Norfolk Southern Railway Company

Main Line Interim Soil Removal Plan

February 3, 2023
Derailment
East Palestine, Ohio

May 16, 2023

Version 4.2

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Version Control

Revision No.	Date Issued	Description
0.0	March 2, 2023	Main Line Interim Soil Removal Plan
	April 7, 2023	Main Line Interim Soil Removal Plan Addendum for Areas 3 and 4
1.0	April 19, 2023	Main Line Interim Soil Removal Plan, Amendment 1
2.0	April 21, 2023	Main Line Interim Soil Removal Plan, Amendment 2
	April 21, 2023	Addendum for the North Ditch and Burn Pits 1 and 2
3.0	April 24, 2023	Main Line Interim Soil Removal Plan, Amendment 3
4.0	April 26, 2023	Main Line Interim Soil Removal Plan (submitted for review; superseded by Revision 4.1 before completion of review)
4.1	May 8, 2023	Main Line Interim Soil Removal Plan
4.2	May 16, 2023	Main Line Interim Soil Removal Plan

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1 Introduction

This Main Line Interim Soil Removal Plan was developed on behalf of Norfolk Southern Railway Company (NSRC) by Arcadis U.S., Inc. (Arcadis) in response to the derailment in East Palestine, Ohio (Site; **Figure 1**) and pursuant to the United States Environmental Protection Agency (USEPA) February 21, 2023, Unilateral Administrative Order for Removal Actions (UAO). Specifically, this Plan was developed to summarize the methodology to excavate the railroad right-of-way and adjacent areas to provide interim removal of principal threat waste. This Plan incorporates information that was provided in the following previously submitted plans for incorporation into this one comprehensive document:

- March 2, 2023 Main Line Interim Soil Removal Plan – Approved by USEPA On-Scene Coordinator
- April 7, 2023 Main Line Interim Soil Removal Plan Addendum for Area 3 and 4 – Approved by USEPA On-Scene Coordinator
- April 19, 2023 Main Line Interim Soil Removal Plan, Amendment 1 – Approved by USEPA On-Scene Coordinator
- April 21, 2023 Main Line Interim Soil Removal Plan, Amendment 2 – Approved by USEPA On-Scene Coordinator
- April 21, 2023 Main Line Interim Soil Removal Plan Addendum for the North Ditch and Burn Pits 1 and 2 – Approved by USEPA On-Scene Coordinator
- April 24, 2023 Main Line Interim Soil Removal Plan, Amendment 3 – Approved by USEPA On-Scene Coordinator
- April 26, 2023 Main Line Interim Soil Removal Plan, Version 4 – Submitted for review but superseded by this Plan before completion of review
- May 8, 2023 Main Line Interim Soil Removal Plan, Version 4.1 – Received comments from the Environmental Unit and Operations Section

This Plan includes activities associated with the following distinct areas at the Site (**Figure 1**):

- Main Lines 1 and 2
- Main Line Areas 3 and 4
- North Ditch, South Ditch, and Burn Pits 1 and 2
- Centerline
- Car Scrapping Areas 3 and 4

As part of a larger group of plans collectively making up the Removal Work Plan, the work described in this Plan will be conducted in accordance with the Quality Assurance Project Plan (QAPP), Quality Management Plan (QMP), Health and Safety Plan (HASP), and other overall documents that provide procedures for sample collection, identification, and analysis. Media-specific sampling and analysis procedures are presented below to support the scope of work discussed herein.

This and other work plans will define the schedule for the project, the required resources, and the project milestones. The work plans and the QAPPs will define the applicable requirements that must be met by the projects. Work will be carried out pursuant to this Plan and the associated QAPP.

2 Site Background

On February 3, 2023, a derailment occurred near the North Pleasant Drive crossing in East Palestine, Columbiana County, Ohio (the derailment). The derailment involved 51 rail cars and resulted in a fire and breaches to tank cars that contained hazardous materials (i.e., vinyl chloride, butyl acrylate, ethylene glycol monobutyl ether, and ethylhexyl acrylate) and non-hazardous materials. After monitoring on February 5, 2023 indicated rising temperatures in a tank car containing vinyl chloride, NSRC, in consultation with response officials, vented and burned product into burn pits on February 6, 2023 in order to prevent a catastrophic explosion of the rail car. The releases of hazardous materials from the damaged cars affected soil and surface water in the area of the derailment.

NSRC immediately mobilized response personnel to the incident. Response crews continue operations to contain and recover the releases. Following the initial response activities, including extinguishing of fires and movement of derailed rail cars, the two NSRC tracks passing through the derailment area (i.e., Main Lines 1 and 2) were replaced, and rail traffic was restored. Steps to recover mass included:

- Construction of an interceptor trench
- Recovery of liquids via vacuum operations
- Excavation of soil and roadbed material from the area between the tracks to a depth of approximately 4 feet – the excavation area extended from the North Pleasant Drive crossing eastward for approximately 1,900 linear feet.

This Plan focuses on the approach for continued excavation and soil sampling in the track area and areas directly affected with impacts related to the incident. Excavation and soil sampling for Main Line 1 is complete, with the exception of Area 4. Remaining excavation activities in Area 4 will be completed during a planned track outage after excavation activities associated with Main Line 2 are complete. Excavation and assessment activities for the portion of Area 3 that is in Main Line 1 is complete. Main Line 2 and North Ditch (east of Pleasant Street) excavation activities were initiated on April 22, 2023 and are ongoing. The North Ditch, Burn Pits 1 and 2, and Area 3 will be excavated (where applicable) and sampled in conjunction with the Main Line 2 excavation activities.

3 Removal Objectives

The purpose of this Plan is to provide details on the removal of the principal threat waste and associated gross impacts from the materials released during the derailment. The hazardous materials released from the derailment are referred to as contaminants of concern (COCs). Based on NSRC and agency review of the COCs mass and toxicity, the materials released from the derailment are consistent with USEPA's definition of principal threat wastes due to their potential to impact soil and groundwater. The overall objectives of the removal actions presented in this Plan include the following:

- Removal of remaining principal threat waste (COC) mass in the railroad right-of-way and areas directly affected by the incident.
- Minimization of the potential for the railroad right-of-way and proximal areas to act as a long-term source of COCs to the environment in the surrounding areas.

The COCs targeted for removal and the associated Regional Screening Levels for the Protection of Groundwater (RSLs) are as follows:

Analyte	CAS	RSL [1] (mg/kg)
Ethyl hexyl acrylate	103-11-7	2
Benzene	71-43-2	0.013
n-butyl acrylate	141-32-2	2.24
Vinyl chloride	75-01-4	0.0034
Ethylene glycol monobutyl ether	111-76-2	0.41
Dipropylene glycol[2]	25265-71-8	Not Applicable
Propylene glycol[2]	57-55-6	Not Applicable
Diethylene glycol[2]	111-46-6	Not Applicable
Polyether polyol[2,3]	9082-00-2	Not Applicable
Ethanol[2]	64-17-5	Not Applicable

Notes:

mg/kg – milligrams per kilogram

[1]RSLs for ethyl hexyl acrylate and n-butyl acrylate are based on ATSDR recommendations. RSLs for benzene and vinyl chloride were calculated using the USEPA RSL calculator and site-specific inputs for soil-to-groundwater screening levels provided by the USEPA. The ATSDR and USEPA memorandum and screening level calculation details are included in **Appendix A**.

[2]Analyte will be collected and analyzed then evaluated under Standard Operating Procedures (SOPs) for quality assurance as existing data per the QAPP.

[3]Polyether polyol (CAS 9082-00-2) is a triol/copolymer of propylene/ethylene oxides. The molecular weight can vary from 700 to 6,000 grams per mole (g/mol) depending on the polymeric formulation. It is a "mixture" and not a standard compound that the laboratory can purchase, calibrate, and analyze. Eurofins proposed analysis of glycerol (CAS 56-81-5) as a surrogate that could be used in place of the polyol. Glycerol (CAS 56-81-5) has a molecular weight of 92 g/mol, which is below the range referenced above for polyether polyol (CAS 9082-00-2), and therefore, not an effective surrogate. Analysis of polyether polyol was not completed previously and will not be completed in the future.

4 Methodologies

The following sections summarize the excavation and soil sampling activities associated with Main Lines 1 and 2, Main Line Areas 3 and 4, the North and South Ditches, Burn Pits 1 and 2, the area between Main Lines 1 and 2 (i.e., Centerline), and Car Scrapping Areas 3 and 4. The horizontal extent of the proposed excavation areas may be expanded if confirmation soil samples and/or soil samples collected via direct push methods indicate concentrations along the perimeter of the subject areas exceed the RSLs. The methodology for Main Lines 1 and 2 provides the general approach for excavation and soil sampling activities. Variations to the general approach are clarified in the subsequent sections. **Figures 2** through **14** show the excavation areas and approximate soil sample locations. Technical Guidance Instruction documents (similar to SOPs) for fieldwork described in this Plan are provided in **Appendix B**. A schedule that reflects the current understanding of operations at the Site is included as **Appendix C**.

4.1 Main Lines 1 and 2 Methodology

To remove additional COC mass remaining within the track footprint, an excavation spanning a larger area than the initial response effort is in progress and encompasses fill and roadbed material beneath and around the two existing tracks (see **Figure 1** for the approximate footprint of the excavation). After removal, these materials will be stockpiled for off-site disposal under an approved soil waste profile. Material to the north and south of the track alignment will also be excavated to remove impacts associated with movement of derailed cars and debris into staging areas.

During the initial soil excavation in the area between the tracks, a stiff glacial till layer was consistently observed at a depth of approximately 4 feet below the railroad track elevation. The physical characteristics of this till unit suggest that it is likely to limit downward migration of COC mass within the track footprint. As a result, removal of the overlying ballast and roadbed material down to the till layer is expected to be an effective approach for overall mass reduction. Where visibly impacted ballast material is present outside of the excavation area along the above-defined railroad corridor, it will be removed concurrently with excavation activities.

The planned excavation will be completed in two phases. The first phase is complete and addressed Main Line 1 (the track on the southern side of the area). The second phase is Main Line 2 (the northern tracks) and excavation commenced on April 22, 2023. In both phases, excavation will extend downward to the top of the stiff till layer, (i.e., top of ground), which is approximately 4 feet below the current elevation of the bottom of railroad ties (i.e., overburden). Visual observations and instrument-based measurements, which include direct reading instrumentation and colorimetric tubes, will be the primary means of identifying the target excavation depth. If visual or instrument indications of impact (staining, etc.) are noted at the till layer, additional material will be removed in targeted locations. Photoionization detector (PID) screening and colorimetric tube observations will be used to identify areas where additional soil excavation will be necessary. At each location for a planned post-excavation soil sample following completion of the initial excavation, a PID reading for overall organic vapor concentrations in air (using an 11.7 eV lamp) and colorimetric tube reading for vinyl chloride concentrations in air will be collected from the top 1 to 2 inches of soil at the floor of the excavation and placed in a ziplock bag for PID headspace analysis. An 11.7 electron volts (eV) lamp will be used in the PID due to its increased effectiveness for detecting the COCs targeted for removal versus that of a 10.6 eV lamp. These readings will be used along with other lines of evidence to judge the need for additional excavation on a location-specific basis, in consultation with Unified Command's designated representatives from NSRC, USEPA, and Ohio Environmental Protection Agency

(OEPA). The soil collected for laboratory analysis will be collected in-situ and will not be from the soil collected, bagged, and screened for headspace analysis.

When removal of the waste material is complete to the initial target excavation depth, in-situ soil samples will be collected from the base of the excavation (to a sample depth of approximately 2 inches), and at 12 to 14 inches below ground surface on a 25-foot grid in Excavation Area 1, and on a 50-foot grid in Excavation Area 2, consistent with previous sampling efforts (these areas are identified on **Figures 1** through **14**). If the upper 12 inches of soil requires removal, then the analytical results from the 12 to 14-inch below grade sample interval will be considered a representative post excavation soil sample for soil within that grid at that depth. If both sample intervals exceed the screening criteria established below, then additional post-excavation samples will be collected after removal of the impacted soil from that grid and subject to the screening process identified below.

Each sample will be analyzed for the COCs listed above via methods 8260, 8270, and 8015. At the discretion of either USEPA and/or OEPA, a co-located, in-situ soil sample located within 1 foot of NSRC's sample point may be collected for laboratory analysis utilizing USEPA's laboratory capabilities. The preliminary and validated results from these samples will be shared with NSRC. The results will be used as part of the soil excavation screening criteria identified below.

To support accurate field identification of sample locations, a grid will be established over the excavation area (**Figures 2** through **14**) in advance using Geographic Information System software and transferred to field Global Positioning System (GPS) equipment. The sample layout will be aligned to establish a line of east-west samples along the center line of each main line track. These soil samples will be used to characterize post-excavation soil conditions.

Following excavation and sample collection, samples will be couriered to Eurofins Laboratory in Lancaster, Pennsylvania to be run on 24-hour turnaround times. Level 2 data packages will be provided upon submittal of the data on the 24-hour turnaround time. Level 4 data packages will be provided by the lab(s) as final data. Sample results for COCs will be compared to RSLs.

These COC sample results will be utilized to determine if additional removal actions need to be taken prior to track reconstruction to mitigate potential threats to groundwater resources. Data will be reviewed by Unified Command's designated representatives from NSRC, USEPA, and OEPA.

Following receipt of analytical samples with COC concentrations below the RSLs in the 0 to 2-inch interval, the track will be rebuilt using new material, consisting of clean gravel and ballast. The roadbed will be constructed with approximately 1.5 to 2 feet of coarse angular stone, overlaid by approximately 1 foot of dense graded aggregate and a minimum of 1 foot of ballast stone (**Figure 15**). Sloping and roadbed construction will be completed consistent with applicable NSRC engineering standards.

If COC concentrations from the 0 to 2-inch sample interval are detected above the RSLs, the analytical results from the 12 to 14-inch interval will be reviewed. If the COC concentrations from the 12 to 14-inch interval are below the RSLs, further excavation will occur to the depth of the bottom of the next sample interval that was below the RSLs.

If COC concentrations from the 12 to 14-inch sample interval are above the RSLs, additional excavation will occur, and additional confirmation samples will be collected after the additional excavation. Excavation and sampling will continue in this manner until COC concentrations from confirmation samples are below the RSLs. If the depth of the excavation extends greater than 2 feet into the till, a temporary dewatering system will be used

for water management unless it can be demonstrated that dewatering is not necessary (i.e., no water infiltration into the excavation).

Sample locations and the extent of excavation will be surveyed with a GPS unit (coordinates and elevation), photo documented, and confirmed with an agency representative that the target depths have been achieved.

Throughout excavation and rebuilding work, NSRC will conduct continuous air quality and dust monitoring to verify the protection of on-site workers and the surrounding community. NSRC continues to distribute direct financial assistance to impacted families from the derailment in East Palestine, Ohio. If the main line soil remediation process temporarily generates conditions impacting those residing within the immediate vicinity of the remediation, then NSRC will provide financial assistance to those families. This includes costs for lodging, travel, food, clothes, or other necessities. For businesses in the immediate vicinity that are impacted by the main line soil remediation process, NSRC will provide financial assistance. No release of liability or other waiver of claims will be required for this financial assistance.

This work will be carried out in accordance with the most current iteration of the approved Air Sampling and Analysis Plan and associated QAPP (CTEH 2023) and will include monitoring and associated action levels for particulates, total volatile organic compounds, vinyl chloride, hydrogen chloride, n-butyl acrylate, and benzene, as appropriate. Active engineering controls (i.e., controls beyond monitoring) are not expected to be required; however, dust suppression equipment, including a water truck and water spraying equipment suitable for the size of the excavation work area, will be on hand for use, if needed.

The removal of all soil, ballast, and other coarse materials from the tracks down to the stiff till layer (with additional, targeted excavation where warranted based on observation of visual impacts and laboratory results) is expected to address the majority of COC-impacted media in this part of the derailment area. This Plan will not impede future remedial actions based on best available information.

4.2 Main Line Areas 3 and 4 Methodology

Main Line Areas 3 and 4 are areas where track was still present, which necessitated the development of a new methodology to assess subsurface conditions. A track-mounted GeoProbe® will be used to advanced soil borings at pre-determined transects between the track gauge of Main Line 1 in Areas 3 and 4 (and, as applicable, for Areas 3 and 4 along Main Line 2) during the implementation of this Plan, as follows:

- For soil borings advanced in Area 3, the transect will be named CON-(grid #)-ML1-A3 and will start at CON-51-ML1-A3 which is approximately 50 feet east of CON-50-ML1-A1.
- For soil borings advanced in Area 4, the transect will be named CON-(grid #)-ML1-A4 and will start at CON-01-ML1-A4 which is approximately 12.5 feet west from the western edge of Pleasant Street.
- The examples above apply to Main Line 1. During work in Main Line 2, the “ML-1” nomenclature will switch to “ML-2”.

Soil borings will be advanced along the transect at approximately 50-foot intervals eastward through Area 3 and 50-foot intervals westward through Area 4. Proposed soil boring locations are shown on **Figures 3** and **4** (Area 4) and **Figures 11** and **12** (Area 3) and are subject to change based on access limitations, site conditions, health and safety concerns, and directives from Unified Command.

Soil borings in the CON transect will be advanced through the ballast and into the underlying glacial till. It is anticipated that the ballast beneath the track will be approximately 4 feet deep through this area. A ballast sample

will be collected from ballast exhibiting the highest PID reading until reaching the glacial till. Ballast sample intervals may be adjusted based on field observations and recovery. A qualified geologist will log the borings and will confirm the ballast till interface has been reached. Once in the glacial till, soil samples will be collected from the initial 0 to 6 inches of the glacial till, 12 to 18 inches below the top of the glacial till, and 24 to 30-inches below the top of the glacial till. The 24 to 30-inch sample will be submitted to the laboratory for extraction but placed on hold until initial results are received and reviewed. Initial results from the 0 to 6 inch and 12 to 18 inch sampling intervals will be evaluated. Actual sample interval sizes may vary due to soil volume sampling requirements. Excavation will be completed per the data evaluation approach (Section 8) and grid clearance process (Section 9) for ballast and soil with concentrations of COCs that exceed the RSLs. Soil samples will be analyzed for the COCs listed in Section 3.

4.3 North and South Ditches and Burn Pits 1 and 2 Methodology

A new methodology was needed to allow for additional excavation of materials to the north and south of the Main Line tracks in select areas, including the North and South Ditches and Burn Pits 1 and 2. Following excavation of the north and south ditches, soil samples will be collected at concurrent intervals with the Main Line grid spacing. Additionally, as the Main Line 2 excavation proceeds eastward, Burn Pits 1 and 2 will also be excavated. Direct push methods may also be used to collect soil samples for delineation purposes. The sampling methodologies for these areas include:

- **North Ditch** - Soil sampling in the North Ditch will be conducted concurrently with the excavation and sampling of each grid for Main Line 2. The sample spacing in the North Ditch will mirror the spacing of Main Line 2. The samples will be collected directly beneath where the channel of the ditch had been excavated, the base of the excavation between the ditch channel and Main Line 2 (where applicable; see attached **Figures 2** through **8**), and the northern bank of the North Ditch.
- **South Ditch** – The sample spacing in the South Ditch will mirror the spacing of Main Line 1. The samples will be collected directly beneath where the channel of the ditch had been excavated, the base of the excavation between the ditch channel and Main Line 1 (where applicable; see attached **Figures 2** through **8**), and the southern bank of the South Ditch.
- **Burn Pits 1 and 2** - Following excavation of the Burn Pits, samples will be collected. The extent of excavation will be established by grid sampling and sidewall sampling as indicated on the attached **Figures 8** through **10**. The depth of the side wall samples will be determined based on the depth that impacts are most readily observed, if at all. If no obvious signs of impacts are observed, the sidewall samples will be collected at the approximate mid-point between the top and the bottom of the excavation.

Aside from the addition of sidewall samples, the sample methodology for the North Ditch and Burn Pits 1 and 2 is consistent with the approach and grid clearance process (Section 9) utilized for Main Lines 1 and 2 (i.e., sample depth of 0 to 2 inches and 12 to 14 inches into the till). Soil samples will be analyzed for the COCs listed above.

4.4 Centerline Methodology

During initial response efforts, the Centerline was excavated to native clay to remove gross impacts in soil. The Centerline was further excavated in association with Main Line 1 and Main Line 2 excavation activities. To

document post-excavation conditions for the Centerline, soil samples will be collected from the base of the excavation in the Centerline area. **Figures 3** through **12** show the proposed sample locations. The sampling locations shown will be considered representative of the area within the surrounding grid cell, excluding any areas that cannot be safely excavated without damaging the stability of Main Line 1. Sampling will be completed utilizing one of the following two previously utilized approaches for sample collection:

- In some areas, the recently placed ballast in Main Line 1 will need to be cleared to provide access to the bottom of the Centerline excavation. This interface is distinguishable as the recently placed, ballast rock is light gray, and the bottom of the excavation is the glacial till material found throughout the Main Line excavation areas. In the areas where the ballast needs to be cleared to provide access to the base of the excavation, the ballast rock will be re-used as fill material in the Centerline area. Samples will be collected from 0 to 2 inches and 12 to 14 inches into the glacial till that represents the bottom of the excavation. The sample methodology for the Centerline is consistent with the approach utilized for Main Lines 1 and 2.

- A track-mounted GeoProbe® will be used to advanced soil borings at the proposed locations. Soil borings will be advanced through the ballast and into the underlying glacial till. It is anticipated that the ballast in the Centerline of the tracks will be approximately 2 feet deep through this area. Since the ballast was recently placed (i.e., not present during the incident), ballast samples will not be collected. A qualified geologist will log the borings and will confirm the ballast till interface has been reached. Once in the glacial till, soil samples will be collected from the initial 0 to 6 inches of the glacial till, 12 to 18 inches below the top of the glacial till, and 24 to 30-inches below the top of the glacial till. The 12- to 18 and 24 to 30-inch samples will be submitted to the laboratory for extraction but placed on hold until initial results are received and reviewed. Initial results from the 0 to 6 inch sampling interval will be evaluated for centerline locations.

If soil samples associated the Centerline exceed the RSLs, additional remedial activities may be required. If additional excavation is completed, the clearance process included in this Plan (Section 9) will be utilized. Soil samples will be analyzed for the COCs listed above. Sampling results from the Centerline will be incorporated into the CSM for the Site and support an overall understanding of remedial progress and planning of future activities.

4.5 Car Scrapping Areas 3 and 4

Car Scrapping Areas 3 and 4, located to the north and south of the Main Line tracks, were used for sorting and staging of debris and rail cars. A new methodology was needed to allow for additional excavation of these areas. The subsurface in these areas will be excavated to a minimum depth of 1 foot. Excavation may be completed to greater depths if field observations (e.g., staining, odors, impacted subsurface debris) indicate that impacts remain. Following excavation, soil samples will be collected on a 25-foot grid spacing. If the depth of the excavation extends into a water bearing zone, efforts will be made to minimize water entering the excavation (e.g., a temporary dewatering system may be used). Water will be removed prior to collection of soil samples. Potential impacts to groundwater, if any, will be evaluated under a separate plan (i.e., Appendix I – Groundwater Characterization Work Plan). The sample methodology for Car Scrapping Areas 3 and 4 will be consistent with the approach utilized for Main Lines 1 and 2. Soil samples will be analyzed for the COCs listed above.

5 Sample Nomenclature

Soil and ballast samples collected in association with the activities in this Plan will be identified consistent with the following nomenclature:

5.1 Main Lines 1 and 2

Example: CON-01-ML1-A1(0”-2”)/2023-03-30

- CON – Prefix used to indicate confirmation soil sample
- 01 – Represents associated grid number
- ML1 – Represents Main Line 1 location
- A1 – Indicates the sample was collected in Area 1
- (0”-2”) – Indicates depth into the bottom of the excavation in inches
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

5.2 Main Line Areas 3 and 4

Example 1: CON-51-ML1-A3 (0”-2”)/2023-03-30

- CON – Prefix used to indicate confirmation soil sample
- 51 – Represents associated grid number
- ML1 – Represents Main Line 1 location
- A3 – Indicates the sample was collected in Area 3
- (0”-2”) – Indicates depth interval the GeoProbe sample was collected from the top of the glacial till in inches
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

Example 2: CON-51-ML1-A3-BAL (0-2)/2023-03-30

- CON – Prefix used to indicate confirmation soil sample
- 51 – Represents associated grid number
- ML1 – Represents Main Line 1 location
- A3 – Indicates the sample was collected in Area 3
- BAL – Indicates the sample matrix is from the ballast overlying the glacial till
- (0-2) – Indicates depth interval the GeoProbe sample was collected from the ground surface in feet
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

5.3 North and South Ditches and Burn Pits 1 and 2

Example 1: CON-01-NORD (0”-2”)/2023-03-30

- CON – Prefix used to indicate confirmation soil sample

- 01 – Represents associated sample location
- NORD – Represents the North Ditch location
- (0”-2”) – Indicates depth into the bottom of the excavation in inches
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

Example 2: CON-01-SD (0”-2”)/2023-03-30

- CON – Prefix used to indicate confirmation soil sample
- 01 – Represents associated sample location
- SD – Represents the South Ditch location
- (0”-2”) – Indicates depth into the bottom of the excavation in inches
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

Example 3: EOE-01-BP1 (2-4)/2023-03-30

- EOE – Prefix used to indicate confirmation soil sample that represents the extent of excavation
- 01 – Represents associated sample location
- BP1 – Represents the Burn Pit 1 location
- (2-4) – Indicates sidewall sample depth interval in feet
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

Example 4: EOE-03-BP1 (0”-2”)/2023-03-30

- EOE – Prefix used to indicate confirmation soil sample that represents the extent of excavation
- 03 – Represents associated sample location
- BP1 – Represents the Burn Pit 1 location
- (0”-2”) – Indicates depth into the bottom of the excavation in inches
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

5.4 Centerline

Example: CON-01-CENT-A1(0”-2”)/2023-03-30

- CON – Prefix used to indicate confirmation soil sample
- 01 – Represents associated grid number
- CENT – Represents Centerline location
- A1 – Indicates the sample was collected in Area 1
- (0”-2”) – Indicates depth into the bottom of the excavation in inches
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

5.5 Car Scrapping Areas 3 and 4

Example: CON-01-CS3(0”-2”)/2023-03-30

CON – Prefix used to indicate confirmation soil sample

01 – Represents associated grid number

CS3 – Represents Car Scrapping Area 3 location

(0”-2”) – Indicates depth into the bottom of the excavation in inches

/2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

5.6 QA/QC Samples

Example 1: DUP-01/2023-03-30

- DUP – Prefix used to indicate duplicate sample
- 01 – Indicates duplicate sample number for the day
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

Example 2: RB-01/2023-03-30

- RB – Prefix used to indicate rinse blank sample
- 01 – Indicates duplicate sample number for the day
- /2023-03-30 – Indicates sample collection date of March 30, 2023 in this example

6 Laboratory Analysis

The samples will be couriered or shipped to Eurofins Laboratory in Lancaster, Pennsylvania under standard chain-of-custody procedures and analyzed under an expedited turnaround time request for the parameters indicated in the table above.

Quality assurance/quality control procedures and laboratory analytical procedures are described in the QAPP. One field duplicate sample and one equipment rinse sample will be collected for every 10 field samples and one matrix spike/matrix spike duplicate sample will be collected for every 20 field samples. Samples placed on hold will not be used as duplicates. Level 2 and 4 laboratory packages will be requested from the laboratory to include summaries of sample, batch, and instrumental quality control results in addition to all raw data that allows full traceability and recalculation of sample results. A Stage IV data validation will be completed on a subset of sample results (e.g., 10-20% of total results) upon completion of the laboratory analysis. The remainder of sample results will be validated using Stage II data validation procedures. Data validation will be Stage 2A and 10% Stage 4 with limited recalculations. The laboratory will provide Scribe-ready electronic data deliverables. Total turnaround times for data are estimated at 24 hours, aside from the glycol analyses that will not be used for grid clearance.

Laboratory SOPs, quality manuals, and accreditation certificates for the methods which will be used for analysis of COCs are be provided in the QAPP.

7 Waste Management

Soil/materials generated during the excavation work will be stockpiled in designated soil staging areas proximal to the NSRC right-of-way south of the tracks, characterized, and transported off-site for treatment and disposal (**Figure 1**). The stockpiled materials will be covered to minimize contact with storm water, and erosion and sedimentation control measures are in place.

Waste profiles associated with soil removed from specific areas will be provided to Unified Command under separate cover prior to off-site treatment and/or disposal; existing analytical data will be used for purposes of characterizing waste from specific areas and identifying associated waste management and disposal requirements.

8 Data Evaluation and Reporting

Sample analytical results will be tabulated and presented on figures for communication with Unified Command, designated representatives from USEPA and OEPA, and applicable stakeholders. Sample results will be compared to RSLs. Decision making associated with this Plan will proceed as follows:

- If the concentrations of COCs in the sample(s) that represent the bottom of the excavation in the Main Line, North Ditch, South Ditch, Burn Pits 1 and 2, and Car Scrapping Areas 3 and 4 are below the RSLs, the associated grid will be cleared for backfill with soil.
- If the concentrations of COCs in the sample(s) that represent the bottom of the excavation in the Main Line, North Ditch, South Ditch, Burn Pits 1 and 2, and Car Scrapping Areas 3 and 4 are above the RSLs, additional excavation of the applicable grid will be completed.
- The samples collected in the glacial till in Main Line Areas 3 and 4 will serve as confirmation samples in the event excavation is required beneath the tracks. If COC concentrations from the confirmation sample of the till are below the applicable RSLs for two consecutive sampling grids, horizontal delineation beneath Main Lines 1 and 2 will be considered complete and additional excavation will not be required.
- If the COC concentrations in a ballast sample in Main Line Areas 3 or 4 exceed the RSLs, the ballast associated with that grid will be removed. If COC concentrations from a confirmation sample in either Area 3 or 4 are equal to or above the applicable RSLs, the excavation of the impacted soil from the grid will occur to the depth of the bottom of the next sample interval that was below RSLs and will extend into the adjacent grid up to the next adjacent confirmation sample that meets the applicable RSLs.
- If COC concentrations in sidewall samples (i.e., north bank samples for the North Ditch, south bank samples for the South Ditch, and sidewall samples for Burn Pits 1 and 2) are below the RSLs, additional sampling or excavation of the applicable grid is not necessary for this Plan. Additional delineation is deferred to the Appendix E Site Characterization and Remediation Work Plan for Derailment-Area Soil.
- If COC concentrations in sidewall samples (i.e., north bank samples for the North Ditch, south bank samples for the South Ditch, and sidewall samples for Burn Pits 1 and 2) are above the RSLs, additional sampling and excavation of the applicable grid may be conducted under this Plan or will be deferred to the Appendix E Site Characterization Work Plan for Derailment-Area Soil. For the Burn Pits, poly sheeting or similar may be placed in the excavation to demarcate the edge of excavation. If additional excavation is not completed, delineation and/or remediation of the applicable grid will be completed under a separate plan (e.g., the Characterization Work Plan for Derailment-Area Soil).
- If the concentrations of COCs in the Centerline sample(s) are below the RSLs, the associated grid will be cleared.
- If the concentrations of COCs in the Centerline sample(s) are above the RSLs, additional excavation of the applicable grid will be completed.

9 Grid Clearance Process

The following grid clearance process will be followed for each area subject to removal activities discussed in this Plan.

As analytical data are received by NSRC, it shall be sent to the Track Excavation Data Review Group (TEDRG) at the following email addresses, at a minimum:

R5_ENVL@epa.gov, R5_OPS@epa.gov, R5_DATA@epa.gov

The email shall include a summary table, map book of grids, and analytical data reports for each sample. The TEDRG will collect the data and integrate USEPA PHILIS mobile laboratory data. The PHILIS data will be compared to the RSLs and NSRC data. Both sets of data will be used independently to identify grids that need further excavation. If the PHILIS data are not available, the NSRC data will be used as the sole results to compare to the screening values.

