FINAL

PHASE II REMEDIAL INVESTIGATION REPORT FOR TAYLOR ROAD BURNING GROUND

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION JOHN H. GLENN RESEARCH CENTER AT NEIL A. ARMSTRONG TEST FACILITY SANDUSKY, OHIO

Prepared for:

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October 2022

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LIST OF ACRONYMS

µg/dL	Micrograms per Deciliter
µg/L	Micrograms per Liter
ACM	Asbestos-Containing Material
AMSL	Above Mean Sea Level
AOC	Area of Concern
AOPC	Area of Potential Concern
ATF	Armstrong Test Facility
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMCOC	Contaminant Migration Chemical of Concern
CMCOPC	Chemical Migration Chemical of Potential Concern
COC	Chemical of Concern
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
CSEM	Conceptual Site Exposure Model
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
D&D	Decontamination and Decommissioning
DAD	Dermal Absorbed Dose
DCE	Dichloroethene
DERR	Division of Environmental Response and Revitalization
DNAP	Division of Natural Areas and Preserves
DNT	Dinitrotoluene
DO	Dissolved Oxygen
DoD	U.S. Department of Defense
DQO	Data Quality Objective
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESV	Ecological Screening Value
EU	Exposure Unit
FRBG	Fox Road Burning Ground
FS	Feasibility Study
FY	Fiscal Year
GAC	Granular Activated Carbon
GIABS	Gastrointestinal Absorption Fraction
gpm	Gallons Per Minute
GRC	Glenn Research Center
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System

LIST OF ACRONYMS (Continued)

HUC	Hydrologic Unit Code
IDW	Investigation Derived Waste
IEUBK	Integrated Exposure Uptake Biokinetic
ILCR	Incremental Lifetime Cancer Risk
IRIS	Integrated Risk Information System
IUR	Inhalation Unit Risk
K_d	Soil/Water Partitioning Coefficient
K_h	Henry's Law Constant
K_{oc}	Water/Organic Carbon Partition Coefficient
LHA	Lifetime Health Advisory
LOAEL	Lowest-Observable-Adverse-Effect Level
MCL	Maximum Contaminant Level
MDC	Maximum Detected Concentration
mg/kg-day	Milligrams per Kilogram per Day
mg/m^3	Milligrams per Cubic Meter
mL/min	Milliliters per Minute
MW	Molecular Weight
NAD 83	North American Datum of 1983
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ng/L	Nanograms per Liter
NASA	National Aeronautics and Space Administration
NCEA	National Center for Environmental Assessment
NFA	No Further Action
NOAEL	No-Observable-Adverse-Effect Level
NPL	National Priorities List
NTU	Nephelometric Turbidity Unit
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
ORP	Oxidation Reduction Potential
OU	Operable Unit
PA	Preliminary Assessment
PBOW	Plum Brook Ordnance Works
PBS	Plum Brook Station
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene
PFAS	Per- and Polyfluoroalkyl Substances
PMU	Project Management Unit
ppb	Parts per Billion
PREscore	Preliminary Ranking Evaluation Score

LIST OF ACRONYMS (Continued)

PSMS	Protected Species Management Strategy
PVC	Polyvinyl Chloride
QC	Quality Control
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
SARA	Superfund Amendments and Reauthorization Act
SI	Site Investigation
SNP	State Nature Preserve
SRBG	Snake Road Burning Ground
SRC	Site-Related Chemical
SVOC	Semivolatile Organic Compound
TAL	Target Analyte List
TCA	Trichloroethane
TCE	Trichloroethene
TNT	Trinitrotoluene
TR	Target Risk
TRBG	Taylor Road Burning Ground
UCL	Upper Confidence Limit
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
VISL	Vapor Intrusion Screening Level
VOC	Volatile Organic Compound

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EXECUTIVE SUMMARY

Leidos has prepared this Phase II Remedial Investigation (RI) Report on behalf of the National Aeronautics and Space Administration (NASA) as part of an RI conducted within the John H. Glenn Research Center at Neil A. Armstrong Test Facility (GRC-ATF) in Sandusky, Ohio (Figure 1-1). This report summarizes Phase II RI activities conducted at Taylor Road Burning Ground (TRBG) and provides conclusions and recommendations regarding the evaluation of groundwater data collected from the investigation activities.

Groundwater was not previously evaluated at TRBG during the 2015 Site Inspection or 2017 Phase I RI. The objective of the Phase II RI is to fully characterize the nature and extent of contamination and evaluate exposure risk to hazardous substances in groundwater, and if necessary, soil vapor, due to historical activities at the three burning grounds. All field activities were performed in accordance with the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020b).

Investigative activities completed in support of the Phase II RI included:

- Installation and development of five permanent groundwater monitoring wells (TRBG-MW01, TRBG MW02, TRBG-MW03, TRBG-MW04, and TRBG-MW05);
- Two seasonal groundwater sampling events each consisting of the five new wells sampled for metals, explosives, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and polychlorinated biphenyls (PCBs).

Due to the nature of the site (former burning ground), Ohio Environmental Protection Agency (Ohio EPA) correspondence stated that if VOCs were not detected as potential chemicals of concern (COCs) for the site, assessing the soil vapor pathway would not be triggered (Ohio EPA 2019). Vapor-forming chemicals were not detected in subsurface soils at TRBG as part of the Phase I RI. Groundwater tested in Phase II of the RI showed different results. VOCs were detected at low concentrations in samples collected at all four monitoring well samples. A desktop evaluation determined that installation of vapor points and collection of soil vapor samples were not warranted at TRBG.

ES.1 SUMMARY OF NATURE AND EXTENT

During the Phase I RI for TRBG, the site was divided into four exposure units (EUs) to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the Primary Burn Area, Secondary Burn Area, Drainage Areas, and Debris Area. The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the EU source area. Conservative transport modeling in the Phase I RI indicated 10 chemicals may leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding maximum contaminant levels (MCLs)/regional screening levels (RSLs). The 10 chemicals included inorganics (selenium and silver); explosives (2,4,6-trinitrotoluene [TNT]; 2,4-dinitrotoluene [DNT]; and 4-Amino-2,6-DNT); SVOCs (benzaldehyde, hexachloroethane, and naphthalene) a pesticide (beta-hexachlorocyclohexane); and a herbicide (dalapon). A qualitative assessment of the sample results was performed, and the limitations and assumptions of the models were considered to identify if any soil contaminant migration chemicals of concern (CMCOCs) were present in soil at TRBG that may potentially impact groundwater. This qualitative assessment concluded that without available groundwater data, two initial CMCOCs (hexachloroethane and naphthalene) should be assessed during future groundwater studies at the site (Leidos 2018b). Hexachloroethane was not detected in groundwater at TRBG; however, the detection limit was greater than the tap water RSL. Naphthalene was only detected in one sample at an estimated concentration of 0.12 µg/L at TRBG-MW001 in the fall of 2021.

Only three metals (cadmium, iron, and manganese) exceeded their respective background concentrations and/or the tap water RSL in groundwater at TRBG in both the total and dissolved samples. Cadmium only exceeded the screening criteria for both total and dissolved cadmium at one location in the fall of 2021 at TRBG-MW03. Total and dissolved iron exceeded screening criteria at TRBG-MW01 at concentrations of 2,100 µg/L in May and 1,600 µg/L in December 2021. Only one sample exceeded the screening criteria in the fall sampling event at TRBG-MW02 at a concentration of 1,100 µg/L. The metal detections appear to be seasonal since most screening criteria exceedances occurred in the fall when less groundwater was available. Bis(2-ethylhexyl)phthalate was the only SVOC detected above the screening criteria in the November 2021 sample from TRBG-MW03. VOCs detected above screening levels were limited to the chlorinated solvents tetrachloroethene (PCE); trichloroethene (TCE); cis-1,2-dichloroethene (DCE); and methylene chloride. Of the four VOCs, only methylene chloride exceeded both its tap water RSL and MCL at TRBG-MW01, TRBG-MW02, and TRBG-MW05.

The groundwater in the overburden is in discontinuous pockets during dry time periods, as evidenced by TRBG-MW04 being dry during both sampling events. During wet periods, the general flow direction in the overburden water-bearing zone is to the north-northeast from TRBG, largely mirroring surface topography (Shaw 2005). Since the majority of the site-related chemicals (SRCs) were detected at TRBG-MW01, TRBG-MW02, and TRBG-MW03, which are located in or upgradient of the soil contamination requiring remedial action, and TRBG-MW-04 is dry in the downgradient direction, it appears the extent of the contaminants in the TRBG groundwater has been adequately characterized. In addition, none of the CMCOCs identified in the Phase I RI were detected in the groundwater above screening criteria.

ES.2 SUMMARY OF FATE AND TRANSPORT

The Phase I RI fate and transport evaluation identified hexachloroethane and naphthalene for future groundwater evaluation to assess the modeling results. Hexachloroethane was not detected in groundwater at TRBG during the Phase II RI. Naphthalene was detected in only one groundwater sample at an estimated concentration equal to the tap water RSL of 0.12 µg/L.

One of the principal migration pathways at the site is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). The rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Once the contaminant leachate percolates through the soil and reaches the water table, it mixes with groundwater beneath the source. The potential receptor location would be a hypothetical domestic water well located beneath the site. However, because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. In addition, the CMCOCs identified in the Phase I RI were not detected in groundwater above screening criteria. The presence of the inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring.

ES.3 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment (HHRA) documents the potential health risks to humans resulting from exposure to groundwater contamination within TRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on U.S. Environmental Protection Agency (USEPA) and Ohio EPA guidance.

GRC-ATF is expected to remain under the control of NASA for the foreseeable future. Although it is unlikely that TRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to represent unrestricted use and evaluate the upper bound for long-term exposure. Generally, sites that “pass” a residential risk assessment can be released for use without restriction. TRBG is best

classified as an inactive area, and plausible receptors include groundskeepers and hunters. No groundwater at GRC-ATF is used for drinking water under current or planned future use. At the time of this report, NASA is working to develop an implementation plan to ensure the property is managed in accordance with the land use control prohibiting groundwater use at GRC-ATF.

The groundwater exposure routes evaluated in the HHRA include ingestion, dermal contact, and inhalation (for certain organic compounds). Risks were calculated for both cancer and non-cancer effects using the USEPA RSL calculator. Lead exposures were evaluated for the resident child using USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) model, which is used to predict the relative increase in blood lead concentration that might result from environmental exposure.

For hypothetical residential land use, the total resident child hazard index (HI) for groundwater (15) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1 for the resident child: the HI of 2 for nervous system effects (due to manganese [2] and aluminum [0.7]), the HI of 6 for dermal effects (due to arsenic [2], and thallium [4]), the HI of 2 for gastrointestinal effects (due to iron [2]), and the HI of 2 for endocrine system effects (due to cobalt [2]). The total incremental lifetime cancer risk (ILCR) of 2E-04 for groundwater exposure is above the upper bound of the target cancer risk range and is associated almost entirely with arsenic. The lead model results for the resident child show that the probability the blood-lead concentration would exceed the level of concern is less than the USEPA target.

After further evaluation of the data for filtered groundwater samples, no organic chemicals or metals were identified as COCs. Arsenic, aluminum, cobalt, iron, manganese, and thallium were eliminated as COCs because they were either not detected in filtered samples or detected at concentrations for which the calculated hazard quotient (HQ) was equal to or less than 1. Note the high turbidity associated with the November/December samples (>1,000 nephelometric turbidity units [NTUs]), which helps account for the decrease in concentrations generally seen in both the filtered samples and in the May/June samples.

Vapor-forming chemicals were not detected in subsurface soils at TRBG as part of the Phase I RI; however, VOCs were detected at low concentrations in groundwater samples collected at all four monitoring wells as part of the Phase II RI. The Vapor Intrusion Screening Levels (VISL) screening results and evaluation of other factors concluded that no chemicals of potential concern (COPCs) were identified for the vapor intrusion pathway.

