstances, the purpose of work zones is two-fold: 1) minimize the exposure to potentially hazardous substances and 2) minimize the spread of hazardous substances outside the immediate work area through decontamination procedures.

A brief overview of site control work zones is provided below:

Hot Zone
❑ Where personnel may be subject to chemical or physical hazards. ❑ Where known or suspected contamination exists and may also be where equipment operation and/or environmental sampling will take place. ❑ To be clearly identified and should be isolated with cones, barricades, or high visibility caution tape. ❑ Large enough to provide sufficient room and buffer to protect both workers and the public.

Warm Zone ❑ Located between the hot and cold zones; beginning at the edge of the hot zone and extends to the cold zone. ❑ Utilized as a control point or corridor for persons entering or exiting the hot zone. ❑ Where personnel and equipment are decontaminated.
Cold Zone ❑ Located outside the hot zone where administrative and other support functions are located. ❑ Where adverse exposure to contaminants and physical hazards are unlikely.

12.1 Decontamination

The purpose of decontamination is to: (1) remove chemical containments from personnel and/or equipment and (2) significantly reduce the spread of chemical contaminants beyond the hot/warm zone.

Decontamination is intended to occur within the warm zone. Depending on the project, there may be a need to decontaminate both personnel and equipment. The decontamination process should be appropriate to the chemical hazards present. For example, refined petroleum contaminated soil on work boots/shoes may only require physical removal of the soil with a sturdy brush. However, decontamination of equipment (i.e. drilling augers) may require additional steps to ensure contaminants are not spread beyond the hot/warm zones. Heavy equipment (i.e. excavators, trucks used for waste transportation, etc.) may require a combination of steps, including the placement of gravel at the entrance/exit of the site.

12.1.1 ***Personnel Decontamination Procedures:***

Remove contaminated items (i.e. gloves) in an "inside out" manner. Contaminated garments are to be placed in designated plastic bags or drums prior to disposal or transfer offsite.

12.1.2 ***Equipment Decontamination Procedures:***

Equipment that has been in contact with water or material from the site (such as the interface probe) will be decontaminated before each sampling location in a Liquinox and de-ionized water solution and rinsed twice in clean de-ionized water. Decontamination solution and rinse water will be captured in a container and disposed with the investigation-derived waste.

12.2 Site Security

Appropriate security measures will be established in coordination with the site owner/operator and communicated to site personnel. The objective of these measures is to (1) protect the public from potential exposure to physical/chemical hazards; (2) avoid public interference with personnel and safe work practices; and (3) prevent theft or vandalism of equipment at the site.

Site specific security measures include: ☒ NA

13.0 PERSONNEL TRAINING

TRC and contractor personnel are required to acknowledge their understanding and willingness to comply with this HASP before admission to the site by signing the "Safety Compliance Agreement" (See **Attachment F**).

Site specific training requirements are indicated below:

☒ TRC Personnel shall meet the training requirements specified in the OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) Standard [29 CFR 1910.120(e) and CCR Title 8 Section 5192(e)].

☐ Kinder Morgan Contractor Safety Videos

☐ ConocoPhillips

☐ ExxonMobil

☐ Refinery Training

☒ Railroad Training:

☐ UPRR Contractor Orientation

☒ BNSF Contractor Orientation

☐ Cal Train Contractor Orientation

☐ "FRA Roadway Worker" Training (work within 25' of track)

14.0 MEDICAL PROGRAM

TRC has established a medical surveillance program to assess, monitor, and help protect the health of employees, in particular, employees who may be exposed to potentially hazardous substances during site work. Personnel undergo medical examinations as follows:

❑ **Initial:** Pre-employment / prior to any assignment involving work in a hazardous or potentially hazardous environment. The initial examination is used to establish a baseline picture of health against which future changes can be measured, and to identify any underlying illnesses or conditions that might be aggravated by chemical exposures or job activities. This exam also certifies whether an employee is medically fit to wear a respirator.

❑ **Periodic:** At least once every 12 to 24 months (depending on the employee's involvement in field activities) to measure changes in health status. This exam certifies whether an employee is still medically fit to wear a respirator.

❑ **Upon notification:** As soon as possible upon notification by an employee that they have developed signs or symptoms indicating possible overexposure to hazardous substances, or in response to an injury or exposure during an emergency situation.

❑ **Exit**: At termination of employment.

15.0 EMERGENCY RESPONSE PLAN

The TRC SSO (depending on which is present) will have controlling authority during an emergency. In the SSO's absence, the Alternate SSO will be in charge.

15.1 Evacuation Protocol

Evacuation protocol, routes and assembly areas from the site will be established by the SSO and communicated to Field Personnel during the Tailgate Safety Meeting(s) prior to initiating work. In the event of an evacuation, personnel will meet at a pre-established assembly areas and the TRC SSO conduct a "head count" to see that everyone is accounted for. Contractor SSO is responsible for being able to provide an accurate head-count of contractor personnel.

15.2 First Aid & CPR

TRC employees and contractors with current First Aid and CPR certification and who are willing to provide First Aid and CPR will be asked to identify themselves at Tailgate Safety Meetings. Their names will be documented on the Tailgate Meeting Checklist (**Attachment F**).

15.3 Emergency Medical Assistance

A list of emergency medical assistance sources has been established as part of this HASP. **Attachment C** lists the names, locations, and telephone numbers of emergency response organizations in the vicinity of the project site. **Attachment D** includes a map to the nearest hospital(s) with an *emergency room*.

A vehicle shall be available onsite during work activities to transport injured personnel to the identified emergency medical facilities, if necessary. Company vehicles are to be equipped with a fire extinguisher and first aid kit.

15.4 Emergency Procedures

In the event of an accident, injury, or other emergency, remember to:

❑ Stop work and REMAIN CALM.

❑ Move personnel to a safe location (evacuation plan).

- ❑ Call 911 or notify other emergency facilities, as necessary.
- ❑ Address medical emergencies and apply first aid, if necessary.
  - Move injured or exposed person(s) from immediate area only if it is safe to do so.
  - If serious injury or life-threatening condition exists, call 911. Clearly describe the location, injury and conditions to the dispatcher. Designate a person to direct emergency equipment to the injured person.
- ❑ Contain physical hazards.
  - Act only if hazard is minimal and you are trained to deal with the situation. Otherwise evacuate and wait for emergency services to arrive.
- ❑ Notify SSO and initiate incident reporting procedures.
  - See page 2 of this HASP for contact information. In the event the SSO is not available, the order of notification should be 1) Assistant SSO, 2) TRC Project Manager and 3) HR Manager (if incident involves injury) or EHS Supervisor (if incident does not involve injury).
  - TRC SSO is to notify TRC Project Manager/Supervisor as soon as reasonably possible.
- ❑ Do not resume work until the SSO has determined it is safe to do so.

15.5 Non-Emergency Medical Assistance

If an injury does occur and it is not life threatening, then the employee or employee's supervisor/project manager should contact WorkCare within the first hour after an injury. WorkCare information is provided in **Attachment H.** This information will help assist the injured employee by connecting them with instant access to a medically qualified professional in order to provide guidance on appropriate first aid measures and medications.

15.6 COVID-19

BNSF and TRC guidelines for field activities conducted during the COVID-19 pandemic are provided in Attachment L along with a TRC-required questionnaire that must be completed at the start of any field work.

16.0 INCIDENT REPORTING

In case of an accident, TRC personnel are to immediately report the incident to their Project Manager/Supervisor and follow the TRC incident reporting procedures detailed in the TRC Health and Safety Management System. TRC's incident reporting/near miss form and vehicle accident form are available through the Project Manager/Supervisor and in **Attachment I**.

All incidents and near misses are investigated in accordance with TRC's Health and Safety Management System. The TRC Incident Report Form is to be completed and submitted to the TRC EHS Supervisor within 24 hours following any incident.

Contractor personnel are to report incidents to their SSO who is then required to report the incident to the TRC SSO, TRC Alternate SSO, or TRC Project Manager immediately.

Some important information to include when reporting an incident are:

1. A description of the event (including date and time)
2. Details regarding personal injury and property damage, if any.
3. Whether emergency services were notified (i.e., medical facilities, fire department, police department) and the basis for that decision. Including time and names of persons/agencies notified, and their response.
4. Clarify the need for and type of TRC support.
5. Immediate corrective action(s) taken.

16.1 BNSF Incident Reporting

Following report of a work-related injury or illness, the TRC Project Manager/Supervisor will promptly report the incident to the BNSF Railway Engineering project representative. The BNSF project representative will work with the TRC Project Manager to complete the BNSF Non-Employee Personal Injury Form and submit the form to the BNSF Railway Accident Reporting Center.

17.0 HEALTH AND SAFETY PLAN (HASP) SIGNATURE PAGE

Job Safety Analysis Author	Date:	HASP Author	Date:
	4/2/20		4/2/20

Review/Approvals:

Site Safety Officer Facility/Field Supervisor	Date:	Project Manager/Supervisor*	Date:
	6/17/20		6/17/20
Local Safety Coordinator* ☐ NA	Date	EHS Supervisor/Safety Professional (CIH, CSP, other)*	Date

Additional Information or Instructions:

* Note: **For most projects, the Project Manager/Supervisor will review, approve and sign the HASP.** In the event the operations are beyond the normal scope of work, additional review is available upon the request from the PM/Supervisor. The Local Safety Coordinator is the first recourse for reviewing HASPs **not** involving high-risk operations. It is recommended that for HASPs involving high-risk operations (i.e. hazardous exposures to chemicals, large scale or deep excavations, confined space entry, etc.), the EHS Supervisor and/or a Safety Professional [Certified Industrial Hygienist (CIH), Certified Safety Professional (CSP) or other professionally qualified person] be consulted for review of the HASP to ensure proper protective measures are being implemented.

ATTACHMENT A

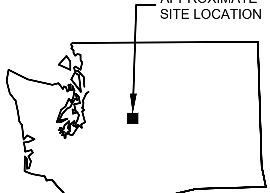
SITE PLAN

SOURCE AERIAL PHOTO: Google Earth Professional, June 2015.

N

APPROXIMATE SCALE (FEET)

0 400 800



PROJECT:	**BNSF Glacier Park East Site** **Chumstick Highway and State Highway 2** **Leavenworth, Washington**
TITLE:	**VICINITY MAP**

DRAWN B ·	R. Collins	PROJ NO ·	333710
CHECKED B ·	M. Piovesan		**FIGURE 1**
APPROVED B ·	K. Woodburne		
DAT ·	April 2020		

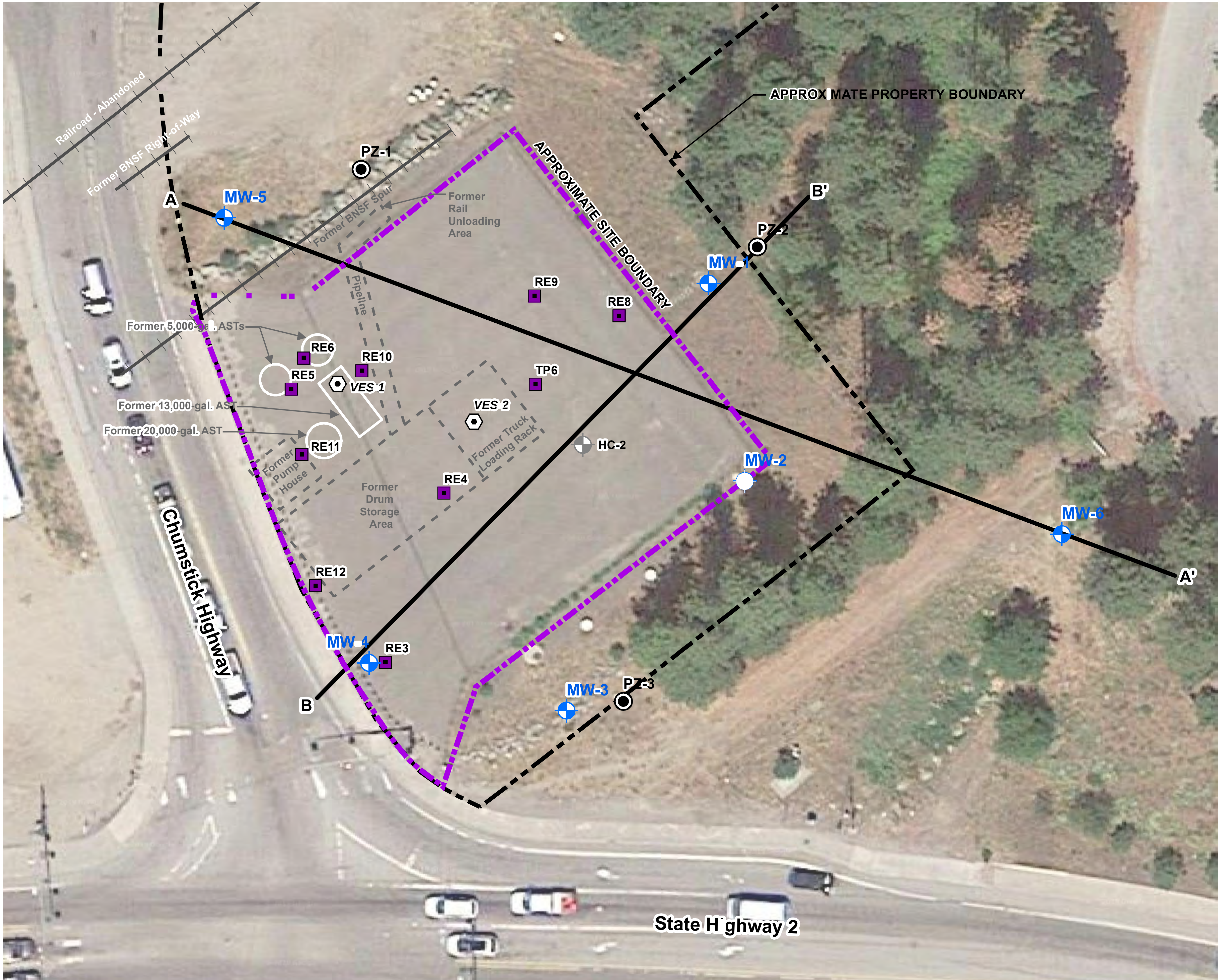
TRC

19874 141st Place N.E.
Woo ·
Phon ·
www.trcsolu ·

FILE NO · Fig1_Vicinity Map_Aerial.dwg

8.5x11 --- ATTACHED XREFS: --- ATTACHED IMAGES: Aerial_Leavenworth_June15;
DRAWING NAME: S:\1-PROJECTS\BNSF\Glacier_Park_Site_Leavenworth\CAD\ Fig1_Vicinity Map_Aerial.dwg --- PLOT DATE: April 16, 2020 - 11:18AM --- LAYOUT: 8x11

Version: 2017-03-03



Legend

Surveyed locations of:

- Monitoring Well
- Piezometer

Approximate locations of:

- Test Pit
- Abandoned Monitoring Well
- Former Vapor Extraction Well
- A — A' Cross Section

SOURCES:
AERIAL PHOTO: Google Earth, July 2017.
BASE PLAN: Groundwater Potentiometric Map by Kennedy/Jenks Consultants, December 2013, and site plans by Geo Engineers, March 2002.

NOTES:
Wells and piezometers surveyed in June 2017 by Landline Surveyors, Leavenworth, Washington.
Coordinate system: NAD83 Washington State Planes, North Zone, US foot.

Property boundary extends farther to the north east.

AST = aboveground storage tank.

PROJECT:
BNSF GLACIER PARK EAST SITE
CHUMSTICK HIGHWAY AND STATE HIGHWAY 2
LEAVENWORTH, WASHINGTON

TITLE:
SITE PLAN

DRAWN BY:	R. COLLINS	PROJ. NO.:	329229.0000.0000
CHECKED BY:	B. HELLAND		
APPROVED BY:	K. WOODBURNE		**FIGURE 2**
DATE:	MAY 2020		

TRC
19874 141st Place N.E.
Woodinville, WA 98072
Phone: 425.489.1938
www.trccompanies.com

FILE NO.: 239229_1_SitePlan.mxd

TRC - GIS

Plot Date: 5/5/2020, 15:48:11 PM by RCOLLINS -- LAYOUT: ANSI B(11"x17")
Path: S:\1-PROJECTS\BNSF\Glacier_Park_Site_Leavenworth\MXD\239229_1_SitePlan.mxd
Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet (Foot US)
Map Rotation: 0

ATTACHMENT B

OCCUPATIONAL HEALTH GUIDELINES AND TOXICOLOGICAL INFORMATION

Table B-1 OCCUPATIONAL HEALTH GUIDELINES AND TOXICOLOGICAL INFORMATION

Contaminant	ACGIH TLV-TWA (ppm)	NIOSH REL (ppm)	OSHA PEL (ppm)	STEL (ppm)	IDLH (ppm)	Routes of Exposure	Known or Suspected Carcinogen	Symptoms
Diesel (as Stoddard solvent)	for Diesel fuel/ Kerosene 14.4 (skin only)	Approx. 60-98	500	250-500 (NIOSH ceiling)	Approx. 3000-5600	Inhalation, Ingestion, Contact	No	Irritation to eyes, skin, mucous membrane; dermatitis, headache, fatigue, blurred vision, dizziness, slurred speech, confusion, convulsions, aspiration, weakness, restlessness, incoordination
Gasoline	300	n/a	n/a	500 (ACGIH)	n/a	Inhalation, Absorption, Ingestion, Contact	Yes	Irritation to eyes, skin, mucous membrane; dermatitis, headache, fatigue, blurred vision, dizziness, slurred speech, confusion, convulsions, aspiration
Benzene	0.5	0.1	1	1 (NIOSH)	500	Inhalation, Absorption, Ingestion, Contact	Yes	Irritation to eyes, skin, nose, resp system, giddiness, headache, nausea, staggered gait, fatigue, anorexia, weakness/exhaustion, dermatitis
Toluene	50	100	200	150 (NIOSH)	500	Inhalation, Absorption, Ingestion, Contact	No	Irritation to eyes, nose; fatigue, weakness, confusion, euphoria, dizziness, headache, dilated pupils, tears, nervousness, muscle fatigue, insomnia, dermatitis
Ethyl benzene	100	100	100	125 (NIOSH& ACGIH)	800	Inhalation, Ingestion, Contact	No	Irritation to eyes, skin, mucous membranes; headache, dermatitis, narcosis, coma
Xylenes (o,m,p,)	100	100	100	150 (NIOSH & ACGIH)	900	Inhalation, Absorption, Ingestion, Contact	No	Irritation to eyes, skin, nose, throat; dizziness, excitement, drowsiness, incoordination, staggering gait, nausea, vomiting, abdominal pain, dermatitis
Naphthalene	n/a	10	10	n/a	250	Inhalation, Absorption, Ingestion, Contact	No	Irritation to eyes, confusion, excitement, malaise (vague feeling of discomfort); nausea, vomiting, abdominal pain; irritation of bladder; profuse sweating; jaundice; hematuria (blood in urine); renal shutdown, dermatitis, optical neuritis, corneal damage

OCCUPATIONAL HEALTH GUIDELINES AND TOXICOLOGICAL INFORMATION

TABLE KEY

ACGIH TLV-TWA	American Conference of Governmental Industrial Hygienists, Threshold Limit Value-Time Weighted Average
NIOSH REL Limit	National Institute of Occupational Safety & Health, Recommended Exposure
STEL	Short Term Exposure Limit (BTEX STELs are by NIOSH)
OSHA PEL	Occupational Safety and Health Administration, Permissible Exposure Limit
IDLH	Immediately Dangerous to Life and Health
ppm	parts per million
CNS	Central Nervous System
n/a	not available (i.e., no value has been established)

DEFINITIONS

Threshold Limit Value: Threshold limit values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed nearly all workers may be repeatedly exposed, day after day, without adverse health effects.

Threshold Limit Value - Time Weighted Average: The time weighted average (TWA) is a concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. TLV-TWAs are established by the ACGIH.

Recommended Exposure Limit: Unless otherwise noted, the recommended exposure limit (REL) is a TWA concentration for up to a 10-hour workday during a 40-hour workweek. RELs are established by NIOSH to reduce or eliminate adverse occupational health effects.

Short Term Exposure Limit: A short term exposure limit (STEL) is defined as a 15-minute TWA exposure that should not be exceeded at any time during a workday. When compared to the REL (or TLV-TWA for ACGIH standards), the STEL allows the worker to be exposed to a higher concentration, BUT for a shorter period of time. Exposures above the REL up to the STEL should not be longer than 15 minutes and should not occur more than four times per day.

Permissible Exposure Limit: Permissible exposure limits (PELs) are TWA concentrations that must not be exceeded during any 8-hour work shift of a 40-hour workweek. PELs are established by OSHA (29 CFR 1910.1000).

Immediately Dangerous to Life and Health: Immediately dangerous to life and health (IDLH) values are established as concentrations from which a worker can escape within 30 minutes without suffering loss of life, irreversible health effects, or other deleterious effects that could prevent him/her from escaping the hazardous environment. The purpose of establishing an IDLH exposure concentration is to ensure that workers can escape from a given contaminated environment in the event of failure of respiratory protection equipment.

Known or Suspected Carcinogen Classification: ACGIH categories for carcinogenicity classification:

A1 – Confirmed Human Carcinogen – The agent is carcinogenic to humans based on the weight of evidence from epidemiologic studies.

A2 – Suspected Human Carcinogen – Human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as a confirmed human carcinogen; OR the agent is carcinogenic in experimental animals at dose(s), by route(s) of exposure, at site(s), of histologic type(s), or by mechanism(s) considered relevant to worker exposure. The A2 is used primarily when there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals with relevance to humans.

A3 – Confirmed Animal Carcinogen with Unknown Relevance to Humans – The agent is carcinogenic in experimental animals at a relatively high dose, by route(s) of administration, at site(s), of histologic type(s), or by mechanism(s) that may not be relevant to human exposure. Available epidemiologic studies do not confirm an increased risk of cancer in exposed humans. Available evidence does not suggest that the agent is likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure.

A4 – Not Classifiable as a Human Carcinogen – Agents which cause concern that they could be carcinogenic for humans, but which cannot be assessed conclusively because of a lack of data. In vitro or animal studies do not provide indications of carcinogenicity which are sufficient to classify the agent into one of the other categories.

A5 – Not Suspected as a Human Carcinogen – The agent is not suspected to be a human carcinogen on the basis of properly conducted epidemiologic studies in humans. These studies have sufficiently long follow-up, reliable exposure histories, sufficiently high dose, or adequate statistical power to conclude that exposure to the agent does not convey a significant risk of cancer to humans; OR evidence suggesting a lack of carcinogenicity in experimental animals is supported by mechanistic data.