The TEDRG shall review all received data at the daily meeting with the intent of clearing or not clearing each excavated grid per this Plan. The review will follow the Track Excavation Confirmation Sampling Decision Tree (**Appendix C**). Data received two hours prior to the scheduled daily meeting will be reviewed at the meeting that same day. Data received within 2 hours of the scheduled daily meeting may be delayed for review until the following day.

At the end of each TEDRG meeting, an email will be sent to Operations Section from the Environmental Unit recommending which grids are cleared or not cleared for restoration. Operations shall review and email the Unified Command Group (UCG) with a copy to and attaching/forwarding the transmittal from Environmental Unit, recommending which grids should be cleared for restoration. Unified Command will notify NSRC which grids will require additional excavation and clearance sampling. The Environmental Unit's recommendations shall indicate which grids recommended for clearance are based on data below RSLs.

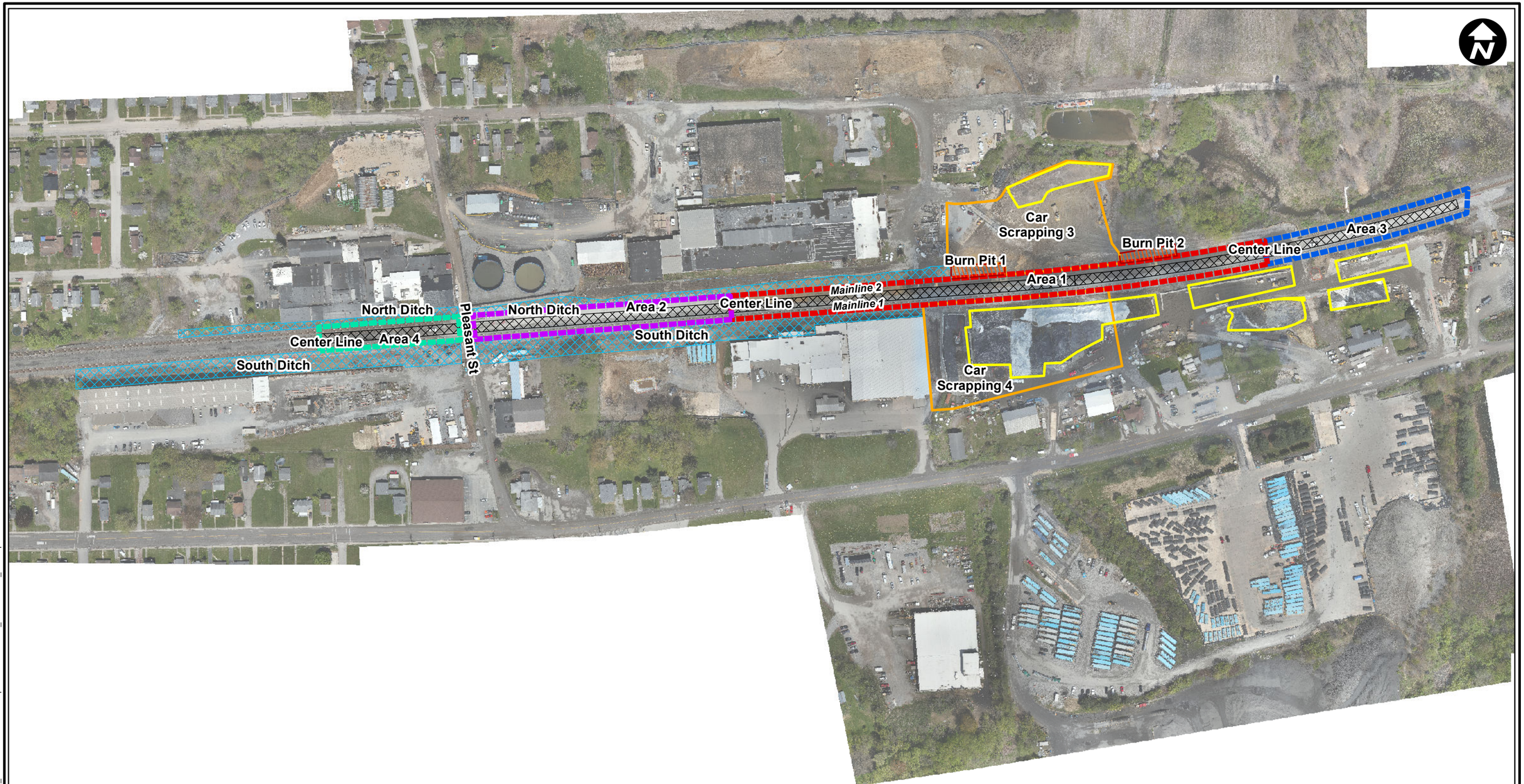
If additional information or clarification is needed on data at the end of each TEDRG meeting, the TEDRG shall request the information from NSRC and Operations. In the hours leading up to the subsequent TEDRG meeting, all efforts will be made to resolve the issues.

Upon receipt of the recommendation emails from Operations and attached Environmental Unit, the Unified Command will review the email and approve or disapprove restoration of each grid as received, or no later than the next scheduled TEDRG meeting.

10 Reference

CTEH. 2023. Air Sampling and Analysis Plan, Version 1.4. Taggart Road Incident, East Palestine, OH. Prepared on behalf of Norfolk Southern by CTEH, LLC. Revised February 22, 2023.

Figures



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PATH: T:_ENV\Norfolk\Southern\East\Palestine_Feb5_2023\MXD\MainlineComprehensivePlan\F1_MainlinePlan_SiteMap.mxd SAVED: 5/8/2023 BY: dholmes

LEGEND

- Waste Staging
- Area 1
- Area 2
- Area 3
- Area 4
- Car Scrapping Area
- Center Line
- North Ditch and South Ditch

Map Date: 5/8/2023

Drone imagery date: 05/06/2023

0 220 440

Feet

NORFOLK SOUTHERN
EAST PALESTINE, OHIO

MAINLINE TRACK SITE PLAN

ARCADIS

FIGURE
1

North Ditch

South Ditch

MW-10

Map Date: 5/7/2023

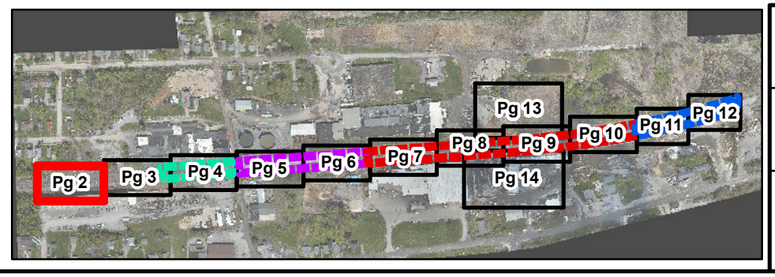
Drone imagery date: 05/06/2023

0 20 40

Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
2

CITY:(KNOXVILLE) DIV/GROUP:(ENV/GIS) LD: D.HOLMES PM: J.SHONFELT TM: M.SUGAR
PATH: T:_ENV\Norfolk Southern\East Palestine_Feb5_2023\MXD\MainlineComprehensiveRevPlan\F2-11ExcavationAreasMapbook.mxd SAVED: 5/7/2023 BY: dholmes

North Ditch

South Ditch

CON-07-ML2-A4

CON-07-CENT-A4

Area 4

CON-06-ML1-A4

Map Date: 5/7/2023

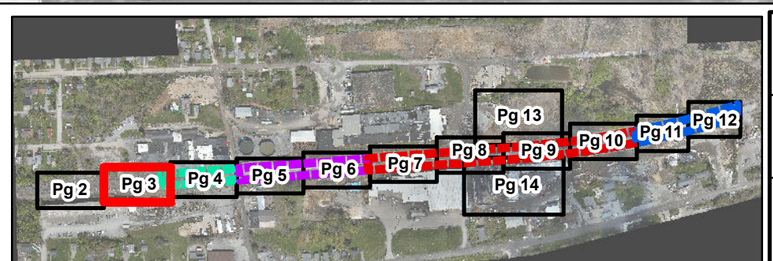
Drone imagery date: 05/06/2023

0 20 40

Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4



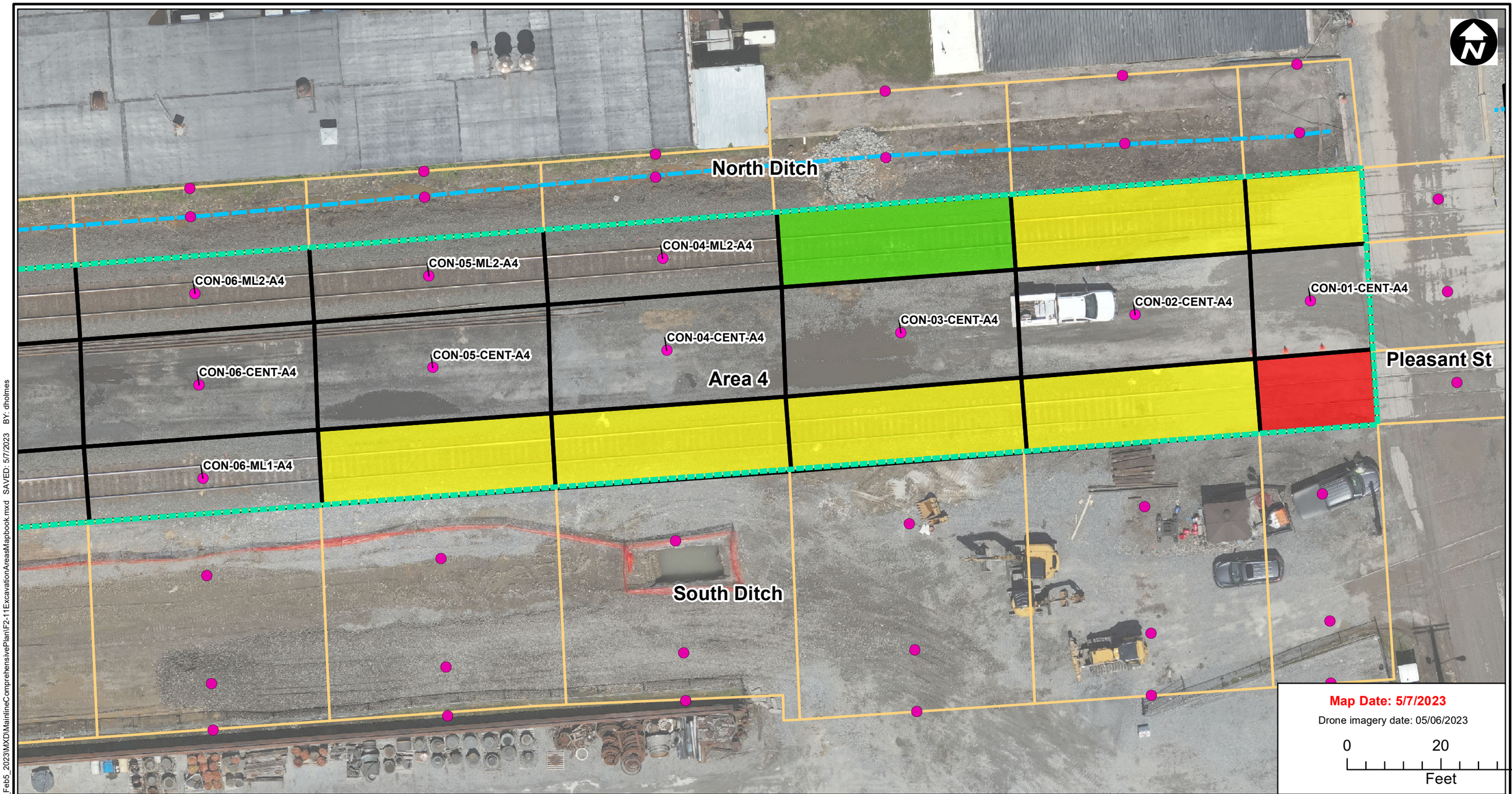
NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
3

CITY:(KNOXVILLE) DIV/GROUP:(ENV/GIS) LD: D.HOLMES PM: J.SHONFELT TM: M.SUGAR
PATH: T:_ENV\Norfolk\Southern\EastPalestine_Feb5_2023\MXD\MainlineComprehensivePlan\F2-1ExcavationAreasMapbook.mxd SAVED: 5/7/2023 BY: dholmes



Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

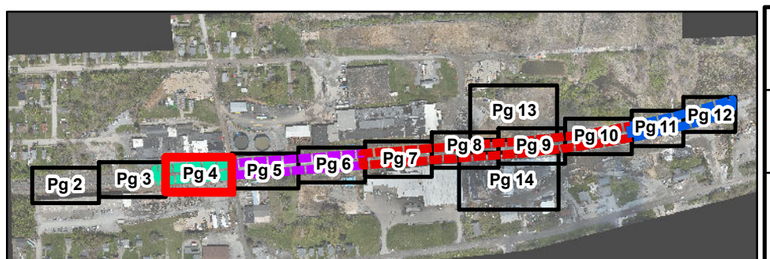
Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared
- Grid Pending UC Approval for Clearance
- Grid Not Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE 4

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North Ditch

Area 2

CON-01-CENT-A2

CON-02-CENT-A2

CON-03-CENT-A2

CON-04-CENT-A2

CON-05-CENT-A2

CON-06-CENT-A2

CON-07-CENT-A2

Pleasant St

South Ditch

Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

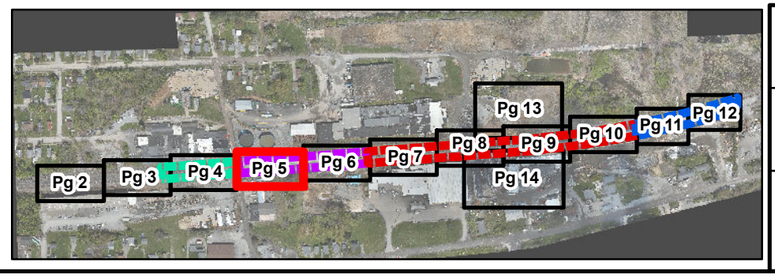
Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE

5

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North Ditch

Area 1

CON-13-CENT-A2

CON-01-CENT-A1

CON-12-CENT-A2

CON-11-CENT-A2

CON-10-CENT-A2

CON-09-CENT-A2

CON-08-CENT-A2

Area 2

South Ditch

Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

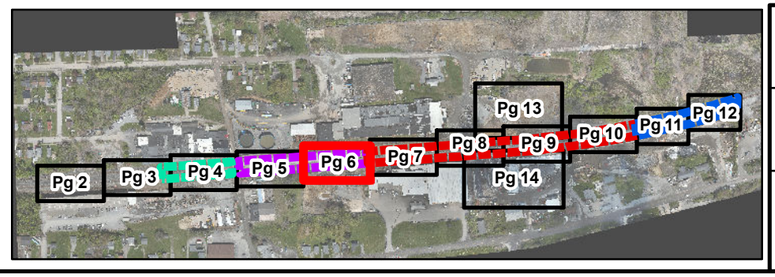
Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE

6

CITY:(KNOXVILLE) DIV/GROUP:(ENV/GIS) LD: D.HOLMES PM: J.SHONFELT TM: M.SUGAR
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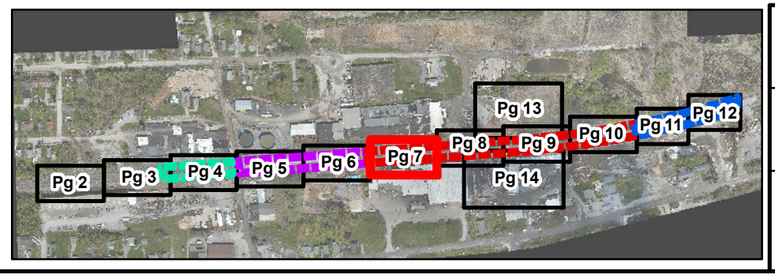
LEGEND

- Proposed Sample Location
- North Ditch
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared
- Grid Pending UC Approval for Clearance



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
7

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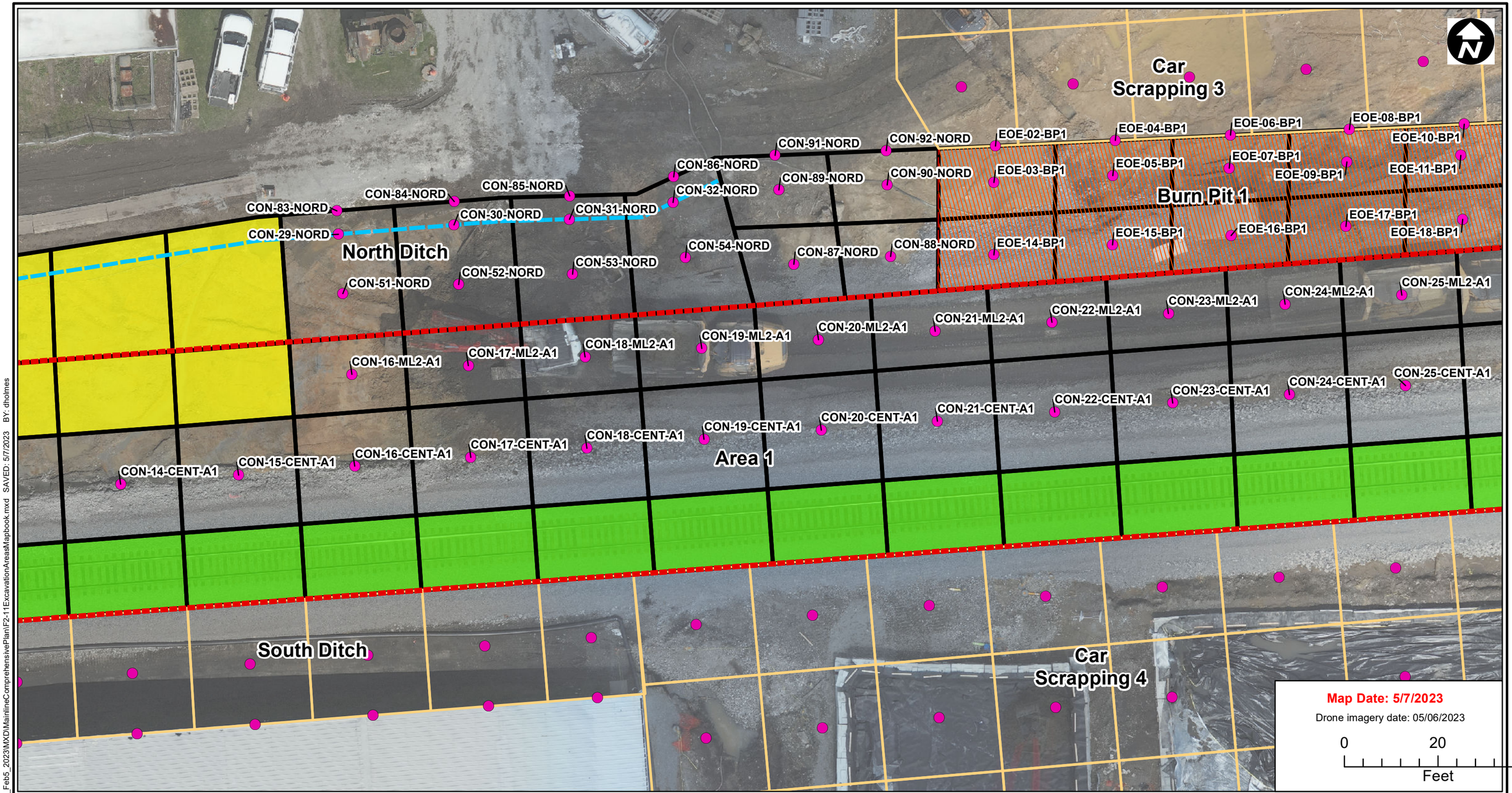


Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

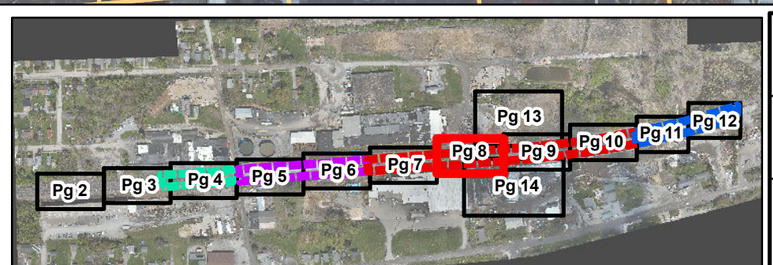
Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Approximate Burn Pit Area
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared
- Grid Pending UC Approval for Clearance

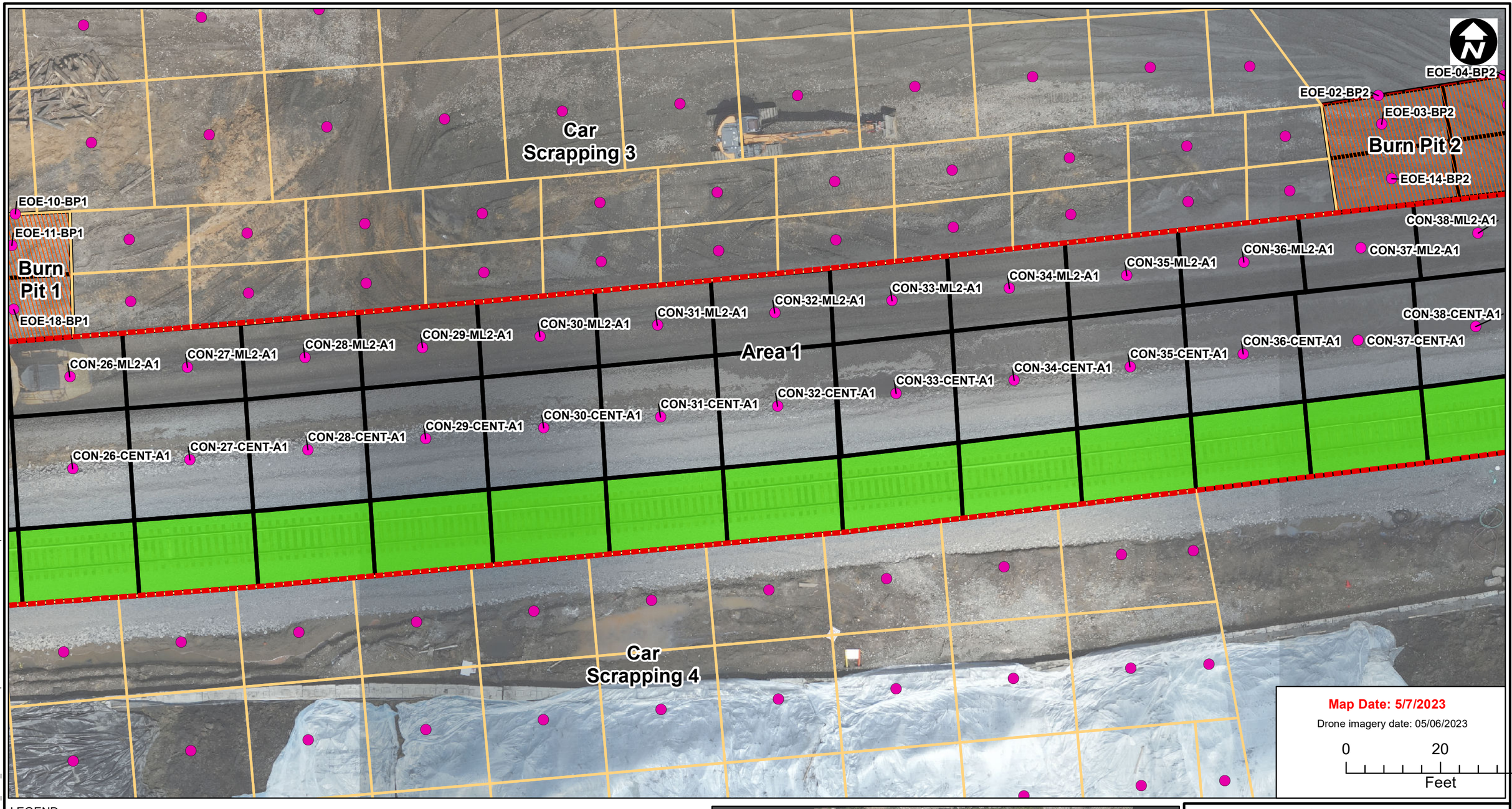


NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE 8



Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

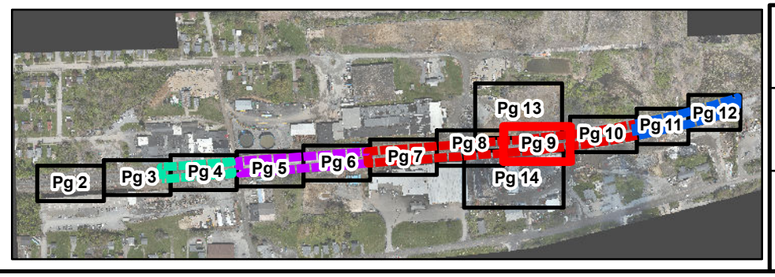
Feet

LEGEND

- Proposed Sample Location
- Approximate Burn Pit Area
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
9

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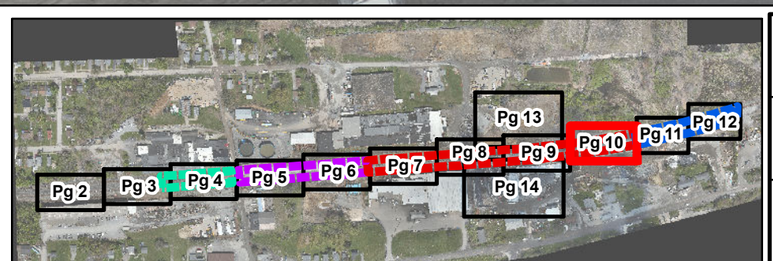
LEGEND

- Proposed Sample Location
- Approximate Burn Pit Area
- Confirmation Sampling Grid Outline
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
10

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CON-56-ML2-A3
CON-55-ML2-A3
CON-06-CENT-A3
CON-54-ML2-A3
CON-05-CENT-A3
CON-04-CENT-A3
Area 3
CON-55-ML1-A3
CON-03-CENT-A3
CON-54-ML1-A3
CON-51-ML2-A3
CON-02-CENT-A3
CON-50-ML2-A1
CON-49-ML2-A1
CON-01-CENT-A3
CON-50-CENT-A1
Area 1

Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

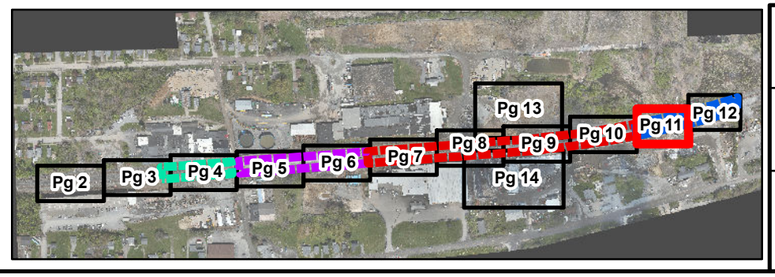
Feet

LEGEND

- Proposed Sample Location
- North Ditch
- Confirmation Sampling Grid Outline
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
11

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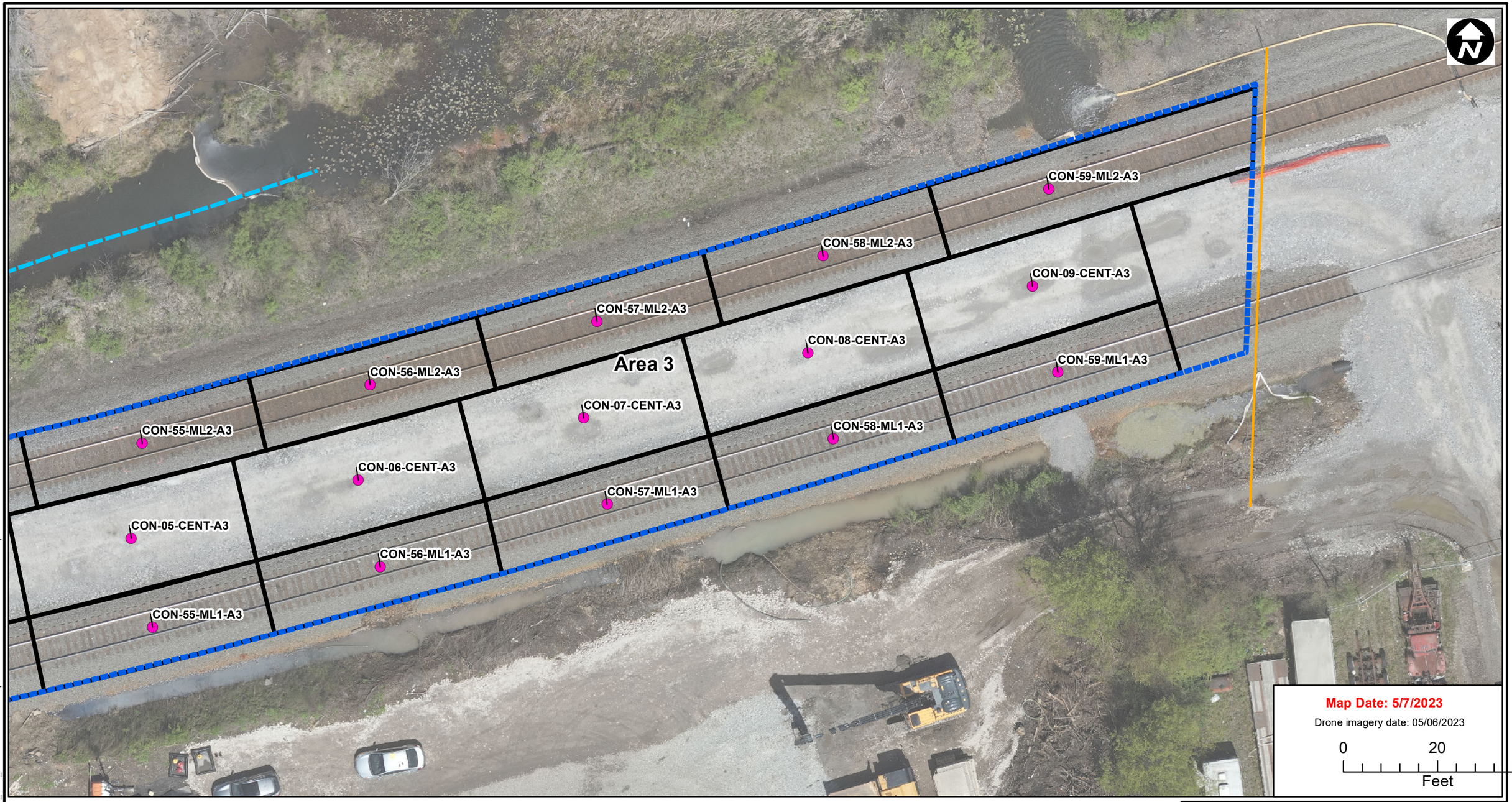
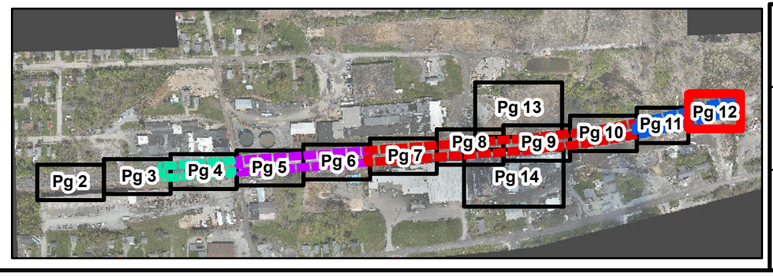