ES.4 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

An ecological risk assessment (ERA) was completed in the Phase I RI Report. TRBG is approximately 5.2 acres and is vegetated with shrubland surrounded by forested area, with a wetland on the western boundary of the site. Wetlands are considered important ecological resources, and there is soil documentation of contamination at TRBG, so further analysis was conducted in a Level II ERA. It was determined that there are no final chemicals of potential ecological concern (COPECs) at TRBG. Consequently, the ERA for TRBG concluded with a Level II Screening ERA, and no further action (NFA) was recommended to be protective of important ecological resources (Leidos 2018b).

Ecological receptors are not typically exposed to groundwater except for caves and when groundwater daylights to surface water. No known caves are at GRC-ATF, and this site does not contain surface water bodies. As a result, ecological exposures to chemicals in the groundwater are not a concern.

ES.5 RECOMMENDATIONS OF THE PHASE II REMEDIAL INVESTIGATION

This Phase II RI only evaluated groundwater at TRBG, as soil was evaluated in the Phase I RI. Based on the Phase II RI results, TRBG groundwater has been adequately characterized, and further investigation is not warranted to complete the RI for groundwater. The nature and extent of potentially impacted media has been sufficiently characterized. Emerging contaminants will continue to be evaluated separately.

The HHRA did not identify any COCs with residential use of groundwater at TRBG. Ecological exposures to chemicals in the groundwater is not a concern. NFA is required to address chemical contamination within groundwater at TRBG.

A Feasibility Study (FS) addressing soil contamination at TRBG was prepared in 2018 (Leidos 2018c). The recommended alternative was excavation and offsite disposal. Since no COCs were identified with residential use of groundwater at TRBG, no additional recommendations are warranted for the FS for groundwater. However, it is recommended that the soil RSLs used in the Phase I RI be compared to current RSLs to determine if any additional COCs are present in surface and subsurface soils and if the remedial cleanup goals in the FS need to be updated.

1. INTRODUCTION

Leidos has prepared this Phase II Remedial Investigation (RI) Report on behalf of the National Aeronautics and Space Administration (NASA) as part of an RI conducted within the John H. Glenn Research Center at Neil A. Armstrong Test Facility (GRC-ATF) in Sandusky, Ohio (Figure 1-1). This report summarizes Phase II RI activities conducted at Taylor Road Burning Ground (TRBG) and provides conclusions and recommendations regarding the evaluation of groundwater data collected from the investigation activities.

This Phase II RI is being conducted in accordance with U.S. Environmental Protection Agency (USEPA), Ohio Environmental Protection Agency (Ohio EPA), and NASA guidance. Investigative activities were conducted in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

1.1 PURPOSE OF REPORT

The primary scope and objectives of this Phase II RI Report for TRBG are to:

- Discuss historical activities, identify potential sources of contamination, and update the conceptual site model (CSM);
- Summarize previous assessments and investigations conducted at the site;
- Characterize the nature and extent of contamination in groundwater;
- Evaluate the impact of groundwater contamination on human health and the environment;
- Present the results of the soil gas evaluation of the potential impact of vapor-forming volatile organic compounds (VOCs) on human health and the environment; and
- Identify any unacceptable risk to be further addressed in a Feasibility Study (FS).

In August 2015, a Site Investigation (SI) of soil, sediment, and surface water was performed at TRBG. This SI was supplemented by the Phase I RI sampling performed in January 2017. Information from all historical documents and data gathered during the 2015 SI and 2017 RI will be used in this report to define the nature and extent of contamination and evaluate potential impacts to human health and the environment at TRBG.

In April 2018, the *Final Remedial Investigation Report for Taylor Road Burning Ground* (Leidos 2018b; herein referred to as the (Phase I RI Report) evaluated soil, sediment, and surface water at TRBG. The Phase I RI Report recommended a Phase II RI be conducted to collect and assess groundwater data at TRBG. This Phase II RI Report evaluates groundwater and soil gas at TRBG. Two rounds of groundwater sampling were performed in May/June and November/December 2021 to address seasonal variations in groundwater. Since no vapor-forming chemicals of concern (COCs) were detected above VISLs in the first or second round of groundwater sampling as part of the Phase II RI, a soil gas investigation was not warranted based on the desktop soil vapor evaluation.

1.2 BACKGROUND

1.2.1 Armstrong Test Facility

1.2.1.1 Site Description

GRC-ATF (formerly known as Plum Brook Station [PBS]) is in southern Erie County, Ohio, approximately 3 miles south of Sandusky, Ohio, and approximately 50 miles west of the NASA John H. Glenn Research Center (GRC) in Cleveland, Ohio (Figure 1-1). The GRC-ATF site is currently 6,740 acres. Local farmers lease approximately 895 acres outside the security fence (Leidos 2018a). Most of GRC-ATF is in Perkins and Oxford Townships, with some lands in Huron and Milan Townships. The site boundaries are Bogart Road to the north, Mason Road to the south, U.S. Highway 250 to the east, and County Road 43 to the west. The northernmost boundary of GRC-ATF occurs at latitude 41°23'39"N and extends as far south as latitude 41°20'04"N. The westernmost longitude occurs at 82°43'12"W and extends as far east as 82°38'39"W.

GRC-ATF is situated in an area known for its agricultural productivity and is bordered by farmland, some of which NASA leases to local farmers. The area surrounding GRC-ATF is largely rural and agricultural, with some recent residential and commercial development. Some food processing facilities are in the area, including dairy and meat processing operations. Tourism and recreation are important economic influences in the Sandusky area. The Erie County Perkins School District currently uses certain former NASA facilities near the former GRC-ATF main gate and outside the fenced area for transportation and storage purposes. Intensive commercial development, consisting of highway-oriented uses (e.g., motels, restaurants, and service stations) and shopping malls, predominate immediately to the east along U.S. Highway 250 and its intersections with Bogart Road and State Highway 2 in Sandusky. A U.S. Army Reserve Center is situated adjacent to the southeastern corner, just off Mason Road (SAIC 2013a).

An 8-foot security fence surrounds approximately 5,845 acres of GRC-ATF. Most of the land at GRC-ATF consists of forestland and old fields. An estimated 75 percent of NASA's property at GRC-ATF is considered unused. The remaining land is used for offices, test facilities, roads, and infrastructure. Public access is restricted at GRC-ATF, and access to the site is gained through the security office on East Scheid Road. The main gate and security office are staffed by armed guards 24 hours per day. During each 8-hour shift, a security guard patrols the inside perimeter road (Patrol Road) of the facility. Persons gain access to the station by showing the guard a badge that authorizes entry.

1.2.1.2 History

GRC-ATF is operated as a satellite facility (or component installation) of NASA GRC. Use of GRC-ATF by the Federal Government began in 1941 when the Army established the Plum Brook Ordnance Works (PBOW) for manufacturing of trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite (MK 1994). The PBOW facility consisted of 9,009 acres inland, 1.35 acres for two pumping stations on Lake Erie, and approximately 700 buildings. Munitions production was conducted from 1941 to 1945, after which buildings and production lines were decontaminated and decommissioned. Between 1941 and 1945, more than one billion pounds of ordnance were estimated to have been manufactured.

In 1956, NASA obtained 500 acres in the northern portion of the site for construction of a nuclear test reactor (MK 1994). This reactor was the first of 15 test facilities that NASA eventually constructed and operated from 1958 to 1973. Between 1958 and 1960, NASA demolished hundreds of buildings, renovated approximately 41 buildings, and used 99 magazines (Gray and Pape 2008). In 1963, NASA acquired an additional 6,000 acres and took control over what is now referred to as GRC-ATF. From 1967 through 1971, NASA purchased approximately 2,000 acres outside the fence line from local farmers as "buffer."

On April 18, 1978, NASA declared approximately 2,152 acres of GRC-ATF as excess. This excess included approximately 1,500 acres outside the fence and was sold as farmland (NASA 2013). The 46 acres outside the fence in the northeastern corner of the PBOW facility near the guard house was conveyed to the Perkins Township Board of Education for use as a bus transportation area. In addition, three parcels have since transferred, including Parcel 4 (3.0951 acres) in March 2016, Parcel 63 (Former Taylor Road Waste Water Treatment Plant [11.5 acres]) in June 2016, and Rye Beach Pump Station (1.35 acres) in December 2014 (Leidos 2018b). According to the April 2018 update of the Environmental Resources Document, NASA currently controls approximately 6,740 acres; this includes approximately 5,845 acres within the fence line and 895 acres outside the fence, which are leased for agriculture (Leidos 2018a).

NASA currently operates GRC-ATF as a space research facility in support of GRC. Most of the aerospace testing facilities built in the 1960s at GRC-ATF have been demolished or are currently on standby or inactive status. Additional tenants at GRC-ATF include the U.S. Department of Agriculture (USDA), U.S. Department of the Interior, the Federal Bureau of Investigation, and the Ohio Air National Guard. Additional details regarding the site history are presented in the *Preliminary Assessment/Visual Site Inspection Report for NASA Plum Brook Station* (TechLaw 1998).

1.2.2 Taylor Road Burning Ground

1.2.2.1 Site Description

TRBG is located in the west-central portion of GRC-ATF, southeast of the intersection of Taylor Road and Ransom Road (Figure 1-2). As noted in the U.S. Army Corps of Engineers (USACE) *Records Review Report for the Plum Brook Ordnance Works* (DM 1995; herein referred to as the 1995 Records Review Report), the TRBG configuration (per a 1944 historical drawing No. 1669-T-603-9-1/2) was approximately 300 feet southeast of Taylor Road and 300 feet east of Ransom Road. An access road from Taylor Road was built to the burn area, which had a northwest-southeast orientation and measured approximately 100 by 140 feet. Surface soil in the burning area was excavated and used to construct a 3-foot-high earthen embankment surrounding the burn area. Eight-inch-diameter drainage tiles were installed throughout the embankment at natural low points. A mesh chicken wire fence was installed on top of the embankment.

Review of historical aerial photographs dated October 1950 indicates a disturbed area having the same configuration as that shown on the construction drawing and in an undated close-up aerial photograph provided by NASA. In the 1950 photograph, bare ground or debris appears to be located along the northern edge and in the southwestern corner of the area. The fire-break area around the burning ground appeared to have been cleared of trees and other materials.

During field reconnaissance of TRBG in March 1994 and the fall of 1994, the area was observed to consist of open field. TRBG is currently surrounded by shrub and a forested area with a wetland present on the western portion of the site. The habitat at TRBG is dominated by shrubland surrounded by forested area. Two ephemeral drainage ditches exist at the site, one west of the burn area and one northeast of the burn area (Figure 1-2). These drainage ditches were dry during the 2015 SI and 2017 RI field activities.

A wetland is associated with a wet weather ditch on the western side of the site that was dry during the 2015 SI and 2017 RI. The wetland runs south and narrows until it hits an access road at the southern boundary of TRBG and then continues east along the access way past the eastern boundary of the site. Another wetland formed south of TRBG and runs along the ditch on the other side of the access way just inside the site boundary.

1.2.2.2 Historical Usage

The Army and NASA have used burning grounds for destruction of both hazardous and non-hazardous material. These burning grounds are considered potential sources of environmental contamination because they were disposal sites for contaminated wastes. The contaminants included explosives, acids, asbestos, waste oil, and solvents.

Per the *Plum Brook Station Preliminary Assessment* (SAIC 1991; herein referred to as the PBS PA), the Army used burning grounds during the decontamination and decommissioning (D&D) of PBOW. These grounds were used for destroying explosives-contaminated wastewater flumes, intermediate settling tanks, and catch basins from the TNT areas. Contaminated putty, packing, and asbestos insulation removed from buildings at the TNT areas were also burned. All contaminated building material from the pentolite production area was also destroyed at the burning grounds. Excavated contaminated soil from the TNT areas and from removal of underground flumes was treated at the burning grounds.