ATTACHMENT C

EMERGENCY SERVICES
PHONE NUMBERS, DIRECTIONS, AND LOCAL AREA MAP

EMERGENCY SERVICES

FACILITY / LOCATION	TELEPHONE
Emergency Situation	911
WorkCare 24 Hour Non-Emergency Notification Number	1-888-449-7787
Cascade Medical Center 817 Commercial St Leavenworth, WA 98826	(**509) 548-5815**
Poison Control Center: Emergency 24-Hour Hotline	(800) 876-4766
Office of Emergency Services: Hazardous Materials Spill Notification	(800) 852-7550
Chelan County Sheriff’s Office	(509) 667-6851
Chelan County Fire District 3	(509) 548-7711

DIRECTIONS TO EMERGENCY ROOM

Google Maps — Front Street & U.S. 2 to Cascade Medical Center: Emergency Room

Front St & US-2

Leavenworth, WA 98826

1. Head west on US-2 W toward 12th St

   0.4 mi

2. Turn left onto 9th St

   472 ft

3. Turn right onto Commercial St

   335 ft

4. Turn left

   39 ft

5. Turn left

   Destination will be on the right

   56 ft

Cascade Medical Center: Emergency Room

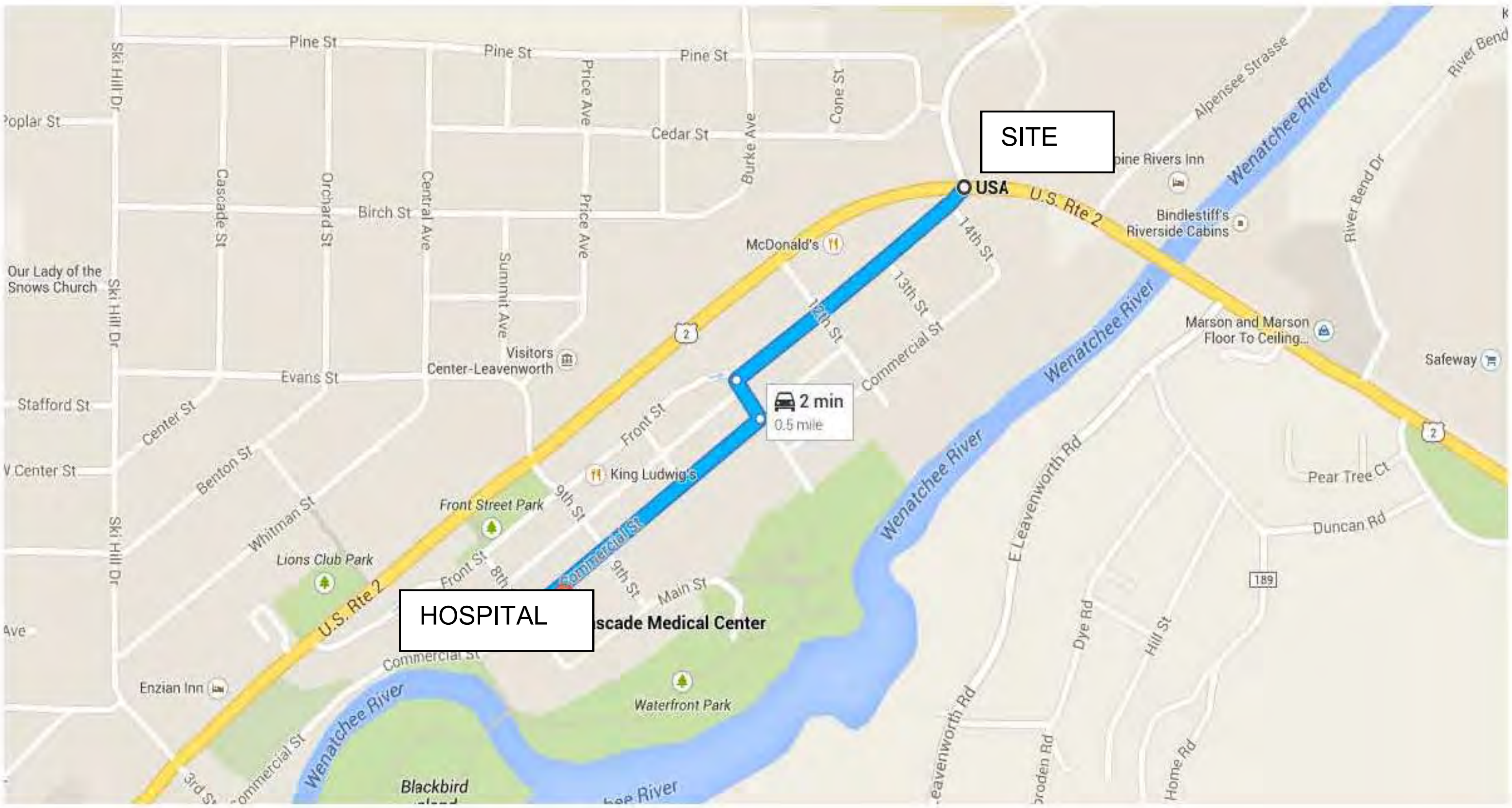
817 Commercial St, Leavenworth, WA 98826

ATTACHMENT D

LOCAL AREA MAP
with route to hospital

Google

Directions from **USA** to **Cascade Medical Center**



ATTACHMENT E

JOB SAFETY ANALYSIS

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from Server
JSA WORK ACTIVITY (Description): Cold Illness Prevention	List of Contractor(s) and key work activity: TRC	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ REFLECTIVE VEST __R__ HARD HAT __R__ GLOVES __R__ SAFETY GLASSES ______GOGGLES ______FACE SHIELD	__A__ HEARING PROTECTION __R__ SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: _____Coveralls ____Tyvek Suit _____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA ______Disposable Particulate Respirator (N95) ______½ face Air Purifying Respirator (APR) ______Particulate Mask: ☐ PM100 ☐ PM95 ______ Cartridge: ☐ P100-Multigas ☐ ____ _____Full face ARP; specify cartridge type: _____ Air Supplied Respirator ____SCBA Air-line	Additional PPE: • Cold Weather clothing • Rain gear

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Working in Temperatures < 30 degrees F or wind chill effects above freezing temperatures	a. Frost bite	a. Proper insulation (layered clothing to adjust to changing environmental temperatures). Keep clothing as dry as possible. a. Perform work during the warmest part of the day. a. Take frequent short-breaks in warm dry shelters-self paced a. Avoid exhaustion and fatigue because energy is needed to keep the muscles warm. a. Use the "Buddy System" for working outdoors.
2. Working in temperatures above freezing > 30 degrees	a. Hypothermia	a. Proper insulation (layered clothing to adjust to changing environmental temperatures). Keep clothing as dry as possible. a. Perform work during the warmest part of the day. a. Take frequent short-breaks in warm dry shelters-self paced a. Pay special attention to protecting feet, hands, face, and head. Up to 40% of body heat can be lost when the head is exposed.
POTENTIAL HEALTH HAZARDS	**SYMPTOMS**	**HAZARD RESPONSE AND FIRST AID (beyond wearing "Required" PPE)**
3. Frost bite	Symptoms: a. Skin first turns red, then purple, later becomes pale, then waxy-white and is cold to the touch. b.Skin of body part affected becomes hard, cold, stinging or aching followed by numbness;affecting nose, ears, cheeks, forehead, wrists, toes and fingers.	Actions to take: a. Unless the frostbite was very mild, call for emergency for special instructions. b. A worker with warm hands may help thaw other's worker hands or fingers merely by enclosing them within the palms and exerting a very gentle pressure. c. Try to elevate worker extremity to improve blood circulation. d. Act immediately, call for emergency. Move the worker to a warm area. Do not leave the worker alone. e. Remove any wet or tight clothing that may cut off blood flow to the affected area and DO NOT RUB affected area.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)		DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**		4/2/20	☐ NEW ☒ REVISED from Server
JSA WORK ACTIVITY (Description): Cold Illness Prevention		List of Contractor(s) and key work activity: TRC	
POTENTIAL HEALTH HAZARDS	**SYMPTOMS**	**HAZARD RESPONSE AND FIRST AID (beyond wearing "Required" PPE)**	
4. Hypothermia	Symptoms: a. Uncontrolled shivering. b. Cool bluish skin. c. Dry tongue and thirst. d. Slurred speech. e. Clumsy movements, irritable, irrational or confused behavior.	Actions to take: a. Act immediately – Call for Emergency help a. Move the person to a warm, dry area. Do not leave the person alone and DO NOT RUB the person's body. b. Loosen and remove any wet clothing and replace with warm, dry clothing or wrap the person in blankets.. c. Administer warm, sweet drinks (sugar water or sports-type drinks) if victim is alert. d. Have the victim move their arms and legs to create muscle heat. e. Place warm bottles or hot packs in the arm pits, groin, neck, and head areas. f. Encourage the person to rest. g. Monitor closely.	
5. Trench Foot	Symptoms: a. Initially appears wet, soggy, white, shriveled. b. Sensations of pins and needles, tingling, numbness and then pain. c. Skin discoloration. Affected portions of foot and toes can appear gray and blotchy. d. Becomes cold, swollen, and waxy appearance. e. May develop blisters, open weeping or bleeding in more extreme cases.	Actions to take: a. Move individual with trench foot to a warm, dry area. b. Rewarm by exposing to warm air. c. Seek medical assistance as soon as possible. d. Elevate feet to reduce swelling. e. DO NOT break blisters, apply lotions, massage, expose to heat, or allow to walk on injury.	

Field Notes:

____

____

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowleable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object?; caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Drilling**	List of Contractor(s) and key work activity: **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ HARD HAT __A__ GLOVES Specify: ☐ Kevlar ☐ Nitrile ☐ Other ________. __R__ SAFETY GLASSES ____GOGGLES ____FACE SHIELD	__R__ REFLECTIVE VEST __A__ HEARING PROTECTION __R__ SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: Coveralls ____Tyvek Suit _____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ ____ Cartridge: ☐ P_{100} Multigas ☐ _____ _____Full face ARP; specify cartiridge type: _____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE:

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

1 JOB TASKS	2 POTENTIAL HAZARDS	3 HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Set up Job Site	a. Physical Injury from being struck by moving vehicles or equipment.	a. Have one person watch traffic while the other creates exclusion zone in a high-use traffic area. a. Create an exclusion zone at least 10-feet beyond the limits of the boring location; use snow fencing, barricades, delineators, cones and/or caution tape in accordance with project specifications. a. Always wear safety vest, establish eye contact with operators utilizing flag men where appropriate. a. Vehicles shall use reverse beepers or flagmen.
2. Drilling	a. Contact with subsurface water, gas, electrical, and/or fiber optic lines in the vicinity of drilling locations. b. Broken wire cable or detached drill stem c. Distracted driller	a. Clear holes to 5 feet below grade with manual tools, prior to using drill rig, except where boring locations have been pre-cleared for underground utilities. a. If unknown lines or obstructions are encountered, stop drilling and notify PM. Do not undermine any utilities. b. Do not stand directly in front of the drill rig while machinery is operating. Stand off to the side by driller's platform or opposite side of drill rig. c. Always communicate with the driller before approaching the operating drill stem.
Field Changes: 3.	a. b. c. d.	a. b. c. d.

JOB SAFETY ANALYSIS

GENERAL SAFETY HAZARDS	LOCATION(S) WHERE HAZARD IS TO BE EXPECTED	³ HAZARD CONTROLS (beyond wearing "Required" PPE)
4. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.
5. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment.
6. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).
7. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).
8. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.
9. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.
10. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. Periodically monitor ambient air concentrations with PID/LEL Meter. Shut down job and move personnel and equipment upwind if methane exceeds 5**% of LEL.** a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.
11. Exposure to chemicals of concern impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.
12. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.

Field Notes:

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¹ List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

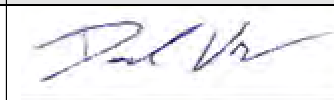
² CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

³ Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Driving a Company Vehicle**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

_____ HARD HAT _____ GLOVES Specify: ☐ Kevlar ☐ Nitrile ☐ Other _____ ____SAFETY GLASSES _____GOGGLES _____FACE SHIELD	____ REFLECTIVE VEST ____ HEARING PROTECTION ____SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: _____Coveralls ____Tyvek Suit _____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ _____ Cartridge: ☐ VOC ☐ ________ _____Full face ARP; specify cartiridge type: _____ Air Supplied Respirator ☐SCBA ☐ Air-line	Additional PPE: • Sun Glasses

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Have correct directions and know best route of travel to make it safely to intended destination.	a Getting lost in a bad area or showing up at the wrong location. Having doubt about where you are exactly supposed to be could cause undo stress while driving.	a. Ask questions and get safest route if destination is not known, an online locator can be used to assist with travel plans. Give other people your travel plans with addresses and phone numbers so you can be contacted.
2. Knowing what TRC's driving rules and policies are before getting behind the wheel on company time.	a. Driver using excuse that they didn't know the rules or policies and following common bad practices while driving.	a. Strong driver training and driving safety stewardship prior to personnel driving company owned vehicles or driving personal vehicles on company time.
3. Vehicle walk around and perimeter check	a. Trip, slip, fall. b. Possible human contact from unknown assailants. c. Struck by other vehicle.	a. Visual verification that vehicle tires are in safe working condition and that there are no sharp objects or foreign debris under the tires. b. Check for possible unsafe human interaction in the surrounding area c. Be conscious of other vehicle activity close by.
4. Unlock and open vehicle door, enter the vehicle and secure seatbelts.	a. Pinch or crush hazard if hand or fingers are not secured inside the vehicle before shutting vehicle door.	a. Ensure driver's seatbelt is functioning properly and verify that passengers seatbelt is also in good working condition then buckle up. Lock vehicle doors once inside as added protection factor. a. Verify all body parts are in the cab prior to closing the vehicle door.

TRC

JOB SAFETY ANALYSIS

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
5. Traveling safely at posted speed limits and following all road rules while driving on Roadways or Freeways	a. Not obeying posted speed limits and not following road rules.	a. Driver must maintain California's DMV best Practice of following a 3 second gap. Keep good visual contact of all lanes and identifying an out in case of emergency maneuver due to other vehicle hazards and poor driving. a. Watch for slower moving and fast approaching vehicles in roadway.
6. Merging while entering Multilane Freeways and Making lane changes while traveling on multilane roadways.	a. Struck from side, rear contact with other vehicles, struck from behind.	a. Use vehicle signals, look over shoulder, check mirrors a. Be aware of fast approaching or slower moving vehicles and maintain speed while initiating merge a. Maintain speed and repeat same steps with all lane changes.
7. Proceeding through marked or signal controlled intersections or crosswalks after coming to a full stop	a. Struck from side, rear contact with other vehicles, struck from behind. b. Hitting pedestrians or bicyclists.	a. Driver should carefully look left and right prior to proceeding through intersection. a. Driver should allow other vehicles to proceed per the traffic rules. a. Driver should maintain lane selection through the intersection and proceed forward remaining in the same lane they stopped in. b. Driver should carefully look left and right prior to proceeding through crosswalks. b. Driver should carefully check blind spots for bicyclists prior to making a right or left turn.
8. Reaching final destination in vehicle and coming to a complete stop while parking	a. Striking other parked vehicles or striking pedestrian walking traffic b. Vehicle engine not completely stopping causing the vehicle to lunge forward.	a. Pay full attention to the new surrounding areas where you'll park. b. Ensure vehicle's engine has completely stopped and set parking break.
9. Opening vehicle door and exiting.	a. Struck by other vehicles b. Stepping onto uneven surface c. Approached by someone unwanted.	a. Take a good look at surrounding areas and make sure there are no signs of oncoming traffic. b. Take a look outside at the ground before you step out making sure surface is level and object free. c. Keep aware of unwanted approaching personnel.
Field Changes: 10.	a. b. c. d.	a. b. c. d.

JOB SAFETY ANALYSIS

Field Notes:

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² CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

³ Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Work Area & Exclusion Zone Set-up**	List of Contractor(s) and key work activity: **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ HARD HAT __R__ GLOVES Specify: ☒ Kevlar ☐ Nitrile ☐ Other ________. __R__ SAFETY GLASSES _____GOGGLES _____FACE SHIELD	__R__ REFLECTIVE VEST __A__ HEARING PROTECTION __R__ SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ ____ Cartridge: ☐ P_{100} Multigas ☐ _____ _____Full face ARP; specify cartiridge type: _____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE: •

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Pre-start Meeting and Site Safety Analysis	a. Bad organization creating confusion and hazard	a. Arrive at site prior to planned start time to evaluate vehicle and pedestrian traffic flow in the work area and in the site vicinity. a. Review site plan with traffic control set-up. a. Identify staging area with good access lateral and vertical for loading and unloading of trucks. a. Identify material and equipment laydown areas.
2. Exclusion Zone Set-up	a. Physical injury or equipment damage from onsite and offsite traffic flow.	a. Use the 'buddy system (one person watching traffic, one person working) when working in a high-use traffic area. a. Use of cones/delineators and caution signs to alert foot traffic moving about the site of potential trip hazards. a . Utilize snow fencing, barricades, delineators, cones and/or caution tape to provide exclusion zone around proposed work locations. Set-up exclusion zone in accordance with TRC's Exclusion Zone Set-up procedures.
3. Control of Work Area and Exclusion Zone	a. Delivery vehicles b. Personnel/vehicle entry onto site c. Fatigue d. Noise and flying debris	a. All vehicles moving on site shall use reverse beepers or flaggers. b. Use visitor check-in log and allow no-one into an exclusion area with out proper PPE as designated on this JSA. b. All personnel onsite must wear appropriate work and protective clothing including:long pants, sleeved-shirt, steel-toed boots, safety vest, safety glasses, and hard hat, Kevlar hi-flex gloves. b. Limit number of times materials, equipment and debris are handled by staging as close to work area as possible. c. Watch on-site personnel for signs of fatigue (shuffling, disorientation, small mistakes, sloppiness, etc.) and have them go to a shaded, protected area where they can rest and rehydrate. c. Set up and maintain rehydrating station. d. Always wear safety glasses and hearing protection working around operating heavy equipment.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Work Area & Exclusion Zone Set-up**		List of Contractor(s) and key work activity: **TRC**	
4. Clean-up and overnight/ weekend storage	a. Slips, trips, and falls b. Bad organization creating confusion and hazard d. Site Security and Anti-Thievery	a. Clean-up work area as you go. Maintain a clean, unobstructed work area by good house keeping and placing unused equipment away from work area. b. Delineate and block access to open pits/trenches/holes with snow-fencing, delineators, cones, and/or caution tape as a warning and prevent persons from falling into these items overnight. d. Do not leave expensive equipment unattended. d. Lock all vehicles and large equipment. Do not leave keys in vehicles.	
Field Changes: 5.	a. b. c. d.	a. b. c. d.	
GENERAL SAFETY HAZARDS	**LOCATION(S) WHERE HAZARD IS TO BE EXPECTED**	**³ HAZARD CONTROLS (beyond wearing "Required" PPE)**	
6. Slips, trips, and falls	a. Throughout work area	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes. a. Be aware of sloped areas and only walk where safe.	
7. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment.	
8. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).	
9. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).	
10. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.	
11. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
12. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. Periodically monitor ambient air concentrations with PID/LEL Meter. Shut down job and move personnel and equipment upwind if methane exceeds 5**% of LEL.** a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.	
13. Exposure to chemicals of concern impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.	
14. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.	

JOB SAFETY ANALYSIS

Field Notes:

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

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JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site Leavenworth, Washington	4/2/20	☐ NEW ☒ REVISED from server

JSA WORK ACTIVITY (Description):	List of Contractor(s) and key work activity:
Groundwater Monitoring and Sampling - Physical and Chemical Concerns	**TRC**

SITE SPECIFIC JSA AUTHOR	TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

JSA REVIEWERS	TITLE/ AFFILIATION	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ REFLECTIVE VEST __R__ HARD HAT __R__ GLOVES: __R__ Kevlar __A__ Nitrile __R__ SAFETY GLASSES ______ GOGGLES ______ FACE SHIELD	__A__ HEARING PROTECTION __R__ SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: _____Coveralls ____Tyvek Suit _____Nomex ____Other (specify):.	☐ RESPIRATORY PROTECTION: ☐ ½ face Air Purifying Respirator (APR) ☐ Particulate Mask: ☐ PM100 ☐ PM95 ☐ Cartridge: ☐ Chemical ☐ Full face ARP ____________________. ☐ Air Supplied Respirator ☐ SCBA ☐ Air-line	☐ ADDITIONAL PPE AVAILABLE ONSITE (List): •

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Moving equipment around on site to and from well locations	a. Physical Injury from being struck by moving vehicles	a Always face traffic when working in or near street (establish eye contact with drivers). a. Use cones/delineators and caution tape/signs to alert pedestrians and traffic. Place work vehicle between oncoming traffic and work area to provide additional traffic barrier a. Use "buddy system" when unable to observe traffic of moving equipment.
	b. Slip/Trip Fall injury	b. Use roads or trails whenever possible b. Occassionally reassess route to avoid dangerous terrain. b. Use portable steps to mount and dismount sampling vehicle b. Maintain good housekeeping and keep work area clear of loose materials and equipment
	c. Pinched fingers or toes and strained muscles	c Wear Kevlar gloves when any potential for hand injury exists c. Use proper lifting techniques c. Use proper tools to pry open well lids c. Use proper tools to open and close purge water drums c. Get assistance when equipment exceeds 50-lbs
	d. Overhead obstacles (branches etc.)	d. Look up, pay attention to possible overhead obstacles. d. Wear eye and head protection when navigating hazardous obstacles.
2. Task Change Safety Analysis.	a. Not mentally focused upon new task / different procedures and skill set to be used	a. Place first aid kit and fire extinguishers in highly visible, nearby location. a. Evaluate site conditions. a. Identify location(s) of all emergency shut-off devices. a. Perform all necessary equipment and safety checks prior to event startup (per operating manual). a. Check sounding and measurement equipment for shorts, frayed wires, or loose connections.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Groundwater Monitoring and Sampling - Physical and Chemical Concerns**		List of Contractor(s) and key work activity: **TRC**	
3. Groundwater Measurements	a. Physical Injury or equipment damage from lack of concentration b. Physical Injury from being struck by moving vehicles. c. Pinched fingers or toes; and strained muscles. d. Lost equipment and damage to well from foreign objects. e. Fire/Explosions	a. Review all plans and logs in field notebook prior to starting a new task. a. Follow cell phone use procedures when working. b. Always face traffic or moving equipment when working (establish eye contact with drivers). b. Use cones/delineators and caution tape/signs to alert pedestrian and traffic. Place work vehicle between oncoming traffic and work area to provide additional traffic barrier. b. Use “buddy system” when unable to observe traffic of moving equipment. c. Wear Kevlar gloves when opening barrels & well lids, lifting sharp or heavy equipment. c. Lift heavy objects utilizing leg muscles rather than depending entirely on your back. Get assistance when equipment exceeds 50-lbs. d. Fasten equipment raising and lowering ropes or cables to object larger than well diameter. Carry no loose pens or tools in pockets, place well lid fasteners away from well opening. e. A hot work must be obtained and proper hot work procedures followed prior to beginning any hot work. e. No Smoking or Open Flames while on site. Request anyone smoking to please extinguish cigarettes. e. Confirm equipment is grounded prior to starting work.	
4. Groundwater Purging	a. Physical injury from being struck by moving vehicles. b. Possible splash hazard. c. Pinched fingers during the opening /closing of purge water storage drums. d. Overfill and spills. f. Muscle strains, cuts and pinches. g. Fire/Explosions	a. Always face traffic when working. a. Place work vehicle between oncoming traffic and work area to provide additional traffic barrier. b. Wear safety glasses b. Wear nitrile gloves when handling of groundwater. c. Wear Kevlar gloves when any potential for hand injury exists. c. Use proper tools for opening and closing purge water storage barrels. d. Observe transfer of purge water and fasten barrel lids properly when purging activities are completed. f. Use proper equipment for lowering and raising depth to measurement devices and hand bailer. f. Use proper physical/pulling techniques for turning on the generator pull start cord. f. Use Proper lifting techniques for pulling the hand bailer. g. A hot work must be obtained and proper hot work procedures followed prior to beginning any hot work. g. No Smoking or Open Flames while on site. Request anyone smoking to please extinguish cigarettes. g. Confirm equipment is grounded prior to starting work.	
5. Sample Storage and Well Closure	a. Damage to Samples b. Well Damage	a. Use procedures outlined in TRC’s Groundwater Monitoring and Sampling Procedures. b. Cap and lock sampled well, then securely fasten well box lids before moving onto next well to be sampled.	
6. Site Clean-up	a. Bad Organization	a. Clean-up area as you work. Prevent puddles of standing water.	