LEGEND

- Proposed Sample Location
- North Ditch
- Ohio / Pennsylvania Border
- Confirmation Sampling Grid Outline
- Area 1
- Area 2
- Area 3
- Area 4

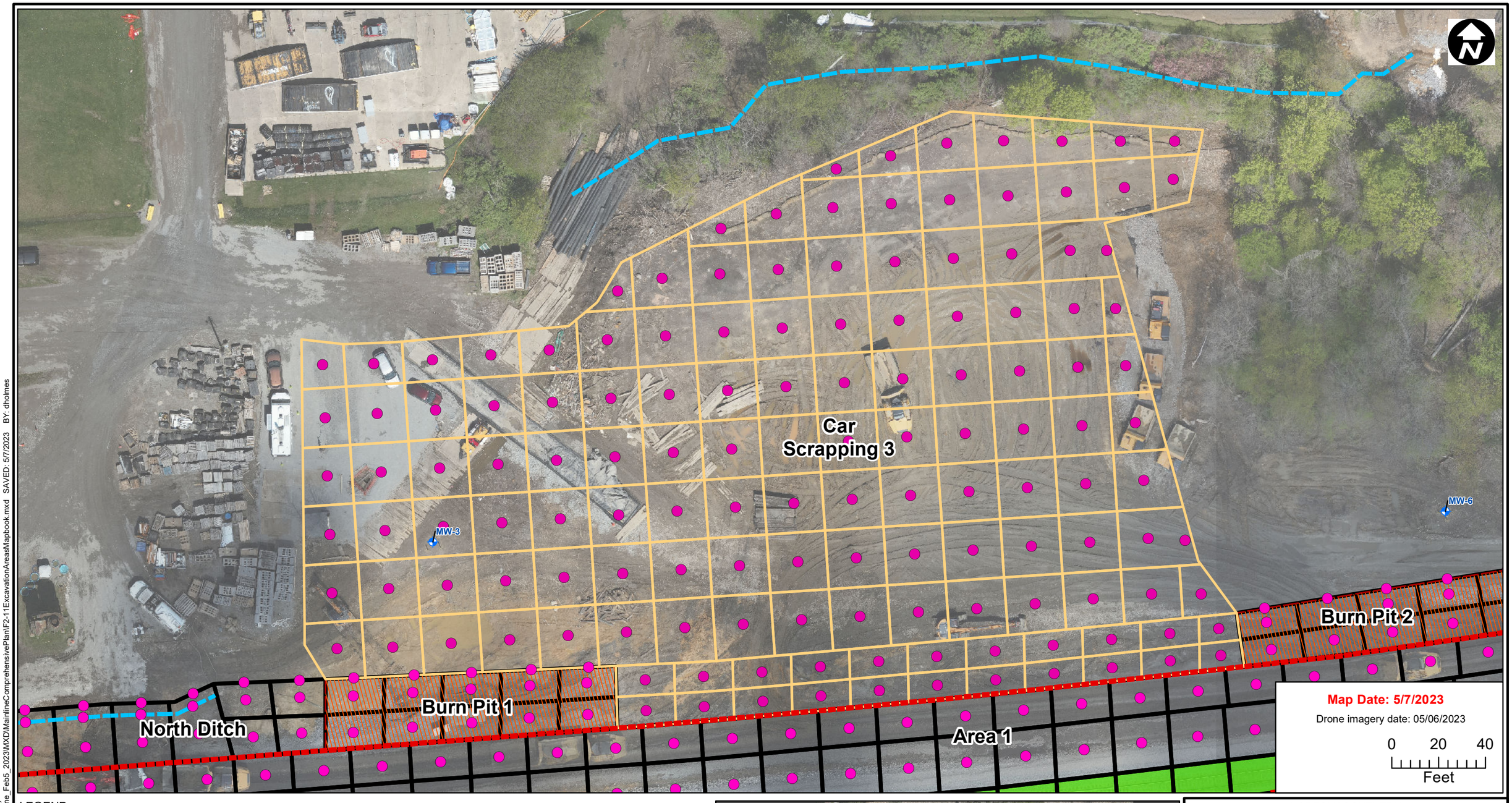


NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
12

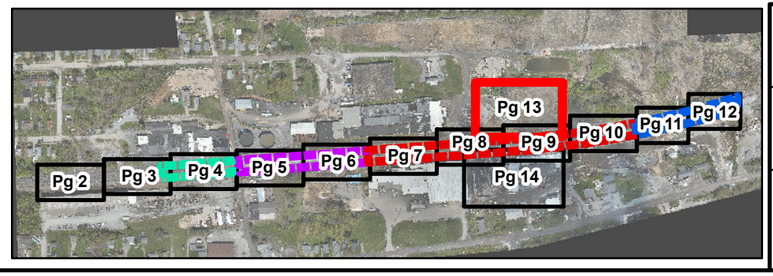


LEGEND

- Proposed Sample Location
- North Ditch
- Approximate Burn Pit Area
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

FIGURE
13

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North Ditch

Area 1

South Ditch

Car
Scrapping 4

Map Date: 5/7/2023

Drone imagery date: 05/06/2023

0 20 40

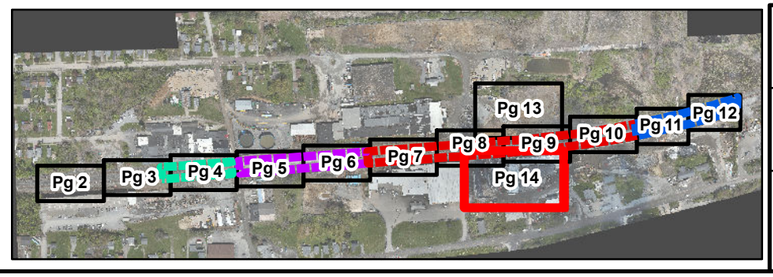
Feet

LEGEND

- Proposed Sample Location
- Approximate Burn Pit Area
- Confirmation Sampling Grid Outline
- Proposed Appendix D Sample Grid
- Area 1
- Area 2
- Area 3
- Area 4

Track Clearance

- Grid Cleared
- Grid Pending UC Approval for Clearance



NORFOLK SOUTHERN
EAST PALESTINE, OHIO

EXCAVATION AREAS

ARCADIS

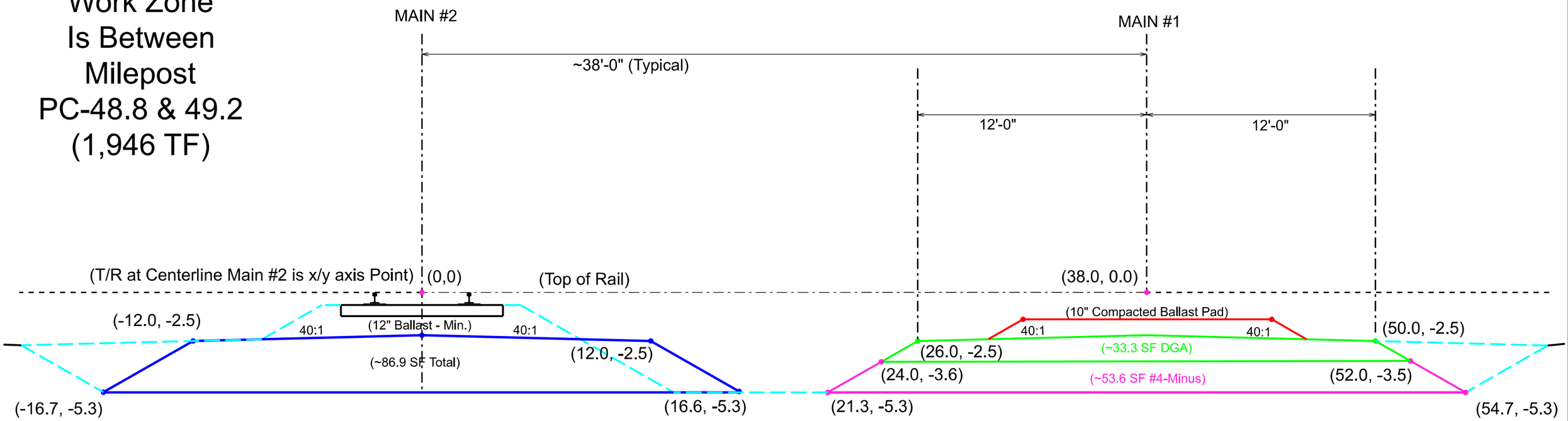
FIGURE
14

CITY:(KNOXVILLE) DIV/GROUP:(ENV/GIS) LD: D.HOLMES PM: J.SHONFELT TM: M.SUGAR
PATH: T:_ENV\Norfolk Southern\East Palestine_Feb5_2023\MXD\MainlineComprehensivePlan\F2-1 ExcavationAreasMapbook.mxd SAVED: 5/7/2023 BY: dholmes

EXCAVATION and ROADBED REPLACEMENT CONCEPT

(Typical Section View Looking Eastward from Pleasant Street - MP PC-49.2)

Work Zone
Is Between
Milepost
PC-48.8 & 49.2
(1,946 TF)



Bottom of Mass Excavation at Top of Stiff Clay Layer
(approximately 4' below bottom of tie)

D&C CONTRACTOR Roadbed Replacement Quanities

Length per track = 3,892 TF (1,946 TF x 2 Tracks)

80.2 SF / TF Total to be Replaced

31.3 SF / TF NS Type B DGA
~8,527 Tons (140 pcf used)

49.9 SF / TF #4-Minus
~13,109 Tons (135 pcf used)

13.8 SF / TF NS Ballast
~2,276 Tons (100 pcf used)

Volume of Existing Roadbed to be Excavated by NS ENVP CONTRACTOR

Length per track = 3,892 TF (1,946 TF x 2 Tracks)

~105.4 SF / Track to be Removed
~7,594 CY / Track to be Removed

~15,190 CY Total to be Removed

Trackwork (Removal / Rplacement) by NS MW&S
Length per track = 3,892 TF (1,946 TF x 2 Tracks)

PREPARED BY NS D&C - February 27, 2023 - DAB - REVISION 2

Appendix A

Screening Level Calculation Information

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
2565 Plymouth Rd
Ann Arbor, MI 48105

MEMORANDUM

SUBJECT: Amended Protection of Groundwater Standards for the East Palestine Derailment Site for 2-ethylhexylacrylate and n-butyl acrylate

FROM: Keith Fusinski, PhD Toxicologist US EPA
East Palestine Derailment

TO: Michelle Kerr, Environmental Unit Leader US EPA
East Palestine Derailment

DATE: 03/04/2023

STATEMENT OF THE ISSUES

Ohio EPA requested Soil to Groundwater protection standards based upon ATSDR provided Updated ATSDR Provisional Comparison Values for Drinking Water for 2-ethylhexylacrylate and n-butyl acrylate.

REASON FOR AMENDMENT

The values ORNL sent before were without the Kd for method 1 which needs a Koc. ORNL researched the Koc values and adjusted the model. This resulted in higher screening levels for Method 1.

ANALYSIS AND RECOMMENDATIONS

The EPA Regional Screening Level (RSLs) Users guide describes two methods for calculating soil to groundwater protection values. EPA toxicologist and Oak Ridge National Laboratory used the Regional Screening Level Users guide equations to derive soil to ground water protection screening levels based upon the following information.

ATSDR Provisional values drinking water values:
2-ethylhexylacrylate 500 µg/L
n-butyl acrylate 560 µg/L

EPA RSL equations used can be found at https://www.epa.gov/risk/regional-screening-levels-rsls-equations#s2gw

The dilution factor of 20 was used as discussed in the EPA's Soil Screening Guidance.

RESULTS

Method 1

CAS	Name	SSL (mg/kg)		with Henry law and Koc
103-11-7	2-ethylhexylacrylate	10.651212	=	500*(1/1000)*20)*((.002*430)+(0.3+0.434*0.0177)/1.5)
141-32-2	n-butylacrylate	3.196922027	=	560*(1/1000)*20)*((0.002*40)+(0.3+0.434*0.0188)/1.5)

Method 2

CAS	Name	SSL (mg/kg)		without Henry Law
103-11-7	2-ethylhexylacrylate	2	=	500*(1/1000)*20)*((0.3+0.434*0)/1.5)
141-32-2	n-butylacrylate	2.24	=	560*(1/1000)*20)*((0.3+0.434*0)/1.5)

Values highlighted in yellow are suggested to be used as soil screening values to be protective of groundwater.

Please note ATSDR's Comparison Values for Soil are

2-ethylhexylacrylate – 3.9 mg/kg
n-butyl acrylate - 4.4 mg/kg

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

May 8, 2023

Memorandum

To: East Palestine Environmental and Planning Unit

From: Judy Canova, PG, Hydrogeologist
Superfund and Emergency Management Division

RE: Updated Proposed Soil Screening Levels for Protection of Groundwater
East Palestine Train Derailment Site

In collaboration with Ohio EPA (OEPA) and the Pennsylvania Department of Environmental Protection, an updated evaluation of soil screening levels (SSL) to protect groundwater was completed for the East Palestine Train Derailment site. A revised Dilution-Attenuation Factor (DAF) of 5.2 was calculated based on the following revised input parameters:

Parameter	Value	Reference
Infiltration	0.25 m/year	Ohio EPA (OEPA) Drinking Water Source Assessment Report
Source Length	1127 m	EPA GIS, Site-specific
Fraction of Organic Carbon	0.002	Default*
Hydraulic Gradient	0.005	Average based on OEPA evaluation of water level data in wells at site
Aquifer Hydraulic Conductivity	1838 m/year	Norfolk Southern and EPA Professional Judgement
Aquifer Thickness	10 m	Site specific data from boring logs
Groundwater Temperature	15^{o} C	Site-specific measurement
Remaining Parameters		Default*

*Default parameters are based on EPA's Soil Screening Guidance User's guide. Input parameters may be updated when site-specific information becomes available.

The proposed SSL should be incorporated into appropriate plans and reports until more site-specific information is collected at which time the SSL may be updated. For example, samples

may be collected and analyzed for Fraction of Organic Carbon. The hydraulic gradient may also be updated when additional wells are installed and the potentiometric map is approved.

An initial SSL for was proposed by Keith Fusinski using a generic DAF of 20. The DAF of 20 may be used for an initial estimation when site-specific hydraulic information is not readily available. However, sufficient information is available to calculate an interim DAF applicable to the site.

The following table summarizes the updated SSLs based on the RSL calculator for soil to protect groundwater and an updated DAF for parameters evaluated by Keith Fusinksi with a default Foc included in the calculation:

Parameter	SSL (RSL)
Benzene	0.013 mg/kg
Vinyl chloride	0.0034 mg/kg
n- Butyl Acrylate	0.9 mg/kg
Diethylene Glycol	Not available
Ethylene Glycol Monobutyl Ether	2.12 mg/kg
2- Ethylhexylacrylate	2.8 mg/kg
Propylene Glycol	421 mg/kg
Dipropylene Glycol	Not available
Ethanol	Not available
Polyether Polyol	Not available

Cc: Keith Fusinski
Michelle Kerr
Linda Watson
Rob Thompson
Timothy Eyerdom
Carrie Rasik
Erin Shaver

Site-specific
Soil to Groundwater Inputs

Variable	Default Value	Site-Specific Value
d (mixing zone depth) m - site-specific	.	10
d_a (aquifer thickness) m - site-specific	.	10
DAF (dilution attenuation factor) unitless	1	5.20128372
DAF (dilution attenuation factor) unitless	1	5.20128372
ED_{res} (exposure duration) yr	70	70
foc (fraction organic carbon in soil) g/g	0.002	0.002
i (hydraulic gradient) m/m	.	0.005
I (infiltration rate) m/yr	0.18	0.25
K (aquifer hydraulic conductivity) m/yr	.	1838
L (source length parallel to ground water flow) m	.	1127
Soil to Groundwater Method	1	1
n (soil porosity) L_{pore}/L_{soil}	0.434	0.434
p_b (dry soil bulk density) kg/L	1.5	1.5
p_s (soil particle density) kg/L	2.65	2.65
$Theta_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.134	0.134
$Theta_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.3	0.3
BW_{0-2} (mutagenic body weight) kg	15	15
BW_{2-6} (mutagenic body weight) kg	15	15
BW_{6-16} (mutagenic body weight) kg	80	80
BW_{16-26} (mutagenic body weight) kg	80	80
BW_{res-a} (body weight - adult) kg	80	80
BW_{res-c} (body weight - child) kg	15	15
$DFW_{res-adj}$ (age-adjusted dermal factor) cm^2-event/kg	2610650	2610650
$DFWM_{res-adj}$ (mutagenic age-adjusted dermal factor) cm^2-event/kg	8191633	8191633
ED_{res} (exposure duration - resident) years	26	26
ED_{0-2} (mutagenic exposure duration first phase) years	2	2
ED_{2-6} (mutagenic exposure duration second phase) years	4	4
ED_{6-16} (mutagenic exposure duration third phase) years	10	10
ED_{16-26} (mutagenic exposure duration fourth phase) years	10	10
ED_{res-a} (exposure duration - adult) years	20	20
ED_{res-c} (exposure duration - child) years	6	6
EF_{res} (exposure frequency) days/year	350	350
EF_{0-2} (mutagenic exposure frequency first phase) days/year	350	350

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Site-specific
Soil to Groundwater Inputs

Variable	Default Value	Site-Specific Value
EF_{2-6} (mutagenic exposure frequency second phase) days/year	350	350
EF_{6-16} (mutagenic exposure frequency third phase) days/year	350	350
EF_{16-26} (mutagenic exposure frequency fourth phase) days/year	350	350
EF_{res-a} (exposure frequency - adult) days/year	350	350
EF_{res-c} (exposure frequency - child) days/year	350	350
ET_{res} (exposure time) hours/day	24	24
$ET_{event-res-adj}$ (age-adjusted exposure time) hours/event	0.67077	0.67077
$ET_{event-res-madj}$ (mutagenic age-adjusted exposure time) hours/event	0.67077	0.67077
ET_{0-2} (mutagenic dermal exposure time first phase) hours/event	0.54	0.54
ET_{2-6} (mutagenic dermal exposure time second phase) hours/event	0.54	0.54
ET_{6-16} (mutagenic dermal exposure time third phase) hours/event	0.71	0.71
ET_{16-26} (mutagenic dermal exposure time fourth phase) hours/event	0.71	0.71
ET_{res-a} (dermal exposure time - adult) hours/event	0.71	0.71
ET_{res-c} (dermal exposure time - child) hours/event	0.54	0.54
ET_{0-2} (mutagenic inhalation exposure time first phase) hours/day	24	24
ET_{2-6} (mutagenic inhalation exposure time second phase) hours/day	24	24
ET_{6-16} (mutagenic inhalation exposure time third phase) hours/day	24	24
ET_{16-26} (mutagenic inhalation exposure time fourth phase) hours/day	24	24
ET_{res-a} (inhalation exposure time - adult) hours/day	24	24
ET_{res-c} (inhalation exposure time - child) hours/day	24	24
EV_{0-2} (mutagenic events) per day	1	1
EV_{2-6} (mutagenic events) per day	1	1
EV_{6-16} (mutagenic events) per day	1	1
EV_{16-26} (mutagenic events) per day	1	1
EV_{res-a} (events - adult) per day	1	1
EV_{res-c} (events - child) per day	1	1
THQ (target hazard quotient) unitless	0.1	1
$IFW_{res-adj}$ (adjusted intake factor) L/kg	327.95	327.95
$IFWM_{res-adj}$ (mutagenic adjusted intake factor) L/kg	1019.9	1019.9
IRW_{0-2} (mutagenic water intake rate) L/day	0.78	0.78
IRW_{2-6} (mutagenic water intake rate) L/day	0.78	0.78
IRW_{6-16} (mutagenic water intake rate) L/day	2.5	2.5
IRW_{16-26} (mutagenic water intake rate) L/day	2.5	2.5

Site-specific
Soil to Groundwater Inputs

Variable	Default Value	Site-Specific Value
IRW_{res-a} (water intake rate - adult) L/day	2.5	2.5
IRW_{res-c} (water intake rate - child) L/day	0.78	0.78
K (volatilization factor of Andelman) L/m^3	0.5	0.5
LT (lifetime) years	70	70
SA_{0-2} (mutagenic skin surface area) cm^2	6365	6365
SA_{2-6} (mutagenic skin surface area) cm^2	6365	6365
SA_{6-16} (mutagenic skin surface area) cm^2	19652	19652
SA_{16-26} (mutagenic skin surface area) cm^2	19652	19652
SA_{res-a} (skin surface area - adult) cm^2	19652	19652
SA_{res-c} (skin surface area - child) cm^2	6365	6365
l_{sc} (apparent thickness of stratum corneum) cm	0.001	0.001
TR (target risk) unitless	1.0E-06	1.0E-06
T_w (groundwater temperature) Celsius	25	15

Site-specific

Risk-Based Regional Screening Levels (RSL) for Soil to Groundwater

Key: I = IRIS; P = PPRTV; O = OPP; A = ATSDR; C = Cal EPA; X = PPRTV Screening Level; H = HEAST; D = OW; W = TEF applied; E = RPF applied; G = see user guide; U = user provided; ca = cancer; nc = noncancer; * = where: nc SL < 100X ca SL; ** = where nc SL < 10X ca SL; SSL values are based on DAF=1; max = ceiling limit exceeded; sat = Csat exceeded.

Chemical	CAS Number	Mutagen?	Volatile?	Chemical Type	SF_o (mg/kg-day)$^{-1}$	SF_o Ref	IUR (ug/m^3)$^{-1}$	IUR Ref	RfD (mg/kg-day)	RfD Ref	RfC (mg/m^3)	RfC Ref	GIABS	ABS	S (mg/L)	K_d (cm^3/g)
Benzene	71-43-2	No	Yes	Organics	5.50E-02	I	7.80E-06	I	4.00E-03	I	3.00E-02	I	1	-	1790	2.92E-01
Butyl acrylate, n-	141-32-2	No	Yes	Organics	-		-		-		-		-	-	2000	8.00E-02
Ethylene Glycol	107-21-1	No	No	Organics	-		-		8.00E-01	A	4.00E-01	C	1	0.1	1000000	2.00E-03
Ethylene Glycol Monobutyl Ether	111-76-2	No	No	Organics	-		-		1.00E-01	I	1.60E+00	I	1	0.1	1000000	5.65E-03
Ethylhexyl acrylate, 2-	103-11-7	No	Yes	Organics	-		-		-		-		-	-	100	8.60E-01
Propylene Glycol	57-55-6	No	No	Organics	-		-		2.00E+01	P	-		1	0.1	1000000	2.00E-03
Vinyl Chloride	75-01-4	Yes	Yes	Organics	7.20E-01	I	4.40E-06	I	3.00E-03	I	1.00E-01	I	1	-	8800	4.35E-02

Site-specific

Risk-Based Regional Screening Levels (RSL) for Soil to Groundwater

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K_{oc} \ (cm^3/g)	Dilution Attenuation Factor (DAF) (unitless)	HLC (atm-m^3/mole)	Henry's Law Constant (unitless)	Henry's Law Constant (15 °C) (unitless)	Henry's Law Constant Used in Calcs (unitless)	H` and HLC Ref	Enthalpy of vaporization @ groundwater temperature $\Delta H_{v,gw}$ \ (cal/mol)	Exponent for $\Delta H_{v,gw}$	Normal Boiling Point BP (K)	BP Ref
1.46E+02	5.201283728557774	0.00555	2.27E-01	0.1463174	1.46E-01	PHYSPROP	8070.4817	0.3490018	353.15	PHYSPROP
4.00E+01	5.201283728557774	0.000657	2.69E-02	0.0144631	1.45E-02	EPI	11148.785	0.4019628	418.15	EPI
1.00E+00	5.201283728557774	6E-8	2.45E-06	1.0678E-6	1.07E-06	PHYSPROP	14779.678	0.3681905	470.45	PHYSPROP
2.82E+00	5.201283728557774	1.6E-6	6.54E-05	0.0000299	2.99E-05	PHYSPROP	13942.399	0.3994551	441.55	PHYSPROP
4.30E+02	5.201283728557774	0.000432	1.77E-02	0.0075884	7.59E-03	EPI	15002.349	0.41	486.65	EPI
1.00E+00	5.201283728557774	1.29E-8	5.27E-07	2.1699E-7	2.17E-07	EPI	15741.792	0.3883713	460.75	PHYSPROP
2.17E+01	5.201283728557774	0.0278	1.14E+00	0.8946132	8.95E-01	PHYSPROP	4666.6627	0.3364447	259.85	PHYSPROP

Site-specific

Risk-Based Regional Screening Levels (RSL) for Soil to Groundwater

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Critical Temperature T_c\ (K)	T_c\ Ref	Noncarcinogenic SL Adult THI=1 (ug/L)	Noncarcinogenic SL Child THI=1 (ug/L)	Carcinogenic SL TR=1E-06 (ug/L)	Water Concentration (Adult) (mg/L)	Water Concentration (Child) (mg/L)	Water Concentration (Cancer) (mg/L)	Maximum Contaminant Level (MCL) (ug/L)
562	CRC	4.07E+01	3.32E+01	4.55E-01	2.11E-01	1.73E-01	2.37E-03	5.00E+00
597.4	CRC	-	-	-	-	-	-	-
719	CRC	2.67E+04	1.60E+04	-	1.39E+02	8.34E+01	-	-
633.9	CRC	3.29E+03	1.98E+03	-	1.71E+01	1.03E+01	-	-
655	YAWS	-	-	-	-	-	-	-
676	CRC	6.66E+05	4.01E+05	-	3.47E+03	2.08E+03	-	-
425	CRC	6.43E+01	4.44E+01	1.88E-02	3.34E-01	2.31E-01	9.76E-05	2.00E+00

Site-specific

Risk-Based Regional Screening Levels (RSL) for Soil to Groundwater

Key: I = IRIS; P = PPRTV; O = OPP; A = ATSDR; C = Cal EPA; X = PPRTV Screening Level; H = HEAST; D = OW; W = TEF applied; E = RPF applied; G = see user guide; U = user provided; ca = cancer; nc = noncancer; * = where: nc SL < 100X ca SL; ** = where nc SL < 10X ca SL; SSL values are based on DAF=1; max = ceiling limit exceeded; sat = Csat exceeded.

Water Concentration (MCL) (mg/L)	MCL-based SL (mg/kg)	Noncarcinogenic Adult SL THI=1 (mg/kg)	Noncarcinogenic Child SL THI=1 (mg/kg)	Carcinogenic SL (mg/kg)	Risk-Based SL (mg/kg)
2.60E-02	1.31E-02	1.07E-01	8.72E-02	1.19E-03	1.19E-03 ca
-	-	-	-	-	
-	-	2.80E+01	1.68E+01	-	1.68E+01 nc
-	-	3.52E+00	2.12E+00	-	2.12E+00 nc
-	-	-	-	-	
-	-	7.00E+02	4.21E+02	-	4.21E+02 nc
1.04E-02	3.36E-03	1.08E-01	7.46E-02	3.16E-05	3.16E-05 ca

Appendix B

Technical Guidance Instructions

TGI – Groundwater and Soil Sampling Equipment Decontamination

Rev: 2

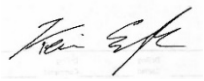
Rev Date: June 14, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	February 23, 2017	All	Conversion from SOP to TGI	Cassandra McCloud / Pete Frederick
	1	May 8, 2020	4, 5	Added note regarding use of Liquinox and 1,4-Dioxane	Marc Killingstad
	2	June 14, 2022	All	Conversion to new TGI format and minor edits.	Kevin Engle / Marc Killingstad

Approval Signatures

Prepared by: 6/14/2022



Name (Preparer) Date

Reviewed by: 6/14/2022

Marc Killingstad (Subject Matter Expert) Date

1 Introduction

This document is intended to provide guidance to staff performing decontamination procedures at project sites. The content in this document describes the intended use, scope and application, personnel qualifications, equipment, cautions, health and safety considerations, procedures, waste management, data recording and management, and quality assurance of decontamination procedures.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

Decontamination is performed on sampling equipment prior to sample collection to ensure that the sampling equipment that contacts a sample, or monitoring equipment that is brought into contact with environmental media to be sampled, is free from analytes of interest and/or constituents that could interfere with laboratory analysis for analytes of interest. Sampling equipment must be appropriately cleaned prior to use for sampling or coming into contact with environmental media to be sampled and following completion of the sampling event prior to shipment or storage. The effectiveness of the decontamination procedure should be verified by collecting and analyzing equipment blank samples.

The sampling equipment cleaning procedures described herein includes pre-field, in the field, and post- field cleaning of sampling equipment which may be conducted at an established equipment decontamination area (EDA) on site, as appropriate and necessary. Sampling equipment that may require decontamination at a given site include soil sampling tools; groundwater, sediment, and surface-water sampling devices; water testing instruments; down-hole instruments; and other activity-specific sampling equipment. Non-disposable equipment will be cleaned before collecting each sample, between each sample collected, and prior to placing sampling equipment in protective cases, or containers for transport. Cleaning procedures for sampling equipment should be monitored by collecting equipment blank samples as required in project work plans, field sampling plans, quality assurance project plans (QAPP), or other pertinent project documents. Dedicated and/or single-use (i.e., not to be re-used) sampling equipment will not require decontamination.

4 Personnel Qualifications

Arcadis field sampling personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or regulations, such as 40-hour hazardous waste operations and emergency response (HAZWOPER) training and/or Occupational Safety and Health Administration (OSHA) HAZWOPER site supervisor training. Arcadis personnel will also have current training as specified in the Health and Safety Plan (HASP) which may include first aid, cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project HASP and other documents will identify other training requirements or access control requirements.

5 Equipment List

The equipment required for equipment decontamination is presented below. Note that certain contaminants may require specific materials be used that are not captured in this list. Always review project and contaminant specific TGIs or work plans to ensure proper equipment is utilized. Note for per- and polyfluoroalkyl substances (PFAS) see *TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*.

- Health and safety equipment, including appropriate personal protective equipment (PPE), as required in the site HASP
- Deionized water that meets the analytical criteria for deionized water with no detectable constituents above the reporting limits for the methods to be used and analytes being analyzed for. Deionized water is used for inorganics, and organic-free water for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, etc.
- Non-phosphate detergent such as Alconox® or, if sampling for phosphorus or phosphorus- containing compounds, Liquinox (or equivalent). NOTE: Liquinox has shown to provide false positives for 1,4-Dioxane and should not be used at sites where that may be a constituent of concern (COC).
- Tap water
- Rinsate collection plastic containers

- Department of Transportation (DOT)-approved waste shipping container(s), as specified in the work plan, field sampling plan, or regulatory requirements if decontamination waste is to be shipped for disposal
- Brushes
- Large heavy-duty garbage bags
- Spray bottles
- (Optional) – Isopropyl alcohol (free of ketones) or methanol. These can be wipes or diluted with water (usually 1part isopropyl/methanol to 10 parts water) if a spray is needed.
- Airtight, sealable plastic baggies, such as Ziploc®-type
- Plastic sheeting

6 Cautions

Rinse equipment thoroughly and allow the equipment to dry before re-use or storage to prevent introducing solvent into sample medium. If manual drying of equipment is required, use clean lint-free material to wipe the equipment dry. Ensure all rinse materials do not adversely affect sample collection efficiency or analytical results.

Store decontaminated equipment in a clean, dry environment. Do not store near combustion engine exhausts. Properly containerize equipment to ensure cross-contamination doesn't happen from other uncontaminated surfaces or equipment.

If equipment is damaged to the extent that decontamination is uncertain due to cracks, gouges, crevices, or dents, the equipment should not be used and should be discarded or submitted for repair prior to use for sample collection.

A proper shipping determination regarding hazardous materials will be performed by a DOT-trained individual for cleaning materials shipped by Arcadis.

Caution should be exercised to avoid contact with the pump casing and water in the container while the pump is running (do not use metal drums or garbage cans) to avoid electric shock.