1.3 CONCEPTUAL SITE MODEL

This section provides additional information to support and present the CSM for use in the assessment and cleanup of TRBG. This CSM presents the contamination sources, exposure pathways, human receptors, and ecological resources. Section 1.2.2.1 presents the site descriptions (history and current conditions), Section 2.0 presents environmental assessments and how data gaps were filled to complete the RI, and Section 3.0 presents the GRC-ATF and site-specific physical characteristics.

1.3.1 Potential Sources

TRBG is considered a potential source of environmental contamination at GRC-ATF due to historical usage as a disposal site and burning ground. While historical documents suggest that NASA used TRBG for burning combustible wastes that were not contaminated with acids or explosives, the Army's previous use specific to TRBG is not as certain. Consequently, TRBG is assumed to have the same primary source of contamination as the other burning grounds that include contaminated wastes, including explosives, waste oil, solvents, asbestos, and acids. Except for some scattered debris, the site has no more primary source material. The source medium or secondary source is surface soil and subsurface soil that were potentially contaminated from burning of the primary source material.

1.3.2 Potential Receptors

The following sections discuss potential human and ecological resources at TRBG. Figure 1-3 presents the pathway network receptor diagram to support the TRBG human health risk assessment (HHRA) and ecological risk assessment (ERA).

1.3.2.1 Human Receptors

TRBG is best classified as an inactive area, and plausible receptors include occasional groundskeepers and hunters. Even though hunting is not currently permitted in this area, hunting is permitted in other areas within GRC-ATF; therefore, a future hunting scenario was evaluated. GRC-ATF is expected to remain under the control of NASA for the foreseeable future. Although it is unlikely that TRBG will be developed for residential purposes, a hypothetical onsite residential scenario was evaluated to assess the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction. Similarly, while it is unlikely that TRBG will be developed for industrial or commercial purposes, a hypothetical industrial scenario is evaluated for long-term non-residential exposure.

Residential (onsite resident), occupational (industrial/commercial/construction worker), and recreation (hunter) exposure scenarios are used to evaluate potential risks from contaminated soil, soil vapor, and groundwater at TRBG.

1.3.2.2 Ecological Resources

TRBG is dominated by terrestrial resources. TRBG primarily consists of dry, mid-successional, cold-deciduous shrubland, which is edged by oak (*Quercus palustris-Quercus bicolor*) seasonally flooded forest.

TRBG has few aquatic resources. No streams or ponds are at the site, and no surface water or sediment exists. The ditches on the site were dry during the 2015 SI and 2017 RI, and thus, the medium in the ditches was classified as soil instead of sediment. The main wetland at the site is ephemeral and is located along the dry ditch to the west of the site until it hits an access road at the southern boundary of TRBG and then continues east along the access way past the eastern boundary of the site. Another wetland formed south of TRBG and runs along the ditch on the other side of the access way just inside the site boundary.

1.4 REPORT ORGANIZATION

This report is organized in accordance with Ohio EPA and USEPA CERCLA RI/FS guidance. The components of the report and a list of appendices are provided below:

- Section 2.0 summarizes previous assessments, evaluations, and investigations at the site.
- Section 3.0 describes the environmental setting, including the topography, meteorology, hydrology, geology, hydrogeology, demography, water resources, and ecology.
- Section 4.0 describes the methods used to perform the Phase II data collection activities.
- Section 5.0 presents the data use, quality, and evaluation methods to support this Phase II RI.
- Section 6.0 discusses the occurrence and distribution of groundwater contamination at the site.
- Section 7.0 presents an evaluation of contaminant fate and transport.
- Section 8.0 includes the methods and results of the HHRA.
- Section 9.0 includes a discussion of the ERA.
- Section 10.0 provides the conclusions and recommendations of this Phase II RI.
- Section 11.0 lists the references used to develop this report.
- Appendices:
    - Appendix A Field Documentation;
    - Appendix B Survey Report;
    - Appendix C Waste Manifests;
    - Appendix D Complete Groundwater Results;
    - Appendix E Analytical Laboratory Reports;
    - Appendix F Data Quality Assessments; and
    - Appendix G Human Health Risk Assessment Supporting Information.