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Groundwater Monitoring and Sampling - Physical and Chemical Concerns**		List of Contractor(s) and key work activity: **TRC**	
7. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. a. Use portable steps to mount and dismount sampling vehicle. Place equipment and tools down on truck bed before mounting and dismounting sampling vehicle. a. Maintain good housekeeping and keep area clear of loose equipment and measurement devices.	
8. Cut/Pinched fingers or toes	a. Throughout work area	a. Wear Kevlar gloves when lifting sharp or heavy equipment.	
9. Strained muscles.	a. Throughout work area	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).	
10. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation (HAZWOPER).	
11. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
12. Field Changes:	a. b. c. d.	a. b. c. d.	

Field Notes:

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JOB SAFETY ANALYSIS

9iuCOMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site Leavenworth, Washington	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Using Hand Tools**	List of Contractor(s) and key work activity: **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

_R_ HARD HAT _R_ GLOVES Specify: ☒ Kevlar ☐ Nitrile ☐ Other _____. _R_ SAFETY GLASSES ____GOGGLES ____FACE SHIELD	_R_ REFLECTIVE VEST _A_ HEARING PROTECTION _R_ SAFETY SHOES: protive toe ____ 5pt.HARNESS / LANYARD PPE CLOTHING: ____Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒NA ____½ face Air Purifying Respirator (APR) ____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ ____ Cartridge: ☐ VOC ☐ ____ ____Full face ARP; specify cartridge type: ____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE:

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Inspection of tool prior to use	a. Misalignment of parts/ binding of moving parts/ breakage of any parts b. Dull or dirty parts	a. If damaged, have the tool repaired prior to use b. Keeping cutting tools sharp and clean makes them easier to control and less likely to bind or break
2. Use of tools	a. Strains, cuts, scrapes b. Flying parts	a. Avoid wet conditions, where tool can become slippery a. Do not wear loose clothing or jewelry. Keep hair, clothing, and gloves away from moving parts. a. Do not overreach. Keeping proper footing and balance will enable better control of the tool in unexpected situations. a. Wear appropriate Kevlar gloves when using a cutting tool and lifting sharp, heavy equipment or material which is likey to break or splinter. a. Do not use a fixed open blade knife for cutting.Use safety knife or approved alternative tool.a. If possible, use a vise or clamp to hold the item to be cut instead of attempting to hold it with your hands. a. Always cut away from the body. b. Wear safety glasses
Field Changes: 3.	a. b. c. d.	a. b. c. d.

GENERAL SAFETY HAZARDS	LOCATION(S) WHERE HAZARD IS TO BE EXPECTED	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
5. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.
6. Cut/Pinched fingers or toes	a. Throughout work area.	a. Wear Kevlar gloves when lifting sharp or heavy equipment. a. Wear slip resistant steel toe shoes.

JOB SAFETY ANALYSIS

9iuCOMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**	DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Using Hand Tools**	List of Contractor(s) and key work activity: **TRC**	

7. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).
8. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).
9. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.
10. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.
11. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.
12. Exposure to chemicals of concern impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.
13. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.

Field Notes:

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[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Hole Clearance**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ HARD HAT __A__ GLOVES Specify: ☒ Kevlar ☒ Nitrile ☐ Other ___________. __R__ SAFETY GLASSES ____GOGGLES ____FACE SHIELD	__R__ REFLECTIVE VEST __A__ HEARING PROTECTION __R__ SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ ____ Cartridge: ☐ P_{100} Multigas ☐ _____ _____Full face ARP; specify cartiridge type: _____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE: •

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Set up Job Site	a. Physical Injury from being struck by moving vehicles or equipment.	a. Have one person watch traffic while the other creates exclusion zone in a high-use traffic area. a. Create an exclusion zone at least 10-feet beyond the limits of the hole clearance; use snow fencing, barricades, delineators, cones and/or caution tape in accordance with project specification.
2. Hole Clearance	a. Damage to underground utilities/piping b. Contact with chemical contamination c. Run-off and Soil Cross-Contamination	a. Contact TRC PM if utility/piping is encountered. b. Wear nitrile gloves when handling water or soil. Wear required PPE, including safety glasses, while on job site. c. Cover all spoils stockpiles with plastic-sheeting and berm in accordance with local and state regulations.
3. Use of Air/Water Knifes	a. Physical injury from high-pressure air/water spray	a. Never place fingers or other body parts in front of high-pressure end of air knife/water knife nozzle. a. Always follow safe working procedures outlined in equipment handbook.
Field Changes: 4.	a. b. c. d.	a. b. c. d.
POTENTIAL HEALTH HAZARDS	**SYMPTOMS**	**[3] HAZARD RESPONSE AND FIRST AID (beyond wearing "Required" PPE)**
5. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.
6. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment.
7. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Hole Clearance**		List of Contractor(s): **TRC**	
8. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).	
9. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.	
10. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
11. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. Periodically monitor ambient air concentrations with PID/LEL Meter. Shut down job and move personnel and equipment upwind if methane exceeds 5**% of LEL.** a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.	
12. Exposure to chemicals of concern impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.	
13. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.	

Field Notes:

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[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Mob & Demob**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

_A_ HARD HAT _A_ GLOVES Specify: ☒ Kevlar ☒ Nitrile ☐ Other ______. _A_ SAFETY GLASSES _____GOGGLES _____FACE SHIELD	_A_ REFLECTIVE VEST _A_ HEARING PROTECTION _A_ SAFETY SHOES: protective toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: ____Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ _____ Cartridge: ☐ VOC ☐ ________ _____Full face ARP; specify cartridge type: _____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE: Sun Glasses

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Inspect Vehicle Equipment	a. Vehicle failures	a. Inspect fluids, tires, connections and safety equipment regularly. a. Inspect gas tank level. a. Note any hazards with vehicle and report to the appropriate employee/supervisor.
2. Loading/Unloading	a. Muscle strains, cuts and pinches	a. Ensure that appropriate PPE is worn and/or accessible including: Kevlar gloves, steel toed boots and safety glasses or goggles. a. Select vehicle size to meet project requirements. a. Prepare an equipment check off list. a. Use proper lifting techniques (Squat to lift and lower. Do not bend at the waist. Keep the weight as close to you as possible. Bow your back in and raise up with your head first. If you must turn, turn with your feet, not your body. Never jerk or twist. Put the weight down by keeping your low back bowed in. Keep you feet apart.), and if necessary (object > 50 lbs.) use additional mechanical lifting aid (tripod and winch) or additional labor. a. Get assistance for heavy objects (object > 50 lbs.).
3. Driving	a. Accidents	a. Pay attention to the task at hand. a. Do not use cell phone while driving. a. Obey traffic laws and drive defensively.
4. Arrival at site	a. Site conditions changed from plan	a. Observe traffic flow. a. Modify traffic control plan if necessary.
5. Loading/Unloading	a. Muscle strains, cuts and pinches	a. Ensure that appropriate PPE is worn and/or accessible including: Kelvar gloves, steel toed boots and safety glasses or goggles. a. Select vehicle size to meet project requirements. a. Prepare an equipment check off list.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Mob & Demob**		List of Contractor(s): **TRC**	
5. Loading/Unloading (contuined)		a. Use proper lifting techniques (Squat to lift and lower. Do not bend at the waist. Keep the weight as close to you as possible. Bow your back in and raise up with your head first. If you must turn, turn with your feet, not your body. Never jerk or twist! Put the weight down by keeping your low back bowed in. Keep you feet apart.), and if necessary (object > 50 lbs.) use additional mechanical lifting aid (tripod and winch) or additional labor. a. Get assistance for heavy objects (object > 50 lbs.). a. Do not use a fixed open blade knife for cutting. Use safety knife or approved alternative tool. a. Use proper tools for the task to performed.	
6. Inspect Vehicle Equipment	a. Vehicle failures	a. Inspect fluids, tires, connections and safety equipment regularly. a. Inspect gas tank level. a. Note any hazards with vehicle and report to the appropriate employee.	
7. Vehicle Rolling Unattended	a. When parked on slope or with engine idling.	a. All large trucks should use chocks at all times when parking or leaving the vehicle unattended. a. When parking on a hill or stopping with the engine idling, use parking brakes, parking gear if available and use chocks immediately upon leaving the driver's compartment. If other personnel are available ask them do the chocking before the driver exits the vehicle, then the driver should double-check the chocks. a. All towed trailers need chocking before disconnecting from main vehicle. a. Vehicles with leveling jacks do not need chocks if the jacks are in use.	
GENERAL SAFETY HAZARDS	**LOCATION(S) WHERE HAZARD IS TO BE EXPECTED**	**³ HAZARD CONTROLS (beyond wearing "Required" PPE)**	
5. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.	
6. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment. a. Wear slip resistant steel toe shoes.	
7. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).	
8. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).	
9. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.	
10. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
11. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.	

JOB SAFETY ANALYSIS

GENERAL SAFETY HAZARDS	LOCATION(S) WHERE HAZARD IS TO BE EXPECTED	HAZARD CONTROLS (beyond wearing "Required" PPE)
12. Exposure to chemicals of concern impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.
13. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.

Field Notes:

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED
JSA WORK ACTIVITY (Description): **Pneumatic Equipment**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

REQUIRED PPE

☐ HARD HAT ☒ GLOVES Specify: ☒ leather ☐ Nitrile ☒ Other Kevlar ☐ SAFETY GLASSES ☒ GOGGLES ☐ FACE SHIELD	☐ REFLECTIVE VEST ☒ HEARING PROTECTION ☒ STEEL TOE SAFETY SHOES ☐ 5 PT.HARNESS / LANYARD ☐ PPE CLOTHING: ☐ Coveralls ☐ Tyvek Suit ☐ Nomex ☐ Other ________.	☐ RESPIRATORY PROTECTION: ☐ ½ face Air Purifying Respirator (APR) ☐ Particulate Mask: ☐ PM100 ☐ PM95 ☒ Cartridge: ☒ Chemical ☐ Full face ARP ☐ Air Supplied Respirator ☐ SCBA ☐ Air-line	☐ MUST HAVE PPE AVAILABLE ONSITE (List):

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Pre-start Meeting and Site Safety Analysis	a. Misunderstood scope of work / confusion	a. Review site plan and Hospital Route. Identify all work tasks. Identify work areas to be traversed and potential hazards within that area.
2. General Use	a. Eye injury b. Trauma from air pressure, ejection of tool c. noise	a. Goggles, situational awareness b. Do not wear loose clothing or jewelry. Keep hair, clothing, and gloves away from moving parts. Ensure that appropriate PPE is worn including: gloves, and steel toed boots. b. Keeping proper footing and balance will enable better control of the equipment in unexpected situations. b. tool retainer (if available) b. Hose and connectors used for conducting compressed air must be designed for the pressure. b. Operate with strict accordance to Manufacture's instructions b. Always follow safe working procedures outlined in equipment handbook. c. hearing protection.
3. Field Changes:	a. b.	a. b.
4. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowleable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object?; caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)		DATE PREPARED FOR HASP:	☐ NEW ☒ REVISED
BNSF Glacier Park East Site Leavenworth, Washington		4/2/20	
JSA WORK ACTIVITY (Description): **Pneumatic Equipment**		List of Contractor(s): **TRC**	
5. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).	

Field Notes:

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LIMITATION: The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get SPX and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. SPX recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite. Similarly, all contractors are required to provide their own JSA(s) for their specialty prior to performing any work for SPX; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowleable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object?; caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site Leavenworth, Washington	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Slug Testing**	List of Contractor(s) and key work activity: **TRC**	

SITE SPECIFIC JSA AUTHOR	TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

JSA REVIEWERS	TITLE/ AFFILIATION	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

_R_ REFLECTIVE VEST _R_ HARD HAT _R_ GLOVES: _R_ Kevlar _A_ Nitrile _R_ SAFETY GLASSES ____ GOGGLES ____ FACE SHIELD	_A_ HEARING PROTECTION _R_ SAFETY SHOES: Protective Toe ____ 5pt.HARNESS / LANYARD PPE CLOTHING: ____Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	☐ RESPIRATORY PROTECTION: ☐ ½ face Air Purifying Respirator (APR) ☐ Particulate Mask: ☐ PM100 ☐ PM95 ☐ Cartridge: ☐ Chemical ☐ Full face ARP ____________ ☐ Air Supplied Respirator ☐ SCBA ☐ Air-line	☐ ADDITIONAL PPE AVAILABLE ONSITE (List):

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Slug Test	a. Physical Injury from being struck by moving vehicles	a Always face traffic when working in or near street (establish eye contact with drivers). a. Use cones/delineators and caution tape/signs to alert pedestrians and traffic. Place work vehicle between oncoming traffic and work area to provide additional traffic barrier a. Use "buddy system" when unable to observe traffic of moving equipment.
	b. Slip/Trip Fall injury	b. Use roads or trails whenever possible b. Occassionally reassess route to avoid dangerous terrain. b. Use portable steps to mount and dismount sampling vehicle b. Maintain good housekeeping and keep work area clear of loose materials and equipment
	c. Pinched fingers or toes and strained muscles	c Wear Kevlar gloves when any potential for hand injury exists c. Use proper lifting techniques c. Use proper tools to pry open well lids c. Use proper tools to open and close purge water drums c. Get assistance when equipment exceeds 50-lbs
	d. Ingestion or contact from impacted groundwater- HVOCs, jet fuel and related aromatic compounds	d. Wear safety glasses d. Wear nitrile gloves when performing all tasks d. No eating, drinking, or smoking while conducting monitoring and sampling activites d. Wash hands prior to eating, drinking, or smoking away from site.
1. Slug Test (Cont.)	e. Vapor inhalation (e.g. hydrogen sulfide, HVOCs) f. Overhead obstacles	e. Use air monitoring equipment to ensure vapors are below occupational criteria e. If air-monitoring equipment indicates that vapors exceed occupational criteria, wear a respirator with appropriate

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site Leavenworth, Washington**	DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Slug Testing**	List of Contractor(s) and key work activity: **TRC**	

	(branches etc.) g. Electrocution h. Lost equipment and damage to well from foreign objects.	chemical cartridge. e. Do not hold face over well when opening. f. Look up, pay attention to possible overhead obstacles. f. Wear eye and head protection when navigating hazardous obstacles. g. Perform all necessary equipment and safety checks prior to startup of electrical equipment (per operating manual). g. Make sure GFCI's are in place and working properly. h. Fasten equipment raising and lowering ropes or cables to object larger than well diameter. h. Carry no loose pens or tools in pockets, place well lid fasteners away from well opening.
2. Task Change Safety Analysis.	a. Not mentally focused upon new task / different procedures and skill set to be used	a. Place first aid kit and fire extinguishers in highly visible, nearby location. a. Evaluate site conditions. a. Identify location(s) of all emergency shut-off devices. a. Perform all necessary equipment and safety checks prior to event startup (per operating manual). a. Check sounding and measurement equipment for shorts, frayed wires, or loose connections.
3. Groundwater easurements	a. Physical Injury or equipment damage from lack of concentration b. Physical Injury from being struck by moving vehicles. c. Pinched fingers or toes; and strained muscles. d. Lost equipment and damage to well from foreign objects. e. Fire/Explosions	a. Review all plans and logs in field notebook prior to starting a new task. a. Follow cell phone use procedures when working. b. Always face traffic or moving equipment when working (establish eye contact with drivers). b. Use cones/delineators and caution tape/signs to alert pedestrian and traffic. Place work vehicle between oncoming traffic and work area to provide additional traffic barrier. b. Use "buddy system" when unable to observe traffic of moving equipment. c. Wear Kevlar gloves when opening barrels & well lids, lifting sharp or heavy equipment. c. Lift heavy objects utilizing leg muscles rather than depending entirely on your back. Get assistance when equipment exceeds 50-lbs. d. Fasten equipment raising and lowering ropes or cables to object larger than well diameter. Carry no loose pens or tools in pockets, place well lid fasteners away from well opening. e. A hot work must be obtained and proper hot work procedures followed prior to beginning any hot work. e. No Smoking or Open Flames while on site. Request anyone smoking to please extinguish cigarettes. e. Confirm equipment is grounded prior to starting work.
4. Well Closure	a. Well Damage	a. Cap and lock sampled well, then securely fasten well box lids before moving onto next well to be sampled.
5. Site Clean-up	a. Bad Organization	a. Clean-up area as you work. Prevent puddles of standing water.
6. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Use portable steps to mount and dismount sampling vehicle. Place equipment and tools down on truck bed before

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Slug Testing**		List of Contractor(s) and key work activity: **TRC**	
		mounting and dismounting sampling vehicle. a. Maintain good housekeeping and keep area clear of loose equipment and measurement devices.	
7. Cut/Pinched fingers or toes	a. Throughout work area	a. Wear Kevlar gloves when lifting sharp or heavy equipment.	
8. Strained muscles.	a. Throughout work area	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).	
9. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation (HAZWOPER).	
10. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
11. Field Changes:	a. b. c. d.	a. b. c. d.	

Field Notes:

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[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Soil Sampling**	List of Contractor(s) and key work activity: **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	COMPANY	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL DATE
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R___ HARD HAT __R___ GLOVES Specify: ☒ Kevlar ☒ Nitrile ☐ Other __________. __R__SAFETY GLASSES _____GOGGLES _____FACE SHIELD	__R__ REFLECTIVE VEST __A__ HEARING PROTECTION __R__SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: ____Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 _____ Cartridge: ☐ VOC ☐ ____________ _____Full face ARP; specify cartiridge type: _____ Air Supplied Respirator ____SCBA _____Air-line	Additional PPE:

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Soil Sampling	a. Ingestion of or contact with impacted soil.	a. Wear safety glasses. a. Wear nitrile gloves when performing all taskts. a. No eating, drinking, or smoking while conducting monitoring and sampling activites a. Wash hands prior to eating, drinking, or smoking away from site. Notify someone prior to sampling of your activites and when you expect them to be complete and that you will check in when complete.
	b. Broken sample jar.	b. Wear Kevlar gloves beneath the nitriles to add a layer of protection from cuts. b. Be aware of material that is being placed in the jar and do not place jagged edged materials in the jar that may cause the jar to break.
	c. Jagged edges in sample material.	c. Wear Kevlar gloves beneath the nitriles to add a layer of protection from cuts. c. Be aware of material and watch hand placement when gathering the material. c. Use a shovel or other tool if possible to transfer the soil from the stockpile to the container.
2. Placing cooler in vehicle	a. Muscle strain from weight of the cooler	a. Be aware of how much ice and samples are in the cooler. a. Use more than one cooler if the weight will be over 50 lbs. a. Get assistance moving cooler if it is too heavy.
Field Changes: 3.	a. b. c. d.	a. b. c. d.
GENERAL SAFETY HAZARDS	**LOCATION(S) WHERE HAZARD IS TO BE EXPECTED**	**[3] HAZARD CONTROLS (beyond wearing "Required" PPE)**
5. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.
6. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment.
7. Strained	a. Throughout work area; particularly when moving	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Soil Sampling**		List of Contractor(s) and key work activity: **TRC**	
muscles.	augers		
8. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).	
9. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.	
10. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
11. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. Periodically monitor ambient air concentrations with PID/LEL Meter. Shut down job and move personnel and equipment upwind if hydrocarbon concentrations are **> 300 ppm or >10% of LEL.** a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.	
12. Exposure to hydrocarbon impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.	
13. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.	

Field Notes:

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[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

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JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Working Alone**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

_R_ HARD HAT _R_ GLOVES Specify: ☒ Kevlar ☒ Nitrile ☐ Other ____. _A_ SAFETY GLASSES ____ GOGGLES ____ FACE SHIELD	_R_ REFLECTIVE VEST _A_ HEARING PROTECTION _R_ SAFETY SHOES: Protective Toe ____ 5pt.HARNESS / LANYARD PPE CLOTHING: ____ Coveralls ____ Tyvek Suit ____ Nomex ____ Other (specify):	RESPIRATORY PROTECTION: ☒ NA ____ ½ face Air Purifying Respirator (APR) ____ Particulate Mask: ☐ PM100 ☐ PM95 ☐ ____ ____ Cartridge: ☐ VOC ☐ ____ ____ Full face ARP; specify cartridge type: ____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE:

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

¹ JOB TASKS	² POTENTIAL HAZARDS	³ HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Working Alone	a. Working alone.	a. Establish contact with supervisor upon arrival at site. a. Make a plan and schedule to check-in with supervisor periodically throughout the work day. a. Alert supervisor when leaving the site. a. Alert supervisor upon return to office. a. Alert supervisor to any site conditions that may become unsafe.
	b. Unauthorized occupants at site.	b. Do not approach unless necessary to complete job. b. If working conditions are not safe due to unauthorized occupants or activities at job site, cease work, leave the site, and contact supervisor. b. If confronted by unauthorized occupants at site, immediately cease work and return to vehicle. Engage vehicle locks and contact authorities.
	c. Ilness/Injury	c. If an illness develops or minor injury occurs, immediately contact supervisor. c. If a serious injury occurs, contact 911.
Field Changes: 2.	a. b. c. d.	a. b. c. d.
GENERAL SAFETY HAZARDS	**LOCATION(S) WHERE HAZARD IS TO BE EXPECTED**	**³ HAZARD CONTROLS (beyond wearing "Required" PPE)**
5. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.
6. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment. a. Wear slip resistant steel toe shoes.
7. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).