7 Health and Safety Considerations

Review the safety data sheets (SDS) for the cleaning agents and materials used in decontamination. If solvent is used during decontamination, use appropriate PPE and work in a well-ventilated area and stand upwind while applying solvent to equipment. Apply solvent in a manner that minimizes potential for exposure to workers and bystanders. Follow health and safety procedures outlined in the HASP.

8 Procedure

A designated area will be established to clean sampling equipment in the field prior to and following sample collection. Equipment cleaning areas will be set up within or adjacent to the specific work area, but not at a location that expose equipment to contamination (i.e., exposed to combustion engine exhaust). Detergent solutions will be prepared in clean containers for use in equipment decontamination. Decontaminated equipment

will be handled by workers wearing clean gloves, properly changed to prevent cross-contamination. The procedures detailed in this section provide an overview of common decontamination techniques. Additional steps may be required based on the type of contaminant present or client/site requirements.

Cleaning Sampling Equipment

1. Wash the equipment/pump with potable water.
2. Wash with detergent solution (Alconox®, Liquinox® or equivalent) to remove all visible particulate matter and any residual oils or grease. NOTE: Liquinox® has shown to provide false positives for 1,4-Dioxane and will not be used at sites where that may be a COC.
3. If equipment is very dirty, precleaning gross debris with a brush and tap water may be necessary.
4. If non-aqueous phase liquids are present, the use of isopropyl alcohol (free of ketones) or methanol is recommended. Cloth wipes or diluted solution can be used to remove the non-aqueous phase liquids that are hard to remove with detergent solution in step 2. Consult with project manager if non-aqueous phase liquids are present onsite and design an appropriate decontamination procedure that includes step 4.
5. Rinse with deionized water.

Decontaminating Submersible Pumps

Submersible pumps may be used during well development, groundwater sampling, or other investigative activities. The pumps must be cleaned and flushed before and between uses. This cleaning process will consist of an external detergent solution wash and tap water rinse, a flush of detergent solution through the pump, followed by a flush of potable water through the pump. Flushing will be accomplished by using an appropriate container filled with detergent solution and another container filled with potable water. The pump will be be flushed with deionized water as the last step prior to use. The pump will run long enough to effectively flush the pump housing and hose (unless new, disposable hose is used). Disconnect the pump from the power source before handling. The pump and hose will be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

9 Waste Management

Equipment decontamination rinsate will be managed in conjunction with all other waste produced during the field sampling effort. Waste management procedures are outlined in the work plan or Waste Management Plan (WMP).

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff

are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Equipment cleaning and decontamination will be noted during project documentation. Information will include the type of equipment cleaned, the decontamination location, specific procedures utilized, solvents and/or cleaning agents used, source of water, and deviations or omissions from this TGI.

Unusual field conditions should be noted if there is potential to impact the efficacy of the decontamination or subsequent sample collection.

An inventory of the solvents brought on site and used and removed from the site will be maintained in the project documentation. Records will be maintained for solvents used in decontamination, including lot number and expiration date.

Containers with decontamination fluids will be labeled.

11 Quality Assurance

Equipment blanks should be collected to verify that the decontamination procedures are effective in minimizing potential for cross contamination. The equipment blank is prepared by pouring deionized water (or organic-free water, for organic analyses) over the clean and dry tools and collecting the water into appropriate sample containers. Equipment blanks should be analyzed for the same set of parameters that are performed on the field samples collected with the equipment that was cleaned as specified in the sampling and analysis plan. Equipment blanks are collected per equipment set, which represents all the tools needed to collect a specific sample.

12 References

USEPA Region 9 - Field Sampling Guidance #1230, Sampling Equipment Decontamination.

USEPA Region 1 - Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells.

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ARCADIS Design & Consultancy for natural and built assets

TGI - INVESTIGATION-DERIVED WASTE HANDLING AND STORAGE

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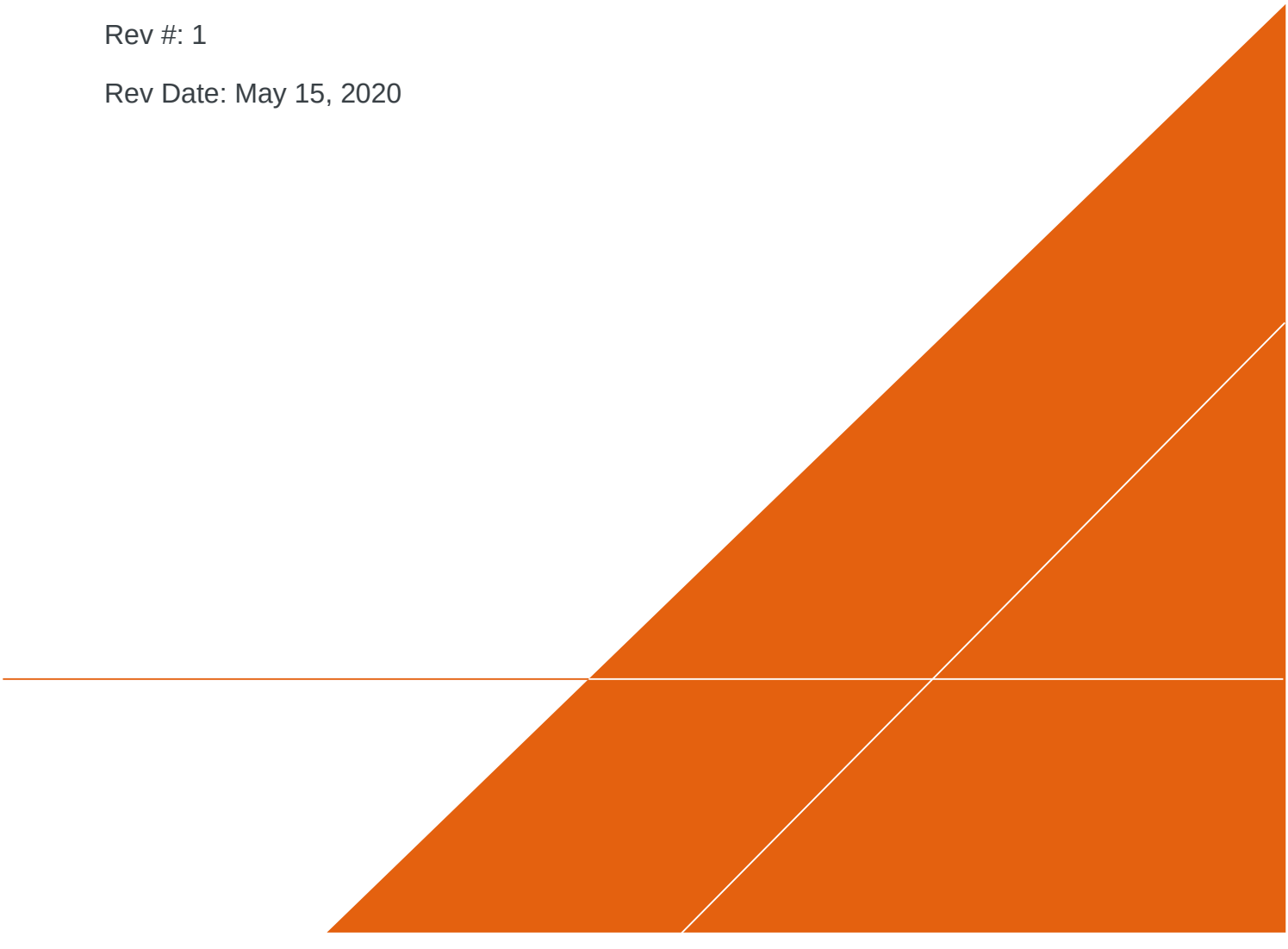

VERSION CONTROL

Revision No	Revision Date	Page No(s)	Description	Reviewed by
0	February 23, 2017	ALL	Conversion from SOP to TGI	Ryan Mattson / Peter Frederick
1	May 15, 2020	ALL	Updated to reflect regulatory changes	

APPROVAL SIGNATURES

Prepared by:		02/23/2017
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Technical Expert Reviewed by:		05/15/2020
	Ryan Mattson (Technical Expert)	Date:

1 INTRODUCTION

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

2 SCOPE AND APPLICATION

The objective of this Technical Guidance Instruction (TGI) is to describe the procedures to manage investigation-derived wastes (IDW), both hazardous and nonhazardous, generated during site activities, which may include, but are not limited to: drilling, trenching/excavation, construction, demolition, monitoring well sampling, soil sampling, decontamination and remediation. For the purposes of this TGI, IDW is considered to be discarded materials which are defined as solid waste by United States Environmental Protection Agency (EPA) standard 40 CFR § 261.2 (which may include liquids, solids, or sludges). IDW may include soil, groundwater, drilling fluids, decontamination liquids, as well as contaminated personal protective equipment (PPE), sorbent materials, construction and demolition debris, and disposable sampling materials. Hazardous or uncharacterized IDW will be collected and staged at the point of generation. Quantities small enough to be containerized in 55-gallon drums will be taken to a designated temporary onsite storage area (discussed in further detail under Drum Storage) pending characterization and disposal. IDW materials will be characterized using process knowledge and appropriate laboratory analyses to determine the waste classification and evaluate proper safe handling and disposal methods.

This TGI describes the necessary equipment, field procedures, materials, regulatory references, and documentation procedures necessary for proper handling and storage of IDW up to the time it is properly transported from the project site and disposed. The procedures included in this TGI for handling and temporary storage of IDW are based on the EPA's guidance document *Guide to Management of Investigation Derived Wastes* (USEPA, 1992). IDW is assumed to be contaminated with the site constituents of concern (COCs) until analytical evidence indicates otherwise. IDW will be managed to ensure the protection of human health and the environment and will comply with all applicable or relevant and appropriate requirements (ARAR). Although not comprehensive, the following laws and regulations on Hazardous Waste Management should be considered as potential ARAR. It is the Arcadis Certified Project Manager (CPM) and/or designated Technical Expert to determine which laws and regulations, at all levels of government, are applicable to each project site and activity falling under this TGI.

Federal Laws and Regulations

- Resource Conservation and Recovery Act (RCRA) 42 USC § 6901-6987.
- Federal Hazardous Waste Regulations 40 CFR § 260-265

Department of Transportation (DOT) Hazardous Materials Transportation 49 CFR

Occupational Safety and Health Administration (OSHA) Regulations 29 CFR

State Laws and Regulations

- To be determined based on location of site and location of treatment, storage, and/or disposal facility (TSDF) to be utilized.

Regional, County, Municipal, and Local Regulations

- To be determined based on location of site and location of treatment, storage, and/or disposal facility (TSDF) to be utilized.

Initial Storage

Pending characterization, IDW will be temporarily stored appropriately within each area of contamination (AOC). Under RCRA, "storage" is defined as the "holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere" (40 CFR § 260.10). The onsite waste staging area will be in a secure and controlled area. Uncharacterized wastes are considered potentially hazardous wastes and must be stored in DOT approved packaging. Liquid wastes must be stored in DOT approved closed head drums or other approved containers (e.g., portable tank containers) that are compatible with the type of material stored therein. Solid materials must be stored in DOT approved open head drums where practicable. Larger quantities of solid IDW can be containerized in bulk containers (such as in a roll-off box). Soil from large excavation projects may be managed in stockpiles with within the AOC and does not need to be containerized until exiting the AOC.

Characterization

Waste characterization can either be based on generator knowledge, such as using historical process knowledge and safety data sheets (SDS), or can be based upon characterization sampling analytical results. IDW typically is not characterized using SDS as it is a mixture of aged chemicals and environmental media. Historical process knowledge should be used to determine if the IDW is a listed hazardous waste (40 CFR § 261.31-33). If the IDW is not a listed hazardous waste, waste

characterization can be completed by laboratory analysis of representative samples of the IDW. The laboratory used for waste characterization analysis must have the appropriate state and federal accreditations and may be required to be pre-approved by the Client. IDW will be classified as RCRA hazardous or non-regulated under RCRA based on the waste characterization determination.

If IDW is characterized as RCRA hazardous waste, RCRA and DOT requirements must be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR § 262 and 49 CFR § 171-178. Waste material classified as RCRA nonhazardous may be handled and disposed of as nonhazardous waste in accordance with applicable federal, state, and local regulations.

Storage Time Limitations

Containerized hazardous wastes can be temporarily stored for a maximum of 90 calendar days from the accumulation start date for a large quantity generator or a maximum of 180 calendar days from the accumulation start date for a small quantity generator. Wastes classified as nonhazardous may be handled and disposed of as nonhazardous waste and are not subject to storage time limitations.

This is TGI may be modified by the CPM and/or Technical Expert for a specific project or client program, as required, dependent upon client requirements, site conditions, equipment limitations, or limitations imposed by the procedure. The resulting procedure employed to execute the work will be documented in the project work plans or reports. If changes to the sampling procedures are required due to unanticipated field conditions, the changes will be discussed with the CPM and/or Technical Expert as soon as practicable, and if approved to be performed, be documented.

3 PERSONNEL QUALIFICATIONS

Arcadis field sampling personnel will have current regulatory- and Arcadis-required health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and cardiopulmonary resuscitation (CPR), as needed. Personnel handling and packaging hazardous waste and performing hazardous waste characterizations must have RCRA hazardous waste management training per 40 CFR § 264.16. Additional state-specific hazardous waste management training is required in certain states (i.e., California).

Although not common practice, in certain situations Arcadis personnel may sign waste profiles and/or waste manifests on a case by case basis for clients, provided the appropriate agreement is in place between Arcadis and the client documenting that Arcadis is not the generator, but is acting as an authorized representative of the generator. Arcadis personnel who sign waste profiles and/or waste manifests will have both current RCRA hazardous waste management training per 40 CFR § 264.16 and current DOT hazardous materials transportation training per 49 CFR § 172.704. Arcadis field personnel will also comply with client-specific training. In addition, Arcadis field sampling personnel will be knowledgeable in the relevant processes, procedures, and Technical Guidance Instructions (TGIs) and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. The project health and safety plan (HASP) and other documents will identify other training requirements or access control requirements.

4 EQUIPMENT LIST

The Following Materials, as required, will be available for IDW handling and Storage:

- Appropriate personal protective equipment as specified in the Site Health and Safety Plan (HASP)
- DOT approved containers
- Hammer
- Leather gloves
- Drum dolly
- Appropriate drum labels (outdoor waterproof self-adhesive)
- Portable tank container
- Appropriate labeling, packing, chain-of-custody forms, and shipping materials as determined by the CPM and/or Technical Expert.
- Indelible ink and/or permanent marking pens
- Plastic sheeting
- Appropriate sample containers, labels, and forms
- Stainless-steel bucket auger
- Stainless steel spatula or knife
- Stainless steel hand spade
- Stainless steel scoop
- Digital camera
- Field logbook

5 CAUTIONS

Filled drums can be very heavy, become unbalanced, or spill its contents. Therefore, use appropriate moving techniques and equipment for safe handling. Similar media (e.g. soils with other soils; or liquids with other liquids) will be stored in the same drums to aid in sample analysis and disposal. Drum lids must be secured to prevent rainwater from entering the drums and leakage during movement. Drums containing solid material may not contain any free liquids. Waste containers stored for extended periods of time may be subject to deterioration. Drum Over Packs may be used as secondary containment. All drums must be visually inspected for condition to ensure that they are in good condition without visible evidence of rusting, holes, breakage, etc., to prevent potential leakage and facilitate subsequent disposal. All drum lids must be verified as having a properly functioning secured lid prior to use.

6 HEALTH AND SAFETY CONSIDERATIONS

As determined by the site's known and suspected hazards, appropriate PPE must be worn by all field personnel within the designated work area. Exposure air monitoring may be required during certain field activities as required in the Site Health and Safety Plan. If soil excavation in areas with potentially hazardous contaminants is possible, contingency plans will be developed to address the potential for encountering gross contamination or non-aqueous phase liquids. All excavation activities shall be in compliance with OSHA standard 29 CFR 1926.651 Excavations, and any other applicable regulations.

Arcadis field personnel and subcontractors will be trained in and perform their work in compliance with all applicable federal, state, and local health and safety regulations as well as Arcadis' HASP and applicable Client health and safety requirements.

7 PROCEDURE

Specific waste temporary storage and handling procedures to be used are dependent upon the type of generated waste, including type of media (e.g. soils or free liquids) and constituents of concern. For this reason, IDW can be stored in a secure location onsite in separate 55-gallon storage drums, where solids can be stockpiled onsite (if nonhazardous) and purge water may be stored in portable tank containers. Waste materials such as broken sample bottles or equipment containers and wrappings will be stored in 55-gallon drums unless they were not in contact with sample media.

Management of IDW

Minimization of IDW should be considered by the project team during all phases of the project. Site managers may want to consider techniques such as replacing solvent based cleaners with aqueous-based cleaners for decontamination of equipment, reuse of equipment (where it can be properly decontaminated), limitation of traffic between exclusion and support zones, and drilling methods and sampling techniques that minimize the generation of waste. Alternative drilling and subsurface sampling methods may include the use of small diameter boreholes, as well as borehole testing methods such as a core penetrometer or direct push technique instead of coring.

Drum Storage

Drums containing hazardous waste will be stored in accordance with the requirements of 40 CFR 265 Subpart I (for containers) and 265 Subpart DD (for containment buildings). All 55-gallon drums will be stored at a secure, centralized onsite location that is readily accessible for vehicular pick-up. Drums confirmed as, or assumed to contain hazardous waste will be stored over an impervious surface provided with secondary spill containment. The storage location will, for drums containing liquid, have a containment system that can contain at least the larger of 10% of the aggregate volume of staged materials or 100% of the volume of the largest container. Drums will be closed during storage and be in good condition in accordance with the Guide to Management of Investigation-Derived Wastes (USEPA, 1992).

Hazardous Waste Determination

Waste material must be characterized to determine if it meets any of the federal definitions of hazardous waste as required by 40 CFR § 262.11. If the waste does not meet any of the federal definitions, it must then be established if any state-specific or local-specific hazardous waste criteria exist/apply.

Generator Status

Once hazardous waste determination has been made, the generator status will be determined. Large quantity generators (LQG) are generators who generate more than 1,000 kilograms of hazardous waste in a calendar month. Small quantity generators (SQG) of hazardous waste are generators who generate greater than 100 kilograms but less than 1,000 kilograms of hazardous waste in a calendar month. Very small quantity generators (VSQG) are generators who generate less than 100 kilograms of hazardous

waste per month. Please note that a generator status may change from month to month and that a notice of this change is usually required by the generator's state agency.

Accumulation Time for Hazardous Waste

A LQG may accumulate hazardous waste on site for 90 calendar days or less without a permit and without having interim status, provided that such accumulation is in compliance with requirements in 40 CFR § 262.17. A SQG may accumulate hazardous waste on site for 180 calendar days or less without a permit or without having interim status, subject to the requirements of 40 CFR § 262.16. VSQG requirements are found in 40 CFR § 262.14. NOTE: The federal VSQG and SQG provisions may not be recognized by some states (e.g., California and Rhode Island). State-specific and local-specific regulations must be reviewed and understood prior to the generation of hazardous waste.

Satellite Accumulation of Hazardous Waste Satellite accumulation (SAA) will mean the accumulation of as much as fifty-five (55) gallons of hazardous waste, or the accumulation of as much as one quart of acutely hazardous waste, in containers at or near any point of generation where the waste initially accumulates, which is under the control of the operator of the process generating the waste, without a permit or interim status and without complying with the requirements of 40 CFR § 262.15 and without any storage time limit, provided that the generator complies with 40 CFR § 262.15.

Once more than 55 gallons of hazardous waste accumulates in SAA, the generator has three days to move this waste into storage.

Storage recommendations for hazardous waste include:

- Ignitable or reactive hazardous wastes must be >50 feet from the property line per 40 CFR § 265.176 (LQG generators only).
- Hazardous waste should be stored on a concrete slab (asphalt is acceptable if there are no free liquids in the waste).
- Drainage must be directed away from the accumulation area.
- Area must be properly vented.
- Area must be secure.

Drum/Container Labeling

Drums will be labeled on both the side and lid of the drum using a permanent marking pen. Old drum labels must be removed to the extent possible, descriptions crossed out should any information remain, and new labels affixed on top of the old labels. Other containers used to store various types of waste (e.g., polyethylene tanks, roll-off boxes, end-dump trailers, etc.) will be labeled with an appropriate "Waste Container" or "Testing in Progress" label pending characterization. Drums and containers will be labeled as follows:

- Appropriate waste characterization label (Pending Analysis, Hazardous, or Nonhazardous)
- Waste generator's name (e.g., client name)
- Project Name
- Name and telephone number of Arcadis project manager
- Composition of contents (e.g., used oil, acetone 40%, toluene 60%)
- Media (e.g., solid, liquid)
- Accumulation start date

- Drum number of total drums as reconciled with the Drum Inventory maintained in the field log book.

IDW containers will remain closed except when adding or removing waste. Immediately upon beginning to place waste into the drum/container, a “Waste Container” or “Pending Analysis” label will be filled out to include the information specified above, and affixed to the container. Once the contents of the container are identified as either non-hazardous or hazardous, the following additional labels will be applied.

- Containers with waste determined to be non-hazardous will be labeled with a green and white "Nonhazardous Waste" label over the "Waste Container" label.
- Containers with waste determined to be hazardous will be stored in an onsite storage area and will be labeled with the "Hazardous Waste" label and affixed over the "Waste Container" label.

The ACCUMULATION DATE for the hazardous waste is the date the waste is first placed in the container and is the same date as the date on the "Waste Container" label. DOT hazardous class labels must be applied to all hazardous waste containers for shipment offsite to an approved disposal or recycling facility. In addition, a DOT proper shipping name will be included on the hazardous waste label. The transporter should be equipped with the appropriate DOT placards. However, placarding or offering placards to the initial transporter is the responsibility of the generator per 40 CFR § 262.33.

Inspections and Documentation

All IDW will be documented as generated on a Drum Inventory Log maintained in the field log book. The Drum Inventory will record the generation date, type, quantity, matrix and origin (e.g., Boring-1, Test Pit 3, etc.) of materials in every drum, as well as a unique identification number for each drum. The drum inventory will be used during drum pickup to assist with labeling of drums. The drum storage area and any other areas of temporarily staged waste, such as soil/debris piles, will be inspected weekly. The weekly inspections will be recorded in the field notebook or on a Weekly Inspection Log. Digital photographs will be taken upon the initial generation and drumming/staging of waste, and final labeling after characterization to document compliance with labeling and storage protocols, and condition of the container. Evidence of damage, tampering or other discrepancy should be documented photographically.

Emergency Response and Notifications

Specific procedures for responding to site emergencies will be detailed in the HASP. If the generator is designated as a LQG, a Contingency Plan will need to be prepared to include emergency response and notification procedures per 40 CFR § 265 Subpart D. In the event of a fire, explosion, or other release which could threaten human health outside of the site or when Client or Arcadis has knowledge of a spill that has reached surface water, Client or Arcadis must immediately notify the National Response Center (800-424-8802) in accordance with 40 CFR § 262.265. Other notifications to state and/or other local regulatory agencies may also be necessary.

Drilling Soil Cuttings and Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities, subsurface soil sampling, or installation of monitoring wells. Depending on the drilling method, drilling fluids known as "muds" may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Soil cuttings will be labeled and stored in 55-gallon drums with bolt-sealed lids.

Excavated Solids

Excavated solids may include, but are not limited to: soil, fill, and construction and demolition debris. Prior to permitted treatment or offsite disposal, potentially hazardous excavated solids may be temporarily stockpiled onsite as long as the stockpile remains in the same AOC from where it was excavated. Potentially hazardous excavated solids removed from the AOC must be immediately containerized in labeled drums or closable top roll-offs lined with 9-mil polyvinyl chloride (PVC) sheeting and are subject to LQG storage time limits. Nonhazardous excavated solids can be stockpiled either inside or outside of the AOC, do not have to be containerized and are not subject to hazardous waste regulations. Potentially hazardous excavated solids must not be mixed with nonhazardous excavated solids. All classes of excavated solid stockpiles should be maintained in a secure area onsite. At a minimum, the floor of the stockpile area will be covered with a 20-mil high density polyethylene liner that is supported by a foundation or at least a 60-mil high density polyethylene liner that is not supported by a foundation. The excavated material will not contain free liquids. The owner/operator will provide controls for windblown dispersion, run-on control, and precipitation runoff. The run-on control system will prevent flow onto the active portion of the pile during peak discharge from at least a 25-year storm and the run-off management system will collect and control at least the water volume resulting from a 24-hour, 25-year storm (USEPA, 1992). Additionally, the stockpile area will be inspected on a weekly basis and after storm events. Individual states may require that the stockpile be inspected/certified by a licensed professional engineer. Stockpiled material will be covered with a 6-mil polyvinyl chloride (PVC) liner or sprayed dust control product. The stockpile cover will be secured in place with appropriate material (concrete blocks, weights, etc.) to prevent the movement of the cover.

Decontamination Solutions

Decontamination solutions are generated during the decontamination of personal protective equipment and sampling equipment. Decontamination solutions may range from detergents, organic solvents and acids used to decontaminate small field sampling equipment to steam cleaning rinsate used to wash heavy field equipment. These solutions are to be labeled and stored in closed head drums compatible with the decontamination solution. Decontamination procedures, including personnel and field sampling equipment, must comply with applicable Arcadis procedural documents.

Disposable Equipment

Disposable equipment includes personal protective equipment (e.g., tyvek coveralls, gloves, booties and APR cartridges) and disposable sampling equipment such as trowels or disposable bailers. If the media sampled exhibits hazardous characteristics per results of waste characterization sampling, contaminated disposable equipment will also be disposed of as a hazardous waste. If compatible with the original IDW waste stream (i.e., the IDW is a solid and the disposal equipment is a solid), the disposable equipment can be combined with the IDW. If these materials are not compatible (i.e., the IDW is a liquid and the disposal equipment is a solid), the disposable equipment will be stored onsite in separate labeled 55-gallon drums. Uncontaminated or decontaminated disposable equipment can be considered nonhazardous waste.

Purge Water

Purge water includes groundwater generated during well development, groundwater sampling, or aquifer testing. The volume of groundwater generated will dictate the appropriate storage procedure. Monitoring

well development and groundwater sampling may generate three well volumes of groundwater or more. This volume will be stored in labeled 55-gallon drums. Aquifer tests may generate significantly greater volumes of groundwater depending on the well yield and the duration of the test. Therefore, large-volume portable polyethylene tanks will be considered for temporary storage pending groundwater-waste characterization.

Purged Water Storage Tank Decontamination and Removal

The following procedures will be used for inspection, cleaning, and offsite removal of storage tanks used for temporary storage of purge water. These procedures are intended to be used for rented portable tanks such as Baker Tanks or Rain for Rent containers. Storage tanks will be made of inert plastic materials. The major steps for preparing a rented tank for return to a vendor include characterizing the purge water, disposing of the purge water, decontaminating the tank, final tank inspection, and mobilization. Decontamination and inspection procedures are described in further detail below.

- Tank Cleaning: Most vendors require that tanks be free of any visible sediment and water before returning, a professional cleaning service may be required. Each specific vendor should be consulted concerning specific requirements for returning tanks.
- Tank Inspection: After emptying the tank, purged water storage tanks should be inspected for debris, chemical staining, and physical damage. The vendors require that tanks be returned in the original condition (i.e., free of sediment, staining and no physical damage).

8 WASTE MANAGEMENT

Soil/Solids Characterization

Waste characterization will be conducted in accordance with waste hauler, waste handling facility, and local/state/federal requirements. In general, RCRA hazardous wastes are those solid wastes determined by a Toxicity Characteristic Leaching Procedure (TCLP) test or to contain levels of certain toxic metals, pesticides, or other organic chemicals above specific applicable regulatory agency thresholds. If the one or more of 40 toxic compounds listed in Table I of 40 CFR § 261.24 are detected in the sample at levels above the maximum unregulated concentrations, the waste must be characterized as a toxic hazardous waste. Wastes can also be considered “listed” hazardous waste depending on site-specific processes.

Composite soil samples will be collected at a frequency of one sample per 250 cubic yard basis for stockpiled soil or one per 55-gallon drum per different waste stream for containerized. A four-point composite sample will be collected per 250 cubic yards of stockpiled material and for each drum waste stream. Sample and composite frequencies may be adjusted in accordance with the waste handling facility’s requirements and may be reduced for large volumes of waste with consistent properties. Waste characterization samples will be considered valid for consistent waste streams for a period of 1 year. Waste characterization samples may be analyzed for the TCLP volatile organic compounds (VOCs), TCLP semi-volatile organic compounds (SVOCs), TCLP RCRA metals, and polychlorinated biphenyls (PCBs), as well as reactivity and flammability (flashpoint). Additional samples may be collected and analyzed by the laboratory on a contingency basis. Site-specific constituents of concern including pesticides may require additional sampling. Please note that state- or local-specific regulations may require a different or additional sampling approaches.

Wastewater Characterization

Waste characterization will be conducted in accordance with the requirements of the waste hauler, waste handling facility, and local/state/federal governments. In general, purge water should be analyzed by methods appropriate for the known contaminants, if any, that have been historically detected in the monitoring wells. Samples will be collected and analyzed in accordance with the requirements of the waste disposal facility. Wastewater characterization samples may be analyzed for TCLP volatile organic compounds (VOCs), TCLP semi-volatile organic compounds (SVOCs), TCLP RCRA metals, and polychlorinated biphenyls, as well as corrosivity (pH), reactivity and flammability (flashpoint). Additional samples may be collected and analyzed by the laboratory on a contingency basis. Site-specific constituents of concern including pesticides may require additional sampling. Please note that state- and/or local-specific regulations may require different or additional sampling approaches.

Sample Handling and Shipping

All samples will be appropriately labeled, packed, and shipped, and the chain-of-custody will be filled out in accordance with current Arcadis sample chain of custody, handling, packing, and shipping procedures and guidance instructions.

It should be noted that additional training is required for packaging and shipping of hazardous and/or dangerous materials. Please refer to the current Arcadis training requirements related to handling and shipping of samples, shipping determinations, and hazardous materials.

Preparing Waste Shipment Documentation (Hazardous and Nonhazardous)

Waste profiles will be prepared by the Arcadis CPM and forwarded, along with laboratory analytical data to the Client for approval/signature. The Client will then return the profile to Arcadis who will then forward to the waste removal contractor for preparation of a manifest. The manifest will be reviewed by Arcadis prior to forwarding to the Client for approval. Upon approval of the manifest, the Client will return the original signed manifest directly to the waste contractor or to the Arcadis CPM for forwarding to the waste contractor. Arcadis personnel may sign waste profiles and/or waste manifests on a case by case basis for clients, provided the appropriate agreement is in place between Arcadis and the client documenting that Arcadis is not the generator, but is acting as an authorized representative of the generator.

Final drum labeling and pickup will be supervised by an Arcadis representative who is trained and experienced with applicable waste labeling procedures. The Arcadis representative will have a copy of the drum inventory maintained in the field book and will reconcile the drum inventory with the profile numbers on the labels and on the manifest. Different profile numbers will be generated for different matrices or materials in the drums. For example, the profile number for drill cuttings will be different than the profile number for purge water. When there are multiple profiles it is critical that the proper label, with the profile number appropriate to a specific material be affixed to the proper drums. A copy of the Arcadis drum inventory will be provided to the waste transporter during drum pickup and to the facility receiving the waste.

9 DATA RECORDING AND MANAGEMENT

Waste characterization sample handling, packing, and shipping procedures will be documented in accordance with relevant Arcadis procedures and guidance instructions as well as applicable client and/or project requirements, such as a Quality Assurance Project Plan or Sampling and Analysis Plan. Copies of the chain-of-custody forms will be maintained in the project file. Arcadis should photograph or maintain a copy of any hazardous waste manifest signed on behalf of Client in the corresponding office DOT record file.