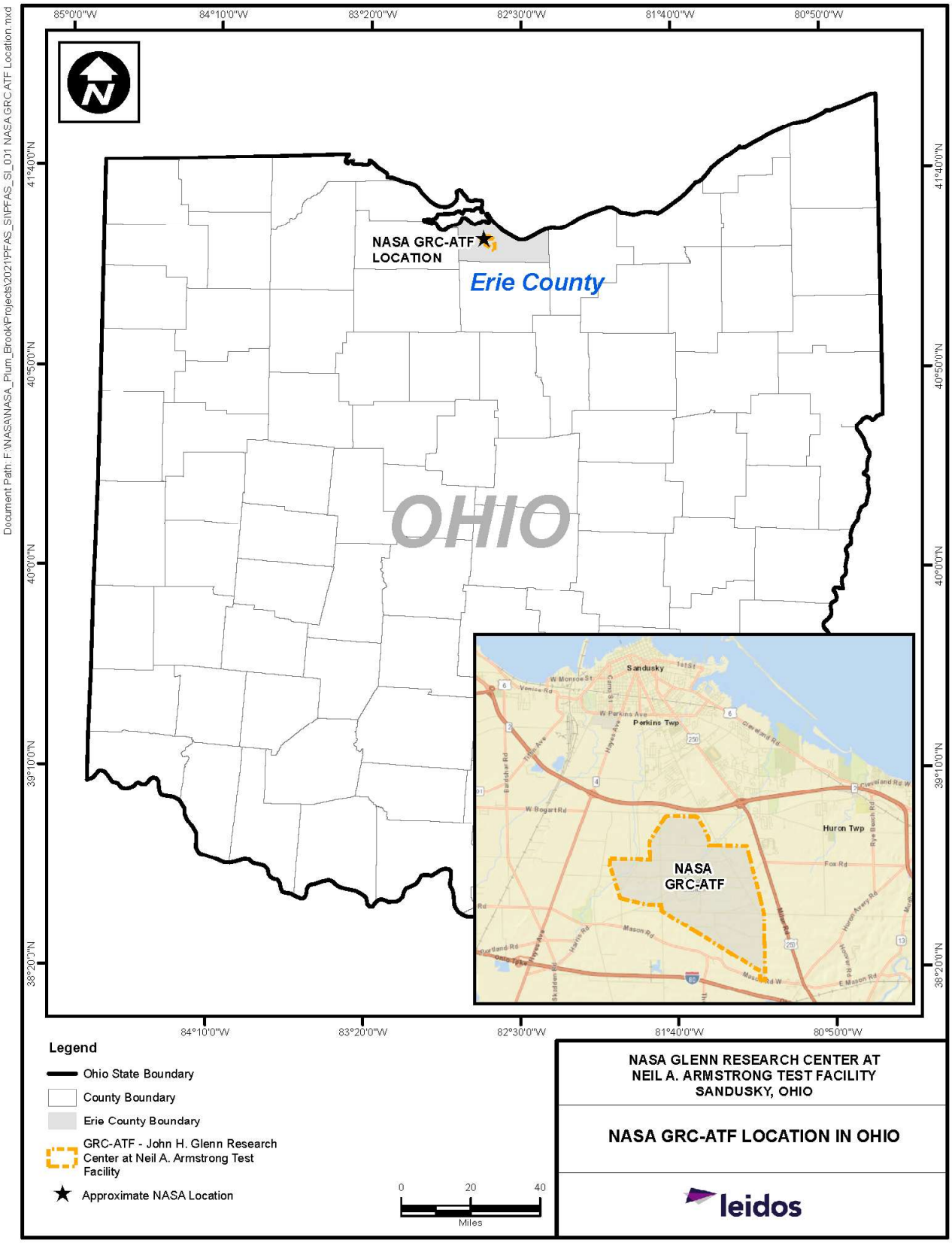


Figure 1–1. General Location of GRC-ATF

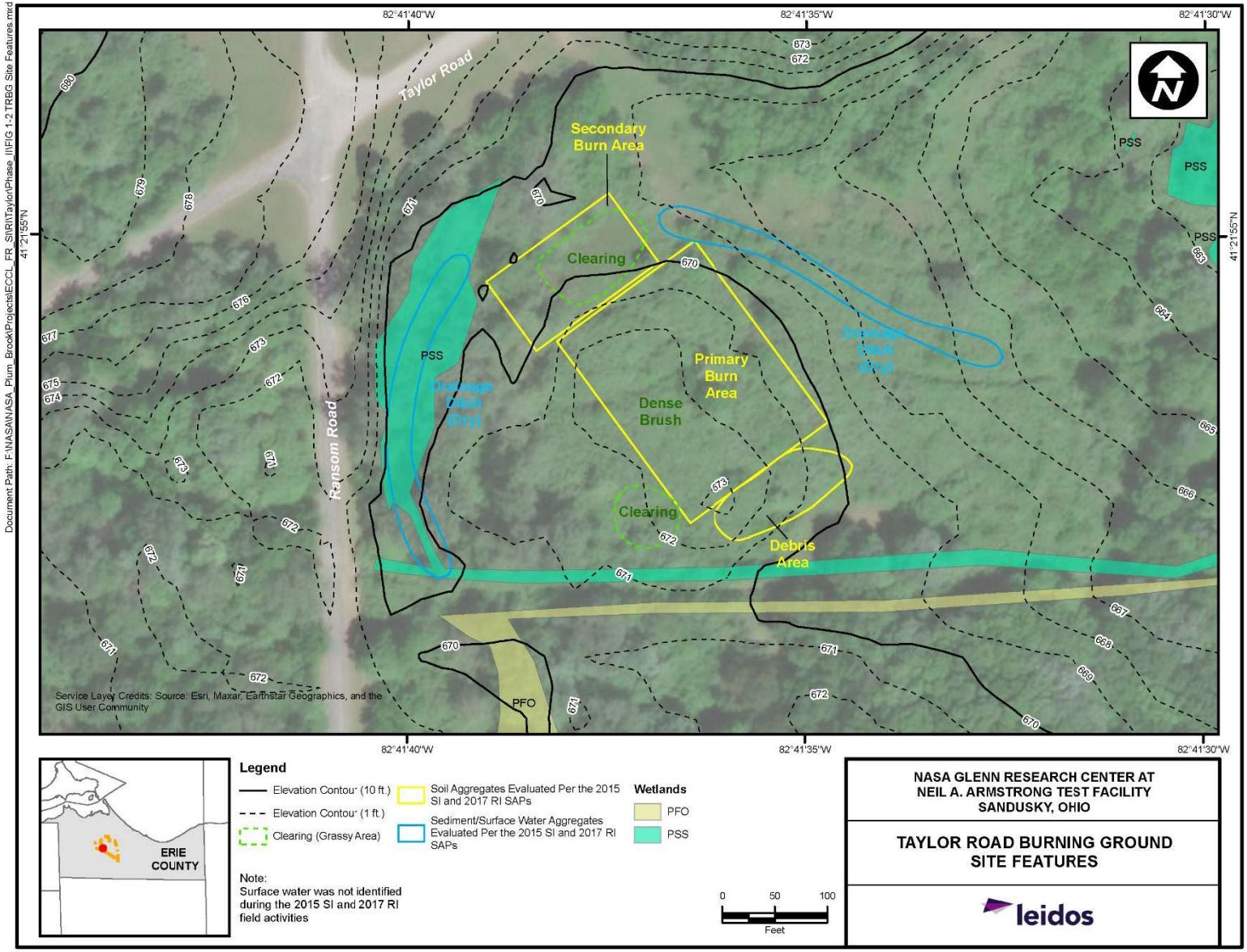


Figure 1–2. Taylor Road Burning Ground Site Features

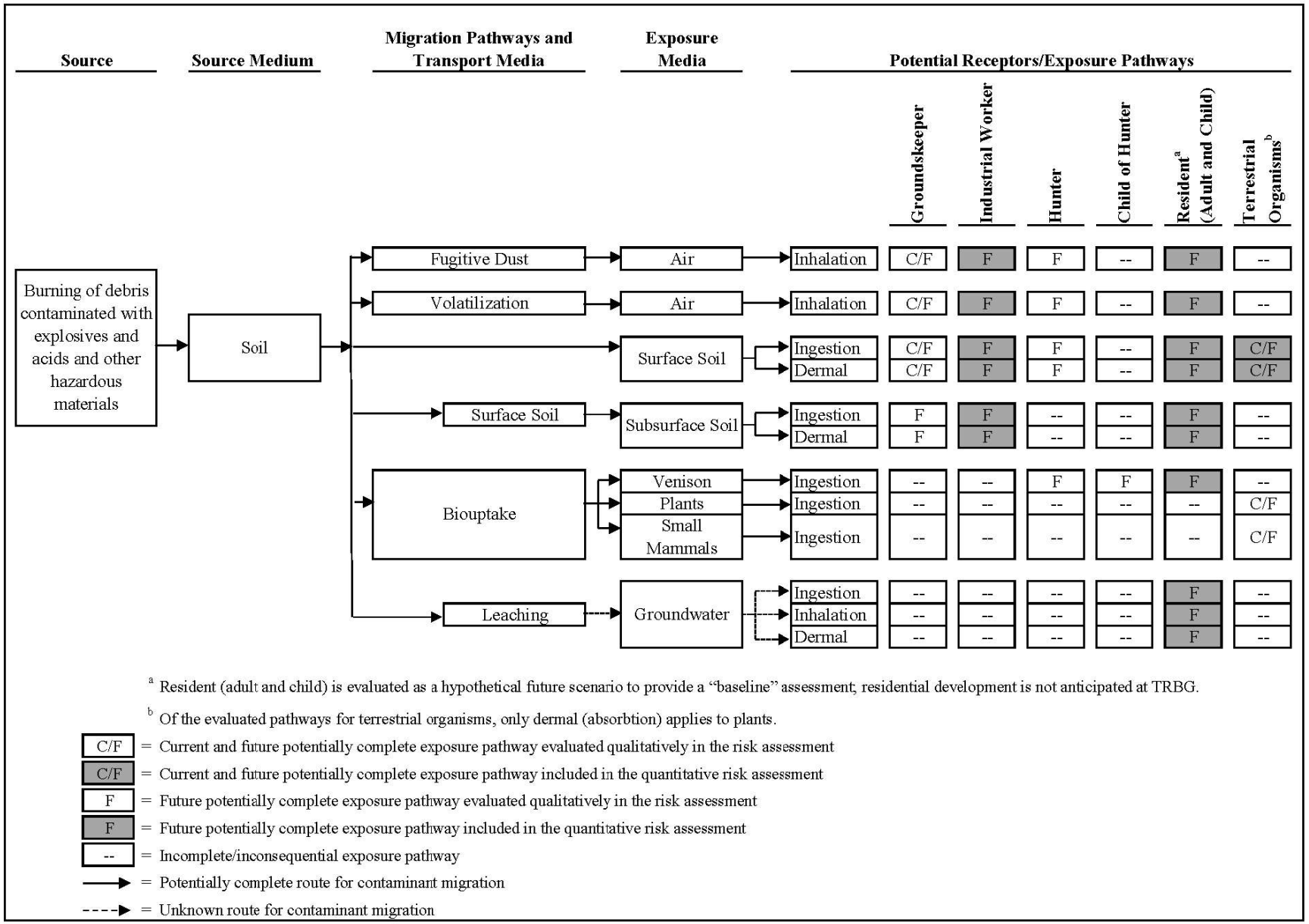


Figure 1–3. Taylor Road Burning Ground Pathway Network Receptor Diagram

2. STUDY AREA INVESTIGATION

2.1 PREVIOUS ASSESSMENTS AND EVALUATIONS

This section summarizes previous assessments and evaluations conducted at TRBG. These activities were generally performed as an initial evaluation and/or prioritization assessment of the site. The data collected as part of these prioritization assessments and evaluations are not used in the nature and extent, fate and transport, HHRA, or ERA due to their age, specific data quality objectives (DQOs), or lack of data quality documentation.

2.1.1 1991 Plum Brook Station Preliminary Assessment

The PBS Preliminary Assessment (PA) (SAIC 1991) was performed to determine if any releases of hazardous substances from the facility had occurred that posed a potential threat to human health and the environment. To perform the assessment, documentation from NASA and various local, state, and Federal Government agencies was compiled and reviewed to obtain all available information pertaining to hazardous substance management at the facility, local and regional environmental conditions, demographics, and indications of hazardous substance contamination in and around the facility. Long-time facility employees were also interviewed regarding their personal recollections of hazardous substance management practices and historical releases.

The PBS PA indicated that NASA established three distinct disposal areas for solid waste generated at GRC-ATF in the 1960s: Disposal Area 1, Disposal Area 2, and Disposal Area 3. Although these areas were primarily used to dispose of or store solid waste or unwanted materials, evidence indicates that they may have been used for to dispose of hazardous waste.

Figure 2-1 shows the locations of these disposal areas, as presented in the PBS PA. Disposal Area 1 contained two sub-areas: Disposal Area 1A and Disposal Area 1B. Disposal Area 1B is at the location of Fox Road Burning Ground (FRBG) and it was reported that hazardous waste possibly was disposed of in this area. Disposal Area 2 was located on the western side of GRC-ATF. Disposal Area 3 is associated with Snake Road Burning Ground (SRBG). Although TRBG was included in Operable Unit (OU) 4, as described below, it was not identified as a disposal area in the PBS PA.

2.1.1.1 Operable Unit 4: Burning Grounds

The PBS PA (SAIC 1991) identified potential sources of environmental contamination and grouped them in preliminary OUs. These sources and units were identified through document reviews, site surveillance, and interviews with GRC-ATF employees. To determine potential sources of environmental contamination, all current management and handling practices for hazardous substances (waste and product) were evaluated, including receipt, storage, use, and disposal of all CERCLA-listed substances. Practices were evaluated to determine whether they resulted in planned or unplanned releases of hazardous constituents to the environment.

The historical management of products and wastes at GRC-ATF was also evaluated in the PBS PA. Through these evaluations, 14 OUs were identified. Several of these OUs consist of multiple potential sources of environmental contamination, which have been grouped to streamline further CERCLA investigations and remedial actions.