JOB SAFETY ANALYSIS

Field Notes:

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

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[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

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JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site **Leavenworth, Washington**	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Working in Inclement Weather**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

JSA REVIEWERS	TITLE / AFFILIATION	
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ REFLECTIVE VEST __R__ HARD HAT __R__ GLOVES __R__ SAFETY GLASSES ______GOGGLES ______FACE SHIELD	__A__ HEARING PROTECTION __R__ SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: _____Coveralls ____Tyvek Suit _____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA ______Disposable Particulate Respirator (N95) ______½ face Air Purifying Respirator (APR) ____Particulate Mask: ☐ PM100 ☐ PM95 ______ Cartridge: ☐ P100-Multigas ☐ _____ _____Full face ARP; specify cartridge type: _____ Air Supplied Respirator ____SCBA _____Air-line	Additional PPE: • Cold weather clothing • Rain gear • Traction devices

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Winter driving vehicle inspection	a. Vehicle failures	a. Inspect fluids, connections, and safety equipment regularly a. Inspect tires for proper tread depth and no signs of damage or uneven wear. Check for proper tire inflation. a. Inspect all exterior lights, defrosters, and wipers. a. Inspect gas level, keep gas level near full. a. Note any hazards with vehicle and report to the appropriate employee. DO NOT USE AN UNSAFE VEHICLE.
2. Working in extreme cold temperatures	a. Frost bite b. Hypothermia c. Trench Foot	a,b,c. Refer to Activity Performed in Cold Illness Prevention JSA. a,b,c. Winter storm survival kit.
3. Driving in precipitation conditions	a. Slippery roads/highways b. Poor visibility c. Skidding d. Hydroplaning	a,b. Pull off the highway. Turn on hazard lights. Remain inside your vehicle. Wait for precipitation to stop. c. Ease your foot off the gas, steer carefully in the direction you want the front of the car to go. If the car does not have anti-lock break, avoid using the breaks. If the car you drive has ABS, brake firmly as you steer into the skid. d. Slow down on wet roads, stay away from puddles. Try to drive in the tire tracks left by the car in front of you. a,b,c,d. Carry a Winter storm survival kit.
4. Working in winter storm conditions	a. Frost bite b. Hypothermia c. Trench Foot d. Trap/strand inside vehicle	a,b,c. Refer to Activity Performed in Cold Illness Prevention JSA. d. Contact emergency road services. Display a trouble sign by hanging a brightly colored cloth on the radio antenna or door and raisin the hood(after snow stops falling). d. Run the engine and heater about 10 minutes each hour to keep warm. When the engine is running, open an upwind window slightly for ventilation. d. Watch for signs of frostbite or hypothermia. d. Do minor exercises to keep up circulation. Clap hands and move arms an legs occasionally. a,b,c,d. Carry a Winter storm survival kit.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site** **Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Working in Inclement Weather**		List of Contractor(s): **TRC**	
5. Working/ walking on snow and ice	a. Slippery surfaces b. Traffic	a. Wear proper foot wear, including insulated boots with good rubber treads. Take short steps and walk at a lower pace. a. Wear tracking devices when walking on ice. b. Be on the look out for vehicles which may have lost traction and are slipping towards you.	

Field Notes:

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[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object?; caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

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TRC

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site Leavenworth, Washington	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Working on Railroad Tracks**	List of Contractor(s): **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
David Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R___ HARD HAT __A___ GLOVES Specify: ☒ Kevlar ☒ Nitrile ☐ Other ___________. __R_SAFETY GLASSES _____GOGGLES _____FACE SHIELD	__R__ REFLECTIVE VEST __R___ HEARING PROTECTION __R___SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: _____Coveralls ____Tyvek Suit _____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA ______½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 _____ Cartridge: ☐ VOC ☐ _____________ ______Full face ARP; specify cartiridge type: ______ Air Supplied Respirator _____SCBA _____Air-line	Additional PPE:

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Mobing to work location on railroad tracks	a. Being hit by train or hi-rail truck b. Running over the rails with vehicle. c. Vehicle tire damage on railroad ties.	a. Verify with flagman what kind of controls are in place on the tracks. a. Verify what tracks these controls are on and which tracks have no contrls. a. Be aware of traffic on the tracks. a. Do not foul the tracks any longer than necessary. b. Be sure to only cross rails at verified crossings or where approved by the flagman. b. If crossing the rails at a location other than a crossing, put wood boards down to make the crossing easier, be sure to remove boards once finished with the crossing. b. Drive slowly when near or between tracks. c. Be sure necessary equipment is in vehicle in case there is tire damage c. Drive slowly when between tracks.
2. Working at boring location on the railroad tracks	a. Being hit by train or hi-rail truck b. Tripping over tracks	a. Verify with flagman what kind of controls are in place on the tracks. a. Verify what tracks these controls are on and which tracks have no contrls. a. Be aware of traffic on the tracks. a. Do not foul the tracks any longer than necessary. b. Do not step on rails when walking near work area. b. Step over the rails when walking near work area. b. Pay attention to where you are walking when walking in work area. b. Do not walk near rails unless it is required for the task.
Field Changes: 3.	a. b. c. d.	a. b. c. d.
GENERAL SAFETY HAZARDS	**LOCATION(S) WHERE HAZARD IS TO BE EXPECTED**	**[3] HAZARD CONTROLS (beyond wearing "Required" PPE)**
4. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State) **BNSF Glacier Park East Site Leavenworth, Washington**		DATE PREPARED FOR HASP: 4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Working on Railroad Tracks**		List of Contractor(s): **TRC**	
5. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. WearKevlar gloves when lifting sharp or heavy equipment.	
6. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).	
7. Unauthorized Personnel in exclusion zone	a. In exclusion zone	a. Use visitor check-in log; do not allow anyone in exclusion zone without proper PPE and training documentation. (HAZWOPER).	
8. Flying debris	a. In exclusion zone	a. Wear ANSI-approved safety glasses working around operating equipment.	
9. Loud Noise	a. In exclusion zone	a. Wear ANSI-approved hearing protection around operating equipment.	
10. Explosion/Fire	a. In exclusion zone	a. No smoking or open flame. Periodically monitor ambient air concentrations with PID/LEL Meter. Shut down job and move personnel and equipment upwind if hydrocarbon concentrations are **> 300 ppm or >10% of LEL.** a. Place 2-20lb ABC Fire extinguishers in location specified by SSO. a. Follow TRC's Cell Phone Use Guidelines.	
11. Exposure to hydrocarbon impacted soil or groundwater	a. In exclusion zone	a. Wear nitrile gloves during handling of soil or groundwater.	
12. Soil and groundwater cross-contamination	a. In exclusion zone	a. Identify and delineate soil stockpile area or storage area of drummed soil cuttings/decontamination water.	

Field Notes:

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

JOB SAFETY ANALYSIS

COMPANY/ PROJECT NAME or ID/ LOCATION (City, State)	DATE PREPARED FOR HASP:	
BNSF Glacier Park East Site Leavenworth, Washington	4/2/20	☐ NEW ☒ REVISED from server
JSA WORK ACTIVITY (Description): **Working Outdoors**	List of Contractor(s) and key work activity: **TRC**	

SITE SPECIFIC JSA AUTHOR	POSITION / TITLE	OFFICE	SIGNATURE
David Verret	Staff Geologist	Woodinville	[signature]

"TRC APPROVED" JSA DEVELOPMENT TEAM	POSITION / TITLE	APPROVAL
David Verret	PNW Office Safety Coordinator	
Dave Sullivan	ECR Safety Director	
Mike Glenn	National Safety Director	

Required PPE (indicate with "R") vs. Must Have Available On-site (indicate "A")

__R__ HARD HAT __R__ GLOVES Specify: ☒ Kevlar ☒ Nitrile ☐ Other ________. __R__SAFETY GLASSES _____GOGGLES _____FACE SHIELD	__R__ REFLECTIVE VEST __A__ HEARING PROTECTION __R__SAFETY SHOES: Protective Toe _____ 5pt.HARNESS / LANYARD PPE CLOTHING: ____Coveralls ____Tyvek Suit ____Nomex ____Other (specify):	RESPIRATORY PROTECTION: ☒ NA _____½ face Air Purifying Respirator (APR) _____Particulate Mask: ☐ PM100 ☐ PM95 ☐ ___ _____ Cartridge: ☐ VOC ☐ _______ _____Full face ARP; specify cartridge type: _____ Air Supplied Respirator ☐SCBA ☐Air-line	Additional PPE: Sunglasses Sunscreen Insect Repellent Rain gear Jackets

Always perform a Safety Assessment: 1) prior to starting work; 2) when changing tasks; and 3) throughout the day. Focus on each new task, procedures, and skill sets to be used.

[1] JOB TASKS	[2] POTENTIAL HAZARDS	[3] HAZARD CONTROLS (beyond wearing "Required" PPE)
1. Working Outdoors	a. Heat stress/Sun exposure	a. Check weather prior to departure to job site. Extreme heat conditions occur at temperatures exceeding 85F and humidity exceeding 50%. a. Wear appropriate clothing for the predicted weather conditions. a. Apply and reapply sunscreen per manufacturer's instructions. a. Schedule and take breaks throughout the day. a. Keep water supply readily available on site. a. Consume adequate water throughout the day to ensure propery hydration – TRC recommends 32 ounces per working hour.
	b. Cold exposure	b. Check weather prior to departure to job site. b. Wear appropriate clothing for the predicted weather conditons. b. Use handwarmers as necessary. b. Schedule and take breaks throughout the day.
	c. Weather	c. Check weather prior to departure to job site. c. Wear appropriate clothing for the predicted weather conditions. c. Have appropriate rain gear available. c. If thunderstorms occur, cease work and return to vehicle. Notify supervisor to delay of work activities and reschedule the work if necessary.
	d. Insect bites/stings	d. Pay attention to surroundings and note possible insect habitat at site. d. Apply insect repellent and/or wear insect repellent clothing if biting insects are observed at the site. d. If bites/stings occur, apply appropriate topical cream from the first aid kit. d. If known allergy exists to insect bites/stings, keep epi-pen on your person. d. If rash or itching mouth/throat develops in response to bite/sting, cease work immediately and contact Work Care for advice on how to proceed.

JOB SAFETY ANALYSIS

GENERAL SAFETY HAZARDS	LOCATION(S) WHERE HAZARD IS TO BE EXPECTED	³ HAZARD CONTROLS (beyond wearing "Required" PPE)
2. Slips, trips, and falls	a. In exclusion zone	a. Clean as you work. Put equipment away when done using it. Blot up puddles of standing water and sweep work area. a. Cover or use appropriate warning to protect all unattended open holes.
3. Cut/Pinched fingers or toes	a. Throughout work area; particularly when moving materials.	a. Wear Kevlar gloves when lifting sharp or heavy equipment. a. Wear slip resistant steel toe shoes.
4. Strained muscles.	a. Throughout work area; particularly when moving augers	a. Use proper lifting techniques; get help when moving heavy objects (>70 lbs).
Field Changes: 5.	a. b. c. d.	a. b. c. d.

Field Notes:

____

____

____

____

____

[1] List all activities/steps which present a significant hazard, preferably in sequence. FOCUS ON POTENTIALLY HAZARDOUS ACTIVITIES; not the trivial ones. Apply common, yet knowledgeable & informed, sense to identify what could reasonably be expected to cause danger.

[2] CONCENTRATE ON SIGNIFICANT HAZARDS. What can go wrong? How can someone get hurt? Can someone be struck by or strike an object? caught on, in or between objects?; fall to ground or lower level?; experience excessive strain or stress? Be exposed to inhalation or skin hazards. Specify the hazards; be descriptive.

[3] Describe actions, procedures or limits necessary to eliminate or minimize the hazards. Be clear, concise and specific. Use objective, observable and quantified terms. Avoid subjective general statements such as, "be careful" or "use as appropriate".

LIMITATION: As part of TRC's EHS Policy, a JSA is provided by TRC for its employees. The purpose of a JSA is NOT to identify all hazards associated with a task, but to identify key potential hazards to get TRC and other onsite personnel thinking about other potential safety hazards and mitigating actions for unsafe conditions and behavior during various works. TRC recognizes that JSA's may not cover every conceivable step or hazard that emerges during a job, so we've provided a "Field Change" section below to amend a JSA if required. The JSA does not supersede or replace any local, state or federal permit, regulation, statute or other entities policies and procedures but is simply a tool for enhancing the execution of safe work at a jobsite under TRC's supervision. Similarly, all subcontractors are required to provide their own JSA(s) for their specialty prior to performing any work for TRC or its customers in accordance with TRC's EHS Policy; however, any unsafe condition or hazard not covered in any JSA is ultimately the direct responsibility of the person or entity performing the work.

ATTACHMENT F

TAILGATE SAFETY MEETING CHECKLIST

AND

HASP COMPLIANCE AGREEMENT

Daily Pre-Job Safety Briefing

Project Name: ____________________ Project Number: __________

Work Location: ____________________ Date: __________

Tasks Performed: ____________________ Time: __________ AM PM

Client Name: ____________________ Submitted By: __________

HASP Available Onsite: Yes ☐ No ☐ Emergency Evacuation Location: __________

Emergency Facility(s): ____________________ Number(s): __________

Physical Address: ____________________

First Aid/CPR Persons: ____________________

For Emergencies Dial 911/For Non-Emergencies Dial WorkCare (888) 449-7787

Personal Protective Equipment Required	Yes	No	Type
Fall Protection	☐	☐	______
body harness, lifelines, barricades, other (specify)			
Eye/Face	☐	☐	______
goggles, face shield, glasses, other (specify)			
Respirator	☐	☐	______
SCBA, supplied air, HEPA, dust, other (specify)			
Foot Protection	☐	☐	______
safety toe, EH rated, rubber boots, other (specify)			
Hand Protection	☐	☐	______
Kevlar, cut resistant, chemical, EH, other (specify)			
Head Protection	☐	☐	______
hard hat, helmet, electrical hazard, other (specify)			
Clothing	☐	☐	______
coveralls, welding, sleeves, rain, FR, reflective vest, chemical, other (specify)			
Hearing Protection	☐	☐	______

Procedures/Programs Required	Yes	No
Hot Work	☐	☐
LOTO/Energy Control	☐	☐
Trenching/Excavation	☐	☐
Signs/Barricades	☐	☐
Confined Space	☐	☐
Cranes/Critical Lifts	☐	☐
Scaffolds/Aerial Lifts	☐	☐
Employee Certification/Training Required		
Crane Operator	☐	☐
Forklift Operator	☐	☐
Mobile Equipment Operator	☐	☐
Railroad/eRailsafe	☐	☐
OSHA 10/30	☐	☐
HAZWOPER	☐	☐
MSHA	☐	☐
Client Specific Training (_____)	☐	☐

Additional Considerations

Work Procedures:
☐ Check for utility clearance ☐ Adequate work zone
☐ Vehicle grounds ☐ Working clearances
☐ Discuss potential exposure to hazards

People: ☐ Worker fatigue ☐ Other work groups
☐ Public safety ☐ Pedestrian control ☐ Experience
☐ Traffic control ☐ Other utilities ☐ Spec. Training

Tools/Equipment: ☐ Inspection of drilling equipment
☐ Inspection of hoses
☐ Inspection of tools
☐ Specialized tools/equipment
☐ Correct tool/equipment for the job

Special Precautions: ☐ Adjacent structures
☐ Condition of structures ☐ Weather conditions
☐ Lighting conditions ☐ Terrain ☐ Water bodies
☐ Spills and leaks ☐ Environmental ☐ Cultural

Other: ____________________

If Conditions CHANGE…Stop Work, Review, and Revise the Plan!!

Daily Pre-Job Safety Briefing

Hazards Associated with the Job (focus on the GEMS)				
Gravity	**Electrical**	**Mechanical**	**Kinetic**	**Other/Environmental**
☐ Falling from a height	☐ Electrical contact	☐ Equipment failure	☐ Traffic	☐ Asbestos/Lead
☐ Falling objects	☐ Utility strike	☐ Cable tension	☐ Driving conditions	☐ Animals/Insects
☐ Falling structures		☐ Moving parts	☐ Moving/Shifting loads	☐ Confined space
☐ Climbing obstructions		☐ Crane/Rigging	☐ Rotating machinery	☐ Excavations
☐ Dangerous trees			☐ Vehicle stability	☐ Heat/Cold
			☐ Heavy equip. operation	☐ Poisonous Plants

List all hazards associated with this task

Barriers to eliminate/control above hazards?

Supervisor Signature Date

Signatures of Crew Members Present

OSHA's Unqualified Minimum Clearances	
Powerline Voltage Phase to Phase (kV)	**Minimum Safe Clearance (ft.)**
50 or below	**10**
Over 50 to 200	**15**
Over 200 to 350	**20**
Over 350 to 500	**25**
Over 500 to 750	**35**
Over 750 to 1,000	**45**

Post Task Safety Analysis

Did any injuries or incidents occur today? If yes, explain.

☐ Yes ☐ No

Was the injury or incident reported to the safety department?

☐ Yes ☐ No ☐ N/A

What problems did you have with today's work assignment?

What can we do tomorrow to improve performance?

HASP COMPLIANCE AGREEMENT

By signing below, I have completed the Tailgate Safety Meeting Checklist, reviewed this Site Health and Safety Plan and the Job Safety Analysis (JSA) and understand their contents. I hereby agree to comply with all safety requirements outlined herein:

TRC

Signature: ___________________________________, Site Safety Officer (SSO)

Print Name: _________________________________ Date: _______________

Signature: ____________________________, Asst. Site Safety Officer (Asst. SSO)

Print Name: _______________________________ Date: _______________

Contractor:

Signature: __________________________________, Site Safety Officer (SSO)

Print Name: _______________________________ Date: _______________

Signature: ___________________________ Asst. Site Safety Officer (Asst. SSO)

Print Name: _________________________________ Date: _______________

Contractor:

Signature: ___________________________________, Site Safety Officer (SSO)

Print Name: __________________________________ Date: ______________

Signature: ____________________________, Asst. Site Safety Officer (Asst. SSO)

Print Name: _________________________________ Date: _______________

TRC Employees / Contractor Personnel / Visitors

Signature: __________________________________Date: ______________

Print Name: _________________________________Company: __________

Signature: __________________________________Date: ______________

Print Name: _________________________________Company: __________

HASP COMPLIANCE AGREEMENT (cont.)

By signing below, I have completed the Tailgate Safety Meeting Checklist, reviewed this Site Health and Safety Plan and the Job Safety Analysis (JSA) and understand their contents. I hereby agree to comply with all safety requirements outlined herein:

TRC Employees / Contractor Personnel / Visitors (cont.)

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

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Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

Signature: ______________________________ Date: ____________________
Print Name: ______________________________ Company: ________________

ATTACHMENT G

TRC SAFETY OBSERVATION FORMS

TRC SAFETY OBSERVATION FORM

Revised January 2014

Location/Project Name: ____________________ **Date:** __________

Observer Name: ____________________

Observee Name: ____________________ **Time:** __________

Task Observed

Description of Task Observed and Background Information

Positive Comments

Conclusions / Why the Questionable Items Occurred?

Feedback Session Conducted By: ____________________ **Date:** __________

Name of Observee's Supervisor: ____________________ **Time:** __________

Questionable Observations/Root Cause Analysis

Personal Factor:
(1) Lack of skill or knowledge
(2) Correct way takes more time/requires more effort
(3) Shortcutting standard procedures is rewarded or appreciated
(4) In past, did not follow procedures or acceptable practices and no incident occurred

Job Factor:
(5) Lack of or inadequate operational procedures or work standards
(6) Inadequate communication of expectations or work standards
(7) Inadequate tools or equipment

Questionable Observation #	Root Cause Analysis #	Solution(s) To Prevent Potential Incident from Occurring	Person Responsible	Agreed Due Date	Date Completed

Results of Verification (were solutions done?) and Validation (were solutions effective?)

Reviewed by (Supervisor): ____________________ **Date:** __________

Approved by (Practice Safety Leader): ____________________ **Date:** __________

TRC OBSERVATION FORM

Revised January 2014

PERSONAL PROTECTIVE EQUIPMENT	Safe	At-Risk	Comments
1. Hearing Protection (e.g. Ear Plugs)			
2. Head Protection (e.g. Hard Hat)			
3. ANSI Rated Eye Protection (e.g. Safety Glasses)			
4. Hand Protection (e.g. Kevlar Gloves)			
5. Foot Protection (e.g. Safety Shoes)			
6. Respiratory Protection			
7. Fall Protection Inspected (e.g. harness)			
8. ANSI Rated Reflective Vest/High Visibility Clothing			
9. Other (Specify)			
BODY USE AND POSITIONING	**Safe**	**At-Risk**	**Comments**
10. Correct Body Use and Positioning When Lifting/Pushing/Pulling			
11. Pinch Points/Moving Equipment - Hands/Body Clear			
12. Mounts/Dismounts Using 3-Points of Contact			
13. Other (Specify)			
WORK ENVIRONMENT	**Safe**	**At-Risk**	**Comments**
14. Work/Walk Surface Free of Obstructions (e.g. tripping hazards)			
15. Housekeeping/Storage			
16. Defined and Secured (e.g. warning devices, barricades, cones, flags)			
17. Suspended Load, Swing Radius & Lift Area is Barricaded			
18. Safety Shut Down Devices			
19. Proper Storage & Labeling /Disposal of Sample & Waste Materials			
20. Cylinders Stored Upright, Secured, & Caps in Place			
21. Manhole/vault Inspected for Hazards			
22. Other (Specify)			
OPERATING PROCEDURES	**Safe**	**At-Risk**	**Comments**
23. Job Planning (HASP reviewed, JSAs, etc.)			
24. Fire Extinguishers Accessible and Inspections Current			
25. Work Permit/Authorization to Work (Hot, Cold, LOTO, Confined Space)			
26. JSA Reviewed & Followed			
27. Hazard Assessment - Hazard Hunt			
28. Interfaces with Other Functions (awareness with other personnel on site)			
29. Operators Looking Behind Prior to Backing Up			
30. Operators Wearing Seat Belts While Operating Equipment			
31. Subsurface Structures Identified			
32. Proper Trench Protective Equipment in Place			
33. Adequate Egress Is Available for Excavation & Trench (within 25 ft. if depth is <4 ft.)			
34. All Materials Set Back at Least 2 Feet From Edge of Trench/Excavation			
35. Other (Specify)			
TOOLS/EQUIPMENT	**Safe**	**At-Risk**	**Comments**
36. Hand Tools (Proper Equipment Selection, Condition, and Use)			
37. Power Tools (Proper Equipment Selection, Condition, and Use)			
38. Equipment, Including Heavy (Proper Equipment Selection, Condition, and Use)			
39. Hoses Inspected			
40. Required Monitoring Equipment Calibrated & Used			
41. Ladders Setup Correctly & Inspected			
42. Right Tools for the Job are Available and in Good Condition - No Fixed Open Blade Knifes (FOBKs)			
43. Other (Specify)			
Total #	0	0	

"Safe Catch" Report

A "Safe Catch" is a potential hazard or incident that has not resulted in any personal injury. Unsafe working conditions, unsafe employee behaviors, improper use of equipment or use of malfunctioning equipment have the potential to cause work related injuries. It is everyone's responsibility to report and/or correct these potential incidents immediately. Please complete this form as a means to report these "Good Catch" situations and submit to your local OSC Representative and Mike Glenn, National Safety Director.