10 QUALITY ASSURANCE

The CPM or APM will review all field documentation once per week for errors or omissions as compared to applicable project requirements including but not limited to: the proposal/scope of work, QAPP, SAP, HASP, etc. Deficiencies will be noted, tracked, and resolved. Upon correction, they will be noted for project documentation.

11 REFERENCES

United States Environmental Protection Agency (USEPA). 1992. Guide to Management of Investigation-Derived Wastes. Office of Remedial and Emergency Response. Hazardous Site Control Division. January 1992.

ARCADIS Design & Consultancy for natural and built assets

TGI – Sample Chain of Custody

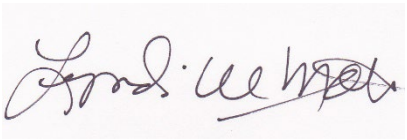
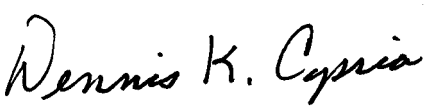
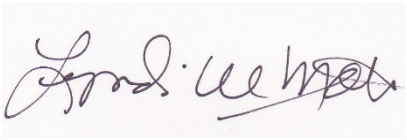
Rev: 3

Rev Date: March 28, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	April 19, 2017	All	Re-write to COC only	Richard Murphy
	1	May 23, 2017	4,7,9	Add: Guidance on use of previous version of TGI. Add: Info on COCs for multiple shipping containers Modify: Move letter i. to letter m. and change to “when appropriate”	Peter Frederick
	2	April 29, 2020	4, 11	Remove obsolete link	Lyndi Mott
	3	December 28, 2022	All	Updated Arcadis format Added to 6c. Collection time between COC and container must match. Added to 6o. Add name of overnight courier when relinquishing samples. Updated reference documents and added internet links.	Lyndi Mott

Approval Signatures

Prepared by:		3/28/2022
	Lyndi Mott (Preparer)	Date
Reviewed by:		3/28/2022
	Dennis Capria (Chain of Custody Reviewer)	Date
Reviewed by:		12/22/2021
	Lyndi Mott (Subject Matter Expert)	Date

1 Introduction

This Technical Guidance Instruction (TGI) provides the procedure for Arcadis field personnel for required documentation during the collection of environmental field samples and transfer of custody to a laboratory. It provides direction for completion of the Chain of Custody form that must accompany collected field samples for analysis by a laboratory.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

This TGI describes the general Chain of Custody (COC) procedures and guidance instructions for samples collected from project sites that are relinquished from Arcadis' possession.

COC is defined as the maintenance of an unbroken record of possession of an item from the time of its collection through some analytical or testing procedure. COC is typically documented by a written record of the collection, possession, and handling of samples collected from a project location. Each sample will be tracked by a documented record that efficiently documents the individuals who were responsible for the sample during each successive transfer of that sample to various recipients beyond Arcadis' possession. This information can be used to legally establish the integrity of the samples and therefore the analytical results derived from the samples. This

information can be used in addition to other records and documentation regarding the samples, such as field forms, field logs, and photographs.

A sample is considered under custody if:

- It is in your possession; or
- It is in your view, after being in your possession; or
- It was in your possession and then you then locked it up to prevent tampering; or
- It is in a designated secure area.

Continued use of previous version of TGI:

Although not recommended, Arcadis program-, project-, and client-teams may be able to use the previous version of this TGI provided that it meets all of the quality expectations of Arcadis and client and meets applicable regulatory requirements. It is up to the program, project, and/or client-team leader to determine whether it is appropriate to adopt the current TGI or to continue using the previous version.

However, all new work not associated with the previous version of this TGI must be performed with the current version of the TGI.

When adopting this new TGI, users of the previous versions must be aware that specific handling, packing, and shipping procedures and guidance has been removed and that those should be addressed within program or project plans (e.g., Quality Assurance Project Plans (QAPP), Work Plans, Sampling and Analysis Plans (SAPs), etc.) or in a more detailed TGI specific to that sampling activity, whether related to media, constituent/analyte, client, state, etc.

In addition, adopting this new TGI will require users to refer to the Arcadis Department of Transportation (DOT) Safety Program for procedures and guidance on the determination and handling, packing, and shipping of samples that are or may be considered hazardous materials.

4 Personnel Qualifications

Arcadis personnel performing work under the purview of this TGI will have received appropriate training and have field experience regarding the collection of samples from project locations. Arcadis personnel will have all other applicable and appropriate training relevant to the sampling work and project site.

5 Equipment List

The following list provides materials that may be required for each COC. Project reporting and documentation requirements must be reviewed with the CPM prior to execution of work. Additional materials, tools, equipment, etc. may be required, and project staff are required to verify with the CPM and/or Technical Expert what specific equipment is required to complete the COC.

- Indelible ink pen (preferably either black or blue ink);
- COC form **(Appendix A)** from either Arcadis, laboratory receiving and analyzing the samples, or other applicable and appropriate entity for the work performed;
- When appropriate, such as for litigation or expert testimony work, custody seals or tape.

6 Cautions

One way in which the law tries to ensure the integrity of evidence is by requiring proof of the chain of custody by the party who is seeking to introduce a particular piece of evidence.

A proper chain of custody requires three types of affirmations: (1) affirmation that a sample is what it purports to be (for example, soil collected from a specified location and depth); (2) affirmation of continuous possession by each individual who has had possession of the sample from the time it is collected until the time it is analyzed or held by a laboratory; and (3) affirmation by each person who has had possession that sample remained in substantially the same condition and not contaminated or affected by outside influences from the moment one person took possession until the moment that person released the evidence into the custody of another (for example, affirmation that the sample was stored in a secure location where no one but the person in custody had access to it).

Proving chain of custody is necessary to "lay a foundation" for the samples in question, by showing the absence of alteration, substitution, or change of condition.

Ensure that appropriate sample containers with applicable preservatives, coolers, and packing material are planned for and provided at the site at the time of sample collection.

Understand the offsite transfer requirements of the samples for the facility at which samples are collected.

If overnight courier service is required schedule pick-up or know where the drop-off service center is located and the hours of operation.

An Arcadis employee appropriately trained at the correct level of internal hazardous materials/DOT)shipping must complete an Arcadis shipping determination to address applicable DOT and International Air Transport Association (IATA) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging, and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.

The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

7 Health and Safety Considerations

Follow the health and safety procedures outlined in the project/site Health and Safety Plan (HASP) as well as other applicable H&S requirements, such as:

- Arcadis Hazardous Material/DOT handling, packaging, and shipping training
- Project site-specific H&S training
- Client-specific H&S training
- Constituent-specific H&S training
- Media-specific H&S training

8 Procedure

Collected samples must be uniquely identified, and properly documented, containerized, labeled with unique identifier, possessed in a secure manner during remainder of sampling event, packaged, and shipped to recipient laboratory.

Sample Identification

The method of sample identification depends on the type of measurement or analyses performed. In some cases, in-situ measurements of existing conditions and/or sample location must be made during sample collection.

These data will be recorded directly on field forms, logbooks, or other project record data sheets used to permanently retain this information for the project file. Examples of location identification information includes: latitude/longitudinal measurements, compass directions, well number, building number, floor number, room name, or proximity to a site feature unique to the site. Examples of in-situ measurements are pH, temperature, conductivity, flow measurement, or physical condition of the media being sampled. Physical samples collected are identified by a unique identifying number or code on a sample tag or label. These physical samples are removed from the sample location and transported to a laboratory for analyses.

In some cases, before samples are placed into individual containers and labeled as individual samples, samples may be separated into portions depending upon the analytical methods and required duplicate or triplicate analyses to be performed.

When completing a COC for samples, personnel must complete the following:

1. Written COCs must be completed with indelible ink (preferably either black or blue colored ink).
2. Written COCs must be completed using legible printed writing, and not cursive writing.
3. All entry fields on the COC form must be completed. If information is not applicable for a specific entry field, personnel will either put “N/A” or use a strike-out line or dash like “----------“ to indicate no applicable information is needed for that field.
4. Use of quotation marks or lines/down arrows to represent repetitive/duplicative text in similar fields.
5. Regardless of the type or specific COC form, the following pertinent information must be provided on the COC form:
    a. Arcadis project number
    b. Arcadis project name
    c. Project location, including street address, city, state, building number, providing as much detail as appropriate
    d. Recipient laboratory contact and sample receiving shipping location information
    e. Entities’/persons’ contact information for who will be receiving analytical results
    f. Name of sampler, i.e., person collecting sample and relinquishing possession of samples to the next entity in the chain of custody
    g. Date of sample collection
    h. If appropriate for the sample media, contaminant/constituent of concern, or analytical method, document time of sample collection using standard military time
    i. Sample analytical method(s)

j. Turnaround time required for analyses and/or reporting

k. Instructions to laboratory regarding handling, timing, analyses, etc. as applicable and appropriate.

l. Printed name and signature of the individual person who collected the samples and relinquishing possession of the samples

m. If appropriate or when documentation of the specific sample collection method will influence how the laboratory handles, prepares, or analyzes the samples, document the sample collection methodology used for collecting the samples (e.g., ASTM D5755)

6. The following additional specific information will be entered on the COC form, regardless of what type of COC is being used:

a. Unique Sample Identifier – The sample identifier (ID) must be unique to the individual sample it is applied to. The information in which the sample ID conveys is determined by the CPM, Technical Expert, and/or other project team members in advance of sample collection so that sample identification is consistently applied for the project. The sample nomenclature may be dictated by a specific client, program, or project database and require unique identification for each sample collected for the project. Consult with the CPM and/or Technical Expert for additional information regarding sample identification.

The sample ID could convey specific information regarding the sample to aid personnel in recognizing what the sample represents, or they may be arbitrary so as to facilitate the anonymity of the sample location, media, constituent of concern, project site, etc.

Examples of unique identifiers include:

1. Well locations, grid points, or soil boring identification numbers (e.g., MW-3, X-20, SB-30). When the depth interval is included, the complete sample ID would be “SB-30 (0.5-1.0) where the depth interval is in feet. Please note it is very important that the use of hyphens in sample names and depth units (i.e., feet or inches) remain consistent for all samples entered on the chain of custody form. DO NOT use the apostrophe or quotes in the sample ID.

2. Sample names may also use the abbreviations “FB,” “TB,” “FD” and “DUP” as prefixes or suffixes to indicate that the sample is a field blank, trip blank, or field duplicate, respectively.

b. List the date of sample collection. All indicated dates must be formatted using either mm/dd/yy (e.g., 03/07/09) or mm/dd/yyyy (e.g., 03/07/2009).

c. List the local time that the sample was collected. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15. The time listed on the COC form must match the sample collection time on the sample container(s).

d. Samples should be indicated to be either “Grab” or “Composite”. Grab samples are collected from only one unique location at one specific point in time.

e. Composite samples are a group of individual samples that are combined for analysis in their totality. Composite samples need to be documented if they are either collected from a number of different locations over a broader area to be representative of the entire area being sampled, or if they are representative of a single location over an extended period of time.

f. If used, preservatives for the individual sample will be noted.

g. The requested analytical method(s) that the samples are being analyzed for must be indicated. As much detail, as necessary, should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering "EPA Method 8082 – PCBs" or "EPA PLM 600-R93-116." In cases where multiple analytical methods and/or analytical parameters are required for an individual sample, each method should be indicated for the sample (e.g., EPA 8082/8260/8270 or EPA PLM/400-point count).

h. If there are project-specific sample analytes to be reported, they should be specifically listed for each individual sample (e.g., 40 CFR 264 Appendix IX).

i. The total number of containers for each analytical method requested should be documented. This information may be included under the parameter or as a total for the sample.

j. When necessary, note which samples should be used for site specific matrix spikes in the Remarks or Comments field.

k. Indicate special project-specific requirements pertinent to the handling, shipping, or analyses. These requirements may be on a per sample basis such as "extract and hold sample until notified," or may be used to inform the laboratory of special reporting requirements for the entire sample delivery group (SDG).

l. Indicate turnaround time (TAT) required for samples on COC. If individual samples have differing TATs, the different TATs for each sample or groups of samples must be clearly indicated.

m. Provide contact name and phone number in the event that problems are encountered when samples are received at the laboratory. The person relinquishing possession of the samples or other member of the project team should contact the final recipient of the samples to confirm receipt and review any special provisions on the COC or questions that they may have.

n. If available, attach the Laboratory Task Order or Work Authorization forms.

o. The "Relinquished By" field must contain the signature of the Arcadis person who relinquished custody of the samples to the next entity in the chain of custody, which may be another person, the shipping courier, or the analytical laboratory. If a courier, enter the shipping courier in the "Received by" such as FedEx. The date/time relinquished should be when the person signs the COC and seals the cooler or shipping container for pick-up by the shipping courier.

p. Dates and times must be indicated using the following format:

   1) Date: either mm/dd/yy e.g., 01/01/17 OR mm/dd/yyyy e.g., 01/01/2017

   2) Time: use military format, e.g., 9:30 a.m. is 0930 and 9:30 p.m. is 2130

q. The "Received By" section is signed by sample courier or laboratory representative who received the samples from the sampler. The laboratory will sign upon laboratory receipt from the overnight courier service.

7. When more than one page of the COC form is required to complete the total number of samples, use as many sheets as necessary to accurately and clearly, document the samples and information. Some COCs may have a standard first page/cover page, and subsequent pages may not contain all the detailed fields as

the first page/cover page. Ensure that any subsequent pages convey all of the necessary and pertinent information for each individual sample as required in this procedure document.

8. Pages of the COC must retain a page count of the total number of pages; e.g., Page 1 of 3, Page 2 of 3, Page 3 of 3.
9. Upon completing the COC forms, forward the original signed COC with the sample package. Ensure that the original COC form is secured with the sample package so that it remains with the physical samples for the duration of transport and handling to its final destination and ensure that the COC form will not be become damaged or rendered unreadable due to sample breakage/leakage if stored inside the sample shipping container or outside influences if COC is stored in an outside plastic pouch to the container.
10. If you've collected enough samples that would require more than one container to ship them all to the same laboratory or location, then each separate/individual container that contains any number of samples must have a separate COC representing only those samples contained within that specific container. For example, if you have 3 total shipping containers for all of your samples, you must have a total of 3 separate, individual COCs for each of the 3 containers representing only those samples in their representative container. Thus, every container holding samples must have its own, individual COC.
11. If electronic chain of custody (eCOC) forms are utilized, ensure that the requirements of this procedure and guidance instructions are followed to the extent possible. Verify that proper signature and COC procedures are maintained with the CPM and/or Technical Expert when using eCOC.

9 Waste Management

Not Applicable.

10 Data Recording and Management

The original signed COC shall be submitted with the samples. Copies of COC records will be transmitted to the CPM or designee at the end of each day unless otherwise directed by the CPM. The sampling team leader retains copies of the chain of custody forms for filing in the project file. Record retention shall be in accordance with client- and project-specific requirements and Arcadis policies, the most stringent will apply.

The option to use the Electronic Chain of Custody (eCOC) form in conjunction with the appropriate sample application(s) may be available through the FieldNow® program but is currently limited to a select list of approved analytical laboratories. Use of the eCOC application is intended to reduce common transcription errors both by field staff and laboratory staff on a conventional handwritten paper COC. Once the eCOC form is completed and approved on the field tablet by field staff, a PDF version of the form is automatically emailed to each assigned team member. In addition, a dedicated or mobile printer is recommended for printing a hard copy of the completed eCOC to be included in each sample cooler to meet laboratory requirements.

11 Quality Assurance

COC forms will be legibly completed in accordance with this procedure and guidance instruction document, as well as other applicable and appropriate project documents such as SAP, Quality QAPP, Work Plan, or other project guidance documents.

COC records will be reviewed by the CPM or their appropriate designee for completeness and accuracy to the applicable requirements. Non-conformances will be noted and corrected in a timely manner on the copies retained by Arcadis as well as contacting the ultimate receiving entity for correction to the originally signed COC in their possession.

12 References

Arcadis Transportation Safety Program requirements, procedures, and guidance instructions.

EPA Samplers' Guide – Contract Laboratory Program Guidance for Field Samplers, EPA document EPA-540-R014-013 October 2014 https://www.epa.gov/sites/default/files/2015-03/documents/samplers_guide.pdf.

EPA Region III – Sample Submission Procedures for the Office of Analytical Services and Quality Assurance (OASQA) Laboratory Branch revision 14.0 October 18, 2018, https://www.epa.gov/sites/default/files/2018-12/documents/sample-submission-procedures-rev14.pdf.

EPA Region IV Science and Ecosystem Support Division Operating Procedure for Sample and Evidence Management May 25, 2016, https://www.epa.gov/sites/default/files/2015-06/documents/Sample-and-Evidence-Management.pdf.

Attachment A

Chain of Custody and Laboratory Analysis Request Form

ARCADIS

ID#

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ____ of ____

Lab Work Order #

Send Results to:

Contact & Company Name:

Telephone:

Address:

Fax:

City State Zip

E-mail Address:

Project Name/Location (City, State):

Project #:

Sampler's Printed Name:

Sampler's Signature

SAMPLE ID	Collection Date	Collection Time	Type (✓) Comp	Type (✓) Grab	Matrix

Preservative									
Filtered (✓)									
# of Containers									
Container Information									
PARAMETER ANALYSIS & METHOD									
									REMARKS

Keys

Preservation Key:
A. H_2SO_4
B. HCL
C. HNO_3
D. NaOH
E. None
F. Other: _____
G. Other: _____
H. Other: _____

Containment Information Key
1. 40 ml Vial
2. 1 L Amber
3. 250 ml Plastic
4. 500 ml Plastic
5. Encore
6. 2 oz. Glass
7. 4 oz. Glass
8. 8 oz. Glass
9. Other: _____
10. Other: _____

Matrix Key:
SO - Soil
W - Water
T - Tissue
SE - Sediment
SL - Sludge
A - Air
NL - NAPL/Oil
SW - Sample Wipe
Other: _____

Special Instructions/Comments

☐ Special QA/QC Instructions (✓)

Laboratory Information and Receipt		Relinquished By	Received By	Relinquished By	Laboratory Received By
Last Name:	Cooler Custody Seal (✓)	Printed Name:	Printed Name:	Printed Name:	Printed Name
☐ Cooler packed with ice (✓)	☐ Intact ☐ Not Intact	Signature:	Signature:	Signature:	Signature:
Specify Turnaround Requirements:	Sample Receipt	Firm:	Firm:	Firm:	Firm:
Shipping Tracking #:	Condition/Cooler Temp:_____	Date/Time:	Date/Time:	Date/Time:	Date/Time:

SOP – Sample Chain of Custody Rev1_May 23, 2017

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TGI – Soil Description

Rev: 4

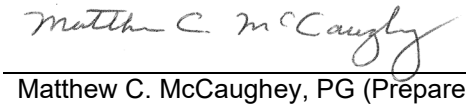
Rev Date: June 14, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	May 20, 2008	17	Original SOP	Joe Quinnan Joel Hunt
	1	September 2016	15	Updated to TGI	Nick Welty Patrick Curry
	2	February 16, 2018	15	Updated descriptions, attachments and references in text	Nick Welty Patrick Curry
	3	April 15, 2022		Minor description edits, intro of grain-size K analysis, revised boring log template	Matt McCaughey Patrick Curry
	4	June 14, 2022		Updated date on cover page and header. Updated revision number from 3 to 4. Updated reference throughout document from ASTM D2488-06 to ASTM D-2488.17 . Change “25% silt and clay; 15% pebbles” to “20% silt and 20% clay” on page 10 of 23. Updates made to Section 8.2.1 Changed reference to Appendix B to Appendix A	

Approval Signatures

Prepared by: 6/14/2022



Matthew C. McCaughey, PG (Preparer) Date

Reviewed by: 6/14/2022

Patrick Curry, PG (Subject Matter Expert) Date

1 Introduction

This Arcadis Technical Guidance Instruction (TGI) describes proper soil description procedures based on visual inspection and testing of soil cores and samples. This document has been developed to emphasize field observation and documentation of details required to:

- Make hydrostratigraphic interpretations guided by depositional environment/geologic settings
- Provide information needed to understand the distribution of constituents of concern; properly design wells, piezometers, and/or additional field investigations; and develop appropriate remedial strategies.

2 Intended Use and Responsibilities

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

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In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, regulation-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM.

3 Scope and Application

This TGI should be followed for unconsolidated material unless there is an established client-required specific procedure or regulatory-required specific procedure. In cases where there is a required specific procedure, it should be followed and should be referenced and/or provided as an appendix to reports that include soil classifications and/or boring logs. When following a required non-Arcadis procedure, additional information required by this TGI should be included in field notes with client approval.

This TGI incorporates elements from various standard systems such as ASTM D-2488-17, Unified Soil Classification System, Burmister and Udden Wentworth. However, none of these standard systems focus specifically on contaminant hydrogeology and remedial design. Therefore, although each of these systems contain valuable guidance and information related to correct descriptions, strict application of these systems can omit information critical to our clients and the projects that we perform.

This TGI includes the following attachments:

- **Attachment A –** Field Soil Description Guide
- **Attachment B –** Particle Size System Comparison
- **Attachment C –** Description of Logging Terms
- **Attachment D –** Blank Boring Log
- **Attachment E –** Completed Boring Log

This TGI does not address details of health and safety; drilling method selection; boring log preparation; sample collection; or laboratory analysis. Refer to other Arcadis procedure, guidance, and instructional documents, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan (HASP), as appropriate.

4 Personnel Qualifications

Soil descriptions should only be performed by Arcadis personnel or authorized sub-contractors with a degree in geology or a geology-related discipline. Field personnel will complete training on the Arcadis soil description TGI in the office and/or in the field under the guidance of an experienced field geologist with at least 2 years of prior experience applying the Arcadis soil description method.

5 Equipment List

The following equipment should be taken to the field to facilitate soil descriptions:

- Field book, field forms or digital devices to record soil descriptions
- Field book for supplemental notes
- This TGI for Soil Descriptions and any project-specific procedure, guidance, and/or instructional documents (if required)
- Field card showing Wentworth scale
- Munsell® soil color chart
- Tape measure divided into tenths of a foot
- Stainless steel knife or spatula
- Hand lens
- Water squirt bottle
- 4-ounce glass jars with lids (for collecting soil core samples)
- Personal protective equipment (PPE), as required by the HASP
- Digital camera

- Folding table

6 Cautions

Drilling and drilling-related hazards including subsurface utilities are discussed in other procedure documents and site-specific HASPs and are not discussed herein.

Soil samples may contain hazardous substances that can result in exposure to persons describing soils. Routes for exposure may include dermal contact, inhalation and ingestion. Refer to the project specific HASP for guidance in these situations.

7 Health and Safety Considerations

Field activities associated with soil sampling and description will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities. Know what hazardous substances may be present in the soil and understand their hazards. Always avoid the temptation to touch soils with bare hands, detect odors by placing soils close to your nose, or tasting soils.

8 Procedure

8.1 General Procedures

- Select the appropriate sampling method to obtain representative samples in accordance with the selected sub-surface exploration method, e.g., split-spoon or Shelby sample for hollow-stem drilling, acetate sleeves for direct push, bagged core for sonic drilling, etc.
- Proceed with field activities in required sequence. Although completion of soil descriptions is often not the first activity after opening sampler, identification of stratigraphic changes is often necessary to select appropriate intervals for field screening and/or selection of laboratory samples.
- Set up boring log field sheet.
    - Determine the proper units of measure. Drillers in both the US and Canada generally work in feet due to equipment specifications. Field geologists typically record drilling depths, core recovery, and sample intervals in feet and grain size in millimeters
    - Use the Arcadis standard boring log form (**Attachment D**). *Note that as of April 2022, several digital logging applications are available through the FieldNow™ program and the Fulcrum app. A future revision of this TGI, likely in early 2023, will emphasize digital logging methods and field boring log forms will no longer be acceptable. FieldNow is discussed further in Section 10.*
    - The boring log template includes a graphic log of the primary soil texture to support quick visual evaluation of grain size. The purpose of the graphic log is to quickly assess relative soil permeability. Note, for poorly sorted soils (e.g., glacial till), the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability. For example, for a dense sand/silt/clay till, the graphic log would reflect the silt/clay, rather than sand.

    - Record depths along the left-hand side at a standard scale to aid in the use of this tool.
- Examine each soil core (this is different than examining each sample selected for laboratory analysis) and record the soil conditions in accordance with guidelines provided in Section 8.2.
- At the end of the boring, record the amount of drilling fluid used (if applicable) and the total depth logged.
- At a minimum, a written or digital boring log should be prepared with the following information:
    - Describe type of surface material (asphalt, grass, topsoil, gravel, etc.)
    - Describe the type of fill or non-native soils and estimated depth to native soils
    - Record sample intervals (soil cores, environmental and/or geotechnical samples)
    - Describe soil conditions in accordance with this TGI
    - Record moisture content and estimated depth to water table or saturated zone
    - Record the total depth and document why drilling was stopped (refusal, target depth achieved, etc.)

8.2 Soil Description Procedures

The standard soil description order is presented below.

- Depth
- PRIMARY TEXTURE
- Principal and Minor Components with Descriptors
    - % Modifiers and grain size fraction
    - Angularity for coarse sand and larger particles
    - Consistency or Density
    - Plasticity for silt and clay
    - Dilatancy for silt and silt-sand mixtures
- Sorting
- Moisture Content
- Color
- Notes

Depth. To measure and record the depth below ground surface (bgs) of top and bottom of each stratum, the following information should be recorded.

- Measured depth to the top and bottom of sampled interval. Use starting depth of sample based upon measured tool length information and the length of sample interval.
- Length of sample recovered, not including slough (material that has fallen into hole from previous interval), expressed as fraction with length of recovered sample as numerator over length of sampled interval as denominator (e.g., 36/60 for 36 inches recovered from 5-ft [60-inch] sampling interval).
- Thickness of each stratum measured sequentially from the top of recovery to the bottom of recovery.
- Any observations of sample condition or drilling activity that would help identify whether there was loss from the top of the sampling interval, loss from the bottom of the sampling interval, or compression of the sampling interval. Examples: 14/24, gravel in nose of spoon; or 36/60 bottom 12 inches of core empty.

Determination of Components. Obtain a representative sample of soil from a single stratum. If multiple strata are present in a single sample interval, each stratum should be described separately. More specifically, if the sample is from a 2-foot-long split-spoon where strata of coarse sand, fine sand and clay are present, then the resultant description should be of the three individual strata unless a combined description can clearly describe the interbedded nature of the three strata. Example: SAND, fine; with interbedded lenses of Silt and Clay, ranging between 1 and 3 inches thick.

Identify principal component and express volume estimates for minor components on logs using the following standard modifiers.

Modifier	Percent of Total Sample (by volume)
and	36 – 50
some	21 - 35
little	10 - 20
trace	<10

Determination of components is based on using the Udden-Wentworth particle size classification (see below) and measurement of the average grain size diameter. Each size class differs from the next larger class by a constant ratio of ½. Due to visual limitations, the finer classifications of Wentworth's scale cannot be distinguished in the field and the subgroups are not included. Visual determinations in the field should be made carefully by comparing the sample to the Soil Description Field Guide (**Attachment A**) that shows Udden-Wentworth scale or by measuring with a ruler.

The following table summarized the modified Udden-Wentworth Scale for grain size classification. Note that gravel is a size category encompassing the granule, pebble, cobble, and boulder size classes.

Udden-Wentworth Scale (Modified by Arcadis, 2008)				
Size Category	**Size Class**	**Millimeters**	**Inches**	**Standard Sieve #**
Gravel (Cobble)	Boulder	256 – 4096	10.08+	
	Large cobble	128 - 256	5.04 -10.08	
	Small cobble	64 - 128	2.52 – 5.04	
Gravel (Pebble)	Very large pebble	32 – 64	0.16 - 2.52	
	Large pebble	16 – 32	0.63 – 1.26	
	Medium pebble	8 – 16	0.31 – 0.63	
	Small pebble	4 – 8	0.16 – 0.31	No. 5 +
	Granule	2 – 4	0.08 – 0.16	No.5 – No.10

Sand	Very coarse sand	1 -2	0.04 – 0.08	No.10 – No.18
	Coarse sand	½ - 1	0.02 – 0.04	No.18 - No.35
	Medium sand	¼ - ½	0.01 – 0.02	No.35 - No.60
	Fine sand	1/8 -¼	0.005 – 0.1	No.60 - No.120
	Very fine sand	1/16 – 1/8	0.002 – 0.005	No. 120 – No. 230
Fines	Silt (subgroups not included)	1/256 – 1/16	0.0002 – 0.002	Not applicable (analyze by pipette or hydrometer)
	Clay (subgroups not included	1/2048 – 1/256	0.00002 – 0.0002	

Identify components as follows. Remove particles greater than very large pebbles (64-mm diameter) from the soil sample. Record the volume estimate of the greater than very large pebbles. Examine the sample fraction of very large pebbles and smaller particles and estimate the volume percentage of the pebbles, granules, sand, silt and clay. Use the jar method, visual method, and/or wash method (Appendix X4 of ASTM D2488) to estimate the volume percentages of each category.

Sieve and hydrometer grain-size analysis can be used to vet the visual description, as well as used to estimate hydraulic conductivity. Lab or field sieve analysis is advisable to characterize the variability and facies trends within each hydrostratigraphic unit. It is recommended that sieve-hydrometer analysis be performed on representative samples from each soil type to estimate the fraction of each grain size category using ASTM D422 Standard Test Method for Particle-Size Analysis of Soils. If desired sieve sizes can be specified to follow the Udden-Wentworth classification (U.S. Standard sieve sizes 6; 12; 20; 40; 70; 140; and 270) to retain pebbles; granules; very coarse sand; coarse sand; medium sand; fine sand; and very fine sand, respectively.

Several empirical formulas provide a reliable means of estimating hydraulic conductivity (K) from grain-size distribution data, provided that the formation does not contain abundant fines that result in cohesive or plastic behavior or include cobble-sized grains (Payne et al. 2008). Grain-size analysis can help bracket the permeability of hydrostratigraphic units (HSUs) and identify order-of-magnitude spatial variations in K. Arcadis has completed modifications to the Excel-based program HydroGeoSieveXL (Devlin 2015) to process sieve data quickly and estimate K. The tool calculates estimated K values from grain-size data using 15 different empirical formulas. A decision matrix then selects which of the formulas is relevant for the soil type and calculates an average K.

Principal Component. The principal component is the size fraction or range of size fractions containing the majority of the volume. Examples: the principal component in a sample that contained 55% small to medium pebbles would be “PEBBLES, small to medium”; or the principal component in a sample that was 20% fine sand, 30% medium sand and 25% coarse sand would be “SAND, fine to coarse” or for a sample that was 40% silt and 45% clay the principal component would be “CLAY and SILT”.

The boring log form (**Appendix D**) includes a graphic log to visually illustrate a relative estimate of soil permeability. To use the graphic log, place an ‘X’ or shade the appropriate column for the primary soil texture. If the soils have a high percentage of a secondary soil texture (i.e., when the ‘and’ modifier’ is used), it’s acceptable to mark off the appropriate column for the secondary soil texture in this instance. However, care should be used to avoid marking off the columns for other minor soil textures because doing so will make it difficult to determine the relative soil permeability of the poorly sorted soils.

As noted above, for poorly sorted soils such as glacial till, the principal component may not correlate to permeability of the sample. In this case, the geologist should use best judgement to graph overall soil type consistent with relative soil permeability.

Minor Component(s). The minor component(s) are the size fraction(s) containing less than 50% volume. Example: the identified components are estimated to be 60% medium sand to granules, 20% silt and 20% clay – there are two identified minor components: silt and clay.

Include a standard modifier to indicate percentage of minor components (see particle size table) and the same descriptors that would be used for a principal component. An example of minor constituents with modifiers include: some silt and clay, low plasticity; little medium to large pebbles, sub-round.