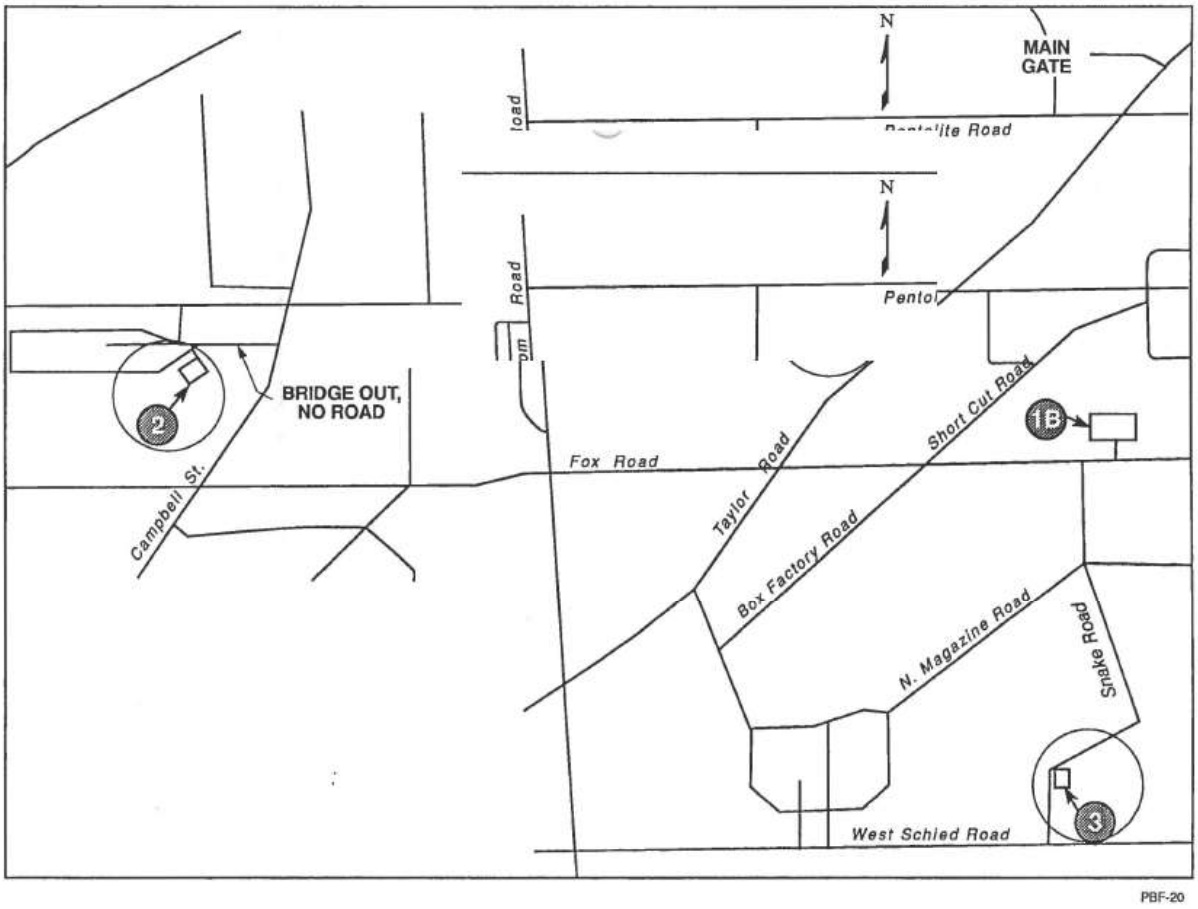


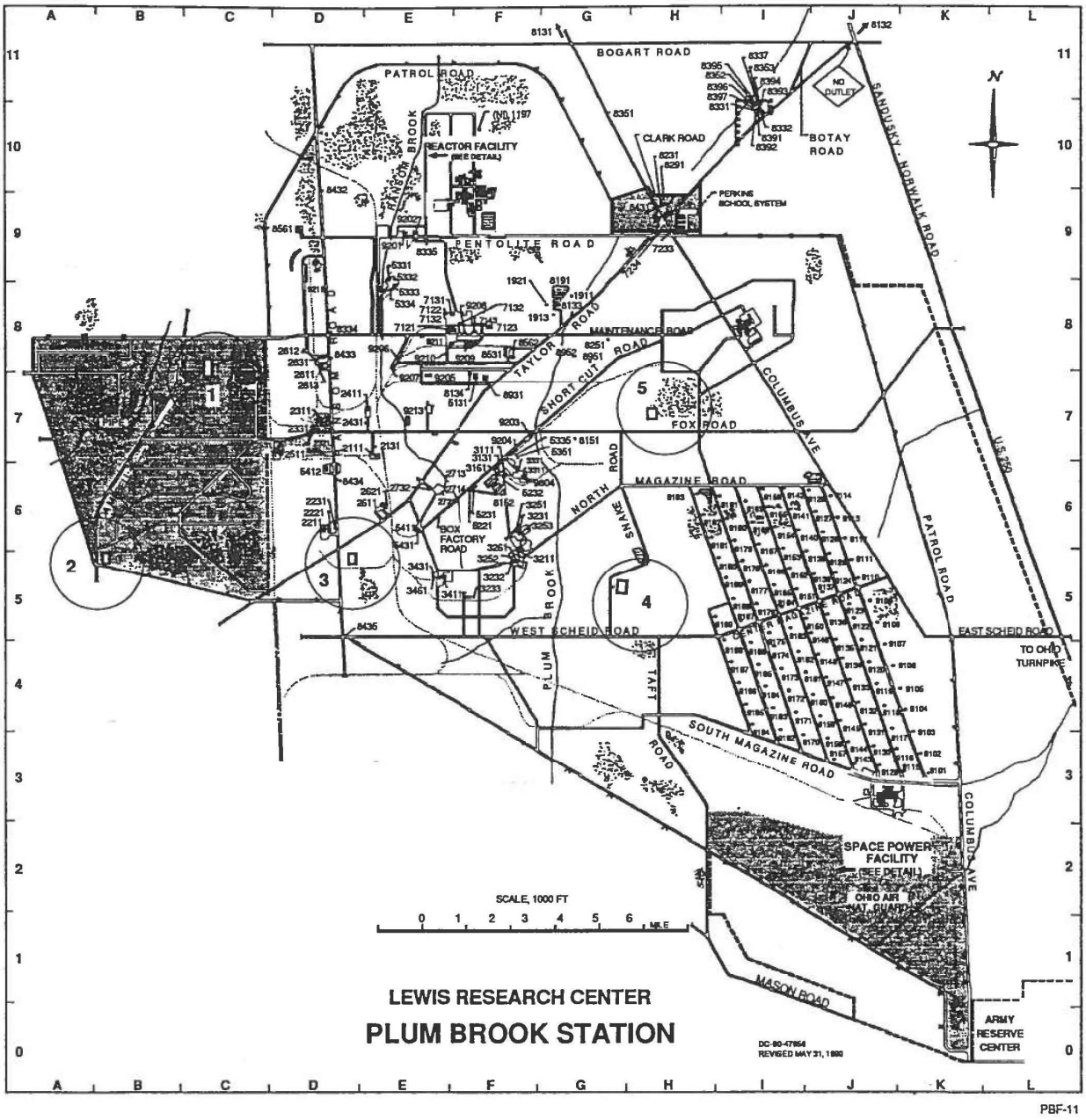
Figure 2–1. Distinct Disposal Areas for Solid Waste (SAIC 1991, Figure 4-1)

OU4 included the following burning grounds (summarized in Figure 2-2), and contaminants included explosives, acids, asbestos, waste oil, and solvents:

- West of Reservoir #2, dimensions unknown;
- East of G-8, dimensions unknown;
- Taylor Road, approximately 100 by 140 feet;
- Snake Road, approximately 100 by 200 feet; and
- Fox Road, no dimensions provided.

The Army used burning grounds during the D&D of PBOW. Five burning grounds formerly used by the Army were identified, although the PBS PA suspected that additional burning grounds may have been used. These grounds were used for destroying explosives-contaminated wastewater flumes, intermediate settling tanks, and catch basins from the TNT areas. Contaminated putty, packing, and asbestos insulation removed from buildings at the TNT areas also were burned. All contaminated building material from the pentolite production area was also destroyed at the burning grounds. Excavated contaminated soil from the TNT areas and from removal of underground flumes was treated at the burning grounds.

NASA also used burning grounds TRBG, FRBG, and SRBG. TRBG was used for destroying combustible wastes that were not contaminated with acids or explosives. FRBG was used in approximately 1962 for combustible and non-combustible waste contaminated or potentially contaminated with acids and explosives. SRBG was used for combustible, non-contaminated solid waste and for waste oil and flammable solvents.



Burning Ground	Name	Use	Comment
1	West of Reservoir #2	DOD	Location approximated, dimensions unknown
2	East of G-8	DOD	Location approximated, dimensions unknown
3	Taylor Road	DOD/NASA	Approximately 100 x 140 feet
4	Snake Road	DOD/NASA	Approximately 100 x 200 feet
5	Fox Road	NASA	

Figure 2–2. Locations of GRC-ATF Burning Grounds (SAIC 1991, Figure 4-2)

2.1.1.2 Hazardous Substance Management

Hazardous substances that the Army destroyed at the burning grounds included materials contaminated with DNT, TNT, pentolite, acids, solvents, waste oil, and asbestos (USACE 1999). The quantity of Army waste destroyed at the burning grounds is unknown. Hazardous materials that NASA disposed of at the burning grounds may have included waste oils, solvents, and other chemicals.

In areas where explosives were encountered, controlled burning was conducted. After destruction by fire, the ground was plowed to a depth of 6 inches and tested again for explosive material. If explosives were detected, the process was repeated.

Soil samples were collected in October 1989 from TRBG and SRBG to approximate depths of 4 feet. These sampling activities were conducted to support the IT Corporation Contamination Evaluation. These samples were used in the PBS PA (SAIC 1991) to evaluate potential environmental impacts associated with the entire OU4. Samples were not collected or assessed from the other three locations included in OU4, including FRBG.

Two samples (SB-01 and SB-02) were collected from TRBG, and four samples (SB-03 to SB-06) were collected from SRBG. Figure 2-3 shows the TRBG sample locations, and Tables 2-1 presents the partial summary of soil sample results as summarized in the PBS PA.

Nitroexplosives were not detected at TRBG. Methylene chloride was the only VOC detected at a low concentration, and bis(2-ethylhexyl)phthalate was the only semivolatile organic compound (SVOC) detected at a concentration of 400 parts per billion (ppb) at SB-01.

Metals were detected at low concentrations at both sampled locations. Installation of groundwater monitoring wells had been planned for these two burning ground areas. Based on soil sampling results that suggested minimal subsurface contamination, groundwater monitoring wells were not installed.

Table 2–1. TRBG: Partial Summary of 1989 Soil Sample Results (SAIC 1991, Table 5-5)

Sample No./Media	Volatile Organic Compound	Semivolatile Organic Compounds	Nitroexplosives	Metals
SB-01/Soil	Methylene Chloride, 10 ppb	Bis(2-ethylhexyl)phthalate, 400 ppb	None detected	Arsenic, 7 ppm Barium, 51 ppm Chromium, 7 ppm Iron, 10,200 ppm Lead, 10 ppm Manganese, 300 ppm Sodium, 65 ppm
SB-02/Soil	None detected	None detected	None detected	Arsenic, 2.8 ppm Barium, 51.3 ppm Chromium, 11 ppm Iron, 15,400 ppm Lead, 10 ppm Manganese, 180 ppm Sodium, 110 ppm

ppb = Parts per Billion
ppm = Parts per Million
TRBG = Taylor Road Burning Ground

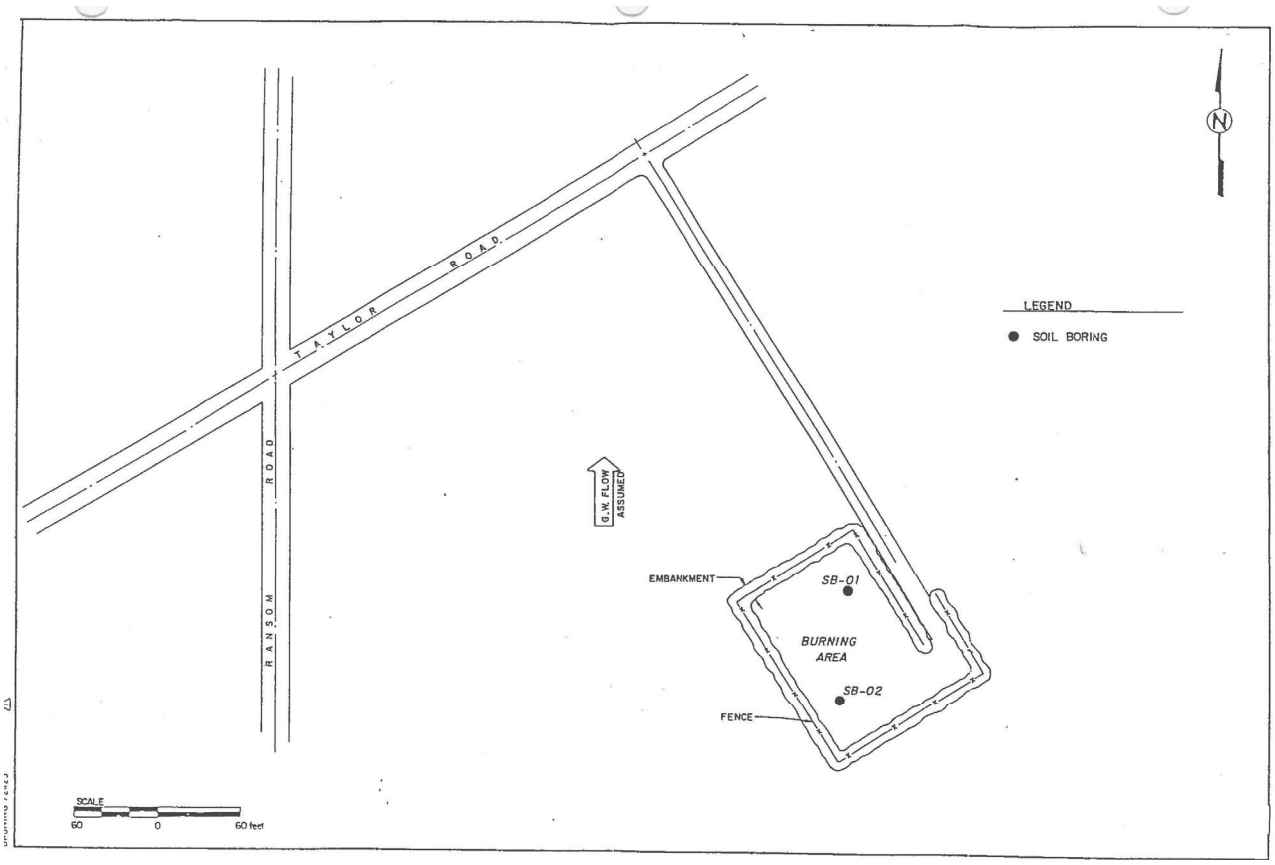


Figure 2–3. 1989 Sample Locations at TRBG (SAIC 1991, Figure 5-9)

2.1.2 Conclusions and Recommendations

OU4 Burning Grounds was one of the four OUs documented where hazardous substances were released to the environment. The environmentally impacted medium at OU4 was soil with solvents and unknown chemicals being the suspected contaminants. The extent and depth of potential contamination at the burning grounds are unknown. Samples at TRBG and SRBG were collected to evaluate potential environmental impacts associated with the entire OU4. The limited soil sampling conducted at TRBG and SRBG indicates that minimal soil contamination had occurred; therefore, groundwater contamination is unlikely. However, groundwater monitoring data were not available at the time the PBS PA was prepared. Consequently, the impacted media may include groundwater.

To quantify the potential hazard resulting from identified sources at GRC-ATF, each OU was assigned a score using USEPA's Hazard Ranking System (HRS). A draft HRS version provided by USEPA Region 5 was applied to all PBS PA OUs identified. This version was an abbreviated form of the HRS that USEPA developed as a simplified initial screening tool.

The HRS score is the primary criterion USEPA uses to determine whether a site should be placed on the National Priorities List (NPL). The NPL identifies sites that warrant further investigation to determine if they pose risks to public health or the environment. Sites on the NPL are eligible for long-term "remedial action" financed under CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA).

The HRS score was based on the evaluation of the following migration pathways: groundwater, surface water, and air. The two other pathways (direct contact and fire/explosion) were evaluated to determine the

need for immediate removal (emergency) action. HRS scores ranged from 0 to 100. Sites that scored 28.5 and above on the original HRS were eligible for the NPL.

Application of the abbreviated HRS model produced the following scores for the OU4 Burning Grounds (cumulative of all five sites of OU4):

- Groundwater pathway – 4.36;
- Surface water pathway – 2.16;
- Soil pathway – 3.8;
- Air pathway – 5.45; and
- Site score – 4.12.

The low HRS scores suggest that environmental impacts from the burning grounds are not significant. Accordingly, the PBS PA recommended giving a low priority for further investigation.