Complete ALL field entries:

Employee Name:		Date:	
Incident Location:		Office:	
Project Number:		Practice:	

Conditions

Please check all appropriate conditions:

☐ Unsafe Act	☐ Unsafe Condition	☐ Unsafe Equipment	☐ Unsafe Use of Equipment

Description of Incident or Potential Hazard:

Task Performed at Time of Incident:

Causes (Primary and Contributing):

Corrective Action(s) Taken (remove the hazard, replace, repair, or retrain):

Employee Signature:		Date Completed:	

Our Mission: To reduce the frequency of incidents by applying local lessons learned globally.

If you have any questions about this report or would like additional information, please reference Compliance Program CP019—TRC Incident Response and Lessons Learned Program, located on TRCNET or contact Mike Glenn, National Safety Director at mglenn@trcsolutions.com.

ATTACHMENT H

WORKCARE PROGRAM INFORMATION

EARLY INCIDENT INTERVENTION®

Immediate Access to Medical Advice for Work Related Incidents

(888) 449-7787

INTRODUCTION

WorkCare, Inc. (WorkCare) and TRC have partnered together to promote Incident Intervention®, a resource designed to support company safety goals/targets—while reducing runaway-costs associated with workplace injuries and illnesses.

PURPOSE

Early Incident Intervention provides TRC employees with **IMMEDIATE** telephonic access to WorkCare clinicians at the time of a presumed, non-emergency workplace injury or illness. Clinicians provide expert guidance on the evaluation of symptoms, appropriate first aid, and the need for additional medical evaluation or treatment.

When utilizing this service within the first hour of an incident, known as the "Golden Hour," licensed medical staff can guide the case so that medical evaluation and treatment are rendered appropriately.

> *"…helps the worker traverse the unpredictable terrain of work-related injuries and illness."*

PRINCIPLES OF EARLY INCIDENT INTERVENTION

- Utilizes principles of the "Golden Hour."
- Provides workers immediate clinician support at the time of an incident.
- Focuses on providing the right care, at the right time in the proper setting.

BENEFITS FOR EMPLOYEES

- Instant access to a medically qualified professional for evaluation of symptoms and possible outcomes.
- Professional guidance on appropriate first aid measures and medications.
- Professional advice regarding the need for additional medical evaluation or treatment.

BENEFITS FOR TRC

- Point of contact for emergency and non-emergency medical clinicians.
- Triages the incident to determine risk and urgency, delivering interventions that are consistent with medical guidelines for the specified injury and illness.
- Maintains communication with clinicians to ensure accurate and timely reporting.

ATTACHMENT I

TRC INCIDENT REPORT FORMS

INCIDENT NOTIFICATION REPORT

(To be completed immediately after an Injury, Illness, Incident or Significant Near Miss by Employee's Supervisor and Employee involved)

Incident Category

☐ Injury/Illness ☐ Near Miss/Loss ☐ Property Damage ☐ Other

1 Incident Location: ______

2 Project #: ______

3 Client: ______

4 Date Incident Occurred: ______ Time: ______

5 Date Incident Reported: ______ Time: ______

TRC Employee Information

6 Name: ______ Phone: ______

7 Office: ______ Address: ______

8 Supervisor Name: ______ Phone: ______

9 Title or Occupation: ______

10 Sector/Practice: ______

Incident Description

11 Task Performed/Description of Incident:

12 Conditions at the Time of Incident (weather, lighting, etc.):

13 Description of Property Damage:

Employee Injury or Illness Description

14 Describe the Injury or Illness:

15 First Aid/Medical Treatment Administered:

16 Was WorkCare Contacted? ☐ Yes ☐ No

17 Name of Doctor's Office, Clinic or Hospital: ______

18 Address: ______ Phone: ______

INCIDENT NOTIFICATION REPORT

(To be completed immediately after an Injury, Illness, Incident or Significant Near Miss by Employee's Supervisor and Employee involved)

Subcontractor Involvement

19 Was a subcontractor involved? ☐ Yes ☐ No
20 Name of Company: ____________________
21 Address: ____________________
22 Contact Name: ____________________ Phone: __________
23 Description of the Incident:

Witness Information

24 Were there witnesses to the incident? ☐ Yes ☐ No
25 Name(s) Address(es) Number(s)

____

____

Immediate Corrective Actions

26 Describe the Immediate Corrective Actions Taken:

Client Notification

27 Is there a client incident notification requirement? ☐ Yes ☐ No
28 Contact Name ____________________
29 Date of Notification: ____________________ Time: __________
30 Notification Method:

Supervisor: __________ Signature: ____________________ Date: __________

Employee: Signature: Date:

ATTACHMENT J

TRC AUTO INCIDENT REPORT

AUTO INCIDENT REPORT

EMPLOYEE INFORMATION (V-1):

Name: ______________________ Phone: (   ) ______________

Sector/Practice: ______________________ Office Location: ______________

Supervisor's Name: ______________________ Supervisor's Phone: (   ) ______________

Project #: ______________________ Client's Name: ______________

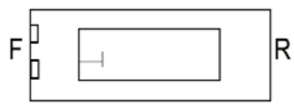
Driver's License #: ______________________ State: ______________

VEHICLE INFORMATION (V-1):

Year/Make/Model of Vehicle: ______________________

License Plate #: ______________________ Vehicle ID # (VIN): ______________

Circle Point of Contact:



Was Vehicle Drivable? ☐ Yes ☐ No

Personal: ☐ Yes Rental: ☐ Yes Fleet: ☐ Yes

Rental Company

INCIDENT INFORMATION:

Date of Incident: ________ Time of Incident: ________ A.M. ________ P.M. Photos Taken: ☐ Yes ☐ No

Location of Incident: ______________________ City/State: ______________

Were The Authorities Contacted? Police: ☐ Yes ☐ No Ambulance: ☐ Yes ☐ No Fire: ☐ Yes ☐ No

Name of Police Dept: ____________ Case #: ____________ Officer Name: ____________

Were Citations Issued? ☐ Yes ☐ No If Yes, To Whom? ______________

Citation Number: ______________________

Were There Any Witnesses? ☐ Yes ☐ No If Yes, Please Provide Name, Address and Phone Below:

Witness Name: ______________________ Witness Phone: (   ) ______________

Witness Address: ____

Traffic Conditions (i.e., heavy, light): ____________ Weather Conditions (i.e., dry, wet, ice, fog): ____________

WorkCare Contacted? ☐ Yes ☐ No

TRC Driver Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Front Seat Passenger Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Rear Driver Side Passenger Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Rear Passenger Side Passenger Injured? ☐ Yes ☐ No Medical Treatment Received? ☐ Yes ☐ No

Describe Injuries:

____

Describe Damage to Property Other Than Motor Vehicles (i.e., guardrails, mailboxes, etc.):

____

AUTO INCIDENT REPORT

OTHER DRIVER & VEHICLE INFORMATION (V-2):

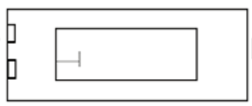
Driver's Name: ______________________ Driver's Phone: (   ) ______________

Driver's Address: ____

Owner's Name (If different than driver): ______________ Owner's Phone: (   ) ______________

Owner's Address: ____

Year/Make/Model of Vehicle: ______________ License Plate #: __________ State: ______

Circle Point of Contact: F  R

Was Vehicle Drivable? ☐ Yes ☐ No

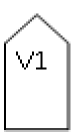
Insurance Company Name: ______________________ Policy Number: ______________________

Insurance Company Phone: (   ) ______________ Number of Passengers in Vehicle: __________

List Persons Injured: ____

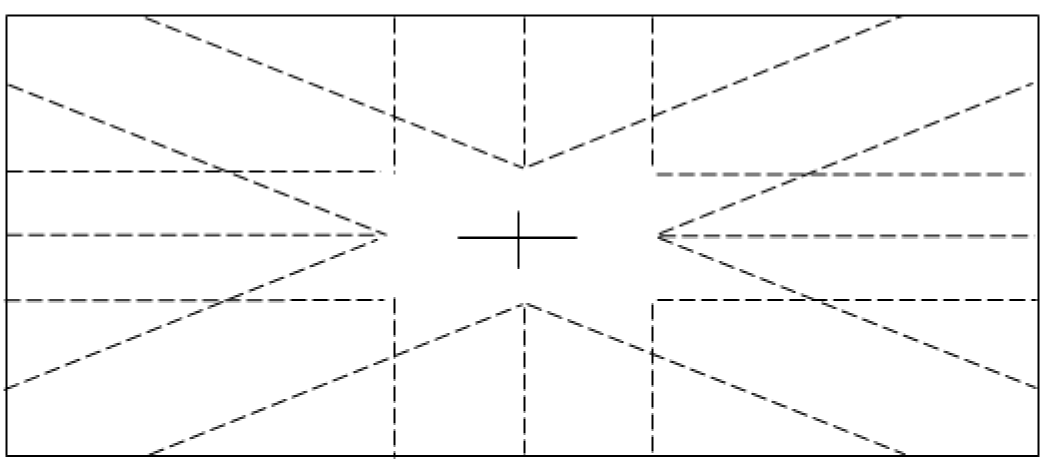
Were Any Other Vehicles Involved in Incident? ☐ Yes ☐ No If yes, provide details below:

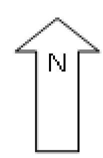
PLEASE DESCRIBE THE INCIDENT AND COMPLETE THE DIAGRAM BELOW. Be sure to indicate as many details as possible (i.e., How many lanes in each direction; Were there any turn lanes; What kind of traffic controls were there – light, stop sign, yield sign, Positions of vehicles on impact).



V-1 TRC Vehicle

V-2 Other Vehicle





Completed By: ______________________ Signature: ______________________

ATTACHMENT K

BNSF SAFETY CHECKLIST
AND QUICK REFERENCE GUIDES

BNSF SAFETY CHECKLIST

Basic RR Training Requirements

- Federal Railroad Administration (FRA) On-Track training
- BNSF Contractor Safety Orientation
- Enrollment in e-RailSafe (unless site is exempted)
- Web-based BNSF MOW/On-Track training. Additional BNSF training may be required for engineering work or work on the tracks (hi-rail inspections).

Project Managers/Task Managers (before fieldwork)

1. Verify that all subcontractors are approved by TRC (SQFs, Insurance, etc.).
2. Prepare project-specific Health and Safety Plan (HASP) that includes completed Job Hazard Analysis/Task Hazard Analysis (JHA/THA), auditing program, and BNSF-specific safety protocols (Maintenance of Way {MOW}) as an appendix. MOW also can be maintained at the project site as a separate document.
3. Prepare and submit electronic Safety Action Plan (SAP) at www.contractororientation.com. Print hard copies for file, for field supervisor, and for submittal to the BNSF environmental representative.
4. Confirm who the primary site contact will be (e.g., Roadmaster, Yardmaster, Water Service Foreman) and communicate with that person to discuss track protection needs prior to mobilizing to the site. Track protection shall only be provided by a BNSF Maintenance of Way (MOW) rules-qualified employee.
5. If intrusive drilling or excavation work is planned, arrange a buried utility locate via the state one-call system. Also contact Railroad's Communications Network Control Center at (800) 533-2891, BNSF signal, communications, and water service. Contact the primary BNSF environmental contact and site contact to discuss if others need to be contacted for a subsurface locate.
6. Verify that field supervisor has, and will use on a daily basis, the Field Job Safety Briefing Documentation card. The Project Manager should review the card information with the field supervisor as necessary.
7. Ensure that onsite and subcontractor personnel are compliant with FRA and BNSF On-Track training requirements. Client-specific training requirements include:
    - FRA/On-Track training
    - e-RailSafe
    - BNSF Contractor Safety Orientation

Site Supervisors (during fieldwork)

1. Conduct initial project safety meeting by reviewing the HASP and the JHA/THA with site environmental and subcontractor field personnel assigned to the project. If track protection is being provided by a flagman, then the BNSF Employee in Charge (EIC) must lead the safety discussion regarding track protection. Daily safety meetings may be combined with daily job safety briefings provided by BNSF personnel.
2. Ensure all on-site personnel have the proper personal protective equipment (e.g., steel toed boots, hard hat, safety glasses, and reflective vests meeting ANSI level II or III orange work wear). Confirm with BNSF personnel at the facility any specific requirements on color of hard hat and reflective vest. **Note: new BNSF rules for slip resistant winter boots.**
3. Verify on-site, prior to conducting work that all environmental and subcontractor personnel have with them proof of having fulfilled the required FRA and BNSF safety training requirements.

Attend job briefing presented by the BNSF EIC and ensure all attendees complete their copy of the Field Job Safety Briefing Documentation Card (attached).

DAILY JOB BRIEFING FIELD DOCUMENTATION CARD (MANDATORY)

After a job briefing, these questions regarding FRA On-Track safety must be understood by the entire field crew who will be working within 25 feet of active railroad tracks. The TRC representative must verify that all field crew members have proof of being current with their FRA and client-specific On-Track training requirements.

1. Who is the Employee-In-Charge (**not us – must be railroad rules qualified**)

____

2. What type of On-Track safety/track protection do I have on the tracks I am working on

____

3. Is this type of protection appropriate for the type of work that I am performing

____

4. If heavy equipment or other personnel are involved in the work, how will it affect my work and safety

____

5. What type of On-Track safety do I have, if any, on adjacent tracks

____

6. When clearing the track, where is my designated place of safety

____

7. What are the track limits of my protection (reference Mile posts, Cross Streets, or Named Tracks)

____

8. What is the time limit of my track protection

____

9. Where can I find FRA and client-specific On-Track safety rules

____

10. Do I understand my On-Track safety and feel that I am adequately protected against trains and on track equipment

____

11. What is the speed limit in the authorized work zone (and adjacent tracks, if applicable)

____

Speed in MPH	Distance in Feet	Speed in MPH	Distance in Feet
5	110	20	1,100
10	220	55	1,210
15	330	60	1,320
20	440	65	1,430
25	550	70	1,540
30	660	75	1,650
35	770	80	1,760
40	880	85	1,870
45	990	90	1,980

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE
Approaching Others & Safety Assessment
Hazardous Energy Control - Lockout/Tagout (LOTO)

Please use/complete the following checklist to ascertain conformance to BNSF's expectations around hazardous energy control / LOTO. If a deficiency is identified, it must be resolved before allowing any applicable work covered by this issue to continue or commence.

Name/Signature:____

Date:____

Project Location/Activity:____

Subject	Yes	No	NA
Maintenance or Servicing Work is or will be performed that requires energy control?			
Do the applicable contractors/consultants performing the work have the required training/qualifications to safely de-energize equipment?			
Is the proper equipment available or being used to isolate energy? • LOTO or other devises distinguishable & red in color • LOTO multi-clasp available, with one lock and one key for all employees servicing same equipment • Pipe disconnects • Valve locks • Hydraulic disconnect and/or bracing • Other			
Have other employees not involved in the work been notified of the work and safe procedures during maintenance/servicing period?			
Are proper procedures being used to fully de-energize all forms of energy (chemical, electrical, potential, pressure, heat/cold, etc.)? • Includes trying to operate equipment after de-energization			
If live overhead lines are present, have lines been de-energized or work under these areas been prevented?			
Have any guards, alarms or other safety devices been removed or deactivated?			

Method(s) used to resolve any identified deficiencies from above (use back side of page as needed):

1. ____
2. ____
3. ____
4. ____

Clearance Zones Around Overhead Power Lines

Regulation

OSHA defines minimum clearances for cranes and derricks around overhead power lines in 29 CFR 1926.1408.

Other Corporate Program/Reference:

Safety Topics – Crane and Boom Operations:
https://bnsfrailway.sharepoint.com/teams/SafetyCommunications/SafetyCommLibrary/crane-and-boom-operations-mw.pdf

Key Definitions

- Work zone for cranes and derricks: the area 360 degrees around the equipment, up to the equipment's maximum working radius.

General Safety Rules when Operating around Overhead Power Lines

- Workers should never be positioned underneath an overhead or suspended load (i.e. on a crane or boom).
- The contractor must assume that all power lines are energized unless the utility owner/operator confirms that the power line has been and continues to be deenergized and visibly grounded at the worksite.
- Determine if any part of the equipment, load line or load (including rigging and lifting accessories), if operated up to the equipment's maximum working radius in the work zone, could get closer than 20 feet to a power line. If so, the operator must meet the requirements in Option (1), Option (2), or Option (3), as follows:
    1. *Deenergize and ground*. Confirm from the utility owner/operator that the power line has been deenergized and visibly grounded at the worksite,
    2. *20 foot clearance for lines less than 350kV*. Ensure that no part of the equipment, load line, or load (including rigging and lifting accessories), gets closer than 20 feet to the power line by implementing the encroachment prevention measures specified below, or
    3. *Table A clearance* must be met. Determine the line's voltage and the minimum approach distance permitted under Table A. Determine if any part of the equipment, load line or load (including rigging and lifting accessories), while operating up to the equipment's maximum working radius in the work zone, could get closer than the minimum approach distance of the power line permitted under Table A (*see* § 1926.1408). If so, then the contractor must follow the encroachment prevention measures provided below to ensure that no part of the equipment, load line, or load (including rigging and lifting accessories), gets closer to the line than the minimum approach distance.
- Where Option 3 is used, the utility owner/operator of the power lines must provide the requested voltage information within two working days of the contractor's request.

TABLE A—MINIMUM CLEARANCE DISTANCES

Voltage (nominal, kV, alternating current)	Minimum clearance distance (feet)
up to 50	10
over 50 to 200	15
over 200 to 350	20
over 350 to 500	25
over 500 to 750	35
over 750 to 1,000	45
over 1,000	(as established by the utility owner/operator or registered professional engineer who is a qualified person with respect to electrical power transmission and distribution).

Note: The value that follows "to" is up to and includes that value. For example, over 50 to 200 means up to and including 200kV.

- *Encroachment Prevention Measures.* Where encroachment precautions are required under Option (2) or Option (3) of this section, all of the following requirements must be met:
    - Conduct a pre job safety review planning meeting with the operator and the other workers who will be in the area of the equipment or load to review the location of the power line(s), and the steps that will be implemented to prevent encroachment/electrocution.
    - If tag lines are used, they must be non-conductive.
    - Erect and maintain an elevated warning line, barricade, or line of signs, in view of the operator, equipped with flags or similar high-visibility markings, at 20 feet from the power line (if using Option (2) of this section) or at the minimum approach distance under Table A (if using Option (3) of this section). If the operator is unable to see the elevated warning line, a dedicated spotter must be used as described below in addition to implementing one of the additional measures described below.
    - Implement at least one of the following measures:
        - A proximity alarm set to give the operator sufficient warning to prevent encroachment,
        - A dedicated spotter who is in continuous contact with the operator. Where this measure is selected, the dedicated spotter must:
            - Not be the same person who is giving signals for any crane/boom or other move
            - Be equipped with a visual aid to assist in identifying the minimum clearance distance. Examples of a visual aid include, but are not limited to: A clearly visible line painted on the ground; a clearly visible line of stanchions; a set of clearly visible line-of-sight landmarks (such as a fence post behind the dedicated spotter and a building corner ahead of the dedicated spotter).
            - Be positioned to effectively gauge the clearance distance.
            - Where necessary, use equipment that enables the dedicated spotter to communicate directly with the operator.
            - Give timely information to the operator so that the required clearance distance can be maintained.
        - A device that automatically warns the operator when to stop movement, such as a range control warning device. Such a device must be set to give the operator sufficient warning to prevent encroachment,
        - A device that automatically limits range of movement, set to prevent encroachment, or
        - An insulating link/device (listed, labeled, or accepted by a Nationally Recognized Testing Laboratory in accordance with 29 CFR 1910.7) installed at a point between the end of the load line (or below) and the load.

- *Operations below Power Lines*
    - No part of the equipment, load line, or load (including rigging and lifting accessories) is allowed below a power line unless the contractor has confirmed that the utility owner/operator has deenergized and (at the worksite) visibly grounded the power line, except where one of the following exceptions applies:
        - For equipment with non-extensible booms: The uppermost part of the equipment, with the boom at true vertical, would be more than 20 feet below the plane of the power line or more than the Table A of this section minimum clearance distance below the plane of the power line.
        - For equipment with articulating or extensible booms: The uppermost part of the equipment, with the boom in the fully extended position, at true vertical, would be more than 20 feet below the plane of the power line or more than the Table A of this section minimum clearance distance below the plane of the power line.

Clearing Underground Utilities

Regulation

This guidance does not restate all federal, state and provincial laws, but rather is a guide for BNSF environmental staff on common best management practices to be employed by our consultants and contractors when completing intrusive subsurface activities. In the event a federal, state or provincial law conflicts with this guidance or requires an activity above and beyond this guidance, it is incumbent upon the contractor or consultant to know and apply applicable laws and regulations. If state or local laws require an activity that is less than what is required in this guidance, the contractor or consultant should take the additional safety steps required in this guidance or contact their BNSF contact to discuss alternative practices that meet BNSF expectations.

Other Environmental Department Quick Reference Guides referencing Underground Utility Clearances:

- Excavation and Trenching
- Working Around Auger Drilling Rigs

General Guidance when Clearing Underground Utilities

- Prior to initiating any activities on site, including completing underground utility clearances, a Job Safety Briefing must be held to identify hazards and risks and discuss ways to actively mitigate or reduce the hazard or risk. Applicable resources include BNSF Environmental's *Site Visit Safety Instructions and Checklist, and Job Safety Analysis for Environmental Remediation*, both of which are available on the BNSF Environmental HazMat intranet website.
- Make a visual survey of the proposed job site looking for evidence of underground construction, markers, vents, manholes, valves, etc. Attention should be paid to nearby buildings which can also identify potential underground utilities (water spigots, gas main, etc.)
- Consistent with ANSI Z535.1, the following colors will be used to identify underground utilities.
  - Pink – temporary survey markings
  - Red – electric power lines, cables, conduits and lighting cables
  - Yellow – gas, oil, steam, petroleum or gaseous materials
  - Orange – communication, alarm or signal lines, cables or conduit
  - Blue – potable water
  - Purple – reclaimed water, irrigation and slurry lines
  - Green – sewers and drain lines
- Delineate all proposed subsurface penetrations, clearly marking the location with white paint, stakes or flags in accordance with ANSI standard Z535.1. In the event of a linear excavation, the route or perimeter of the excavation must be marked.
- Check available plans, maps, GIS information, and corporate contracts & deeds that apply to the work site.
- If work is to be completed on BNSF property (e.g., soil borings, monitor well installations, trenching, test pits, gross excavation), BNSF signals and telecommunication departments must be notified by dialing (817) 593-4357 and following the prompts. Additionally, BNSF electrical and water service must be contacted for location of affected services. Finally, discuss locations of proposed excavation with local facility personnel who are familiar with the facility and past operations.
- Not less than 2 business days, nor more than 10 days, prior to initiating intrusive subsurface activities, the contractor should initiate a utility locate through the state-specific One-Call utility clearance service. In the event of an emergency, an emergency locate can be requested. Typically, the service can be contacted by dialing 8-1-1; however, the contractor should check the state-specific requirements to determine if a county within a state has a separate number (e.g., Flathead and

Lincoln Counties, MT). Confirmation as to the length of time the clearance is valid for should also be made, as it varies by state.