8.2.1 Secondary Descriptors

The following are the descriptors used outside of the principal and minor components. Note that plasticity should be provided as a descriptor for clay and clay mixtures. Dilatancy should be provided for silt and silt mixtures. Angularity should be provided as a descriptor for pebbles and coarse sand.

Angularity. Describe the angularity for coarse sand and larger particles in accordance with the table below (ASTM D-2488-17). Figures showing examples of angularity are available in ASTM D2488-17 and the Arcadis Soil Description Field Guide (**Appendix A**).

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Sub-Angular	Particles are like angular description but have rounded edges
Sub-Rounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges.

Plasticity. Describe the plasticity for silt and clay based on observations made during the following test method (ASTM D-2488-17).

- As in the dilatancy test (described below), select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material, adding water, if necessary, until it has a soft, but not sticky, consistency.
- Shape the test specimen into an elongated pat and roll by hand on a smooth surface or between the palms into a thread about 1/8 inch (3 mm) in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation. Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 inch. The thread will crumble when the soil is near the plastic limit.

Description	Criteria
Non-plastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Dilatancy. Describe the dilatancy for silt and silt-sand mixtures using the following field test method (ASTM D-2488-17).

- From the specimen, select enough material to mold into a ball about ½ inch (12 mm) in diameter. Mold the material adding water, if necessary, until it has a soft, but not sticky, consistency.
- Smooth the ball in the palm of one hand with a small spatula.
- Shake horizontally, striking the side of the hand vigorously with the other hand several times.
- Note the reaction of water appearing on the surface of the soil.
- Squeeze the sample by closing the hand or pinching the soil between the fingers, and not the reaction as none, slow, or rapid in accordance with the table below. The reaction is the speed with which water appears while shaking and disappears while squeezing.

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

Note that silt and silt-sand mixtures will be non-plastic and display dilatancy. Clay mixtures will have some degree of plasticity but do not typically react to dilatancy testing. Therefore, the tests outlined above can be used to differentiate between silt-dominated and clay-dominated soils.

Sorting. Sorting is the opposite of grading, which is a commonly used term in the USCS or ASTM methods to describe the uniformity of the particle size distribution in a sample. Well-sorted samples are poorly graded and poorly sorted samples are well graded. Arcadis prefers the use of sorting for particle size distributions and grading to describe particle size distribution trends in the vertical profile of a sample or hydrostratigraphic unit because of

the relationship between sorting and the energy of the depositional process. For soils with sand-sized or larger particles, sorting should be determined as follows:

Description	Criteria
Well Sorted	the range of particle sizes is limited (e.g., the sample is comprised of predominantly one or two grain sizes)
Poorly Sorted	A wide range of particle sizes are present

You can also use sieve analysis to estimate sorting from a sedimentological perspective; sorting is the statistical equivalent of standard deviation. Smaller standard deviations correspond to higher degree of sorting (see Remediation Hydraulics, 2008).

Consistency or Density. This can be determined by standard penetration test (SPT) blow counts (ASTM D-1586) obtained when using hollow-stem auger drilling methods and a split spoon sampling device. Otherwise, some field tests are available as outlined below. When drilling with hollow-stem augers and split-spoon sampling, the SPT blow counts and N-value is used to estimate density. The N-value is the blows per foot for the 6" to 18" interval. For example, for a 24-inch split spoon soil core, the recorded blows per 6-inch interval are: 4/6/9/22. Since the second interval is 6" to 12", the third interval is 12" to 18", the N value is 6+9, or 15. Fifty blow counts for less than 6 inches is considered refusal. In recent years, more common drilling methods include rotary-sonic or direct push. When blow counts are not available, density is determined using a thumb test. Note however, the thumb test only applies to fine-grained soils.

Fine-grained soil – Consistency

Description	Criteria	Blow Counts (6-12 to 12-18-inch split spoon interval)
Very soft	Easily penetrated several inches by thumb	N-value < 2
Soft	Easily penetrated one inch by thumb	N-value 2-4
Medium Stiff	Indented about ½ inch with much effort	N-value 5-8
Stiff	Indented with ¼ inch with great effort	N-value 9-15
Very Stiff	Readily indented by thumbnail	N-value 16-30
Hard	Indented by thumbnail with difficulty	N-value > than 30

Coarse-grained soil – Density

Description	Criteria	Blow Counts (6-12 to 12-18-inch split spoon interval)
Very loose	Density classification of coarse-grained soils is only required when blow counts from standard penetration tests are performed during hollow-stem auger drilling	N-value 1- 4
Loose		N-value 5-10
Medium dense		N-value 11-30
Dense		N-value 31- 50
Very dense		N-value >50

Moisture Content. Moisture content should be described for each soil sample in accordance with the table below (percentages should not be used unless determined in the laboratory). *Note that some drilling methods (e.g., sonic) can compress and dry out the sample during drilling. Therefore, it can be difficult to determine if a sample is saturated, or merely moist. In this case, care should be taken to try and determine a static water level within the borehole by measuring depth to water through the drill casing, if possible.*

Description	Criteria
Dry	Absence of moisture, dry to touch, dusty
Moist	Damp but no visible water
Wet	Visibly free water

Color. Color should be described using simple basic terminology and modifiers based on the Munsell system. Munsell alpha-numeric codes are required for all samples. If the sample contains layers or patches of varying colors this should be noted, and all representative colors should be described. The colors should be described for moist samples. If the sample is dry, it should be wetted prior to comparing the sample to the Munsell chart.

Notes. Additional comments should be made where observed and should be presented as notes with reference to a specific depth interval(s) to which they apply. Some of the significant information that may be observed includes the following.

- Odor - You should not make an effort to smell samples by placing near your nose since this can result in unnecessary exposure to hazardous materials. However, odors should be noted if they are detected during the normal sampling procedures. Odors should be based upon descriptors such as those used in NIOSH “Pocket Guide to Chemical Hazards”, e.g., “pungent” or “sweet” and should not indicate specific chemicals such as “phenol-like” odor or “BTEX” odor.
- Structure
- Bedding planes (laminated, banded, geologic contacts).
- Presence of roots, root holes, organic material, man-made materials, minerals, etc.
- Mineralogy

- Cementation
- NAPL presence/characteristics, including sheen (based on client-specific guidance).
- Reaction with HCl - typically only used for special soil conditions, such as caliche environments.
- Origin, if known (Lacustrine; Fill; etc.).

8.3 Example of Soil Descriptions

The standard generic description order is presented below.

- Depth
- PRIMARY TEXTURE
- Principal and Minor Components with Descriptors
    - % Modifiers and grain size fraction
    - Angularity for coarse sand and larger particles
    - Consistency or Density
    - Plasticity for silt and clay
    - Dilatancy for silt and silt-sand mixtures
- Sorting
- Moisture Content
- Color
- Notes

10-15 feet CLAY, trace silt, trace small to very large pebbles, subround to subangular up to 2" diameter; medium to high plasticity, stiff, moist, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR5/2).

Unlike the first example where a density of cohesive soils could be estimated, this rotary-sonic sand and pebble sample was disturbed during drilling (due to vibrations in a loose sand and pebble matrix) so no density description could be provided. Neither sample had noticeable odor so odor comments were not included.

9 Waste Management

Project-specific requirements should be identified and followed. The following procedures, or similar waste management procedures are generally required.

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal. PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

10 Data Recording and Management

10.1 Digital Data Collection Process Overview

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

10.2 Digital Data Collection Tools for Soil Descriptions

Arcadis is transitioning from the use of paper forms to a digital soil description logging process using web-based FieldNow applications accessible on field tablets and smart phones. Company-wide roll out of a FieldNow application for soil descriptions is targeted by the end of 2022.

Paper forms are included in Revision 3 (April 2022) of this Soil Description TGI. Specifically, a blank boring log and completed boring log are provided in **Attachment D** and **Attachment E**. Additional guidance and examples of the digital data collection tools for soil descriptions will be provided in the next revision to this TGI.

10.3 Additional Guidance

The general logging scheme for soil descriptions is described in this document. Depending on project data quality objectives, specific soil description parameters that are not applicable to project goals may be omitted at the project manager's discretion. In any case, use of consistent procedures is required.

Completed logs and/or logbook will be maintained in the task/project field records file. Digital photographs of typical soil types observed at the site and any unusual features should be obtained whenever possible. Photographs should include a ruler or common object for scale. Photo location, depth and orientation must be recorded in the daily log or logbook and a label showing this information in the photo is useful.

For projects involving soil logging and soil sampling, the soil sample should be recorded on the Arcadis boring log form and the field logbook based on Data Quality Objectives for the task/project.

11 Quality Assurance

Soil descriptions should be completed only by appropriately trained personnel. Descriptions should be reviewed by an experienced field geologist for content, format and consistency. Edited boring logs should be reviewed by the original author to assure that content has not changed.

12 References

ASTM D-1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils.

ASTM D-2488-17, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

ASTM D422, 63rd Edition, 1972 - Standard Test Method for Particle-Size Analysis of Soils.

Devlin, J.F. 2015. HydroGeoSieve XL: an Excel-based tool to estimate hydraulic conductivity from grain-size analysis. Hydrogeology Journal, DOI 10.1007/s10040-015-1255-0.

Folk, Robert L. 1980. Petrology of Sedimentary Rocks, p. 1-48.

Payne, F. C., Quinnan, J. A., & Potter, S. T. 2008. Remediation Hydraulics. Boca Raton: FL: CRC Press.

United States Bureau of Reclamation. Engineering Geology Field Manual. United States Department of Interior, Bureau of Reclamation. http://www.usbr.gov/pmts/geology/fieldmap.htm.

Munsell® Color Chart – available from Forestry Suppliers, Inc.- Item 77341 “Munsell® Color Soil Color Charts.

Field Gauge Card that Shows Udden-Wentworth scale – available from Forestry Suppliers, Inc. – Item 77332 “Sand Grain Sizing Folder.”

NIOSH Pocket Guide to Chemical Hazards.

Attachment A

Soil Field Reference Guide

The purpose of this attachment is to present a field reference guide for use during soil logging. Field staff are encouraged to bring a laminated copy of this reference guide into the job site.

SOIL DESCRIPTION FIELD GUIDE (APRIL, 2022; REV. 3.0)

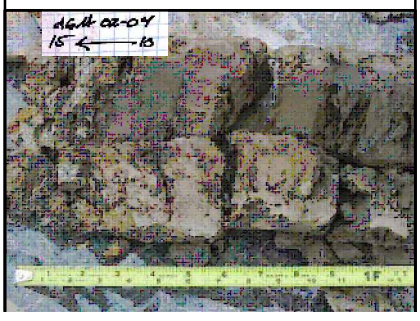
ARCADIS Design & Consultancy for natural and built assets

FINE-GRAINED SOILS

Description	Criteria
	Descriptor - Plasticity
Nonplastic	A 1/8-inch (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.
	Descriptor - Dilatancy
No Dilatancy	No visible change when shaken or squeezed.
Slow	Water appears slowly on the surface of soil during shaking and does not disappear or disappears slowly when squeezed.
Rapid	Water appears quickly on surface of soil during shaking and disappears quickly when squeezed.
Minor Components with Descriptors	
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Consistency
Very soft	N-value < 2 or easily penetrated several inches by thumb.
Soft	N-value 2-4 or easily penetrated 1 inch by thumb.
Medium stiff	N-value 5-8 or indented about 1/2 inch by thumb with great effort.
Stiff	N-value 9-15 or indented about 1/4 inch by thumb with great effort.
Very stiff	N-value 16-30 or readily indented by thumb nail.
Hard	N-value > than 30 or indented by thumbnail with difficulty.
Color using Munsell	
Geologic Origin (if known)	
Other	

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10-15 feet CLAY, trace silt, trace small to very large pebbles, subround to subangular up to 2" diameter; medium to high plasticity, stiff, moist, dark grayish brown (10YR 4/2). NOTE: Lacustrine; laminated 0.1 to 0.2" thick, laminations brownish yellow (10YR 4/3).



DESCRIPTION ORDER

Depth Interval
PRIMARY TEXTURE (e.g., SAND)
Principal and Minor Components with Descriptors:
- % Modifiers and grain size fraction
- Angularity coarse sand and larger
- Consistency or Density
- Plasticity for silt and clay
- Dilatancy for silt and silt-sand

Sorting for granular sediments
Moisture Content
Color
Other NOTES

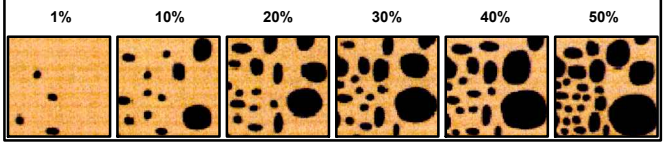
MINOR COMPONENTS % MODIFIERS

Modifier	Percent of Total Sample (by volume)
and	36 - 50
some	21 - 35
little	10 - 20
trace	<10

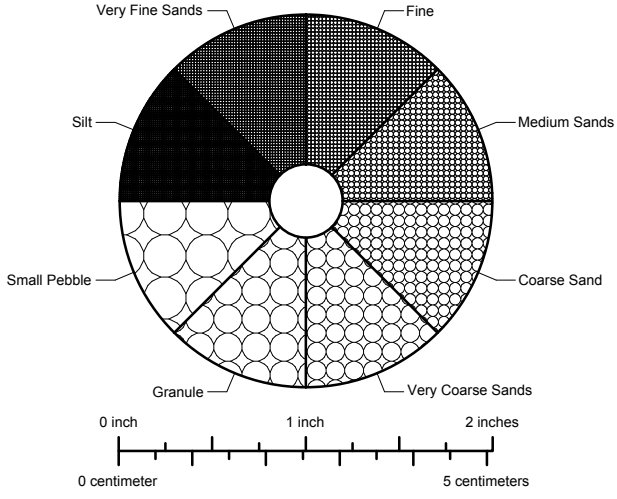
UDDEN-WENTWORTH SCALE

Fraction	Sieve Size	Grain Size	Approximate Scale
Boulder		256 - 4096 mm	Larger than volleyball
Large Cobble		128 - 256 mm	Softball to volleyball
Small Cobble		64 - 128 mm	Pool ball to softball
Very Large Pebble		32 - 64 mm	Pinball to pool ball
Large Pebble		16 - 32 mm	Dime size to pinball
Medium Pebble		8 - 16 mm	Pencil eraser to dime size
Small Pebble	No. 5+	4 - 8 mm	Pea size to pencil eraser
Granule	No. 10 - 5	2 - 4 mm	Rock salt to pea size
Very Coarse Sand	No. 18 - 10	1 - 2 mm	See field gauge card
Coarse Sand	No. 35 -18	0.5 - 1 mm	See field gauge card
Medium Sand	No. 60 - 35	0.25 - 0.5 mm	See field gauge card
Fine Sand	No. 120 - 60	0.125 - 0.25 mm	See field gauge card
Very Fine Sand	No. 230 - 120	0.0625 - 0.125 mm	See field gauge card
Silt and Clay. See SOP for description of fines	Not Applicable	<0.0625 mm	Analyze by pipette or hydrometer

PARTICLE PERCENT COMPOSITION ESTIMATION



GRAPH FOR DETERMINING SIZE OF PARTICLES



FOR COARSE-GRAINED SOILS

Description	Criteria
	Descriptor - Angularity
Angular	Particles have sharp edges and relatively planar sides withunpolished surfaces.
Subangular	Particles are similar to angular but have rounded edges.
Subround	Particles have nearly planar sides but have well-roundedcorners and edges.
Round	Particles have smoothly curved sides and no edges.
Minor Components with Descriptors	
	Sorting Cu= d60/d10
Well Sorted	Near uniform grain-size distribution Cu= 1 to 3.
Poorly Sorted	Wide range of grain size Cu= 4 to 6.
	Moisture
Dry	Absence of moisture, dry to touch, dusty.
Moist	Damp but no visible water.
Wet	Visible free water; soil is usually below the water table. (Saturated)
	Density
Very loose	N-value 1 - 4
Loose	N-value 5 - 10
Medium Dense	N-value 11 - 30
Dense	N-value 31 - 50
Very dense	N-value >50
Color using Munsell	
Geologic Origin (if known)	
Other	
	Cementation
Weak Cementation	Crumbles or breaks with handling or little finger pressure.
Moderate Cementation	Crumbles or breaks with considerable finger pressure.
Strong Cementation	Will not crumble with finger pressure.
	Reaction with Dilute HCl Solution (10%)
No Reaction	No visible reaction.
Weak Reaction	Some reaction, with bubbles forming slowly.
Strong Reaction	Violent reaction, with bubbles forming immediately.

EXAMPLE OF SOIL DESCRIPTION AND PHOTO

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR 5/2).

SOIL DESCRIPTION FIELD GUIDE (APRIL, 2022; REV. 3.0)

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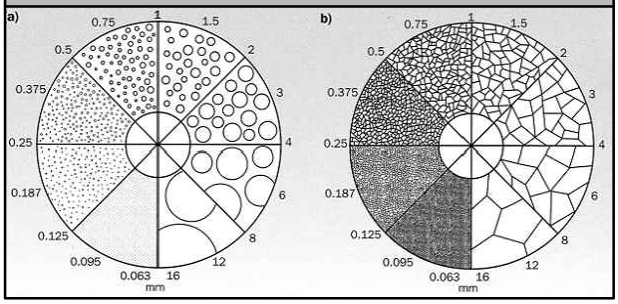
VARIATIONS IN SOIL STRATIGRAPHY

Term	Thickness of Configuration
Parting	0 - to 1/16-inch thickness.
Seam	1/16 - to 1/2-inch thickness.
Layer	1/2 - to 12-inch thickness.
Stratum	> 12-inch thickness.
Pocket	Small erratic deposit, usually less than 1 foot in size.
Varved Clay	Alternating seams or layers of sand, silt, and clay (laminated).
Occasional	≤ 1 foot thick.
Frequent	> 1 foot thick.

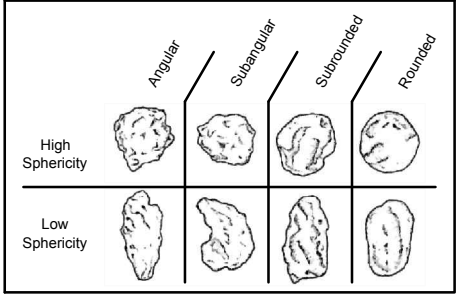
SOIL STRUCTURE DESCRIPTIONS

Term	Description
Homogeneous	Same color and appearance throughout.
Laminated	Alternating layers < 1/4 inch thick.
Stratified	Alternating layers ≥ 1/4 inch thick.
Lensed	Inclusions of small pockets of different materials, such as lenses of sand scattered through a mass of clay; note thickness.
Blocky	Cohesive soil can be broken down into small angular lumps, which resist further breakdown.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear to be polished or glossy, sometimes striated.

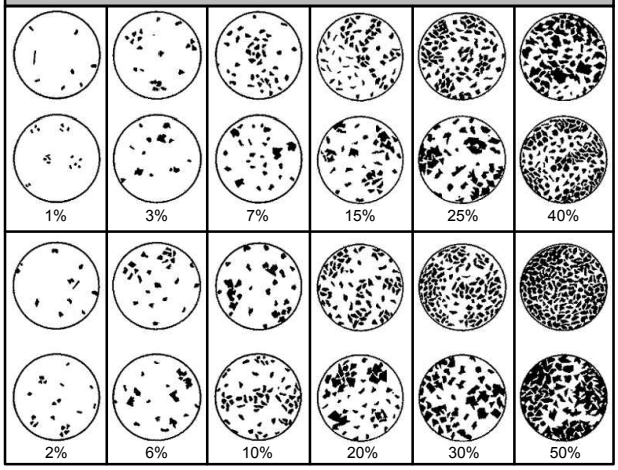
GRAPH FOR DETERMINING SIZE OF PARTICLES



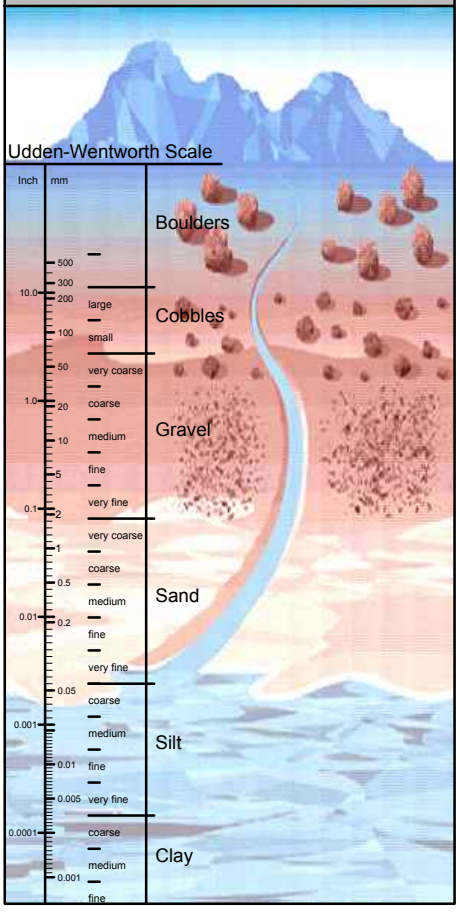
ANGULARITY CHART



PARTICLE PERCENT COMPOSITION ESTIMATION



SORTING



SETTLING TABLE (SILT/CLAY)

Diameter of Particle (mm)	<0.625	<0.031	<0.016	<0.008	<0.004	<0.002	<0.0005
Depth of Withdrawal (cm)	10	10	10	10	5	5	3
Time of Withdrawal	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec	hr:min:sec
Temperature (Celsius)							
20	00:00:29	00:01:55	00:07:40	00:30:40	00:61:19	04:05:00	37:21:00
21	00:00:28	00:01:52	00:07:29	00:29:58	00:59:50	04:00:00	
22	00:00:27	00:01:50	00:07:18	00:29:13	00:58:22	03:54:00	
23	00:00:27	00:01:47	00:07:08	00:28:34	00:57:05	03:48:00	
24	00:00:26	00:01:45	00:06:58	00:27:52	00:55:41	03:43:00	33:56:00
25	00:00:25	00:01:42	00:06:48	00:27:14	00:54:25	03:38:00	
26	00:00:25	00:01:40	00:06:39	00:26:38	00:53:12	03:33:00	
27	00:00:24	00:01:38	00:06:31	00:26:02	00:52:02	03:28:00	
28	00:00:24	00:01:35	00:06:22	00:25:28	00:50:52	03:24:00	31:00:00
29	00:00:23	00:01:33	00:06:13	00:24:53	00:49:42	03:10:00	
30	00:00:23	00:01:31	00:06:06	00:24:22	00:48:42	03:05:00	

Attachment B

Particle Size System Comparison

The purpose of this attachment is to illustrate how the Udden-Wentworth particle sizes and descriptive terms compares to other particle size systems.

When in the field, it is a customary practice to compare current soil descriptions to historical soil boring logs for reference purposes. When reviewing boring logs prepared by others, field staff should first note the particle size system used and recognize these particle size systems may differ. This will avoid confusion when cross referencing between historical and new boring logs and when reviewing existing geologic cross-sections.

For example, a well-sorted sand with grain sizes ranging from 1 to 2 mm should be classified as a very coarse sand by the Udden-Wentworth system. As shown in this attachment, the same particle size would be classified as a medium sand by the United Soil Classification System. The later system has fewer particle size grades and in general, is less descriptive than the Udden-Wentworth system.

PARTICLE SIZE SYSTEM COMPARISON

Grain size distribution in millimeters (mm)

Udden-Wentworth — Remediation Geologists and Engineers

		V. Fine	Fine	Medium	Coarse	V. Coarse	Granule	Pebbles				Cobbles		
								Small	Medium	Large	V. Large	Small	Large	
CLAY	SILT	SAND					GRAVEL							
0.039	0.065	0.125	0.25	0.5	1	2	4	8	16	32	64	128	256	
	1/16	1/8	1/4	1/2										

United Soil Classification System — Geotechnical Engineers

		Fine	Medium	Coarse	Fine	Coarse	
CLAY	SILT	SAND			GRAVEL		COBBLE
	0.074	0.42		2	4.75	19	75	300

U.S. Dept. of Agriculture — Soil Scientists

		V. Fine	Fine	Medium	Coarse	V. Coarse	
CLAY	SILT	SAND					GRAVEL
0.002	0.05	0.10	0.25	0.5	1	2	75

Remediation Hydraulics 2008, page 195): The Udden-Wentworth scale is preferred "...because the geometric progression of grain-size diameter also reflects relationships that are important when considering the erosion and deposition of sediments during the depositional process. The correlation between increasing grain size and degree of sorting and permeability is the most important, as permeability structure is responsible for the mobile and immobile porosity within aquifer systems. "

Attachment C

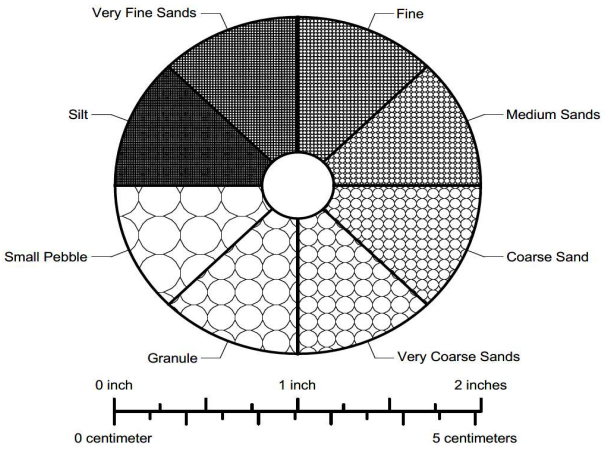
Description of Soil Logging Terms

The purpose of this attachment is to concisely define the soil logging terms used when filling out boring logs. During report preparation, project staff could use this sheet as an index placed in front of the completed boring logs. Also, it can serve as a supplemental reference sheet during field activities.

Description of Logging Terms

Note: Soil descriptions based on Arcadis Technical Guidance and Instructions (TGI) procedures. Key terms defined below.

GRAPH FOR DETERMINING SIZE OF PARTICLES



Udden Wentworth Soil Sizes

Boulder	> 256 mm
Large Cobble	128 to 256 mm
Small Cobble	64 to 128 mm
Very Large Pebble	32 to 64 mm
Large Pebble	16 to 32 mm
Medium Pebble	8 to 16 mm
Small Pebble	4 to 8 mm
Granule	2 to 4 mm
Very Coarse Sand	1 to 2 mm
Coarse Sand	0.5 to 1 mm
Medium Sand	0.25 to 0.5 mm
Fine Sand	0.125 to 0.25 mm
Very Fine Sand	0.062 to 0.12 mm
Silt/Clay	<0.065 mm

Primary Texture *(e.g. CLAY, SILT, SAND, GRANULE, PEAT, MUCK, FILL, etc.)*
List particle size with the highest percentage per sample interval (e.g. SAND)
Always CAPITALIZE the primary texture
Follow primary texture with a comma followed by grain-size descriptors, etc.

Minor Texture

And	(36 to 50%)
Some	(21 to 35%)
Little	(10 to 20%)
Trace	(>10%)

Angularity

Angular	Sharp edges
Sub-Angular	Rounded edges
Sub-Rounded	Well-rounded
Rounded	Smooth curved edges

Sand Density (Blow Counts/ft)

Very Loose	0-4
Loose	5-10
Medium Dense	11-30
Dense	31-50
Very Dense	<50

Silt/Clay Consistency (Blow Counts/ft)

Very Soft	0-2,	thumb easily penetrates several inches
Soft	3-4,	thumb easily penetrates one inch
Medium Stiff	5-8,	thumb indents 0.5 in. with much effort
Stiff	9-15,	thumb indents 0.25 in. with great effort
Very Stiff	16-30,	thumbnail is readily intended

Sorting

Well Sorted	1 to 3 Particle Sizes
Poorly Sorted	4+ Particle Sizes

Moisture Content

Dry	Dry to touch
Moist	No visible water
Wet	Visible free water

Plasticity (for silts and clays)

Non-Plastic	3 mm thread can not be rolled
Low Plasticity	3 mm thread can barely be rolled
Medium Plasticity	3 mm thread can easily and quickly rolled, but not rerolled
High Plasticity	3 mm thread can be rolled slowly, but can be rerolled

Dilatancy (for silts and silt-sand mixtures)

None	No visible change in the specimen
Slow	Water appears slowly during shaking / disappears slowly or not at all upon squeezing
Rapid	Water appears quickly during shaking / disappears quickly upon squeezing

Example Description

10 -15 feet SAND, medium to very coarse, little granules to medium pebbles, subround to subangular, trace silt; poorly sorted, wet, grayish brown (10YR5/2).

Attachment D

Blank Boring Log

The purpose of this attachment is to present a blank field form for use during soil logging. A digital version (Microsoft Excel) of this field form is available from the authors (upon request). If project specific modifications to this boring log template are warranted, please contact the Site Investigation Community of Practice leader for further assistance.

BORING LOG

ARCADIS

Boring ID:		**Project Name:**		**Page:**	/
Permit ID:		**Date Started:**		**Ground Elevation:**	
Site Address:		**Date Completed:**		**Vertical Datum:**	
City, State:		**Total Depth:**		**Northing:**	
Drilling Co:		**Depth to Water:**		**Easting:**	
Driller:		**Hole Diameter:**		**Horizontal Datum:**	
Drilling Method:		**Core Device:**		**Prepared by:**	
Boring Status:		**Drilling Fluid:**		**Reviewed by:**	

Drilling Information				Graphical Log for Primary Texture									Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel			
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	Vapor Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.

BORING LOG

Boring ID: _____ **Project Name:** _____ **Page:** _____ / _____

Drilling Information				Graphical Log for Primary Texture										Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel				
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	Vapor Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.

Attachment E

Completed Boring Log

The purpose of this attachment is to provide an example of a completed boring log for reference purposes to field staff. The example provided is for a soil boring completed outside the waste mass of a closed municipal landfill near Baltimore, Maryland. The objective of the drilling program was to determine the depth to groundwater to determine the appropriate depth interval to install a soil gas monitoring well and groundwater monitoring well across the first water-bearing zone. The site geology consists of unconsolidated sediments of the Mid-Atlantic Coastal Plain, specifically the Upper Patapsco formation. These sediments were deposited in a moderate gradient fluvial environment during the Cretaceous period. The landfill was constructed into a regional clay confining unit.