2.1.3 1994 Site Investigation

Under the direction of NASA and in accordance with CERCLA, Morrison Knudsen Corporation performed an SI at GRC-ATF. The purpose of the SI was to collect information concerning conditions at the facility sufficient to assess the threat posed to human health and the environment and to determine the need for any additional investigation. This investigation included reviewing previous information, sampling waste and environmental media to test PBS PA hypotheses, evaluating and documenting HRS factors, and collecting additional non-sampling information.

The 1994 SI Report used the OUs from the 1991 PBS PA and their corresponding locations and plotted them on a large-scale map to determine possible project management units (PMUs). Identification of the PMUs allows characterization and remediation, if necessary, of the potential sources of environmental contamination to proceed in an organized manner. The development of the PMUs and assignment of sources was based upon four criteria:

1. Geographic layout of the GRC-ATF site and proximity of sources;
2. Similarities in suspected types of contamination and affected environmental media;
3. Existing level of knowledge regarding the nature of contamination and anticipated priority for further response action; and
4. Similarity in age, type, and usage of OUs.

The 1994 SI Report established five PMUs based upon surface drainage patterns. The PBS PA (SAIC 1991) had identified the surface water pathway as being the principal means of contaminant transport from the sources on GRC-ATF to the receptors downstream. The boundaries between these PMUs were established by an inspection of the overland flow and the creek or ditch that would receive that flow. The five PMUs identified are as follows:

- PMU 1 – Pipe Creek;
- PMU 2 – Ransom Ditch/Brook;
- PMU 3 – Plum Brook;
- PMU 4 – Lindsley Ditch; and
- PMU 5 – Kuebelar, Scheid, and Schlessman Ditches.

TRBG (identified as "Taylor and Ransom Road Burning Ground" in the 1994 SI Report) was in PMU 2 – Ransom Brook. As shown in Figure 2-4, PMU 2 is situated along the Ransom Brook drainage area. Ransom Road borders PMU 2 on the west and Patrol Road borders it on the north and south. The eastern edge of the area follows the border of the GRC-ATF drainage area.

PMU 2 covers approximately 1,200 acres. Most of the area is covered with tall grasses. The northern and southern portions are heavily wooded. Ransom Brook originates in PMU 2 near TNT Area "B" and runs south to north, bisecting the PMU.

The 1994 SI Report identified soil contamination at TRBG, referencing the surface soil sampled in 1989 by the IT Corporation. No additional samples were collected at TRBG in support of the 1994 SI Report.

The 1994 SI Report used the Preliminary Ranking Evaluation Score Version 2.0 computer program to assist in HRS site scoring of GRC-ATF. The following is the HRS results for PMU 2:

- Groundwater migration = 0.65;
- Surface water migration = 0.18;
- Soil exposure = 12.88;
- Air migration = 1.44; and
- Site score = 6.49.

Based upon the evaluation of the facility and historical records, the 1994 SI Report recommends that no further action (NFA) under CERCLA is necessary. Areas that indicated levels of contamination above background should be scheduled and remediated under different Federal and state authorities.

2.1.4 1995 Records Review Report

The *Records Review Report for the Plum Brook Ordnance Works* (DM 1995) summarized information regarding seven OUs identified in the PBS PA (SAIC 1991). These OUs are called areas of concern (AOCs) in the 1995 Records Review Report (DM 1995).

AOC 4: Burning Grounds was included as one of the seven AOCs summarized in the 1995 Records Review Report. This report included historical site documents and photographs, historical aerial photographs, environmental investigation reports, and TNT manufacturing process information. The TNT manufacturing process information is not pertinent to AOC 4: Burning Grounds.

The 1995 Records Review Report (DM 1995) also summarizes the site history, potential sources, and environmental investigations discussed in previous sections of this Phase II RI Report.

2.2 Phase I Remedial Investigation

During the 2015 SI and 2017 RI described in the following subsections, data of sufficient provenance and quality were collected to be used to support the evaluations in the Phase I RI Report (Leidos 2018b), including soil nature and extent, fate and transport, HHRA, and ERA. The field activities for these events are described below.

Figure 2-5 presents all locations for samples collected during these investigations and is divided into subsites (Primary Burn Area, Secondary Burn Area, and Subsurface) depicted in the *Final Multi-site Investigation Report* (Leidos 2016b; herein referred to as the 2016 SI Report) and *Multi-site Remedial Investigation Sampling and Analysis Plan* (Leidos 2016a). A re-evaluation of the exposure units (EUs) was performed and presented in the Phase I RI Report (Leidos 2018b).

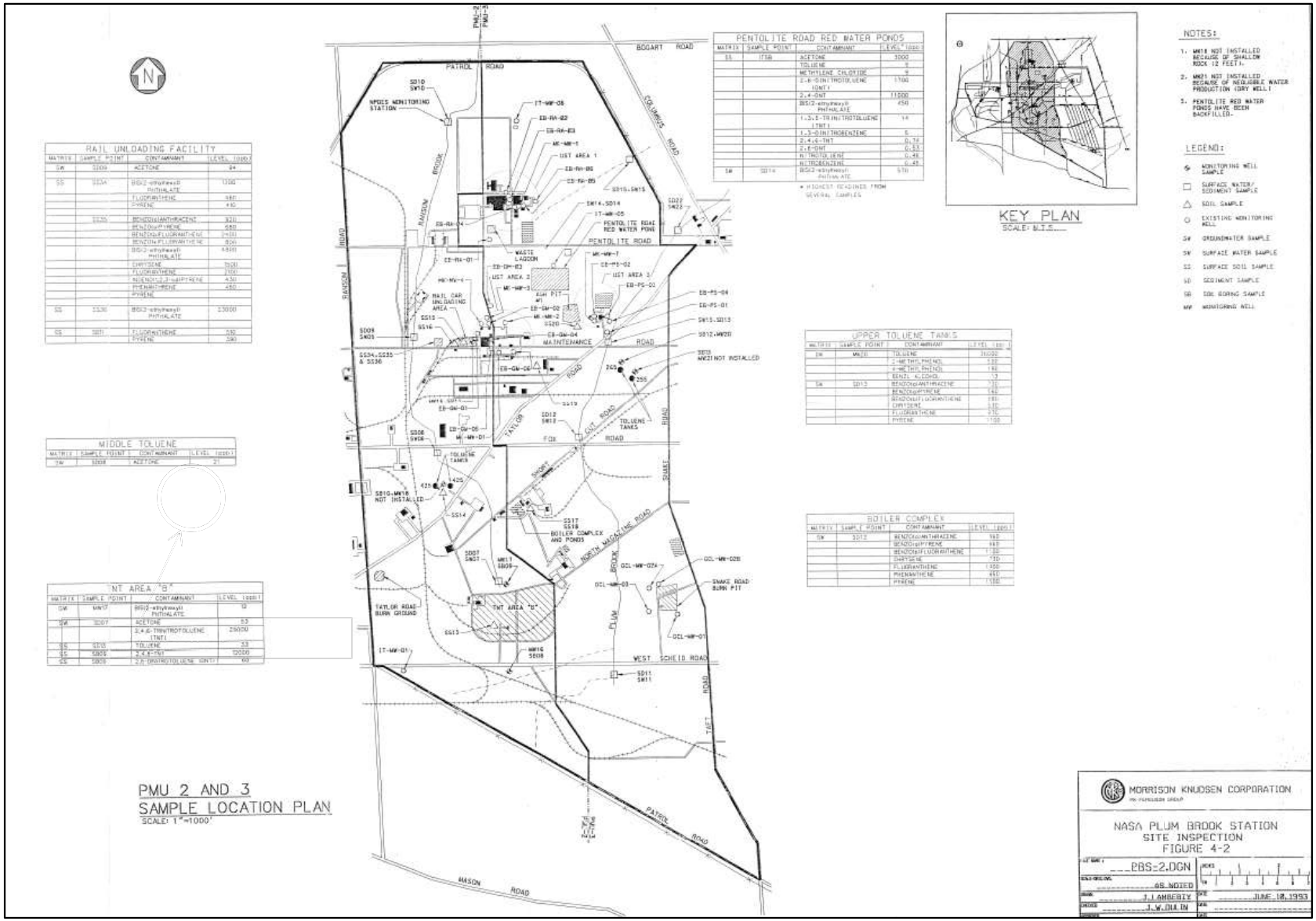


Figure 2–4. PMUs 2 and 3 (MK 1994, Figure 4-2)

The Phase I RI Report (Leidos 2018b) provides site photographs (Appendix D), boring logs and field forms (Appendix E), and analytical data (Appendix F) for both investigations to supplement the findings and conclusions.

2.2.1 2015 Site Investigation

The GRC-ATF Multi-site SI, which included TRBG, was conducted in August 2015, as summarized in the 2016 SI Report (Leidos 2016b). SI field activities were conducted between August 3 and August 21, 2015, in accordance with the *Multi-site Site Characterization Sampling and Analysis Plan* (SAIC 2011). The primary objectives of the SI were to determine the presence or absence of contamination in surface soil, subsurface soil, sediment, and surface water at each site and to either:

- Obtain an NFA decision with regulatory concurrence for qualifying sites;
- Identify the DQOs for conducting follow-on RIs at sites that do not meet the criteria for NFA; or
- Identify qualifying sites for interim removal actions and engineering evaluation/cost analysis.

Groundwater was not included as part of this SI.

2.2.1.1 Field Activities

SI activities at TRBG included 11 soil borings, 11 surface soil samples, 18 subsurface soil samples, and 8 sediment samples. Soil samples were analyzed for VOCs, SVOCs, herbicides, pesticides, polychlorinated biphenyls (PCBs), explosives, target analyte list (TAL) metals, and asbestos (only 0- to 2-foot below ground surface [bgs] interval).

Eight sediment samples were collected from two drainage ditches on either side of the Primary Burn Area. No surface water was observed in the drainage ditch; however, water was encountered below grade. The sediment samples are included in the soil media in the evaluations. These sediments were analyzed for VOCs, SVOCs, herbicides, pesticides, PCBs, explosives, TAL metals, and asbestos. Table 2-2 lists the samples collected and the analyses conducted for each sample in 2015.

Multiple compounds were detected in each medium sampled. In addition, each medium sampled contained one or more compounds at concentrations greater than relevant screening criteria. Sample results indicate TRBG has been impacted by historical site use. A site walk was conducted to detect painted debris, but no painted debris was identified.

A site assessment was also performed by an Asbestos Hazard Evaluation Specialist. This assessment included collecting 19 soil samples to analyze asbestos content and identifying 1 piece of asbestos-containing material (ACM). Two of the 19 soil samples contained chrysotile and/or amosite asbestos at concentrations greater than 1 percent. The ACM was considered friable and contained 20 percent chrysotile.

2.2.1.2 Environmental Hazard Assessment

An ecological risk screening and HHRA were conducted to determine the presence of chemicals of potential ecological concern (COPECs) or chemicals of potential concern (COPCs).

The results of the surface soil and sediment sample screening were used to conduct ecological risk screening. The ecological risk screening identified 20 COPECs in surface soil, including 1 or more metal, SVOC, PCB, pesticide, and explosive. No COPECs were identified in sediment.