- The consultant/contractor performing the excavation or drilling must also initiate a privately contracted utility locate service before conducting any intrusive work. The private utility locate service will be utilized to review and confirm the presence/absence of "known" utilities previously identified by the state-specific One-Call utility clearance service. The private utility locate service must use geophysical methods (e.g., electromagnetic conductance or inductance, or ground penetrating radar) to attempt to identify unknown utilities or obstructions. The consultant overseeing the work must be present during the privately contracted utility locate to discuss all locations and planned activities. Each location must be clearly marked and flagged using the appropriate color with cones, flags, paint, etc. to preserve the cleared locations. Virtual maps or photographs housed on electronic devices are <u>not considered</u> appropriate substitutes for clearly marked and preserved locations in the field.
- Following the utility locate services and prior to invasive subsurface activities, each excavation or boring location must be cleared manually to five (5) feet below ground surface. A tile probe should be used at each location to test for unknown obstructions. If a tile probe is not available, an air-knife or water-jet can be used to clear the first several feet of soil to check for subsurface obstructions. The hole should be cleared to 120% of the diameter of the largest tool used for drilling to clear tangential structures. Drilling should proceed cautiously through the first ten (10) feet of the soil column.
- The contractor and/or consultant present during the private utility locate is required to be present during the actual invasive subsurface activities.
- Keep a detailed list and map of all utilities as located
- Hold daily job safety briefings with all work groups to ensure project scope has not changed
- If work activities are extended, inspect surface markings (flags, paint, etc.) every third day to ensure they stay visible as work progresses
- If work activity must be conducted within 3 feet of an existing located utility, manually expose the utility in question using non-conductive tools/shovels and protect it in-place to include de-energizing when possible before completing the work activities. Do not use power tools or equipment in completing the manual clearance of known utilities. A representative from the department or utility (ownership of underground utility – Signals, Telecom, etc.) must be present.
- Develop emergency response procedures necessary to respond to known or potential hazards including damage to underground facilities
- Prepare an emergency response plan with applicable phone numbers
- If damage is caused or discovered, stop work immediately and assess damage and risks
- Report damage to "one-call center", facility contact, and the BNSF Project Manager
- Protect personnel, notify local emergency providers if necessary
- Notify the Service Interruption Desk (817-352-2832 (North/Central) or 817-352-2833 (South)) if rail operations are affected.
- In case of fire or serious risk of fire, explosion, etc., make an emergency notice to all affected personnel.

Regulation(s)

- Federal Railroad Administration (FRA), 49CFR part 214. The OSHA standard for Confined Spaces, Title 29 Code of Federal Regulations (CFR) Part 1910.146 and 1926.1201, addresses the practices and procedures necessary to enter confined spaces safely while employees or contractors perform servicing and maintenance activities. The standard outlines measures for confined spaces — whether permit required or not.
- Does not apply to excavation work as defined in 29CFR1926.650

Corporate Confined Space(s) Reference

- https://employee.bnsf.com/safety/Pages/confined-space-program.aspx

Key Definitions

- Confined Space: See below

- Hazardous Atmosphere: Means an atmosphere that may expose employees to risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness from one or more of the following causes:
  1. Flammable gas, vapors, or mist in excess of 10 percent (%) of its lower flammable limit (LFL);
  2. Airborne combustible dust at a concentration that meets or exceeds it LFL;
  3. Atmospheric oxygen concentration below 19.5 percent (%) or above 23.5 percent (%);
  4. Atmospheric concentration of any substance for which a dose or a permissible exposure limit (PEL) is published in Subpart G, Occupational Health and Environmental Control, or in Subpart Z, Toxic and Hazardous Substance, of this part (29 CFR 1910.1000) and which could result in employee exposure in excess of its dose or permissible exposure limit
  5. Any other atmospheric condition that is immediately dangerous to life or health (IDLH).

- Permit Required Confined Space: See below

- Non-Permit Confined Space: Means a confine space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

- Attendant: A trained individual stationed outside a permit space who assesses the status of authorized entrants and who must perform the duties specified in section 3.3 of this program. An attendant shall remain at point of entry at all times unless relieved by another attendant, may only monitor one confined space at a time and cannot perform any other duties that interfere with monitoring entry. Note to the definition of ''Attendant'': An entry supervisor also may serve as an authorized entrant, as long as that person is trained and equipped as required by this program for each role he or she fills. Also, the duties of Attendant may be passed from one individual to another during the course of an entry operation.

- Authorized Entrant: An employee who is trained as an entrant and authorized by the entry supervisor to enter a permit space and perform the duties as required. Note to the definition of Authorized Entrant: An Authorized Entrant also may serve as an attendant, as long as that person is trained and equipped as required by this program for each role he or she fills. Also, the duties of Authorized Entrant may be passed from one individual to another during the course of an entry operation.

- Entry Supervisor: The qualified/trained person responsible for determining if acceptable entry conditions are present at a permit space where entry is planned, for authorizing entry and overseeing entry operations, and for terminating entry as required by this program.

What is a Confined Space?
Means a space that (must meet all three):

1. Large enough and so configured that an employee can bodily enter and perform assigned work; and
2. Has limited or restricted means for entry or exit (i.e. silos, storage bins, vessels, or tanks, etc.); and
3. Not designed for continuous employee occupancy.

What is a Permit Required Confined Space?
Means a confined space that has one or more of the following characteristics:

1. Contains or has the potential to contain a hazardous atmosphere;
2. Contains a material that has the potential for engulfing an entrant;
3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor which slopes downward and tapers to a smaller cross-section; or
4. Contains any other recognized serious safety or health hazard.

Procedures

- **Entering a Non-Permit Required Confined Space?**
  Before beginning any work, the following steps must be followed to safely enter a permit required confined space as outlined in BNSF's Confined Space Program:
  - Proper training
  - Know and understand confined spaces in work environment
  - Ensure a confined space permit exists or is created
  - Follow the Non-Permit Required Confined Space (NRCS) entry procedures & checklist
  - Use air monitoring equipment

- **Entering Permit Required Confined Space?**
  Before beginning any work, the following steps must be followed to safely enter a permit required confined space as outlined in BNSF's Confined Space Program:
  - Proper training or ensure contractor employees have the proper training and certifications
  - Know and understand confined spaces in work environment
  - Ensure a confined space permit exists or is created
  - Follow Permit Required Confined Space (PRCS) entry procedures & entry permit
  - Use air monitoring equipment:
    - Continuous forced fresh air ventilation must be utilized during each confined space
    - Eliminate any hazardous atmosphere prior to persons entering the space as verified through air monitoring
    - Follow reclassification of confined spaces, if needed
    - Ensure appropriate PPE and on site rescue services are provided/available
    - Debrief & close permit

What are some types of BNSF confined spaces?

- Permit Required:

- Sanitary Sewage Manhole
- Waste Water Grit Chamber
- Equalization Waste Water Tank
- Above Ground Storage Tank

- Non Permit Required:
  - Utility Closets
  - Below Grade Trenches
  - Storage Vaults

Training

- Initial awareness training shall be administered to ensure that all *employees* understand the purpose and function of the confined space program if they perform or supervise employees who perform work near confined spaces
- Employees shall acquire the required knowledge and skills through applicable training/certification required to implement confined space procedures if they will be performing the duties of an attendant, entrant, entry supervisor or rescue team
- Refresher training shall be provided at least every 3 years for all affected employees
- All training shall be documented and include the following:
  - Each employee's name,
  - Date(s) trained,
  - The name of the person(s)/organization conducting the training, and
  - The content of the training.

Reference(s)

- BNSF Confined Space Entry Program (SFTY-1200-4003-02-SYS-1/1/2017)
- FRA 49 CFR 214
- OSHA 1910.146
- OSHA 1926.1201

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE

Core Safety Rules

Purpose

To ensure that each employee understands his or her rights and responsibilities under the Employee Safety Rules applicable to all employees not otherwise covered by craft-specific rules.

Employee Rights and Responsibilities

- Take sufficient time to perform tasks safety
- Perform job tasks only when you have received the training and authorization to complete the tasks
- Assure you are alert and attentive when performing tasks
- Warn co-workers of unsafe working conditions or behaviors
- Comply with all safety rules, mandates, instructions, training practices and policies
- Comply with warnings, whether verbal, written, or posted
- Never complete a task alone that requires two or more people to complete safely
- Conduct yourself in a way that supports a safe environment free of harassment, practical jokes, and horseplay.

Guidelines

- A large part of complying with the rules is being situationally aware. Know whether any hazards are in the area, and do not lose focus.
- Always remember that the railroad is a safe but unforgiving environment. Losing awareness – even momentarily- can result in an accident that leads to a serious injury or loss of life.
- Always approach others about safety!
- Keep in mind that while we all like to have fun at work, horseplay and practical jokes are unprofessional and could lead to a lapse in safety-focus.

Other Corporate Program/Reference

- Safety Rules for Employees: http://depot2.bnsf.com/ops/timetables-and-rulebooks/BNSF%20Safety%20Rule%20Books/Employee%20Safety%20Rules.pdf
- Safety Programs https://employee.bnsf.com/safety/Pages/safety-programs.aspx

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE
FALL PROTECTION

Regulation(s)

- Federal Railroad Administration (FRA) / Title 49 Code of Federal Regulations (CFR); 214.103, 214.105, 214.107, 214.109. The FRA / OSHA standard for Fall Protection. Title 29 Code of Federal Regulations (CFR) Part 1910, 1915 (https://www.osha.gov/SLTC/fallprotection/standards.html) and 1926 (https://www.osha.gov/SLTC/fallprotection/construction.html) and associated sections and subparts contained therein, addresses the practices and procedures necessary for compliance with fall protection while employees or contractors perform servicing and maintenance activities.

Corporate Fall Protection Reference

- https://employee.bnsf.com/safety/Pages/fall-protection-program.aspx

Key Definitions

- Affected Employee: An employee whose job requires them to operate or use a machine or equipment on which servicing or maintenance is performed where there is a risk of fall from a height 4 foot (Ladders, Scaffolds, and Lifts), for FRA Bridge Safety Workers working at a height of 12 (twelve) feet or more, and/or when performing work on building roofs within 6 ft (2m) from roof's edge requires fall protection. An employee is an Affected employee if they are using fall protection equipment, systems and/or procedures, or whose job requires them to work in and area in which such activities are being performed. Most BNSF environmental employees are affected employees.
- Anchor - a secure point of attachment for lifelines, lanyards or deceleration devices
- Competent / Qualified Person: A person who has been trained and explicitly permitted to use fall protection equipment (by possession of recognized degree, certificate, professional training, or by extensive knowledge, training and experience has successfully demonstrated his/her ability to solve or resolve problems related to the subject matter per OSHA: 29CFR 1926.450(b)) in order to perform, construction, service or maintenance. Employees operating or performing maintenance on waste water treatment plants, oil/water separators, storm water treatment systems, and/or remediation systems may be a "Competent Person".
- Deceleration distance - the additional vertical distance a falling employee travels, excluding lifeline elongation and free fall distance, before stopping, from the point at which the deceleration device begins to operate. It is measured as the distance between the location of an employee's body belt or body harness attachment point at the moment of activation (at the onset of fall arrest forces) of the deceleration device during a fall, and the location of that attachment point after the employee comes to a full stop.
- Fall arrest – Designed to stop a worker's fall after descent has begun
- Fall restraint – Secure the worker to an anchor using a lanyard of proper design
- Free fall - the act of falling before a personal fall arrest system begins to apply force to arrest the fall.
- Leading edge - the edge of a floor, roof, or formwork for a floor or other walking/working surface (such as the deck) which changes location as additional floor, roof, decking, or formwork sections are placed, formed, or constructed. A leading edge is considered to be an "unprotected side and edge" during periods when it is not actively and continuously under construction.
- Opening - a gap or void 30 inches (76 cm) or more high and 18 inches (48 cm) or more wide, in a wall or partition, through which employees can fall to a lower level.
- Personal fall arrest system - a system used to arrest an employee in a fall from a working level. It consists of an anchorage, connectors, a body belt or body harness and may include a lanyard, deceleration device, lifeline, or suitable combinations of these.

What is fall protection and why is it performed?

- Fall protection is an umbrella term that encompasses different types of systems and programs; systems that are designed to arrest a free fall, systems that are designed to restrain a worker in a position to prevent him from reaching a fall hazard, and policies that may eliminate fall hazardous. The BNSF Railway will prioritize the elimination of fall protection hazards. If the hazards cannot be eliminated, then employees will be required to use personal fall protection systems. Procedures, systems and equipment are intended to prevent employees from falling off, onto or through working levels and to protect employees from falling objects.

- <u>Fall protection protocol and fall restraint equipment is in place to protect employees from injury</u>.
- It is important to **always** refer to the applicable fall protection standard and procedures for each specific task **before** beginning any construction, service or repair work.

When is fall protection required?

- Tasks and workplaces requiring fall protection are identified during workplace fall hazard surveys, risk assessments, job hazard analysis, etc. These assessments shall consider tasks and circumstances at the work area which might impact the safety of workers while working at heights, fall hazards regardless of height, and working above dangerous hazards.
- Fall protection is required to ensure the safety of workers when there is a risk of fall from a height 4 foot (Ladders, Scaffolds, and Lifts), and FRA Bridge Safety Worker a height of 12 (twelve) feet.
- When performing work on building roofs specifically close to the edge, consult local regulations for the specifics/areas requiring fall protection. Generally, working within 6 ft (2m) from roof's edge requires fall protection.

How is Fall Protection achieved?

- <u>Elimination or substitution</u> – eliminate the hazard or substitute a process, sequence or procedure to eliminate a fall hazard
- <u>Engineering Controls / Passive fall protection</u> – Isolate the potential of falling using, walls, guardrails, handrails or covering floor openings
- <u>Administrative controls</u> – Develop policies, procedures, practices and guidelines to mitigate the risk. Provide training, instruction and supervision to help mitigate the hazard.
- <u>Personal Protective Equipment</u>
  - <u>Fall restraint</u> – Secure the worker to an anchor using a lanyard of proper design
  - <u>Fall arrest</u> – Designed to stop a worker's fall after descent has begun

How do I know what standard to follow; OSHA or FRA?

- <u>Generally ladders are regulated by OSHA</u> – Fixed ladders require fall protection at heights of 24 feet or greater. This includes a single ladder from surface level, as well as shorter ladders that are entirely above 24 feet, such as a series of ladders. New Fixed Ladders higher than 24 feet require a ladder safety system (LSS), or personal fall arrest system that meets all the requirements of 29 CFR 1910.28. Existing Fixed Ladders higher than 24 feet that have a cages or wells will be required by November 18, 2036 to replace the cages or wells with a ladder safety system (LSS) or personal fall arrest system that meets all requirements of 29 CFR 1910.28. New Fixed ladders equipped with a personal fall arrest system or ladder safety system (LSS) shall have rest platforms provided at a maximum intervals of 150 feet.
- <u>Rolling stock carries the FRA exemption</u> - As a best practice, you would not want to tie off to moving equipment unless you were in a safe/reinforced area (similar to a seat belt in a cab) as crushing exposure is generally a more catastrophic risk than falls.
- <u>Railroad Bridges and other structures on railroad property may carry the FRA exemption</u> - FRA requirements apply to on-track locations, such as bridge work, which requires specialized *Bridge Inspector* training. OSHA regulations would not apply to ladders, platforms, and other surfaces on signal masts, cantenary systems, turntables, and similar structures or to walkways beside the tracks in yards or along the right-of- way. FRA will determine the need for and feasibility of general standards.
- <u>Remember</u> - BNSF Railway applies a standardized 4 ft. height limit for fall protection where FRA practices (exemptions and/or height requirements, such as bridges), as well as OSHA exemptions do not apply.

Guidance

- Fall Protection questions/concerns should be directed to your local Manager of Safety or the System Safety email contact at bnsf.safety1@bnsf.com. In case of a fall or near miss, the onsite Supervisor and / or Safety Department Representative will perform a thorough investigation and the findings reviewed to make necessary changes to the Fall Protection practices.

Training

- Initial training shall be administered to ensure that all *affected employees* understand the purpose and function of the fall protection program if they perform, or supervise employees who perform work requiring fall protection equipment to be used in performance of their duties.
- *Authorized employee*s shall acquire the necessary knowledge and skills required to implement energy control procedures.
- Refresher training shall be provided at least every 3 years for all *affected employees* and at least annually for *authorized employee*s.

- All training shall be documented and include the following:
  - Each employee’s name,
  - Date(s) trained,
  - The name of the person(s)/organization conducting the training, and
  - The content of the training.

References

- BNSF Fall Protection Program (SFTY-1200-4005-02-SYS-1/1/2017)
- FRA Track and Rail and Infrastructure Integrity Compliance Manual Volume III – Railroad Workplace Safety Chapter 2 – Bridge Worker Safety Standards (January 2015)

Hazardous Energy Control - Lockout/Tagout (LOTO)

Regulation

- The OSHA standard for The Control of Hazardous Energy (Lockout/Tagout), Title 29 Code of Federal Regulations (CFR) Part 1910.147, addresses the practices and procedures necessary to disable machinery or equipment, thereby preventing the release of hazardous energy while employees perform servicing and maintenance activities. The standard outlines measures for controlling hazardous energies — electrical, mechanical, hydraulic, pneumatic, chemical, thermal, and other energy sources. In addition, 29 CFR 1910.333 sets forth requirements to protect employees working on electric circuits and equipment. This section requires workers to use safe work practices, including lockout and tagging procedures. These provisions apply when employees are exposed to electrical hazards while working on, near, or with conductors or systems that use electric energy.

Corporate Hazardous Energy Control Program (HECP) Reference

- http://depot2.bnsf.com/ops/Safety/HECP/HECP%20Appendices/Hazardous%20Energy%20Control%20Program%20(HECP).pdf

Key Definitions

- Affected Employee: An employee whose job requires them to operate or use a machine or equipment on which servicing or maintenance is performed during Lockout or Tagout, or whose job requires them to work in and area in which such activities are being performed. Most BNSF environmental employees are affected employees.
- Authorized Employee: A person who has been trained and explicitly permitted to lockout and/or tagout machines or equipment in order to perform service or maintenance. Employees operating or performing maintenance on waste water treatment plants, oil/water separators, stormwater treatment systems, and/or remediation systems may be an “Authorized Employee”.
- LOTO-required machines/equipment: Machines or equipment where the unexpected energization, start up or release of stored energy or chemicals could occur and cause personal injury or damage equipment during service or maintenance operations.

What is Lockout/Tagout (LOTO) and why is it performed?

- LOTO is the required procedure of shutting down and locking equipment/tools before repairs or servicing begins to prevent line-of-fire/release-of-energy or pinch point exposures to those working on that equipment. Once the equipment is properly shut down and secured with a lock, a tag is placed along with the lock in a visible location on the machine to let other workers know that it is currently being serviced and who is performing this work.   The lock used by the Authorized Employee should not be a common lock and only the Authorized Employee should have the key.
- Both lockout and tagout are in place to protect employees from injury.
- It is important to **always** refer to the applicable LOTO procedures for each specific piece of equipment **before** beginning any service or repair work.

When is LOTO required?

LOTO procedures must be in place:

- During maintenance, repair, or service of equipment if it could unexpectedly start up, energize, or release stored energy;
- Whenever guards or other safety devices are removed or bypassed; or
- Anytime part of the body is placed in a danger zone during equipment “cycle” or operation.

How is LOTO achieved?

Before beginning any work on equipment, the following steps must be followed to achieve LOTO:

- Obtain and review the LOTO procedures for that specific piece of equipment.
- Notify all affected employees.
- Shut down/de-energize the equipment, using normal controls.

- Apply LOTO devices and/or block energy sources. **Note:** Each person working on the equipment must have his/her own lock with only one unique key. There is no master key.
- Verify isolation.
  - Try out the lockout and test the machine to be sure that lockout procedure is effective.

How does a Hazardous Energy Control Plan (HECP) help protect workers during LOTO procedures?
This written procedure guide lists the steps required to de-energize and apply LOTO to a specific piece of equipment.

- The HECP is usually located at the equipment that requires LOTO.
- All affected personnel must be notified before LOTO is applied and when it is removed.
- Workers should check to ensure that the part of the equipment to be worked on is de-energized. Use a volt meter or manipulate the controls to ensure that no residual energy is in place.
- **Completion:** Inform all affected personnel and follow written procedures when removing LOTO and putting equipment back into service.

What is the difference between Lockout, Tagout and Blockout?

- Lockout refers to the placement of a **lockout device** on an energy-isolating device – such as a circuit breaker, disconnect switch, line valve or block – to prevent the equipment from being energized. This prevents an unexpected surge of energy that could potentially injure an employee.
- Tagout refers to the placement of a written warning device, i.e., a **tag**, stating "Danger – Do Not Operate" that identifies the name and craft of the authorized employee who placed it.
  - The tag is placed on an energy-isolating device to indicate to other workers that the device and equipment being controlled **must not** be operated until the tagout device is removed by the worker who attached it.
- Blockout refers to the placement of a mechanical device or material to block movement so that no movement is possible.

Is it acceptable to work on equipment that is protected by a co-worker's LOTO lock and tag?

- No. Do not rely on a co-worker's lockout/tagout. A worker must place his or her own lock and tag directly on the energy-isolating device and keep the key in their possession while repairing and servicing equipment.
- **Remember:** ONE PERSON. ONE LOCK. ONE LIFE.

What are some types of lockout devices?

- Some of the most common lockout devices include locks, blocks, chains, multi-lock hasps, wheel valve covers and ball valve covers. **Note:** All lockout hardware should be red in color.

What about equipment that will not accommodate a lockout device?

- In cases where a lock is not physically possible, tagout only procedures can be used.
- A supervisor must first verify that lockout cannot be achieved.
- The tag must be placed in the same location that the lockout device would have been attached.
- Other measures – such as removal of a valve handle – must also be used to reduce the likelihood of inadvertent energizing of the machine.

Should LOTO locks be used on non-equipment items?

- LOTO locks should only be used to lock applicable BNSF equipment/tools when required.

When is LOTO not required when servicing or repairing equipment?

- Cord and plug-connected equipment, powered by a single energy source that is unplugged when the plug is under the exclusive control of the employee, does not require LOTO.
- **Note:** Electrical plug lockout devices must be used if and when the plug is not under the immediate, physical control of the employee working on the equipment.

Training

- Initial training shall be administered to ensure that all *affected employees* understand the purpose and function of the energy control program and energy control procedures including the prohibition relating to attempts to reenergize locked out/tagged out machines or equipment.
- *Authorized employees* shall acquire the necessary knowledge and skills required to implement energy control procedures.
- Refresher training shall be provided at least every 3 years for all *affected employees* and at least annually for *authorized employees*.
- All training shall be documented and include the following:
    - Each employee's name,
    - Date(s) trained,
    - The name of the person(s)/organization conducting the training, and
    - The content of the training.