BORING LOG

ARCADIS

Boring ID:	MW-08	**Project Name:**	Acme Landfill	**Page:**	1 / 1
Permit ID:	MD-PG-100	**Date Started:**	7/18/2018	**Ground Elevation:**	50.5 ft
Site Address:	100 Landfill Road	**Date Completed:**	7/18/2018	**Vertical Datum:**	NAVD 88, feet
City, State:	Baltimore, Maryland	**Total Depth:**	35 ft below ground	**Northing:**	123456.79
Drilling Co:	Earth Matters	**Depth to Water:**	19 ft below ground	**Easting:**	123456.79
Driller:	Rod E. Piper	**Hole Diameter:**	2-inch	**Horizontal Datum:**	NAD 83 feet, MD State
Drilling Method:	Direct-push/hollow-stem	**Core Device:**	5-foot macrocore sampler	**Prepared by:**	Sandy Pebbles
Boring Status:	completed as well	**Drilling Fluid:**	none	**Reviewed by:**	Clay Brown

Drilling Information				Graphical Log for Primary Texture										Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel				
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	VOC Vapor Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth Interval (ft), PRIMARY TEXTURE, Principal and Minor Components with Descriptors (% modifiers and grain size fraction, angularity for coarse sand and larger, consistency/density, plasticity for silt and clay, dilatancy for silt/silt-sand); Sorting, Moisture Content, Color. NOTES: *Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)*	Driller's Observations, Geologic Formation, Field Screening Results, Sample Interval etc.
0 to 1			< 1												0-0.5 ft, topsoil with organics	Grass covered area
1 to 2			< 1				X								0.5-5 ft, SAND, fine, trace silt, trace pebble, round; poorly sorted, moist, yellowish brown (7.5 YR 5/8). NOTE: some cementation, does not react with HCl	continuous macro-core logging
2 to 3	0-5	43.2/60	< 1				X									
3 to 4			< 1				X									cemented sand @3.6-4 ft
4 to 5			< 1				X									
5 to 6			< 1				X	X	X						5-10 ft, SAND, fine to coarse, round to subround; well sorted, moist, light to strong brown (7.5 YR 6/4 to 7.5 YR 5/6).	
6 to 7			< 1				X	X	X							
7 to 8	5-10	40.8/60	< 1				X	X	X							
8 to 9			< 1				X	X	X							
9 to 10			< 1				X	X	X							
10 to 11			< 1				X	X	X						10-12.5 ft, same as above with trace silt	
11 to 12			< 1				X	X	X							
12 to 13	10-15	36/60	< 1				X	X	X							
13 to 14			< 1				X	X	X						12.5 to 15 ft, same as above, color change to pink (7.5 YR 7/3) and reddish yellow (7.5YR 6/8)	
14 to 15			< 1				X	X	X							
15 to 16			< 1						X	X					15-18.9 ft, SAND, coarse to very coarse, round to subround; well sorted, moist, strong brown (7.5YR 5/6) to reddish yellow (7.5YR 6/6)	
16 to 17			< 1						X	X						
17 to 18	15-20	55.2/60	< 1						X	X						
18 to 19			< 1		X	X	X								18.9-22.7 ft, SAND, very fine to fine, and SILT, coarse to very coarse, poorly sorted, wet, light gray (7.5YR 7/1)	water table encountered @ 18.9 ft
19 to 20			< 1		X	X	X									
20 to 21			< 1		X	X	X									
21 to 22			< 1		X	X	X									
21 to 23	20-25	36/60	< 1		X	X	X									
23 to 24			< 1	X	X										22.7-25 ft, CLAY and SILT, high plasticity, soft to stiff at 25 ft, dry to moist, light gray (2/5YR 7/1) w/ red mottling (2.5YR 4/6)	Middle Patapsco Confining Unit
24 to 25			< 1	X	X											
25 to 26			< 1	X	X										25-31.1 ft, CLAY and SILT, high plasticity, stiff; dry to moist, light gray (2/5YR 7/1) with red mottling (2.5YR 4/6)	
26 to 27			< 1	X	X											
27 to 28	25-30	30/60	< 1	X	X											
28 to 29			< 1	X	X											
29 to 30			< 1	X	X											
30 to 31			< 1	X	X											
31 to 32			< 1		X											
32 to 33	30-35 ft	60/60	< 1		X											
33 to 34			< 1		X										31.1-35 ft, SILT, low plasticity, high dilatancy; wet, gray (7.5YR 7/1)	End of direct-push boring @ 35 ft
34 to 35			< 1		X											

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TGI – Soil Drilling and Sample Collection

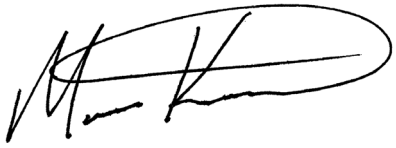
Rev: #2

Rev Date: April 8, 2022

Version Control

Issue	Revision No.	Date Issued	Page No.	Description	Reviewed By
	0	October 11, 2018	All	Updated and re-written as a TGI	Marc Killingstad
	1	May 12, 2020	None	Review – no changes necessary	Marc Killingstad
	2	April 8, 2022	All	Updated to new format and minor content (e.g., PFAS)	Chris Shepherd/Marc Killingstad

Approval Signatures

Prepared by:		4/8/2022
	Chris Shepherd (Preparer)	Date
Reviewed by:		4/8/2022
	Marc Killingstad (Subject Matter Expert)	Date

1 Introduction

This document describes general and/or specific procedures, methods, actions, steps, and considerations to be used and observed by Arcadis staff when performing work, tasks, or actions under the scope and relevancy of this document. This document may describe expectations, requirements, guidance, recommendations, and/or instructions pertinent to the service, work task, or activity it covers.

It is the responsibility of the Arcadis Certified Project Manager (CPM) to provide this document to the persons conducting services that fall under the scope and purpose of this procedure, instruction, and/or guidance. The Arcadis CPM will also ensure that the persons conducting the work falling under this document are appropriately trained and familiar with its content. The persons conducting the work under this document are required to meet the minimum competency requirements outlined herein, and inquire to the CPM regarding any questions, misunderstanding, or discrepancy related to the work under this document.

This document is not considered to be all inclusive nor does it apply to any and all projects. It is the CPM's responsibility to determine the proper scope and personnel required for each project. There may be project- and/or client- and/or state-specific requirements that may be more or less stringent than what is described herein. The CPM is responsible for informing Arcadis and/or Subcontractor personnel of omissions and/or deviations from this document that may be required for the project. In turn, project staff are required to inform the CPM if or when there is a deviation or omission from work performed as compared to what is described herein.

In following this document to execute the scope of work for a project, it may be necessary for staff to make professional judgment decisions to meet the project's scope of work based upon site conditions, staffing expertise, state-specific requirements, health and safety concerns, etc. Staff are required to consult with the CPM when or if a deviation or omission from this document is required that has not already been previously approved by the CPM. Upon approval by the CPM, the staff can perform the deviation or omission as confirmed by the CPM. All deviations or omissions should be documented.

2 Intended Use and Responsibilities

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3 Scope and Application

This Technical Guidance Instruction (TGI) describes general drilling procedures and the methods to be used to field screen and collect soil samples for laboratory analysis in unconsolidated or weakly consolidated sediments. For soil description procedures, please refer to the *TGI - Soil Description*. For monitoring well installation in granular aquifers, please refer to the *TGI - Monitoring Well Installation*. For per- and polyfluoroalkyl substances (PFASs) drilling and soil sampling procedures, please refer to: *TGI – PFAS-Specific Drilling and Monitoring Well Installation, TGI – Per- and Polyfluoroalkyl Substances (PFAS) Field Sampling Guide*, and *TGI – Equipment and Reagent Blank Sample Collection for PFAS Analysis*.

Overburden (unconsolidated sediments) drilling is commonly performed using the hollow-stem auger drilling method. Other drilling methods suitable for overburden drilling, which are sometimes necessary due to site-specific geologic conditions, include: direct-push, drive-and-wash, spun casing, rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and hand tools may also be used. Drilling within consolidated materials such as fractured rock is commonly performed using water-rotary (coring or tri-cone roller bit), air rotary or rotasonic methods. For guidance when drilling in consolidated materials (i.e., bedrock), please refer to *the TGI – Bedrock Core Collection and Description.*

The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling depths, targeted chemicals, site or regional geologic knowledge, types of sampling to be conducted, required sample quality and volume, and cost.

Field screening of soil samples is commonly performed using a photoionization detector (PID) and/or a flame ionization detector (FID). These instruments are used to measure relative concentrations of volatile organic compounds (VOCs) for the selection of samples for further laboratory or field analysis. Field screening for dense non-aqueous phase liquids (DNAPL) may be performed using hydrophobic dye (Oil Red O or Sudan IV), which is pertinent at chlorinated solvent sites.

Collection of soil samples for laboratory analysis may be performed using a variety of techniques including grab samples, undisturbed cores, and composite or homogenized samples. Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample. Samples for VOC analysis will not be homogenized or composited and are collected as discrete grab samples.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). Some lubricants (e.g., vegetable oil-based lubricants) may be acceptable, if the constituents won't interfere with the analyses.

4 Personnel Qualifications

Arcadis field personnel will have completed or are in the process of completing site-specific training as well as having current health and safety training as required by Arcadis, client, or state/federal regulations, such as 40-hour HAZWOPER training and/or OSHA HAZWOPER site supervisor training. Arcadis personnel will also have current training as identified in the site-specific Health and Safety Plan (HASP) which may include first aid,

cardiopulmonary resuscitation (CPR), Blood Borne Pathogens (BBP) as needed. The HASP will also identify any access control requirements.

Prior to mobilizing to the field, Arcadis field personnel will review and be thoroughly familiar with relevant site-specific documents including but not limited to the task-specific work plan or field implementation plan (FIP), Quality Assurance Project Plan (QAPP), HASP, historical information, and other relevant site documents.

Arcadis field personnel will be knowledgeable in the relevant processes, procedures, and TGIs and possess the demonstrated required skills and experience necessary to successfully complete the desired field work. Personnel responsible for overseeing drilling operations will have at least 16 hours of prior training overseeing drilling activities with an experienced geologist, environmental scientist, or engineer with at least 2 years of prior experience.

Arcadis personnel directing, supervising, or leading soil sampling activities will have a minimum of 1 year of previous environmental soil sampling experience. Field employees with less than 6 months of experience will be accompanied by a supervisor (as described above) to ensure that proper sample collection techniques are employed.

Additionally, the Arcadis field team will review and be thoroughly familiar with documentation provided by equipment manufacturers and become familiar with the operation of (i.e., hands-on experience) all equipment that will be used in the field prior to mobilization.

5 Equipment List

The following materials will be available, as required, during soil boring drilling, field screening, andsampling activities:

- Site-specific HASP and health and safety documents identified in the HASP
- FIP/work plan that includes site map with proposed boring locations, fieldsampling plan (with corresponding depths, sample analyses, sample volume required, and sample holding time), and previous boring logs (as available)
- Appropriate personal protective equipment (PPE), as specified in the HASP
- Including but not limited to disposable chemical resistant gloves and Level D PPE
- Traffic cones, delineators, and caution tape as appropriate for securing the work area as specified in the Traffic Safety Plan (TSP)
- Photoionization detector (PID), flame ionization detector (FID) or other air/soil screening equipment, asneeded, in accordance with the HASP or workplan
- Sampling equipment:
- Drilling equipment required by *ASTM D1586*, when performing split-spoon sampling including clean sample sleeves
- Disposable plastic liners, when drilling with direct-push equipment
- Stainless steel hand auger and stainless-steel spade if using manual methods
- Appropriate soil sampling equipment (e.g., stainless steel spatulas/spoons/bowls, knife)
- Sealable plastic bags (e.g., Ziploc®)

- Air-tight sample containers and 8-oz. glass Mason jars or driller's jars
- Aluminum foil
- Appropriate sample blanks (trip blank supplied by the laboratory), as specified in the FSP
- Soil sample containers and labels (supplied by the laboratory) appropriate for the analytical method(s) with preservative, as needed (parameter-specific)
- Sample labels
- Indelible ink pens
- Engineer's ruler or survey rod
- Plastic sheeting (e.g., Weatherall Visqueen)
- Appropriate transport containers (coolers) with ice and appropriate labeling, packing, and shipping materials
- Decontamination equipment (buckets, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels) in accordance with the *TGI for Groundwater and Soil Sampling Equipment Decontamination*
- Forms/notes:
    - Tablet with digital forms, etc., if appropriate
    - Appropriate soil boring log (**Attachment 1**)
    - Chain-of-custody forms
    - Field notebook
    - Digital camera (or smart phone with camera)
- Drums or other containers appropriate for soil and decontamination water, as specified by the site investigation-derived waste (IDW) management plan, and appropriate drum labels

6 Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service in accordance with the work plan, client requirements, and Arcadis guidance. See appropriate guidance forproper utility clearance protocol. Work will be performed in accordance with the Arcadis *Utility Location and Clearance Health and Safety Standard* and the *Utilities and Structures Checklist* will be completed before beginning any intrusive work.

Prior to beginning field work, the project technical team will ensure that all field logistics (e.g., access issues, health and safety issues, communication network, schedules, etc.) and task objectives are clearly understood by all team members. An internal call with the project technical team to review the FIP/work plan scope and objectives is strongly recommended prior to mobilization to ensure that the field work will be effectively and efficiently executed.

Some regulatory agencies have specific requirements regarding borehole abandonment and grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the

drilling plan.

If DNAPL is known or expected to exist at the site, refer to the project specific documents (e.g., DNAPL Contingency Plan) for additional details regarding drilling to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquid (LNAPL) is known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions. Water used for drilling, decontamination of drilling/sampling equipment, or grouting boreholes uponcompletion will be of a quality acceptable for project objectives. Testing of water supply will be considered.

Specifications of materials used for backfilling the borehole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPL is likely to be present or in groundwater with high salinity. In these situations, neat cement grout is preferred.

Store and/or stage empty and full sample containers and coolers out of direct sunlight. Sample container threads should be wiped down with a clean, nonabrasive material (e.g., paper towels) to better ensure the sample container is properly sealed. Be careful not to over-tighten lids with Teflon® liners or septa. Over-tightening can impair the integrity of the seal and cancause the glass to shatter and create a risk for hand injuries.

NOTE: *Field logs and some forms are considered to be legal documents. All field logs and forms will therefore be filled out in indelible ink. Do not use permanent marker or felt-tipped pens for labels on sample container or sample coolers. Permanent markers could introduce volatile constituents into the samples.*

NOTE: *An Arcadis employee that is appropriately trained at the correct level of internal hazardous materials/DOT (Department of Transportation) shipping must complete an Arcadis shipping determination to address applicable DOT and IATA (International Air Transport Association) shipping requirements. Review the applicable Arcadis procedures and guidance instructions for sample packaging and labeling. Prior to using air transportation, confirm air shipment is acceptable under DOT and IATA regulations.*

7 Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Review all site-specific and procedural hazards as they are provided in the HASP, and review Job SafetyAnalysis (JSA) documents in the field each day prior to beginning work.

Prior to drilling, utility clearance must be performed (see Section 5). Appropriate personal protective equipment (PPE) will be worn at all times in line with the task and thesite-specific HASP.

Working outside at sites with suspected contamination may expose field personnel to hazardous materials such as contaminated groundwater or NAPL (e.g., oil). Other potential hazards include biological hazards (e.g., stinging insects, ticks in long grass/weeds, etc.), and potentially the use of sharp cutting tools (scissors, knife). Only use non-toxic peppermint oil spray for stinging insect nests. Review client-specific health and safety requirements, which may preclude the useof fixed/folding-blade knives

and use appropriate hand protection.

If thunder or lightning is present, discontinue drilling and sampling until 30 minutes have passed after the last occurrence of thunder or lightning.

8 Procedure

The procedures for drilling and the methods to be used to field screen and collect soil samples for laboratory analysis are presented below:

8.1 Drilling Procedures

8.1.1 Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area.
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance boring to target depth:
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using the appropriate tooling (e.g., split-barrel sampler) and sample containers
        i. Split-barrel or drive-ahead samples are obtained during drilling
        ii. A common sampling method that produces high-quality soil samples with relatively littlesoil disturbance is described in *ASTM D1586 – Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils* (ASTM D1586).
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
    e. Rotasonic drilling produces soil cores that, for the most part, are relatively undisturbed, but note that when drilling in consolidated or finer-grained sediment the vibratory action during core barrel advancement may create secondary fractures or breaks. The core is retrieved by vibrating the soil/rock into a separate core bag, typically in 5-foot or 10-foot increments. The soil cores may consolidate or expand during retrieval, depending on soils, etc.
    f. Dual-rotary removes cuttings by compressed air or water/mud and allow only a

generalassessment of geology unless separate coring tools and techniques are used

g. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)

3. Describe each soil sample as outlined in the appropriate project records (refer to the description procedures outlined in the *TGI - Soil Description*)

    a. Record descriptions on the soil boring log (**Attachment 1**) and/or field notebook

    b. When possible, photo document the samples (e.g., soil cores, split-barrels)

    c. During soil boring advancement, document all drilling events in field notebook, including blow counts (i.e., the number of blows from a soil sampling drive weight [140 pounds] required to drive the split-barrel sampler in 6-inch increments) and work stoppages

    d. Blow counts will not be available if rotasonic, dual-rotary, or direct-push methods are used; however, if standard penetration testing is required during rotasonic drilling, an automatic drop hammer may be used in conjunction with the method to switch from core barrel advancement to standard penetration testing

    e. If soils are screened with a PID/FID or another instrument, document the measurement in accordance with the work plan

4. The drilling contractor will be responsible for obtaining accurate and representative samples, informing the supervising Arcadis geologist of changes in drilling pressure, drilling penetration rates, and keeping a separategeneral log of soils encountered, including blow counts

    a. The term “samples” means soil materials from particular depth intervals, whether or not portions of these materials are submitted for laboratory analyses

    b. Records will also be kept of occurrences of premature refusal due to boulders, construction materials that may have been used as fill, etc.

    c. Where a boring cannot be advanced to the desired depth, the boring will be abandoned, and an additional boring will be advanced at an adjacent location to obtain the required sample in accordance with the work plan

    d. Where it is desirable to avoid leaving vertical connections between depth intervals (e.g., if DNAPL or perched LNAPL are known or expected to exist at the site), the borehole will be sealed using cement and/or bentonite (see **Section 5** above)

    e. Multiple refusals may lead to a decision by the supervising geologist to abandon that sampling location

8.1.2 Direct-Push Method

The direct-push drilling method may also be used to complete soil borings. Examples of this technique include Geoprobe®, Diedrich Environmental Soil Probe (ESP) System, or AMS PowerProbe.

Environmental probe systems typically use a hydraulically operated percussion hammer.

Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff to medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual tube liner for samplingsoil

(dual tube sampling system).

The outside diameter (OD) of the outer casing ranges from 2.25 to 6 inches and the OD of the inner sampling tube diameter ranges from 1.4 to 4.5 inches. The outer casing isolates overlying soil and permits the unit to continue to probe at depth. The dual tube sampling system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, a single rod system may be used that does notprovide a cased boring and which limits tremie-grouting from the bottom up.

Direct-push drilling can generally achieve target depths 100 feet or less depending on the site geology. The known or expected site conditions (e.g., presence of NAPL) will be evaluated when selecting the typeof direct-push sampling system to be employed.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
    a. Verify utilities were cleared (see Section 5) and use soft dig technique to clear borehole, if applicable
    b. Clean sampling equipment in accordance with the FIP/work plan prior to drilling
2. Advance soil boring to target depth.
    a. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) using clean/disposable sampling equipment (plastic liners)
    b. Always change disposable gloves before handling the sampling equipment
    c. Collect, document, and store samples for laboratory analysis as specified in theFIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
3. Decontaminate equipment between samples in accordance with the FIP/work plan (or equivalent)
4. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

8.1.3 Manual Methods

Manual methods may also be used to complete shallow soil borings. Examples of this technique include using a spade, spoon, scoop, hand auger, or slide hammer. Manual methods are typically used to collect surface soil samples (0 to 6 inches) or to complete soil borings/collect soil samples from a depth of 5 feet or less.

1. Find/identify boring location, establish work zone, and set up sampling equipment decontamination area
2. Clear the ground surface of brush, root mat, grass, leaves, or other debris
3. Use a spade, spoon, scoop, hand auger, or slide hammer to collect a sample of the required depth interval
4. Use an engineer's ruler or survey rod to verify that the sample is collected to the correct depth and

record the top and bottom depths from the ground surface

5. To collect samples below the surface interval, remove the surface interval first; then collect the deeper interval
    a. To prevent the hole from collapsing, it may be necessary to remove a wider section from the surface or use cut polyvinyl chloride (PVC) pipe to maintain the opening
    b. Collect soil samples at appropriate interval as specified in the FIP/work plan (or equivalent) and transfer to the appropriate, laboratory-supplied container
    c. Collect, document, and store samples for laboratory analysis as specified in the FIP/work plan (or equivalent; see below for additional details on sample collection procedures)
    d. Field screen samples as specified in the FIP/work plan (or equivalent; see below for additional details on field screening procedures)
6. Decontaminate equipment between samples in accordance with the FIP/work plan (orequivalent)
7. Describe samples in accordance with the procedures outlined in **Step 3** under ***Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods*** above (refer to the description procedures outlined in the *TGI - Soil Description*)

8.2 Field Screening Procedures

8.2.1 PID and FID Screening

Soils are typically field screened with a PID or FID for a relative measure of the total VOCs at sites where VOCs are known or suspected to exist. PIDs and FIDs require calibration in accordance with the work plan(s) and manufacturer's specifications and PIDs should be calibrated based on the target chemicals. The PID employs an ultraviolet lamp to measure VOCs and the ionizationenergy (IE) of the site constituents need to be considered when selecting the type of lamp (e.g., 10.6 eV, 11.7 eV) that will be used. In general, any compound with an IE lower than that of the lamp photons canbe measured. The FID has a wide linear range and responds to almost all VOCs.

Field screening is performed using one (or both) of the following two methods:

1. Upon opening the sampler, the soil is split open and the PID or FID probe is placed in the opening and covered with a clean, gloved hand. Such readings will be obtained at several locations along the lengthof the sample.
2. A portion of the collected soil is placed in a jar, which is covered with aluminum foil, sealed, and allowed to warm to room temperature (see below). After warming, the cover is removed, the foil is pierced withthe PID or FID probe, and a reading is obtained.

Prior to usage, the PID or FID must be calibrated according to the manufacturer's specifications at a minimum frequencyof once per day prior to collecting PID or FID readings. The PID will be calibrated to a benzene-related compound (isobutylene) or other appropriate gas, while the FID will be calibrated to methane. The time, date, and calibration procedure must be clearly documented in the field notebook and/or the calibration form.

If at any time the PID or FID results appear erratic or inconsistent with field observations, then the instrument will be recalibrated.

If calibration is difficult to achieve, then the PID's lamp will be checked for dirt or moisture and cleaned, or technical assistance will be required. Maintenance and calibration records will be kept as part of the field quality assurance program.

Initial PID readings will be recorded on the soil boring log (**Attachment 1**) and/or in the field notes. The soil sample will be separated from the slough material (if any) by using disposable gloves and a pre-cleaned stainless-steel spoon or tool.

For the second method, a representative portion of the sample will be placed in a pre-cleaned air-tight container (as quickly as possible to avoid loss of VOCs), filling the container half full to allow for the accumulation of vapors above the soil. An aluminum foil seal will be placed between the glass and cap and the cap will be screwed on tightly. Unless the screening will be performed immediately after the sample is placed in the container, the sample containers will be stored in a cooler chilled to approximately4ºC until screening can be performed.

The headspace of the container will be measured using a PID or FID as follows:

1. Samples will be taken to a warm workspace and allowed to equilibrate to room temperature for atleast one hour.
2. Prior to measuring the soil vapor headspace concentration, the container will be shaken.
3. The headspace of the sample will then be measured directly from the container by piercingthe aluminum foil seal with the probe of the PID or FID and measuring the relative concentration of VOCs in the headspace of the soil sample. The initial (peak) reading must be recorded.

8.2.2 NAPL Screening

To screen for the potential presence of non-aqueous phase liquid (NAPL) in soil, drilling procedures must allow for high-quality porous media samples to be taken. Split-barrel samplers or direct-push samplers will be collected continuously ahead of the auger, drill casing/rods, or probe rods. Upon opening each split-barrel sampler or direct-push plastic liner sleeve, the soil will immediately be evaluated for the presence of visible NAPL and odors. If suspected NAPL is immediately visible in the sample, its depth will benoted.

Additionally, the soil will be screened for the presence of organic vapors using a PID or FID, in accordance with the work plan, if applicable. During screening, the soil will be split open using a clean spatula or knife and the PID or FID probe will be placedin the opening and covered with a clean, gloved hand (**Method 1** above). Such readings will be obtained along the entire length of the sample. Alternatively, **Method 2** for PID/FID screening (outlined above) may also be performed. If the PID or FID examination reveals the presence of organic vapors above 100 parts permillion (ppm), the sample will undergo further detailed evaluation for visible NAPL.

The assessment for NAPL will include the following tests/observations:

- Evaluation for Visible NAPL Sheen or Free-Phase NAPL in Soil Sampler
    - NAPL sheen will be a colorful iridescent appearance on the soil sample
    - NAPL may also appear as droplets or continuous accumulations of liquid with a color typically ranging from yellow to brown to black, depending on the type of NAPL
    - Creosote DNAPL (associated with wood-treating sites) and coal tar DNAPL (associated with manufactured gas plant [MGP] sites) are typically black and have a characteristic, pungent odor
    - Pure chlorinated solvents may be colorless in the absence of hydrophobic dye. Solvents mixed

with oils may appear brown

- Particular care will be taken to fully describe any sheens observed, staining, discoloration, droplets (blebs), or NAPL saturation

- Soil-Water Pan Test
  - A portion of the selected soil interval with the highest PID or FID reading above 100 ppm will be placed in a disposable polyethylene dish along with a small volume of potable or distilled water
  - The dish will be gently tilted back and forth to mix the soil and water, and the surface of the water will be viewed in natural light to observe the development of a sheen, if any
  - A small quantity of Oil Red O or Sudan IV hydrophobic dye powder should be added in accordance with the work plan, and the soil and dye will be manually mixed for approximately 30 to 60 seconds and smeared in the dish tocreate a paste-like consistency
  - A positive test result will be indicated by a sheen on the surface of the water and/or a bright red color imparted to the soil following mixing with dye
- Soil-Water Shake Test
  - A small quantity of soil (up to 15 cc) will be placed in a clear, colorless, jar containing an equal volume of potable or distilled water (40-mL vials are well suited to this purpose, but not required)
  - After the soil settles into the water, the surface of the water will be evaluated for a visible sheen under natural light
  - The jar will be closed and gently shaken for approximately 10 to 20 seconds
  - Again, the surface of the water will be evaluated for a visible sheen or a temporary layer of foam
  - A small quantity (approximately 0.5 to 1 cc) of Oil Red O or Sudan IV powder will be placed in the jar in accordance with the work plan
  - The sheen layer, if present, will be evaluated for a reaction to the dye (change to bright red color)
  - The jar will be closed and gently shaken for approximately 10 to 20 seconds
  - The contents in the closed jar will be examined under natural light for visible bright red dyed liquid inside the jar

- A positive test result will be indicated by the presence of a visible sheen or foam on the surface ofwater, a reaction between the dye and the sheen layer upon first addition of the dye powder, a bright red coating on the inside of the vial (particularly above the water line), or red-dyed droplets within the soil

NOTE: *If NAPL is obviously present upon opening the soil sampler or evaluating the soil sample within the split-spoon sampler or direct-push liner sleeve, it is not necessary to perform a soil-water pan test or soil-water shake test. In addition, it is not necessary to perform both a soil-water pan test and a soil-water shake test; either test method is acceptable. The pan test may be preferred in some circumstances because the presence of a sheen may be easier to see on a wider surface. Further, these tests will only be performed if specified in the work plan(s).*

NOTE: *When using hydrophobic dye in the tests above, color will be assessed outdoors under natural light during the period between sunrise and sunset, regardless of the degree of cloud cover. The hydrophobic dye Safety Data Sheets (SDS) will be incorporated into the HASP and reviewed prior to use and the dyes will be carefully handled and disposed in accordance with regulations, if applicable*.

8.3 Soil Sample Collection for Laboratory Procedures

If not specifically identified in the FIP/work plan, soil samples will be selected for laboratory analysis based on:

1. Their position in relation to identified source areas
2. The visual presence of source residues (e.g., NAPL or staining)
3. The relative levels of total VOCs based on field screening measurements
4. The judgment of the field coordinator
5. Moisture content or relative position with regard to apparent groundwater table/saturation

Samples designated for laboratory analysis will be placed in the appropriate containers.

Sample containers for VOC analysis will be filled first immediately following soil core retrieval to reduce loss of VOCs.

If samples will be collected for other analyses, a sufficient amount of the remaining soil willthen be homogenized as described below and sample containers will be filled for other parameters.

VOC samples will be collected as discrete samples using a small diameter core sampler (e.g., En Core® Sampler, Terra Core™ Sampler).

The En Core® Sampler is a disposable volumetric sampling device that collects, stores and delivers soil samples without in-field chemical preservation. The En Core® Sampler requires the use of a reusable T-handle.

The Terra Core™ Sampler is a one-time use transfer tool, designed to collect soil samples and transfer them to the appropriate containers for in-field chemical preservation (e.g., methanol).

The small diameter core samplers will be used according to the manufacturer's instructions (e.g., En Novative Technologies). Some regulatory agencies have specific requirements regarding VOC sample

collection. Determine whether the oversight agency has specific requirements prior to commencing sampling and collect samples at appropriate interval as specified in the FIP/work plan (or equivalent). Samples may require homogenization across a given depth interval, or several discrete grabs (usually five) may be combined into a composite sample.

NOTE: *Samples for VOC and PFAS analysis will NOT be homogenized or composited and will be collected asdiscrete samples as described above*.

The procedure for mixing samples is provided below.

1. Mix the materials in a stainless steel (or appropriate non-reactive material) bowl using a stainless-steel spoon (or disposable equivalents)

a. When dealing with large sample quantities, use disposable plastic sheeting and a shovelor trowel

b. NOTE: *When preparing samples for metals analyses, do not use disposable aluminum(or metal tools or trays other than stainless steel), as it may influence the analytical results*

2. Flatten the pile by pressing the top without further mixing

3. Divide the circular pile by into four equal quarters by dividing out two diameters at right angles

4. Mix each quarter individually using appropriate non-reactive bowls, spoons and/or sheeting

5. Mix two quarters (as described above) to form halves, then mix the two halves to form a composite orhomogenized sample

6. Place composite or homogenized sample into specified containers

7. Remaining material will be disposed of in accordance with project requirements and applicableregulations

8. Sample containers will be labeled with sample identification number, date, and time of collection andplaced on ice in a cooler (target 4° Celsius)

9. Samples selected for laboratory analysis will be documented (chain-of-custody forms), handled, packed, and shipped in accordance with the procedures outlined in the FIP/work plan (or equivalent).

8.4 Soil Boring Abandonment

All soil borings need to be abandoned in accordance with ***TGI for Monitoring Well and Soil Boring Decommissioning***. See Attachment E of the TGI for specifics.

9 Waste Management

Investigative-Derived Waste (IDW) generated during drilling activities, including soil and excess drilling fluids (if used), and decontamination liquids, will be stored on site in appropriately labeled containers and disposed of properly. Disposable materials will be stored and disposed of separately. Containers must be labeled at the time of collection and will include date, location(s), site name, city, state, and description of matrix contained (e.g., soil, PPE). Waste will be managed in accordance with the *TGI – Investigation-Derived Waste Handling and Storage,* the procedures identified in the FIP/work plan or QAPP as well as

state-, federal- or client-specific requirements. Be certain that waste containers are properly labeled and documented in the field log.

10 Data Recording and Management

Digital data collection is the Arcadis standard using available FieldNow® applications that enable real-time, paperless data collection, entry, and automated reporting. Paper forms should only be used as backup to FieldNow® digital data collection and/or as necessary to collect data not captured by available FieldNow® applications. The Field Now® digital form applications follow a standardized approach, correlate to most TGIs and are available to all projects accessible with a PC or capable mobile device. Once the digital forms are saved within FieldNow®, the data is instantly available for review on a web interface. This facilitates review by project management team members and SMEs enabling error or anomalous data detection for correction while the staff are still in the field. Continual improvements of FieldNow® applications are ongoing, and revisions are made as necessary in response to feedback from users and subject matter experts.

Management of the original documents from the field will be completed in accordance with the site- specific QAPP.

In general, drilling activities will be documented on appropriate field/log forms as well as in a proper field notebook. All field data will be recorded digitally or with indelible ink. Field forms, logs/notes (including daily field and calibration logs), digital records, and chain-of-custody records will be maintained by the field team lead. Any deviations or omissions from this TGI should be documented.

Initial field logs and chain-of-custody records will be transmitted to the Arcadis CPM and Technical Lead at the end of each day unless otherwise directed by the CPM. The field teamleader retains copies of the field documentation.