Table 2–2. Samples Collected During the 2015 Site Investigation

Sample Location	Sample ID	Depth (ft)	Analysis Suite
TRBG-SL-009	TRBGSL0025	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-009	TRBGSL0026	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-009	TRBGSL0027	6–9	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-010	TRBGSL0028	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-010	TRBGSL0029	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-010	TRBGSL0030	6–10	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-011	TRBGSL0031	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-011	TRBGSL0032	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-011	TRBGSL0033	6–6.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SDSW-001	TRBGSD0001	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SDSW-002	TRBGSD0002	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SDSW-003	TRBGSD0003	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SDSW-004	TRBGSD0004	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SDSW-005	TRBGSD0005	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SDSW-006	TRBGSD0006	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SDSW-007	TRBGSD0007	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SDSW-008	TRBGSD0008	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-001	TRBGSL0001	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-001	TRBGSL0002	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-001	TRBGSL0003	6–6.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-002	TRBGSL0004	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-002	TRBGSL0005	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-002	TRBGSL0006	6–6.5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-003	TRBGSL0007	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-003	TRBGSL0008	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-004	TRBGSL0010	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-004	TRBGSL0011	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-004	TRBGSL0012	6–7	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-005	TRBGSL0013	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-005	TRBGSL0014	2–6	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-005	TRBGSL0015	6–9	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-006	TRBGSL0016	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-006	TRBGSL0017	2–4	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs
TRBG-SL-007	TRBGSL0019	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-007	TRBGSL0020	2–5	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs

Table 2-2. Samples Collected During the 2015 Site Investigation (Continued)

Sample Location	Sample ID	Depth (ft)	Analysis Suite
TRBG-SL-008	TRBGSL0022	0–2	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs, Asbestos
TRBG-SL-008	TRBGSL0023	2–4	TAL Metals, Explosives, Herbicides, PCBs, Pesticides, SVOCs, VOCs

ID = Identification
PCB = Polychlorinated Biphenyl
SI = Site Investigation
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List
VOC = Volatile Organic Compound

Potential COPCs were identified by comparing measured medium-specific concentrations to risk-based screening levels available at the time of the SI. The HHRA identified lead and PCBs as COPCs for surface soil. Benzo(a)pyrene, PCB-1254, and PCB-1260 were identified as COPCs in subsurface soil in the Primary Burn Area. SVOCs and PCBs were identified as COPCs in sediment in the western ditch.

2.2.1.3 Recommendations

Results of the SI activities indicated that the surface soil, subsurface soil, and sediment should be evaluated in an RI. Surface water was not identified at the site and was not considered a medium of concern. Further evaluation in an RI was recommended for surface soil and sediment to fully evaluate the potential risk of the identified COPECs to ecological receptors and potential risk to human health related to the COPCs identified in surface soil, subsurface soil, and sediment.

Asbestos sampling at TRBG indicated 3 of 20 samples contained chrysotile and/or amosite asbestos at concentrations greater than 1 percent. ACM included cementitious material and soil. Based on the asbestos sampling results, the SI recommended addressing the presence of ACM to mitigate potential risks to human health and ecological receptors and recommended an interim removal action for the debris observed during the SI.

2.2.2 2017 Phase I Remedial Investigation

To supplement the 2015 SI, a Phase I RI was performed in accordance with the *Multi-site Remedial Investigation Sampling and Analysis Plan* (Leidos 2016a). The primary objectives of the Phase I RI were to:

- Discuss historical activities, identify potential sources of contamination, and develop a CSM;
- Summarize previous assessments and investigations conducted at the site;
- Characterize the nature and extent of contamination in soil, sediment, and surface water;
- Evaluate the impact of soil, sediment, and surface water contamination on human health and the environment; and
- Identify any unacceptable risk to be further addressed in an FS.

2.2.2.1 Soil Sampling

Six surface soil samples and four subsurface soil samples were collected from six locations (TR-1 to TR-6), as presented in Figure 2-5. Table 2-3 lists the soil samples collected and the analyses conducted for each sample.

Table 2–3. Soil Samples Collected During the 2017 Remedial Investigation

Sample Location	Sample ID	Depth (ft)	Analysis Suite
TR-1	TRBGSL0034	0–2	TAL Metals, Pesticides, SVOCs
TR-1	TRBGSL0035	2–5	TAL Metals, Pesticides, SVOCs
TR-2	TRBGSL0036	0–2	TAL Metals, Pesticides, SVOCs
TR-3	TRBGSL0037	0–2	TAL Metals, Pesticides, SVOCs
TR-3	TRBGSL0038	2–5	TAL Metals, Pesticides, SVOCs
TR-4	TRBGSL0039	0–2	TAL Metals, Pesticides, SVOCs
TR-4	TRBGSL0045	2–5	TAL Metals, Pesticides, SVOCs
TR-5	TRBGSL0041	0–2	TAL Metals, PCBs, Pesticides, SVOCs
TR-5	TRBGSL0043	2–5	TAL Metals, Pesticides, SVOCs
TR-6	TRBGSL0042	0–2	TAL Metals, PCBs, Pesticides, SVOCs

ft = Feet
ID = Identification
PCB = Polychlorinated Biphenyl
RI = Remedial Investigation
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List

2.2.2.2 Sediment and Surface Water Sampling

No surface water was identified in the drainage ditches; therefore, no surface water samples were collected at the site. Five sediment samples (TR-7 to TR-11) were collected and analyzed for the same sample suite as the soil samples. Table 2-4 lists the sediment samples collected and the analyses conducted for each sample.

Table 2–4. Sediment Samples Collected During the 2017 Remedial Investigation

Sample Location	Sample ID	Depth (ft)	Analyses Suite
TR-7	TRBGSD0009	0–0.5	TAL Metals, PCBs, Pesticides, SVOCs
TR-8	TRBDSD0010	0–0.5	TAL Metals, PCBs, Pesticides, SVOCs
TR-9	TRBGSD0011	0–0.5	TAL Metals, SVOCs
TR-10	TRBGSD0012	0–0.5	TAL Metals
TR-11	TRBGSD0013	0–0.5	TAL Metals

ft = Feet
ID = Identification
PCB = Polychlorinated Biphenyl
RI = Remedial Investigation
SVOC = Semi-volatile Organic Compound
TAL= Target Analyte List

2.2.2.3 Temporary Wells

To assist future evaluation of groundwater at this site, two temporary wells were attempted during field activities. Temporary well TR-MW-1 was installed to 7 feet bgs, where it encountered refusal. The temporary well was completely dry, and no sample was collected. Temporary well TR-MW-2 was installed to 7.5 feet bgs, where it encountered refusal. Minimal water was produced from this temporary well, and no sample was able to be collected.

2.2.2.4 Environmental Hazard Assessment

An ERA and HHRA were conducted to determine the presence of COPECs or COPCs (Leidos 2018b). TRBG is approximately 5.2 acres and is vegetated with shrubland surrounded by forested area, with a wetland present on the western boundary of the site. Wetlands are considered important ecological resources, and there is documentation of contamination at TRBG, so further analysis was conducted in a Level II ERA.

Soil data were collected, but no sediment or surface water was found at the site. Surface soil data were screened against ecological screening values (ESVs) recommended in Ohio EPA guidance, and preliminary COPECs were identified for each EU. Preliminary COPECs were further analyzed to determine if ecological risk was probable with the information available, and exposure pathway analysis was completed on the wetland. Frequency of detection, average concentration, sample location, migration to wetlands, and impact of recommended human health remediation were considered as applicable for each EU. Using this combination of factors, it was determined that there are no final COPECs at TRBG. Consequently, the ERA for TRBG concluded with a Level II Screening ERA, and NFA was recommended to be protective of important ecological resources.

The HHRA documented the potential health risks to humans resulting from exposure to soil contamination within TRBG. Under the residential scenario at the Primary Burn Area, the two PCBs (1254 and 1260) are identified as COCs for surface soil, and PCB-1254 is identified as a COC for subsurface soil. No COPCs were identified in surface or subsurface soil at the Secondary Burn Area. No COCs were identified for surface soil at the Debris Area. PCB-1254 was identified as a COC for surface soil in the Drainage Area.

2.2.2.5 Recommendations

The Phase I RI recommended an assessment in an FS for the COCs identified. The HHRA identified the following EUs, sample locations, and COCs:

- Primary Burn Area at sample locations TR-6, TRBG-SL-002, and TRBG-SL-001 to address PCBs (1254 and 1260) in surface soil and PCB-1254 in subsurface soil; and
- Drainage Area at sample location TRBG-SDSW-004 to address PCB-1254 in surface soil.

Remediation of these locations will also address the three surface soil sample locations (TRBG-SL-001, TRBG-SL-002, and TRBG-SDSW-004) that had detectable asbestos, as well as the area that contained the one piece of ACM (white cementitious material at TRBG-SL-001). Sample location TRBG-SDSW-004 had less than 1 percent asbestos. Sample location TRBG-SL-001 had 3.5 percent chrysotile in the soil. This location also had co-located ACM identified as white, cementitious material that contained 20 percent chrysotile which, given the size, was presumed to be removed during sampling activities. Sample location TRBG-SL-002 had 1.75 percent chrysotile in the soil. It was recommended that the removal and disposal of the metal fragments, debris, and piping identified in the Debris Area be included in site remedial activities.

2.3 2021 Phase II Remedial Investigation

To supplement the 2017 Phase I RI, which recommended a Phase II RI be performed to assess groundwater, a Phase II RI was performed at TRBG in accordance with the *Final Burning Grounds Phase II Remedial Investigation/Sampling and Analysis Plan* (Leidos 2020b). The Phase II RI activities were performed from April 26 through December 2, 2021, to complete a data set that fully characterizes the nature and extent of contamination, assesses potential impacts soil may have on groundwater, and provides data to update and complete the HHRA and ERA. The field activities, findings, and results of the Phase II RI activities are summarized throughout this Phase II RI Report.

2.3.1 Soil Sampling

No additional soil sampling was warranted for the Phase II RI, as the Phase I RI concluded that soils have been adequately characterized.

2.3.2 Sediment and Surface Water Sampling

No additional sediment or surface water samples were planned. Consistent with historical observations, surface water was not present in the drainage ditch during the 2021 Phase II RI.

2.3.2.1 Groundwater Sampling

The 2018 Phase I RI Report (Leidos 2018b) conservative transport modeling indicated that 10 chemicals had potential to leach from soil and migrate to the groundwater table beneath their respective sources at concentrations exceeding MCLs/regional screening levels (RSLs). Therefore, it was recommended that groundwater samples be collected and assessed at TRBG. The Phase II RI activities included the following:

- Installing five new monitoring wells at TRBG;
- Sampling the newly installed monitoring wells during two seasonal events; and
- Analyzing groundwater samples for TAL metals, explosives, VOCs, SVOCs, and PCBs, at a minimum.

Table 2–5. Groundwater Samples Collected During the 2021 Phase II Remedial Investigation

Sample Location	Sample IDs	Analysis Suite
TRBG-MW01	TRBGGW1001 TRBGGW1006	TAL Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
TRBG-MW02	TRBGGW1002 TRBGGW1007A/TRBGGW1007B	TAL Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
TRBG-MW03	TRBGGW1003 TRBGGW1008	TAL Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
TRBG-MW04	Not Sampled (dry)	Not applicable
TRBG-MW05	TRBGGW1005 TRBGGW1010A/TRBGGW1010B	TAL Metals (filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs

ft = Feet
ID = Identification
PCB = Polychlorinated Biphenyl
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound
TAL = Target Analyte List

2.4 2022 PFAS SITE INSPECTION

Based on recommendations from the *Final PFAS (Per- and Polyfluoroalkyl Substances) Preliminary Assessment for the National Aeronautics and Space Administration (NASA) Glenn Research Center at Plum Brook Station* (Leidos 2019), soil, groundwater, sediment, and/or surface water samples were collected from eight areas of potential concern (AOPCs) at GRC-ATF during the 2021 per- and polyfluoroalkyl substances (PFAS) SI field activities. TRBG was one of the eight AOPCs where samples were collected during the SI. Sample locations and complete analytical results are provided in the PFAS SI Report (Leidos 2022). NASA is assessing potential PFAS contamination at TRBG under a separate investigation; therefore, PFAS are not included in this RI.