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE
HOT WORK

Hot work is any work that involves burning, welding, using fire or spark producing tools, or that produces a source of ignition. Welding, cutting & grinding operations are common to the RR industry. This can be dangerous in the fact that these operations may cause the surrounding area to catch fire and/or combust and pose hazards to personnel and equipment as well as the community or creating wildfires if it goes uncontrolled. Can occur outdoors or indoors.

Regulation(s)

- Hot Work is basically covered under OSHA Subpart Q (Welding, Cutting & Brazing) 1910.252 requirements. NFPA also has a standard for Hot Work under 51B. Both of these address the practices and procedures necessary to abide by Hot Work requirements while employees or contractors perform servicing and maintenance activities that include welding, cutting, brazing, grinding.

Corporate Hot Work Reference

- Not specifically identified, but various safety policies follow the general requirements – Fire Prevention, Welding, & Cutting, Electrical, Confined Space(s), Right-Of-Way Fires, Bridge Work, Wooden Snowsheds & Tunnels, etc.

Key Definitions

- Fire Watch: An individual posted in specific circumstances by the PAI. The fire watch will observe the hot work and monitor conditions to ensure that a fire or explosion does not occur as a result of the work performed.

- Hot Work: Any work involving welding, brazing, soldering, heat treating, grinding, powder-actuated tools, hot riveting and all other similar applications producing a spark, flame, or heat, or similar operations that are capable of initiating fires or explosions.

- Hot Work Permit: The employer's written authorization to perform operations (for example, riveting, welding, cutting, burning, and heating) capable of providing a source of ignition.

Why the Importance of Hot Work?

- To prevent fires, personnel safety & equipment; while welding, cutting, brazing & grinding there can be many materials nearby that are combustible

Procedures

- All employees and contractors working under BNSF supervision shall comply with the elements of the Hot Work Safety as identified in the appropriate programs (Confined Spaces, Work on Wood Bridges, Tunnels & Snowsheds).

- This program covers welding, brazing, soldering, heat treating, grinding, powder-actuated tools, hot riveting and all other similar applications producing a spark, flame, or heat.

- This program does not cover use of candles, laboratory activities, pyrotechnics or special effects, cooking equipment, electric soldering irons or torch-applied roofing (See NFPA 241).

- All hot work performed by outside contractors shall be in conformance with NFPA 51B at a minimum.

- Hot work operations in confined spaces require additional safeguards and are addressed in the Confined Space Program.

- Hot work on and near building systems and piping may require additional safeguards.

Before beginning any work, the following steps must be followed to safely conduct Hot Work:

- Proper training
- Establish permissible areas for hot work.
- Determine site-specific flammable materials, hazardous processes, or other potential fire hazards present or likely to be present in the work location.
- Ensure that all individuals involved in hot work operations (including contractors) are:
- Trained in the safe operation of their equipment and the safe use of the process. These individuals must have an awareness of the risks involved and understand the emergency procedures in the event of a fire.
- Familiar with this procedure.
- Familiar with site-specific flammable materials, hazardous processes and conditions, and other potential fire hazards.

What are some types of BNSF Hot Work examples?

- Confined Spaces
- Permit Confined Spaces
- Fuel Storage Tank and systems (pumps, piping, etc)
- Electrical rooms
- Generators
- Rooms with combustible materials
- Rail thermite welding

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE

Safe Driving (Company or Rental Vehicle)

Purpose

To ensure the safety of each employee who drives a company or rental vehicle, and provide guidance on proper vehicle use.

General Safety Rules when Operating a Company or Rental Vehicle

- Employees shall operate all vehicles that they use for business safely. All Drivers must:
  - Have a valid state driver's license.
  - Comply with all applicable state and local motor vehicle laws. The vehicle operator is responsible for any traffic citations.
  - Wear seat belts, whether operating or riding as a passenger in the vehicle.
  - Report and participate in the investigation of any vehicle collisions or property damage accidents (reference below BNSF flow chart for reporting instructions)
  - Operate vehicles only when they are in safe operating condition. Each employee shall inspect the vehicle to assure that the vehicle is in sound operating condition.
- Driving on company business and/or driving a company vehicle while under the influence of intoxicants and other drugs (which could impair driving ability) is forbidden and is sufficient cause for discipline, up to and including termination of employment.
- While driving a BNSF owned or rented vehicle (off rail), do not:
  - Use cellular or mobile telephones, or similar hand-held electronic devices for voice communications in other than hands-free mode.
  - Manually enter or read text from cellular or mobile telephones, or similar hand-held electronic devices (e.g. emailing, performing any electronic text retrieval or entry, accessing a web page, etc.).
  - Dial or answer cellular or mobile telephones by pressing more than a single button
  - Use notebook computers, laptops or similar devices. Display screen of such devices capable of being closed must be closed. Devices not capable of closing the screen must be turned off.
- Employees must be aware of and comply with any local, state or federal laws governing use of wireless equipment while driving (e.g., laws banning use of wireless phone while driving).
- No driver shall operate a company vehicle when his/her ability to do so safely has been impaired by illness, fatigue, injury, or prescription medication.
- Drivers are responsible for the security of company vehicles assigned to them. The vehicle engine must be shut off, ignition keys removed, and vehicle doors locked whenever the vehicle is left unattended.

Defensive Driving Guidelines

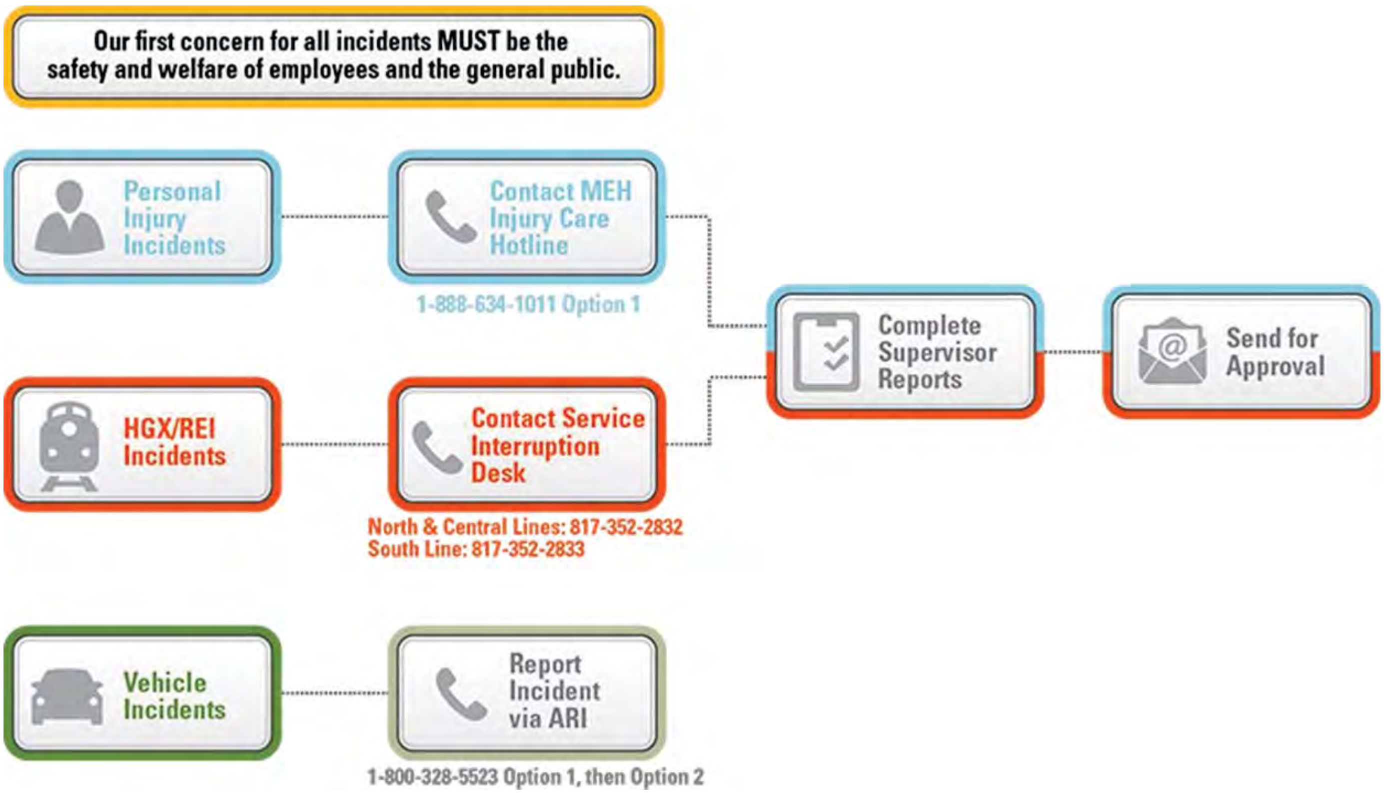
- Drivers are required to maintain a safe following distance at all times. Drivers should keep a two second interval between their vehicle and the vehicle immediately ahead. During slippery road conditions, the following distance should be increased to at least four seconds.
- Drivers must yield the right of way at all traffic control signals and signs requiring them to do so. Drivers should also be prepared to yield for safety’s sake at any time. Pedestrians and bicycles in the roadway always have the right of way.
- Drivers must honor posted speed limits. In adverse driving conditions, reduce speed to a safe operating speed that is consistent with the conditions of the road, weather, lighting, and volume of traffic. Tires can hydroplane on wet pavement at speeds as low as 40 mph.
- Radar Detectors are strictly prohibited in company vehicles.
- Turn signals must be used to show where you are heading; while going into traffic and before every turn or lane change.
- When passing or changing lanes, view the entire vehicle in your rear view mirror before pulling back into that lane.
- Be alert of other vehicles, pedestrians, and bicyclists when approaching intersections. Never speed through an intersection on a caution light. When the traffic light turns green, look both ways for oncoming traffic before proceeding.
- When waiting to make left turns, keep your wheels facing straight ahead. If rear ended, you will not be pushed into the lane of oncoming traffic.
- When stopping behind another vehicle, leave enough space so you can see the rear wheels of the car in front. This allows room to go around the vehicle if necessary, and may prevent you from being pushed into the car in front of you if you are rear-ended.
- Avoid backing where possible, but when necessary, keep the distance traveled to a minimum and be particularly careful.
  - Check behind your vehicle before backing.
  - Back to the driver’s side. Do not back around a corner or into an area of no visibility.

Weather
During inclement weather:

- Slow down.
- Do not use the cruise control.
- Apply traction devices as needed (for example, snow chains).

If requested, or if in your opinion it is unsafe to proceed, pull off the road at a secure location until the weather clears sufficiently to drive.

Other Corporate Program/Reference
BNSF Injury and Accident Reporting Guideline:



Excavation and Trenching

Regulation

The OSHA standard for Excavation, Title 29 Code of Federal Regulations (CFR) Part 1926.650 - .652, addresses the practices and procedures necessary to ensure worker safety in an excavation are adequately protected from cave-ins by an adequate protective system. The standard also addresses other potential hazards including falls, falling loads, hazardous atmospheres and incidents involving mobile equipment. The standards apply to all open excavations made in the Earth's surface, including trenches. Following the requirements of the standards will prevent or greatly reduce the risk of cave-ins and other excavation-related incidents.

Key Definitions

- Excavation: Any man-made cut, cavity, trench, or depression in an earth surface formed by earth removal.
- Trench (Trench excavation): a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth is greater than the width, but the width of a trench (measured at the bottom) is not greater than 15 feet (4.6 meters).
- Competent Person: an individual (generally a professional engineer or other trained and certified person) who is capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous, or dangerous to workers, soil types and protective systems required, and who is authorized to take prompt corrective measures to eliminate these hazards and conditions. Under the Excavation standards, tasks performed by the competent person include: classifying soil; inspecting protective systems; designing structural ramps; monitoring water removal equipment; and conducting site inspections.

Trench Safety Measures

Trenches 5 feet (1.5 meters) deep or greater require a protective system unless the excavation is made entirely in stable rock. If less than 5 feet deep, a competent person may determine that a protective system is not required. Trenches 20 feet (6.1 meters) deep or greater require that the protective system be designed by a registered professional engineer or be based on tabulated data prepared and/or approved by a registered professional engineer in accordance with 1926.652(b) and (c).

General Trenching and Excavation Rules

- Keep heavy equipment away from trench edges.
- Identify other sources that might affect trench stability.
- Keep excavated soil (spoils) and other materials at least 2 feet (0.6 meters) from trench edges.
- Know where underground utilities are located before digging.
- Test for atmospheric hazards such as low oxygen, hazardous fumes and toxic gases when > 4 feet deep.
- Inspect trenches at the start of each shift.
- Inspect trenches following a rainstorm or other water intrusion.
- Do not work under suspended or raised loads and materials.
- Inspect trenches after any occurrence that could have changed conditions in the trench.
- Ensure that personnel wear high visibility or other suitable clothing when exposed to vehicular traffic.
- A means of egress, including a stairway, ladder ramp or other safe means of egress shall be located in trench excavations that are 4 feet (1.22 meters) or more in depth so as to require no more than 25 feet (7.62 meters) of lateral travel for employees.
- Emergency rescue equipment, such as breathing apparatus, a safety harness and line, or a basket stretcher, shall be readily available where hazardous atmospheric conditions exist or may reasonably be expected to develop during work in an excavation. This equipment shall be attended when in use.
- All non-essential personnel should refrain from standing near the edges of an open excavation.

Protective Systems

There are four different types of protective systems (see attached OSHA Quick Card).

- **Benching** means a method of protecting workers from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near vertical surfaces between levels. *Benching cannot be done in Type C soil.*

- **Sloping** involves cutting back the trench wall at an angle inclined away from the excavation.

- **Shoring** requires installing aluminum hydraulic or other types of supports to prevent soil movement and cave-ins.

- **Shielding** protects workers by using trench boxes or other types of supports to prevent soil cave-ins.

Designing a protective system can be complex because you must consider many factors: soil classification, depth of cut, water content of soil, changes caused by weather or climate, surcharge loads (e.g., spoil, other materials to be used in the trench) and other operations in the vicinity.

Additional Information

Visit OSHA's Safety and Health Topics web page on trenching and excavation at
www.osha.gov/SLTC/trenchingexcavation/index.html
www.osha.gov/dcsp/statestandard.html

Working Around Auger Drilling Rigs

Regulation

OSHA does not have specific guidance directed at working around auger drilling rigs; however OSHA defines minimum clearances for cranes and derricks around overhead power lines in 29 CFR 1926.1408. For further clarification of clearance zones when working around overhead power lines and minimum expectations, please review the Quick Reference Guide titled *Clearance Zones around Overhead Power Lines*. The National Groundwater Association has published the *Environmental Remediation Drilling Safety Guideline,* which can be downloaded at http://www.ngwa.org/Documents/erdsg.pdf.

Other Corporate Program/Reference:

Safety Topics – Crane and Boom Operations:
https://bnsfrailway.sharepoint.com/teams/SafetyCommunications/SafetyCommLibrary/crane-and-boom-operations-mw.pdf

Key Definitions

- Exclusion zone for drilling rig: the area 360 degrees around the equipment, up to the equipment's maximum mast height.

General Safety Rules when Operating around Auger Drilling Rigs

- To the extent practical, the location sited for the boring should be level ground with clearly identified means of entry and egress, well ventilated, and clear of surface obstructions such as large rocks, fallen trees, loose pipes or isolated equipment.

- Prior to initiating drilling activities, the contractor should initiate a utility locate through the state-specific One-Call utility clearance service. Typically, the service can be contacted by dialing 8-1-1. Additionally, if making subsurface penetrations on BNSF property (e.g. soil borings, monitor well installations, trenching, test pits, gross excavation), BNSF signals and telecommunication departments should be notified by dialing (817) 593-4357 and following the prompts. A tile probe should be used at each location to test for unknown obstructions. If a tile probe is not available, an air-knife or water-jet can be used to clear the first few feet of soil to check for subsurface obstructions. The hole should be cleared to 120% of the diameter of the largest tool used for drilling to clear tangential structures. Drilling should proceed cautiously through the first ten (10) feet of the soil column.

- Before raising the mast, look up to check for overhead obstructions. The contractor must assume that all power lines are energized unless the utility owner/operator confirms that the power line has been and continues to be de-energized and visibly grounded at the worksite.

- Determine if any part of the equipment, load line or load (including rigging and lifting accessories), if operated up to the equipment's maximum working radius or height in the work zone, could get closer than 20 feet to a power line. If so, the operator must meet the requirements outlined in the Quick Reference Guide titled *Clearance Zones around Overhead Power Lines*.

- As part of the safety tailgate meeting, each crew member and observer should be shown how to shut-down the rig in an emergency, and where the fire extinguisher, blood-borne pathogen kit, and first-aid kit are located.

- In high-traffic areas, the work area around the rig should be cordoned off with either barricades or traffic cones, spaced far enough away from the rig that the driller and crew are allowed to work unimpeded, yet close enough to prevent by-standers from entering the work area. In areas of particularly high frequency traffic (e.g. intermodal facilities), a traffic control plan may be warranted and personnel should wear high-visibility workwear.

- Tools, materials, and supplies should be stored so that work can proceed in an orderly fashion, with sufficient room in the work area to move about without tripping hazards being present. Equipment should not be stored in places that would interfere with escape routes in an emergency.

- Work areas, platforms, walkways and other access-ways should be kept free of obstructions such as materials and tools, and substances such as debris, grease, ice, and mud, in order to minimize the tripping, slipping and falling hazards around the drill rig.

- During active operations, only the driller and crew should be positioned within the exclusion zone, defined as the area with a radius of at least one mast length around the rig. The geotechnical work station should be positioned outside of this exclusion zone and all observers should remain outside the exclusion zone during active operation.

- When completing drilling in support of environmental investigations, all crew members should don the appropriate PPE and minimize contact with soil, sediment, groundwater or known contaminants (e.g. NAPL).

- Workers should never be positioned underneath an overhead or suspended load (i.e. on a crane or boom).

- Augers should only be cleared of cuttings with a shovel or other tool. Never reach into a rotating auger to clear cuttings by hand.

- In the event of inclement weather (rain, sleet, snow), drilling should cease. In the event of an electrical storm, drilling should cease when thunder or lightning or within five (5) miles of the drilling location. All workers must shelter away from the drilling rig. If possible the mast should be lowered.

- All open boreholes should be covered and protected or backfilled adequately and according to local and state regulations on completion of the drilling.

- Never move between boring locations with the mast extended. The mast should be lowered and all augers, rods, tools, and equipment properly stored before moving the rig between boring locations.

- Prior to demobilization, verify all waste materials has been removed from the site or are properly contained, labeled and scheduled for pickup.

ENVIRONMENTAL DEPARTMENT QUICK REFERENCE GUIDE
WORKING AROUND TRACK AND IN YARDS

Regulation(s)
- FRA Track and Safety Compliance Manual, Volume 3

Corporate Rule
- Employee Safety Rules S1.6.2, S13.1

Key Definitions
- Fouling Track - Fouling a track means the placement of an individual in such proximity to a track that the individual could be struck by a moving train or other on-track equipment, or in any case is within four feet of the nearest rail. FRA

Procedures

- Employees are prohibited from fouling a track, including in a yard, except when duties require it and safeguards are utilized.
- Always conduct a safety briefing before doing work near tracks and when tasks or situations change.
- Know your track protection!
- Always ask yourself: **Do I need to foul the track? Is it safe to foul the track? How do I determine if it is safe to foul the track?**

- When crossing or fouling tracks:
  - **Do not cross within 25 feet of the end of standing equipment** unless the appropriate protection has been established.
  - **Do not cross in front of approaching equipment** unless you are sufficiently ahead of the equipment to cross safely.
  - **Do not walk between rails or foul the track,** except when duties require and proper protection is provided. Use caution during bad weather and when visibility is impaired.
- When crossing over rail equipment, such as locomotives or cars:
  - Obtain positive confirmation that the equipment will not be moved.
  - Cross only through cars with a crossover platform and preferably with handholds.
  - Do not step on the coupler or uncoupling lever.

- Always identify exposures and look to minimize risks when working around track. It is important to consider and identify exposures present for a given task. While there are multiple exposures present when duties require fouling a track, some of the most common are listed below and should be covered during the safety briefing.

Line of Fire/Release of Energy

- When working near tracks, only walk between rails or foul the track when duties require.
- Before fouling track, determine whether it is safe to do so.
- If the track is occupied, ensure the appropriate protection has been provided for the task to be performed.
- Be aware of your surroundings at all times (including movement on adjacent tracks) to ensure that you are not in the line of fire from unexpected movement.
- Verify tracks intended for railcar or engine movement are clear of obstructions before removing the appropriate protection to allow the movement.

Life-Saving Processes

- When working near track, always remember to follow and use the most critical procedures and brief with co-workers about these procedures.
- When parking or spotting equipment next to tracks, use the clearance lines to ensure equipment is parked a safe distance from the track.

Ascending/Descending

- Use caution when stepping off equipment to avoid stepping into the foul of an adjacent track. Never get on or off moving equipment, except in an emergency to prevent injury.

Walking/Path of Travel

- Conditions such as weather, lighting and range of vision can affect your safe path of travel or the ability to visually check all equipment. For example, equipment can appear to be farther away than it actually is during periods of darkness. Snow and rain can obscure vision, and create slip, trip or fall hazards.

- To minimize risk when working near track:
    - Remain alert and attentive. **Always expect the movement of trains, locomotives, cars or other equipment at any time, on any track and in either direction.**
    - Look in both directions, watch for moving equipment on adjacent tracks, and cross in front of approaching equipment only when sufficiently ahead of the movement to do so.
    - Don’t lose focus of movement on adjacent tracks.

ATTACHMENT L

COVID-19 GUIDELINES FOR FIELD ACTIVITIES AND SCREENING QUESTIONNAIRE

COVID-19: BNSF Onsite Safe Work Practices

The safety and well-being of our employees, the clients we serve and the community at large is of the utmost importance to TRC. Our Corporate and Environmental Sector leadership and safety teams closely monitor the COVID-19 situation via information from the Center for Disease Control (CDC), World Health Organization (WHO) and various state and local agencies – these internal safety support groups provide daily status and policy updates to all TRC staff. We are confident that we can pre-screen our staff before they enter your facility and maintain proper social distancing to prevent transmission of COVD-19 in either direction.

Our current standard pre-screening actions consist of:

- We confirm that no TRC employees have traveled to a CDC Warning Level 3 country within the 2 weeks prior to each field project, and travel outside the US has been restricted until further notice.
- We confirm on a daily basis that no TRC employees exhibit COVID-19 symptoms.
- We ask our staff to complete daily pre-work temperature checks. Any employee with a temperature greater than the CDC threshold of 100.4°F or who feels ill is immediately sent home to self-quarantine and seek immediate care and may not return to work for at least 14 days or until cleared by a health professional. If the employee is assigned to a field project away from their home office, they are immediately sent to the hotel to self-quarantine and contact their personal healthcare provider ASAP. The same return-to-work criteria applies. In both cases, the TRC Safety Leadership and our HR staff are notified for additional support as needed.
- Our TRC offices are broadly distributed across the continental US – 90% of domestic sources are located within an eight hour drive of one of our offices. As such, we can continue to cost-effectively deliver resources to your facility if domestic air travel is restricted or becomes problematic.
- We ask our staff to document daily who and when contact has occurred with on-site personnel should the need arise for future exposure notifications.