Additionally, all documents (and photographs) will be scanned and electronically filed in the appropriate project directory for easy access. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of drilling activities, soil descriptions, soil boring information, and quantities of materials used.

In addition, the locations of soil borings will be documented photographically and in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

Records generated as a result of this TGI will be controlled and maintained in the project record files in accordance with project requirements.

11 Quality Assurance

Quality assurance procedures shall be conducted in accordance with the Arcadis Quality Management System or the site-specific QAPP.

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate TGI.

Field-derived quality assurance blanks will be collected as specified in the FIP/work plan and/or site- specific QAPP, depending on the project quality objectives. Typically, field rinse blanks (equipment blanks) will be collected when non-dedicated equipment (e.g., split-spoon sampler, stainless steel spoon) is used during soil sampling. Field rinse blanks will be used to confirm that decontamination procedures are sufficient and samples are representative of site conditions. Trip blanks for VOCs, which aid in the detection of contaminants from other media, sources, or the container itself, will be kept with the coolers and the sample containers throughout the sampling activities and during transport to the laboratory.

Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.

12 References

ASTM D1586 - *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*. ASTM International. West Conshohocken, Pennsylvania.

13 Attachments

Attachment 1. Soil Boring Log Form

Attachment 1

Soil Boring Log Form

BORING LOG

ARCADIS

Boring ID:		**Project Name:**		**Page:**	
Permit ID:		**Date Started:**		**Ground Elevation:**	
Site Address:		**Date Completed:**		**Vertical Datum:**	
City, State:		**Total Depth:**		**Northing:**	
Drilling Co:		**Depth to Water:**		**Easting:**	
Driller:		**Hole Diameter:**		**Horizontal Datum:**	
Drilling Method:		**Core Device:**		**Prepared by:**	
Boring Status:		**Drilling Fluid:**		**Reviewed by:**	

Drilling Information				**Primary Texture**											**Soil Description (Udden-Wentworth System)**	**Field Notes**
				Fines		**Sand**					**Gravel**					
Drilling Depth (ft bgs)	**Core Interval (ft)**	**Core Recovery (inches)**	**PID Reading (ppm)**	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

BORING LOG

Boring ID: ____________ **Project Name:** ____________ **Page:** ___ / ___

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

BORING LOG

ARCADIS

Boring ID: ____________________ **Project Name:** ________________________________ **Page:** _____ / _____

Drilling Information				Primary Texture											Soil Description (Udden-Wentworth System)	Field Notes
				Fines		Sand					Gravel					
Drilling Depth (ft bgs)	Core Interval (ft)	Core Recovery (inches)	PID Reading (ppm)	clay	silt	very fine	fine	medium	coarse	very coarse	granule	pebble	cobble	boulder	Depth interval (ft), Moisture, PRIMARY TEXTURE, Modifier/Minor Texture, Sorting, Angularity, Consistency, Plasticity, Color - Only Record Sand Density with Standard Penetration Tests Minor Texture Modifiers: Trace (<10%), Little (10 to 20%), Some (21 to 35%), And (36 to 50%)	Driller's Observations, Particle Size Percentages, Geologic Formation, Field Screening Results, Sample Interval etc.

Appendix C

Schedule

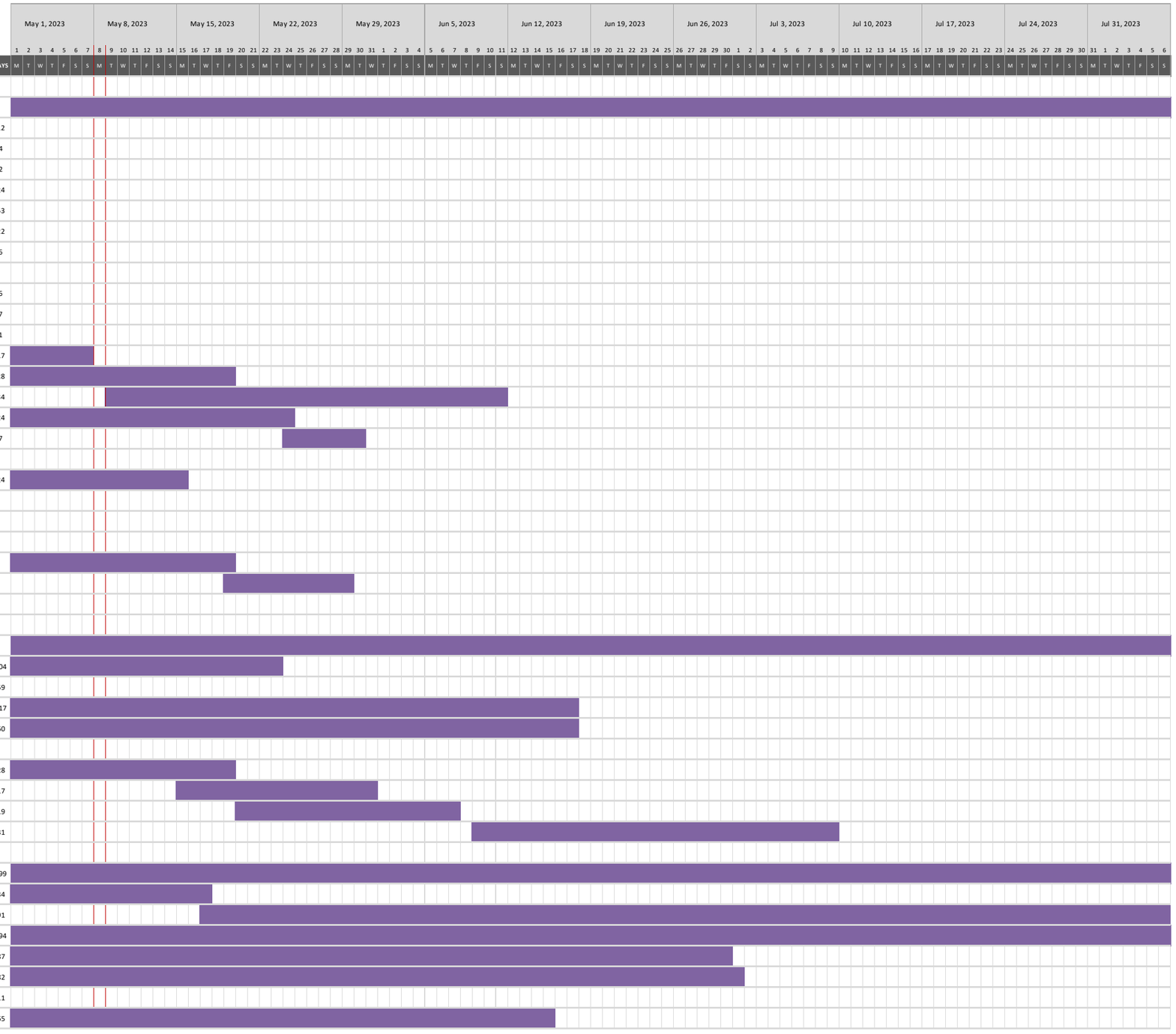
Gantt Chart for East Palestine Derailment Site Work

Norfolk Southern Railway Company

Project Start: Fri, 2/3/2023

Display Week: 0

TASK	START	END	DAYS
Main Line 1 Removal (South Track)			
Soil Profile Approval	2/3/23	Ongoing	
Disposal Of Existing Stockpiles	2/27/23	3/10/23	12
Temporary Stockpile Construction	2/27/23	3/2/23	4
Main Line Track 1 Removal	3/3/23	3/4/23	2
Soil Excavation	3/4/23	3/27/23	24
Soil Disposal Main Line 1	3/4/23	4/25/23	53
Main Line 1 Subgrade Installation	3/21/23	4/11/23	22
Main Line 1 Track Installation	4/12/23	4/17/23	6
Main Line 2 Removal (North Track)			
Legal Hold on Railcars	2/26/23	3/3/23	6
Tank Car Removal	3/3/23	3/9/23	7
Main Line Track 2 Removal	4/21/23	4/21/23	1
Area 3 Investigation	4/21/23	5/7/23	17
Soil Excavation	4/22/23	5/19/23	28
Soil Disposal Main Line 2	5/9/23	6/11/23	34
Main Line 2 Subgrade Installation	5/1/23	5/24/23	24
Main Line 2 Track Installation	5/24/23	5/30/23	7
Area 4 & Pleasant Street Work			
Area 4 Investigation/Sampling	4/22/23	5/15/23	24
Area 4 Remediation (follows investigation evaluation)	TBD	TBD	
Pleasant Street Crossing Replacement (follows remediation implementation)	TBD	TBD	
Area Between Tracks			
Excavation	2/13/23	5/19/23	
Area Between Tracks Investigation / Sampling	5/19/23	5/29/23	
Area Between Tracks - Final Remediation (once evalua	TBD	TBD	
Surface Water Activities			
Surface Water Sampling	2/5/23	Ongoing	
Maintain Surface Water Bypass	2/9/23	5/23/23	104
Stream In-Situ Treatment	2/6/23	4/5/23	59
Sulphur Run Sediment Washing	2/21/23	6/17/23	117
Leslie Run Interim Sediment Washing	4/19/23	6/17/23	60
Site Remediation			
North Ditch	4/22/23	5/19/23	28
North Incident Area	5/15/23	5/31/23	17
South Ditch (incl. Beer Car Area) (piping)	5/20/23	6/7/23	19
South Incident Area	6/9/23	7/9/23	31
Waste Management and Disposal			
Contaminated Water Disposal*	2/14/23	8/31/23	199
Contained-in System Set-Up and Install / Shakedown	4/14/23	5/17/23	34
Contained-in Water Treatment System Operation	5/17/23	8/15/23	91
Contaminated Soil Disposal	2/3/23	8/15/23	194
Frac tank Cleaning	4/5/23	6/30/23	87
Frac tank Demob	4/11/23	7/1/23	82
2x1M Tank Cleaning and Demob	8/15/23	8/25/23	11
Roll-off Box Disposal (Soil, solids)	4/12/23	6/15/23	65



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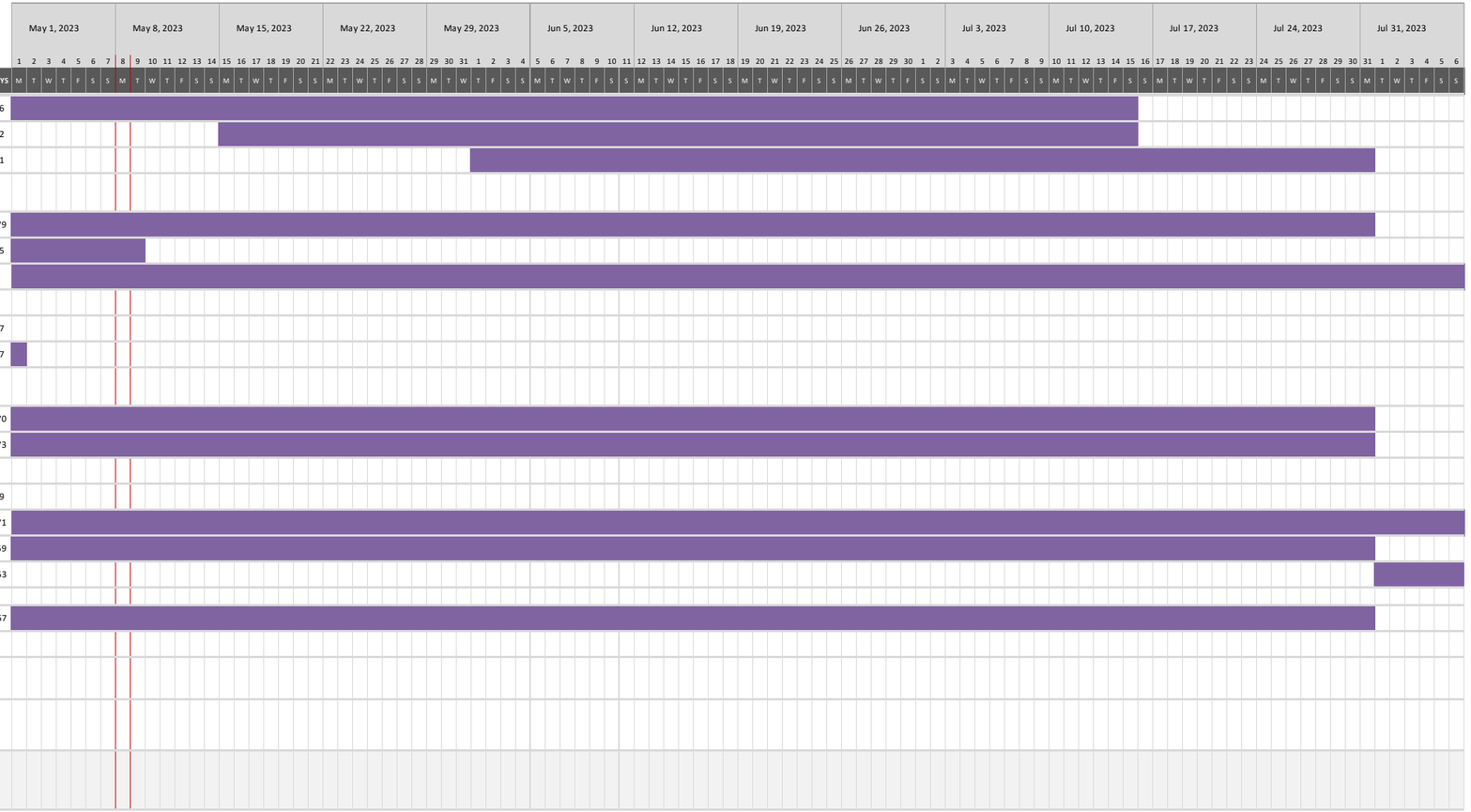
TASK	START	END	DAYS
Staging Area Closure/Demobilization	5/1/23	7/15/23	76
Staging Area Confirmation Sampling	5/15/23	7/15/23	62
Staging Area and General Site Restoration	6/1/23	7/31/23	61
Air Sampling - Original Plan submitted 2/3/23 and Revised Plan submitted 4/7/23			
Sitewide Air Monitoring	2/3/23	7/31/23	179
In Home Air Monitoring	2/14/23	5/9/23	85
Community Impact Mitigation - Original Plan submitted on 3/6/23 and Revised Plan submitted on 4/11/23	3/6/23	Ongoing	
Res/Com/Ag Soil Sampling - Original Plan submitted 2/27/23 and Revised Plan submitted 4/5/23			
Phase 1 - Assessment	3/9/23	4/14/23	37
Phase 1 - Reporting	3/16/23	5/1/23	47
Potable Water Well Sampling - Original Plan submitted on 2/10/23 and Revised Plan submitted 4/5/23			
Municipal Well Sampling and Reporting	2/12/23	7/31/23	170
Private Well Sampling and Reporting	2/9/23	7/31/23	173
Sentinel Well / Onsite Well Monitoring			
Sentinel Monitoring Well Installation	2/14/23	4/13/23	59
Onsite / Staging Area Monitoring Well Installation	2/25/23	8/14/23	171
Monitoring Well Sampling - Sampled weekly	2/23/23	7/31/23	159
Monitoring Well Sampling - Sampled monthly	8/1/23	12/31/23	153
Home Cleaning			
Home Cleaning	2/15/23	7/31/23	167



Note 1: The timeframe for the Area 4 remediation and crossing replacement will be scheduled at a later date upon completion of track 2 remediation and procurement of required crossing and signal materials.

Notes: This schedule is an estimate and is subject to change based on several factors, including without limitation, obtaining required regulatory approvals, access, weather, equipment malfunction, receipt of laboratory results, etc.

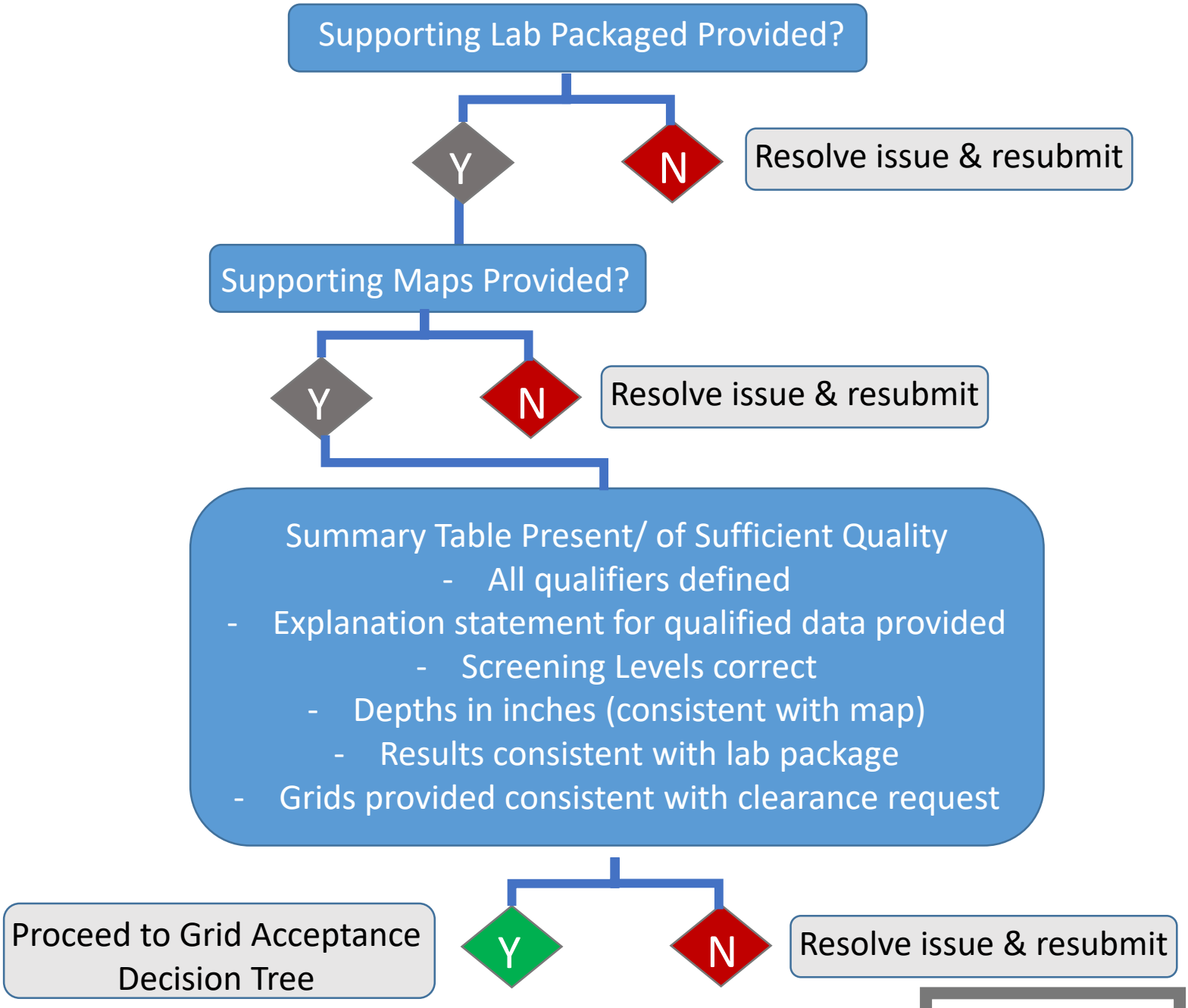
*Requirements for water collection and disposal are expected to decrease as soil is removed and operations areas decrease in extent. Precise end date for water collection and treatment will be identified based on future data and results.

Appendix D

Track Excavation Confirmation Sampling Decision Tree

Track Excavation Confirmation Sampling Decision Tree

Sampling Results Table Acceptance Decision

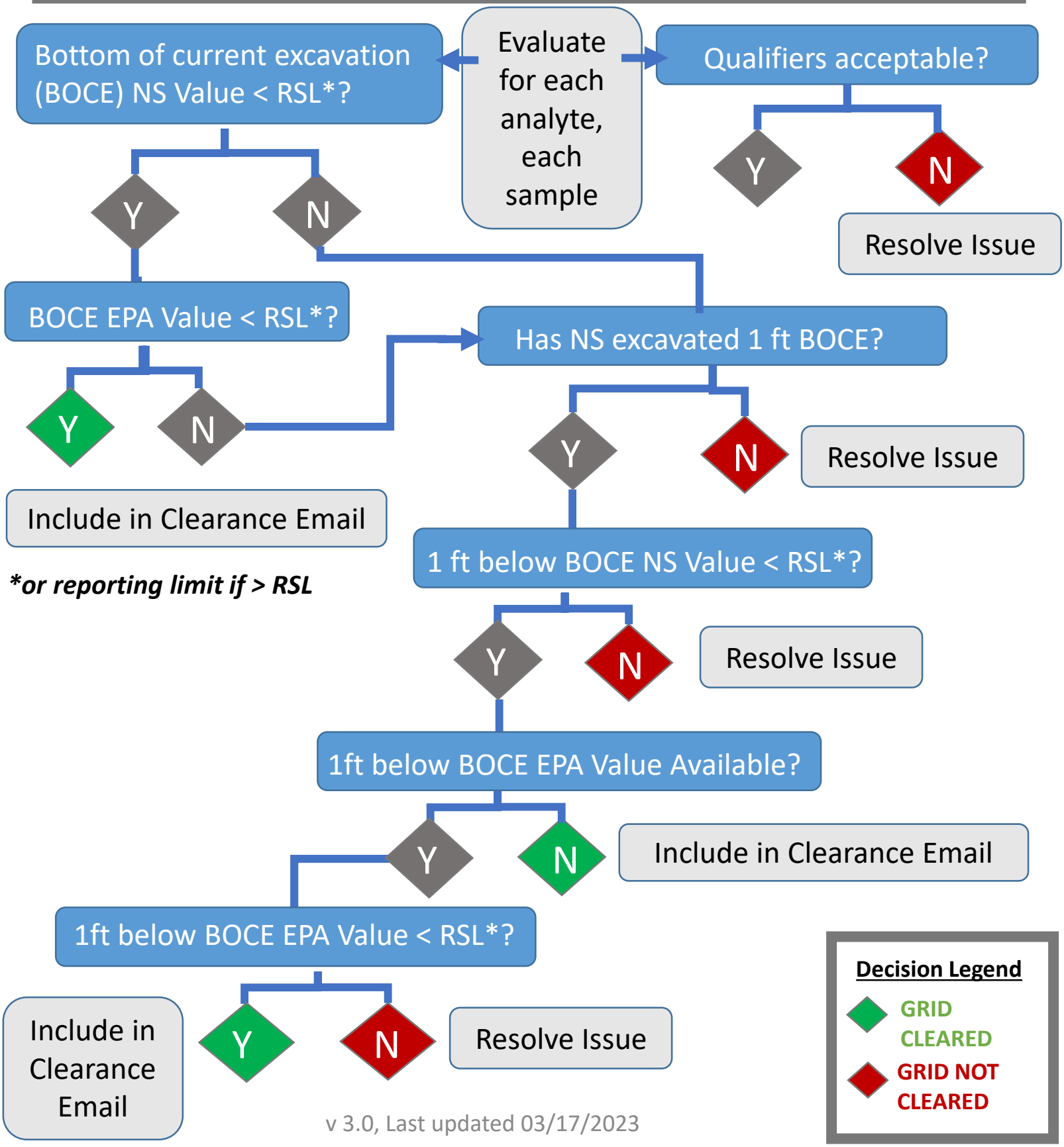


Decision Legend

- **ACCEPTED**
- **REJECTED – COMMENTS PROVIDED**

Track Excavation Confirmation Sampling Decision Tree

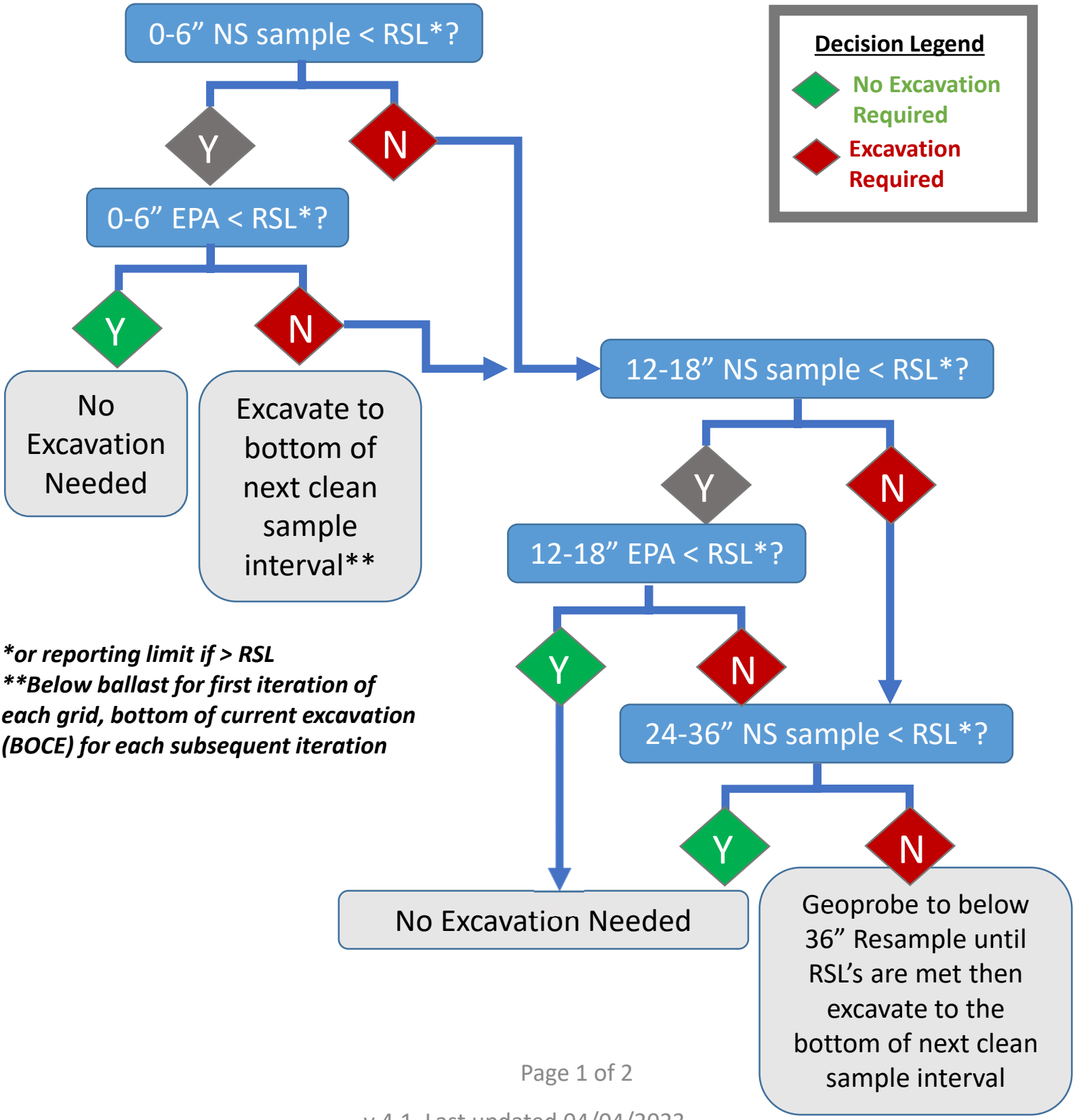
Grid Acceptance Decision (by parameter, per sample)



v 3.0, Last updated 03/17/2023

Track Excavation Confirmation Sampling Decision Tree – Area 3, 4 Addendum

Excavation Depth Decision (soil by parameter, per sample)



or reporting limit if > RSL

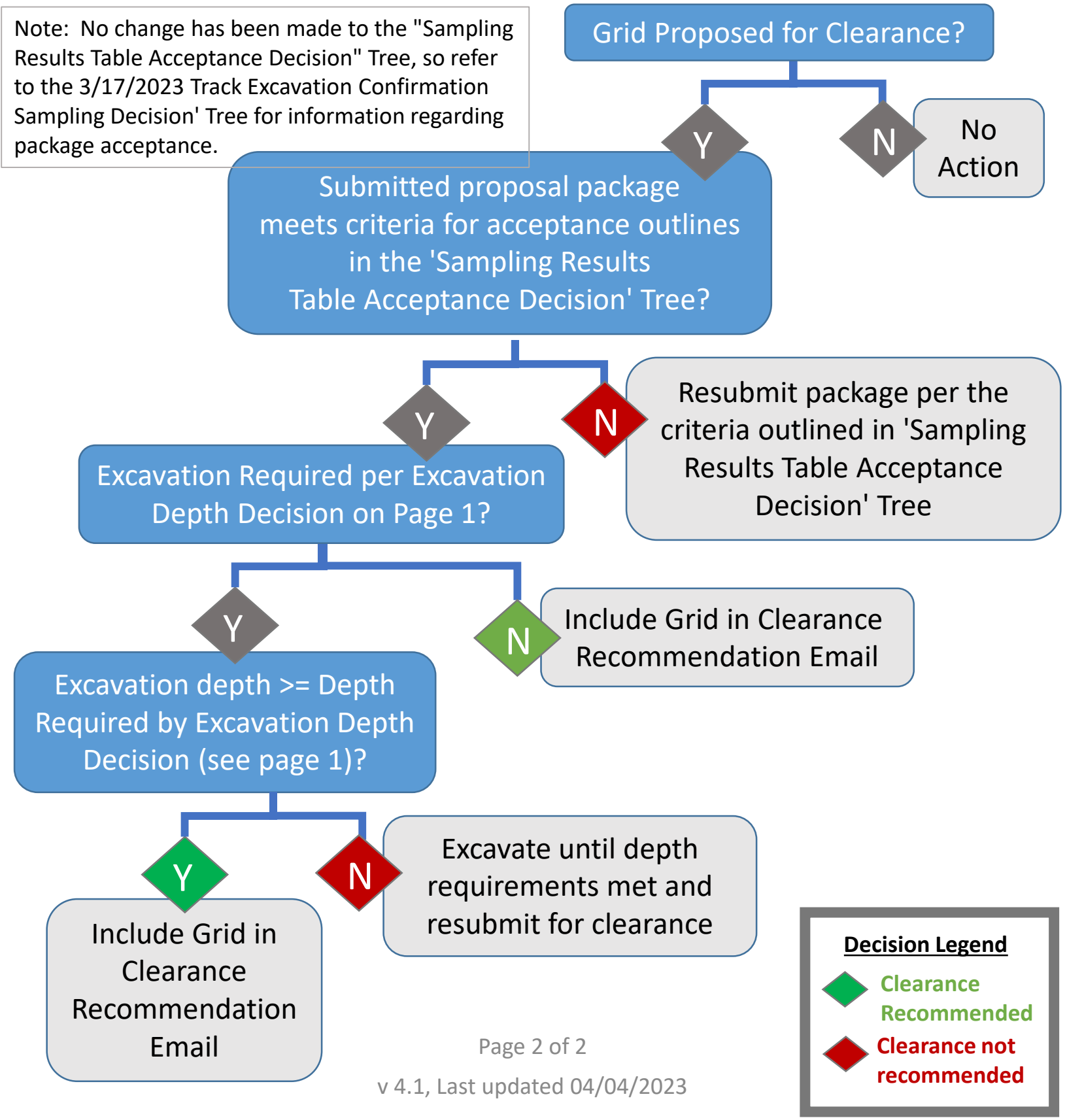
****Below ballast for first iteration of each grid, bottom of current excavation (BOCE) for each subsequent iteration***

v 4.1, Last updated 04/04/2023

Track Excavation Confirmation Sampling Decision Tree – Area 3, 4 Addendum

Grid Clearance Decision (soil by parameter, per sample)

Note: No change has been made to the "Sampling Results Table Acceptance Decision" Tree, so refer to the 3/17/2023 Track Excavation Confirmation Sampling Decision' Tree for information regarding package acceptance.



v 4.1, Last updated 04/04/2023

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