TRC will not send staff to a location where they may be exposed to COVID-19. Before we arrive on-site, we will ask you to confirm that there have been no cases of COVID-19 at the facility and that there is no risk of exposure to our staff.

While at your facility:

- We ask that any pre-work safety meetings be conducted virtually or in groups smaller than 10 people following social distancing practices.
- We will continue the daily temperature checks described above.
- We make review of corporate best-practices related to COVID-19 part of our daily tail-gate meeting.
- We ask that any communication with staff at your facilities be conducted either electronically or in a location outside the vehicle where proper social distancing can be maintained.
- Our field staff will communicate amongst themselves, the home office and your staff, as necessary by either cell phone or radio.
- We request that lavatory or portable toilet facilities with soap and hot water for hand-washing or hand sanitizer dispenser be available for our staff. If this is not feasible, please advise us.

If you have any questions regarding our approach to performing work safely at your facility, please don't hesitate to contact your project manager or Kari Means at (512) 589-9944.

1. ASSESSING FIELD ACTIVITIES FOR COVID-19 RISK

Following TRC's health and safety management system, work activities should be assessed to identify possible hazards and the precautions necessary to mitigate risk to an acceptable level, including risks associated with COVID-19. TRC is following the US Occupational Safety and Health Administration's (OSHA) risk assessment guidance for COVID-19. Project-specific controls that are developed through the risk assessment process must be communicated to project employees and also listed in the project Health and Safety Plan.

1.1. Risk Assessment

To determine appropriate precautions, OSHA has divided job tasks into four risk exposure levels: very high, high, medium, and lower risk. The majority of TRC's work is considered Low risk.

- **Very High:** Exposure risk jobs are those with high potential for exposure to known or suspected sources of COVID-19 during specific medical, postmortem, or laboratory procedures. Workers in this category include healthcare workers and healthcare or laboratory personnel collecting or handling specimens from known or suspected COVID-19 patients.
  - **Precautions:** TRC does not engage in Very High-risk work.
- **High:** Exposure risk jobs are those with high potential for exposure to known or suspected sources of COVID-19. Workers in this category include healthcare delivery and support staff (e.g., doctors, nurses, and other hospital staff who must enter patients' rooms) exposed to known or suspected COVID-19 patients.
  - **Precautions:** TRC does not engage in High-risk work.
- **Medium:** Exposure risk jobs include those that require frequent and/or close contact with (i.e., within 6 feet of) people who may be infected with COVID-19, but who are not known or suspected COVID-19 patients. In areas without ongoing community transmission, workers in this risk group may have frequent contact with travelers who may return from international locations with widespread COVID-19 transmission. In areas where there is ongoing community transmission, workers in this category may have contact be with the general public (e.g., in schools, high-population-density work environments, and some high-volume retail settings).
  - **Precautions**
    - Continue to follow the CDC's guidelines for social distancing and hand hygiene.
    - Where appropriate, limit client and third-party access to the worksite or restrict access to only certain workplace areas.
    - Consider strategies to minimize face-to-face contact (e.g., drive through windows, phone-based communication, telework).

- Employees and Project Managers with medium exposure risk may need to wear some combination of gloves (i.e., nitrile), a face mask (or ½ mask tight-fitting respirator), and/or a face shield or goggles. PPE ensembles for workers in the medium exposure risk category will vary by work task, the results of the hazard assessment, and the types of exposures workers have on the job.

- **Lower:** Exposure risk (caution) jobs are those that do not require contact with people known to be, or suspected of being, infected with COVID-19 nor frequent close contact with (i.e., within 6 feet of) the general public. Workers in this category have minimal occupational contact with the public and other coworkers.
  - **Precautions** – While OSHA does not recommend specific controls for Low-risk work, TRC will continue to follow the CDC's primary precautions including social distancing and hand hygiene.

1.2. Best Practices

TRC has identified additional best practices that can be used to further mitigate potential exposure to COVID-19. In addition, the CDC's COVID-19 guidelines which include social distancing and hand hygiene, the following options should be considered.

- **Travel**
  - Drive in separate vehicles
    - If vehicle has two passengers, both passengers should wear face coverings
  - Consider completing tasks alone
  - Sanitize your hands after using the fuel pump
  - Sanitize interior surfaces of rental vehicles
  - Driving instead of flying
- **Project Sites**
  - Use disposable chemical resistant gloves (i.e., nitrile) when disinfectant wipes are not available
  - Schedule work during "off hours" when less people are around
  - Wait until 3 days after last person left the area, if possible
  - Wear a face covering if you can't work alone
  - Consider using a ½ mask tight-fitting respirator when N95 masks are not available (if deemed appropriate)
  - Contact clients via telephone or video conference instead of face-to-face meetings

- **Construction sites**
  - Avoid "tailgate meetings" or "water cooler meetings" without following social distancing protocols
  - Avoid sharing pens/pencils
  - Safety Meetings should be held in groups of 10 or less and should observe 6' personal distance
  - Face coverings are recommended to be worn by TRC and their subcontractors
  - Stagger lunch times to minimize social gatherings; consider eating in separate areas
  - All lunch waste, bottles and cans should be disposed of immediately after use
  - Never share PPE (hard hats, high visibility vests, personal floatation device, safety glasses, etc.
  - Avoid community coffee pots in field offices
  - Provide disposable paper cups at drinking stations
  - Wear gloves when operating equipment and if possible, limit one operator to a piece of equipment. Sanitize controls after use
  - No sharing hand tools
  - Set up hand cleaning or sanitizing stations at various locations on the site, ideally near port-o-lets
  - Put your clothing directly in the washing machine at the end of shift
  - Limit number of workers in confined spaces as much as possible
  - Use telephones or Teams meetings to avoid face-to-face meetings when possible

2. SYMPTOMS AND PRECAUTIONS FOR COVID-19

2.1. Background

The 2019 novel coronavirus, or COVID-19, is a new respiratory virus first identified in Wuhan, Hubei Province, China. It's called a "novel" — or new — coronavirus, because it is a coronavirus that has not been previously identified.

Both the COVID-19 and influenza (flu) are respiratory illnesses, which have similar symptoms. Both are contagious and both can be mild or severe, even fatal in rare cases. The key difference between the novel coronavirus and influenza is we know what to expect from the flu.

2.2. Symptoms and Steps to Follow If You Develop Symptoms

Symptoms and Warning Signs	Take the following steps
Symptoms may appear **2-14 days after exposure** to the virus. People with these symptoms may have COVID-19: • **Cough** • **Shortness of breath** • **Fever, equal to or** greater than 100.4°F (38.0°C) • **Chills** • **Repeated shaking with chills** • **Muscle pain** • **Headache** • **Sore throat** • **New loss of taste or smell** This list is not all inclusive. Other less common symptoms have been reported, including gastrointestinal symptoms like nausea, vomiting, or diarrhea.	1. Notify your field and direct supervisor that you feel ill. 2. Supervisor shall notify Office Practice Leader/Practice Leader, Mike Glenn (949-697-7418), and your HR Business Partner immediately. 3. Immediately isolate yourself and return to your place of lodging (return home if nearby). 4. Contact your personal healthcare provider asap (consider using the Cigna app) for evaluation and follow their instructions. 5. Update your field and direct supervisor of your health and work status (e.g., when do you expect to return to work). 6. If you're diagnosed with COVID-19 notify Mike Glenn (949-697-7418) and your HR Business Partner immediately. This communication will be treated as confidential.
If you develop any of the following **emergency warning signs:** • **Trouble breathing** • **Persistent pain or pressure in the chest** • **New confusion** • **Inability to wake or stay awake** • **Bluish lips or face** This list is not all inclusive so please consult with your medical provider for further guidance.	1. Get medical attention immediately. 2. If you're diagnosed with COVID-19, notify Mike Glenn (949-697-7418) and your HR Business Partner immediately. This communication will be treated as confidential.

Source: CDC COVID-19 Symptoms https://www.cdc.gov/coronavirus/2019-ncov/about/symptoms.html

2.3. COVID-19 Self-Quarantine and Return to Work Process

- The SVP, Director of Corporate EHS and/or the Director, Corporate EHS and Compliance will facilitate a self-quarantine and return to work process for employees that have been impacted by the COVID-19. Employees will be placed into one of three categories based on their exposure to the pandemic.
  - **Category 1:** Employee reporting symptoms and/or receives negative test result of COVID-19.
  - **Category 2:** Employee suspects exposure to COVID-19 but does not develop symptoms.
  - **Category 3:** Employee receives a positive test for COVID-19.
- No matter the category all employees shall notify a member of the Corporate EHS Team regarding the development of symptoms, suspected exposure or positive test. Upon notification to the Corporate EHS Team will notify HR and work the employees Supervisor/Project Manager to make appropriate client notifications.
- Employees of each category will be required to quarantine for the appropriate amount of time based on the medical opinion of a third-party medical provider and the best available guidance from government agencies such the Center for Disease Control (CDC).
- Prior to returning to work after a quarantine has been issued to an employee, the employee shall receive a medical clearance from his/her third-party medical provider and provide a copy the Corporate EHS Team. Examples for each category are listed here:
  - **Category 1:** Employee must receive clearance to return to work from third party medical provider (WorkCare is an option for employees).
  - **Category 2:** Employee can return work following quarantine period of 14 days provided they remain symptom free. Telephonic healthcare provider such as WorkCare may be optional.
  - **Category 3:** Recovered employee, must be symptom free without medication for at least 72 hours and at least 10 days from initial symptoms, provides Safety and HR clearance from third party medical provider prior to returning to work.

2.4. Transmission

COVID-19 can be spread from person to person through droplets caused by an infected person coughing, sneezing or talking and can be spread by an infected person for several days before their symptoms appear.

2.5. Precautions

- Wear face coverings in settings where social distancing measure are difficult to maintain.
- Practice Social Distancing
    - Practice social distancing by avoiding large gatherings and maintaining distance (approximately 6 feet) from others when possible.
    - Do not share eating or drinking utensils, avoid close conversation, and other direct physical contact like hand shaking. “Close contact” does not include activities such as walking by a person or briefly sitting across an office.
- Hand Hygiene
    - According to the CDC, washing hands with soap and water is the best way to get rid of germs in most situations. If soap and water are not readily available, you can use an alcohol-based hand sanitizer that contains at least 60% alcohol. You can tell if the sanitizer contains at least 60% alcohol by looking at the product label.
- Practice good respiratory hygiene – covering mouth and nose when coughing or sneezing, using tissues and disposing of them correctly.
- Obtain immunizations recommended by healthcare providers to help avoid disease.
- Early self-isolation of those feeling unwell, feverish and having other symptoms of flu.
- Avoiding touching your eyes, nose or mouth.
- Frequently disinfect all areas that are likely to have frequent hand contact (like doorknobs, faucets, handrails).

2.6. Client Meetings/Interactions

Be aware of any restrictions or requirements that clients have in place regarding visiting client facilities or attending meetings. Verify with supervisor/project managers prior to visiting client facilities or meetings in person.

The safety of our employees and their families, subcontractors, clients, and visitors is TRC's highest priority. As the COVID-19 pandemic continues to evolve and spread, TRC will continue to monitor the CDC, WHO, and local agencies in order to provide up-to-date information to protect all of those in our community.

To prevent the spread of COVID-19 and reduce the potential risk of exposure to our employees, subcontractors, and visitors, we request all personnel involved with on-site project-related work complete this assessment questionnaire. This questionnaire will be completed upon arrival to the jobsite and prior to conducting any job-related tasks. Your participation is important to help us take precautionary measures to protect you and everyone on our team.

Date: ______________________________

Name: ______________________________

Company/Organization: ______________________________

Email Address: ______________________________

Phone Number: ______________________________

Project Name: ______________________________

1. Do you have signs of a fever or measured temperature above 100.4°F or greater, a dry cough, tiredness, or trouble breathing within the past 72 hours?

   ☐ Yes ☐ No

2. Have you had "close contact" with an individual diagnosed with COVID-19? "Close contact" means living in the same household as a person who has tested positive for COVID-19, caring for a person who has tested positive for COVID-19, being within 6 feet of a person who has tested positive for COVID-19 for 15 minutes or more, or coming in direct contact with secretions (for example, sharing utensils or being coughed on) from a person who has tested positive for COVID-19 while the person was symptomatic.

   ☐ Yes ☐ No

3. Have you, or anyone inside your residence been exposed to someone else who is currently being quarantined by a doctor or a local public health official?

   ☐ Yes ☐ No

Be aware that your client may have additional requirements as well. Please consult the COVID-19 Client Documents on TRCNet to review your client's guidance. Only personnel who answer "No" to all questions listed above will be granted site access. **Copies of completed questionnaires are to be maintained onsite with the HASP and project documents. If the answer is "Yes" to question 1, please contact your Supervisor, Office Practice Leader/OPL, Mike Glenn, and your HR Business Partner.**

ATTACHMENT M

BNSF ENVIRONMENTAL SAFETY
AND JOB BRIEFING TEMPLATE

MY SAFETY ↔ MY LIFE ↔ MY RESPONSIBILITY

ENVIRONMENTAL DEPARTMENT / JOB SAFETY BRIEFING

(DATE/LOCATION/MANAGER): JOHN MICHAEL LEASE (JML) SITE

WORK PLANNED FOR TODAY (NEW BRIEFING REQUIRED DAILY – REBRIEFING REQUIRED WHEN RISKS/CONDITIONS CHANGE):

☐ **Stop Work Authority**: You have obligation and authority to report an unsafe situation to the Safety Officer / Project Manager

Weather:

Temperature (F):	**Wind Speed / Gusts:**	**Wind Direction:**
Conditions (current/predicted):		**Humidity:**

IS THERE AN APPLICABLE JSA TO BE REVIEWED: ***YES, see HASP***

EXPOSURES: Which of the five EXPOSURES are present for the work to be performed? How do we control/mitigate the RISKS to the EXPOSURES?

1. LIFE SAVING PROCESSES – Confirm location of life-saving resources and key assignments on the table below. Identify the greatest risk(s) to life in planned work and method of mitigating risk(s) in lines below. Capture additional notes on back of form.

Closest Hospital Name/Address/Phone: Cascade Medical Center Emergency Room 817 Commercial St, Leavenworth, WA, 98826		**Work Site Address:** Right-of-way adjacent to 5640 Sunset Highway Cashmere, Washington, 98815	
Emergency Meeting Location/Evacuation Route:			
Location of Emergency Equipment:	**First Aid Kit:** TRC vehicle	**Fire Extinguisher:** TRC vehicle	**Eye Wash:** TRC vehicle
Assignments:	**CPR:**	**First Aid:**	**Call 911:**

RISKS/MITIGATION:

2. WALKING/PATH OF TRAVEL – Review primary path(s) of travel for planned work. Identify any risks along the path(s) of travel (e.g. rail, ties, loose gravel, steep slopes, and heavy veg.) and method to avoid or mitigate risk(s) noted in lines below. Capture additional notes on back of form.

RISKS/MITIGATION: ____

____

3. Line of Fire/Release of Energy – Review work area for potential Line(s) of Fire/Release of Energy. Identify position(s) or location(s) to avoid being hit, cut/struck, or sprayed if something shifts, moves, releases, or travels unexpectedly. Capture additional notes on back of form.

RISKS/MITIGATION: ____

____

4. PINCH POINTS – Review work area for potential pinch point(s). Identify methods of mitigating risk(s) in lines below. Capture additional notes on back of form.

RISKS/MITIGATION: ____

____

5. ASCENDING/DESCENDING – Review work area for potential areas of ascending or descending, paying particular attention to ladders, steps, and steep slopes. Identify methods of mitigating risk(s) in lines below. Capture additional notes on back of form.

RISKS/MITIGATION: ____

____

REBRIEFING REQUIRED – Identify circumstances requiring a rebriefing:

CIRCUMSTANCES: ____

____

ADDITIONAL REFERENCES/POTENTIALLY REQUIRED BRIEFINGS

☐ Permit Programs (Confined Space, Hot Work)	☐ Clearance Zones (overhead lines, water bodies, utility clearance, overhead work)
☐ On track safety & expecting locomotive/car movement at any time (see below)**	☐ Hazardous Energy Control Program
☐ Fall Protection / Elevated Work	☐ Vehicle Safety / Traffic Patterns
☐ Chemical Handling/Transfer	☐ Spill Response
☐ Chemical / Other Exposure Safety	☐ Task Specific PPE
☐ Adjacent work activity	☐ Walking & Working Surfaces / Slips,Trips, Falls
☐ Unsafe behaviors	☐ Approaching Others / Behavior Based Safety
☐ Tools / Equipment	☐ Other

BNSF

MY SAFETY ↔ MY LIFE ↔ MY RESPONSIBILITY

IF "ON TRACK SAFETY" WAS CHECKED ABOVE PLEASE COMPLETE BELOW:

Type of track:	☐ Controlled	☐ Non-Controlled	Track Speed:	Confirm Type of Protection (BLUE or RED) with Roadmaster:
Working Limits:	Track Number(s):		Track Limits: _______ to _______	Time Limits: _______ to _______
Adjacent Track Protection:	☐ YES	☐ NO	Track Limits: _______ to _______	Time Limits: _______ to _______
Employee In Charge (EIC):	Name:			Cell Phone:

FLAGMEN OR LOOKOUT (*MUST SERVE NO OTHER WORK ROLE*):________________________________

TRAIN APPROACH WARNING:________________________________

CLEARING TIME/SIGHT DISTANCE:________________________________

EVACUATION AREA:________________________________

Additional Personal Protective Equipment (PPE)

PPE required for job:	☐ Level A	☐ Level B	☐ Level C	☐ Level D

☐SCBA	☐Supplied Air Respirator	☐Air Purifying Respirator FF (Cartridge type):	
☐Fully-Encapsulated Suit	☐Coverall (type):	☐Air Purifying Respirator HF (Cartridge type):	
☐Boots:	☐Ear Plugs	☐Glove (Inner):	☐Safety Glasses
☐Boot Covers	☐Ear Muffs	☐Glove (Outer):	☐Chemical Goggles
☐FRC/Bunker Gear	☐PFD	☐Hard Hat	☐Face Shield
☐Com. Device:	☐Traffic Cones/Signs	☐Reflective Vest	☐Tension Straps/Tie-Down/Tarp
☐Bonding and Grounding	☐LOTO	☐Chem-Resistant Apron	☐MSDS
☐Harness/Lanyard	☐GFCI	☐Barrier Cream	☐Eye Wash
☐Evacuation Plan	☐Ventilation:	☐Decon Station/Response Zones established and clearly identified	

DEBRIEFING NOTES – What went well today? What do we need to improve or change?

____

____

CONCERNS TO BE ADDRESSED – Who will address the concerns raised and by when?

____

Reminder: As conditions change, be certain to rebrief with all workgroups

Led by:________________________________

Attendees Initials Below:

ATTACHMENT N

BNSF UNDERGROUND CABLE LOCATION AND ACKNOWLEDGEMENT FORM

BNSF Railway
Underground Cable Location & Acknowledge

Date: ________________ Project: ________________

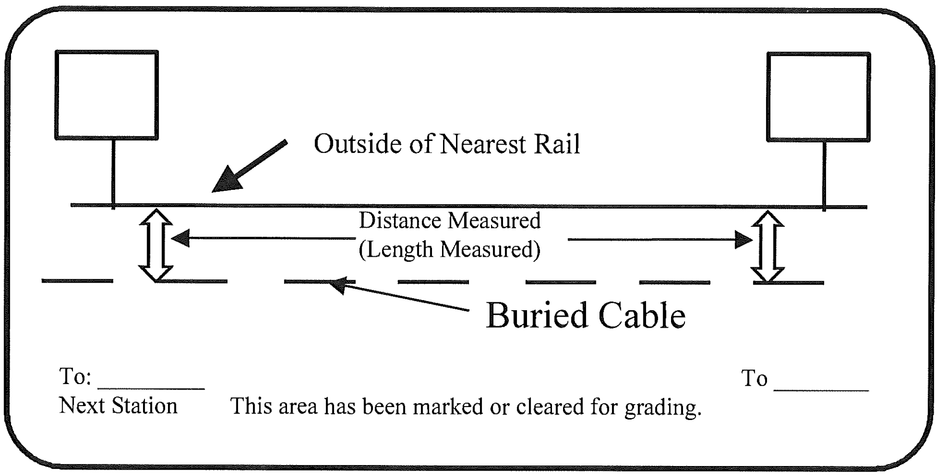
Meeting Location: ____________________ Time: ______________

Attendees at proposed work-site (Signature of representative)

☐ BNSF Signal ____________________ ☐ Grading Contractor ______________

☐ Project Inspector ____________________ ☐ Flag person on duty ______________

No grading will be permitted in this area without this completed form in the possession of the above.



This area has been marked or cleared for grading.

Notes:

All signal cables must be marked with paint and flags (as ground conditions permit) prior to any grading.

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 Revision March 1, 2001

Appendix C

Deliverable Review Form

Deliverable Review Form

Project Name: Glacier Park East **Review Date:** *9/30/2020*

Deliverable Name: Supplemental Remedial Investigation Work Plan **Response Date:** *10/26/2020*

Deliverable Review					Response		
Comment No.	Reviewer Name	Page, Figure, Specification or Sheet No.	Section / Paragraph	Reviewer's Comment	Responder Name	Response Comment	Resolved?
1		Appendix A	5.3	*Quality Assurance Project Plan and Sampling and Analysis Plan – Specifies the use of sonic drilling, which Ecology concurs with. However, please include heat observations in the soil boring logs to allow interpretation of potential effects of drilling on subsurface contamination*		Relative temperatures will be noted on boring logs.	Yes
2			6.3	*The last sentence in paragraph two currently states: "If petroleum-impacted soil is identified via visual or field screening methods, the soil borings will be advanced to the depth where petroleum-impacted soil is no longer observed, or to the maximum anticipated depth." These borings should be drilled until petroleum-impacted soil is no longer observed or until groundwater is reached, whichever is shallower.*		If petroleum impacted soil is identified in borings prior to the target depth, borings will be advanced to the depth where petroleum impacted soil is no longer observed or until groundwater is encountered, which ever is shallower.	Yes
3		General Comment by Ecology		*The sRIWP does not address delineating the southern edge of the groundwater contamination located at MW-3. This remains a data gap that must be addressed prior to the supplemental Feasibility Study.*		BNSF understands Ecology's comment with regard to the groundwater plume delineation. However, the scope of work outlined in the SRI WP is intended to provide information on groundwater hydrogeology and flow direction, which is critical in determining potential offsite locations for additional groundwater sampling points or monitoring wells.	