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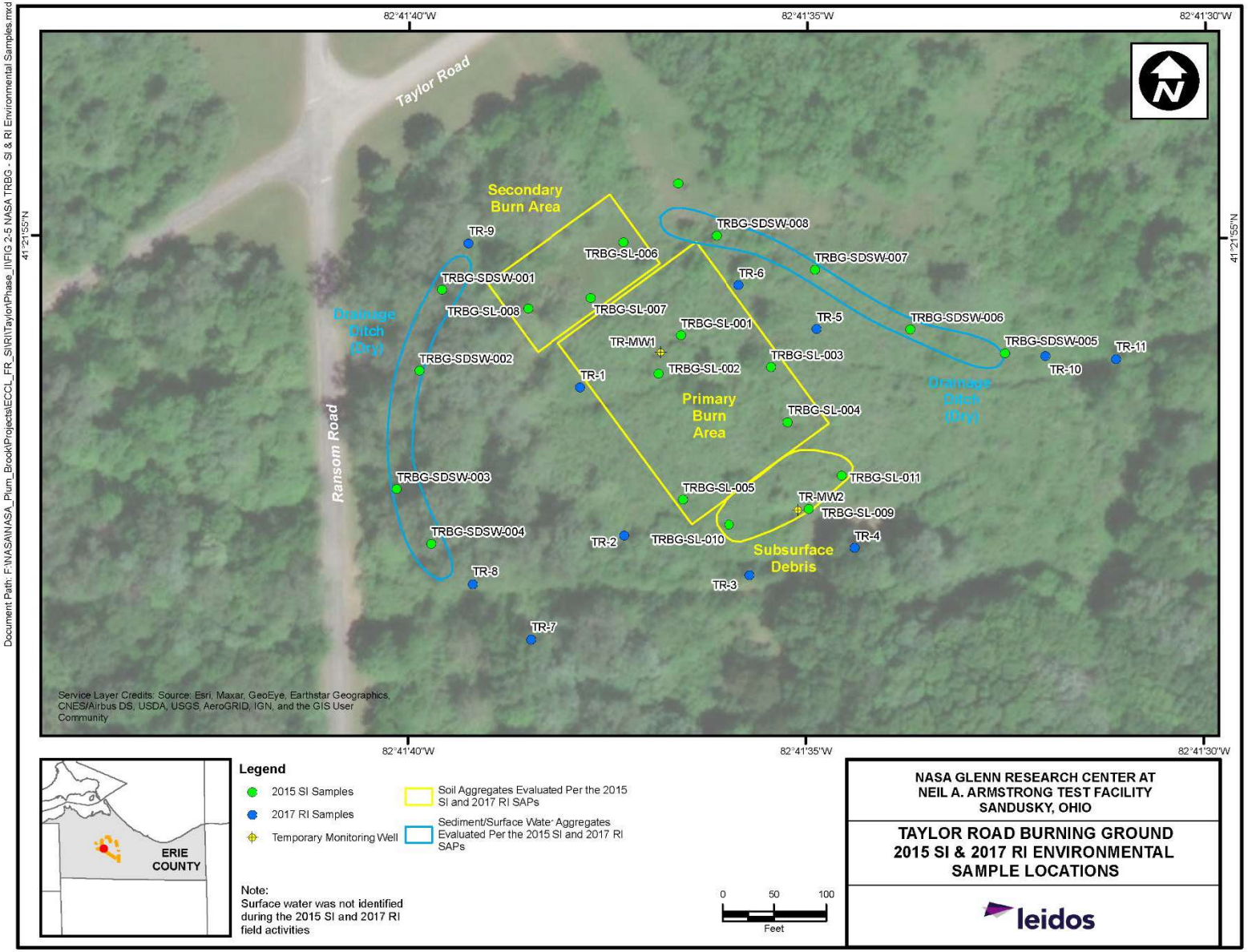

Figure 2–5. TRBG 2015 and 2017 RI Environmental Sample Locations

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3. PHYSICAL CHARACTERISTICS

This section describes the physical features, topography, geology, hydrogeology, and environmental characteristics of TRBG that are factors in identifying the potential contaminant transport pathways, receptor populations, and exposure scenarios to evaluate human health and ecological risks.

3.1 SURFACE FEATURES AND TOPOGRAPHY

3.1.1 Armstrong Test Facility

Erie County is part of the Central Lowland Province and is an area of lake plain and till plain physiography with relatively uniform, level topography. GRC-ATF is situated on land that was once a lake bottom formed from glacial melt waters. GRC-ATF is relatively flat and slopes gently northward. The average slope of the land is less than 6 percent. Topographic relief across GRC-ATF is approximately 50 feet, with higher elevations (±675 feet above mean sea level [AMSL]) present along the south-southwestern facility boundary and lower elevations (±625 feet AMSL) present along the northern facility boundary. The lowest ground surface elevations at GRC-ATF are associated with the two primary surface water drainages features: Plum Brook (north-central portion of facility) and Pipe Creek (northwestern portion of facility).

The general topography of GRC-ATF and the surrounding area is shown in Figure 3-1. This figure shows two adjacent U.S. Geological Survey 7.5-minute series topographic maps: Sandusky Quadrangle (northern portion of facility) and Kimball Quadrangle (southern portion of facility).

3.1.2 Taylor Road Burning Ground

TRBG is in the southwestern portion of GRC-ATF at the southeastern corner of the intersection of Ransom Road and Taylor Road (Figure 1-2). Topographic elevations at the site range from ±667 feet AMSL in the ditch in the northeastern portion of the site to ±673 feet AMSL between the Primary Burn Area and Debris Area.

3.2 METEOROLOGY

At GRC-ATF, the climate is continental in character and influenced by proximity to Lake Erie, which is approximately 4 miles to the north. Summers are moderately warm and humid with temperatures occasionally exceeding 32°C (90°F). Winters are cold and cloudy with temperatures falling below -18°C (0°F) an average of 5 days per year. Annual temperature extremes typically occur after late June for summer climates and in January for winter. First frost typically occurs in October (SAIC 2013a). The predominant wind direction is south-southwest throughout the year. Wind direction was measured via an onsite wind monitoring tower in 2008 (Green Energy Ohio 2009).

Wind data from 2013 to 2020 at the Erie-Ottawa International Airport at Carl R Keller Field in Port Clinton, Ohio (IEM 2020) are presented in Figure 3-1 of the *Final Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020b). The wind direction is predominantly southwest. The Erie-Ottawa International Airport at Carl R Keller Field is approximately 20 miles north of GRC-ATF.

Based on long-term statewide weather records, Ohio receives an average of 38 inches of precipitation per year. Of these, about 10 inches (26 percent) become runoff, which moves immediately to surface water bodies such as streams and lakes. Of the 38 total inches of precipitation annually, 26 inches will enter the soil surface through infiltration. Twenty of these 26 inches go into soil storage and later are returned to the atmosphere by the combination of evaporation and transpiration (Ohio State University 2013). Accordingly, the Ohio Department of Natural Resources (ODNR) estimates average annual water loss for the area, which

includes GRC-ATF, to be between 22 and 23 inches (Harstine 1991). The 2-year, 24-hour rain event was estimated at 2.5 inches for the part of the United States containing Erie County (USDC 1963). Daily high and low temperatures and precipitation data are published in a Cooperative Data Report for this location. More detailed climatological data for GRC-ATF can be obtained from the National Weather Service station Cleveland Hopkins International Airport (less than 50 miles east of GRC-ATF) at http://www.weather.gov/cle/CLENormals.

3.3 SURFACE WATER HYDROLOGY

3.3.1 Armstrong Test Facility

GRC-ATF is in the Lake Erie watershed. Watersheds are categorized according to the Hydrologic Unit Code (HUC) numbering system. The HUC number can range from 2 to 16 digits—the greater the number of digits, the smaller the area of the watershed. Smaller watersheds are nested within larger watersheds. Therefore, GRC-ATF is also located in the Sandusky River Watershed (HUC 04100011). More locally, much of GRC-ATF is drained by the Pipe Creek-Frontal Sandusky Bay Watershed (HUC 041000110102), which includes Plum Brook stream. The waterways in the southeastern portion of GRC-ATF flow toward, and are included in, the Sawmill Creek Watershed (HUC 041000110101). In general, streams at GRC-ATF travel northward toward Lake Erie.

In 2011 to 2012, a wetlands and other waters delineation was conducted at GRC-ATF. A total of 1,050 wetlands, 373 waterways totaling more than 308,726 linear feet, and 15 ponds totaling 15 acres, were delineated as part of the 2012 EnviroScience wetland delineation effort (EnviroScience 2012).

The largest of the major streams crossing GRC-ATF include Pipe Creek, Kuebelar Ditch, Ransom Brook, and Plum Brook. The waterways at GRC-ATF were categorized into three types in the 2011 to 2012 delineation: ephemeral, with 103,400 linear feet; intermittent, with 163,000 linear feet; and perennial, with 42,300 linear feet (EnviroScience 2012). In general, the streams at GRC-ATF travel northward and converge into Pipe Creek, Ransom Brook, Plum Brook, and Sawmill Creek and eventually flow into Lake Erie. The major ditches and streams at GRC-ATF are shown in Figure 3-2 and presented in Table 3-1. The streams could receive some of their volume from groundwater. There are no catch basins specifically intended to collect runoff.

Table 3–1. Major Ditches and Stream at GRC-ATF

Stream	Drainage Areas in Acres	
	Entering	Leaving
Pipe Creek	11,800	12,600
Ransom Brook	*	824
Storrs-Hemminger Ditch	*	130
Plum Brook	260	1,960
E.C. Smith Ditch	*	44
Lindsley Ditch	*	722
Schlessman Ditch	*	238
Scheid Ditch	*	505
Kuebelar Ditch	148	658
Scheid-Olemacher Ditch	40	273
Scherer Ditch	754	778

*Stream originates within station boundaries
ATF = Armstrong Test Facility
GRC = John H. Glenn Research Center

Ohio EPA classifies all surface waters at GRC-ATF as warmwater habitat. Other use designations applicable to GRC-ATF streams include primary contact recreation (swimming) and agricultural and industrial water supply. Hemming Ditch and Plum Brook ultimately discharge to Lake Erie within the Sheldon Marsh State Nature Preserve (SNP) and are afforded special protection by ODNR.

The largest surface water body near GRC-ATF is Sandusky Bay on Lake Erie, approximately 4 miles to the north. Lake Erie has a surface area of approximately 9,910 square miles and an estimated volume of 116 cubic miles (ODNR 2009). Other surface water features include Bellevue Reservoir Number 5, which is 14 miles to the south-southwest. Numerous other ponds and streams are within a 15-mile radius. The Erie County Health Department does not permit surface water to be used for private drinking water supply.

3.3.2 Taylor Road Burning Ground

TRBG contains two surface water drainage ditches that intermittently contain flow related to precipitation runoff from the surrounding area (Figure 1-2). Surface drainage at TRBG ultimately flows toward Ransom Brook (Figure 3-2), which exits the property to the north.

3.4 GEOLOGY

3.4.1 Armstrong Test Facility

The bedrock in northern Ohio consists of Devonian and Silurian age carbonates (limestone and dolomite) and clastics (shale, siltstone, and sandstone) (USDA 2006). These units unconformably overlie older sedimentary sequences of Ordovician and Cambrian Age rocks, which in turn unconformably overlie pre-Cambrian basement rocks. GRC-ATF is situated along the eastern flank of the Findlay Arch, where bedrock dips gently to the east. The bedrock formations become progressively younger from west to east. Depth to the bedrock at GRC-ATF varies from 2 to 25 feet with scattered bedrock outcrops.

Four Devonian Age formations comprise the upper bedrock surface across GRC-ATF, from youngest to oldest:

- Ohio Shale (black, thin bedded with bituminous and carbonaceous material);
- Plum Brook Shale/Prout Limestone (light gray, calcareous);
- Delaware Limestone (buff, earthy, fossiliferous, interbedded with brown crystalline dolomite); and
- Columbus Limestone (brown to gray, fine crystalline, fossiliferous, with tan to buff gray sandy dolomite at base).

The Delaware Limestone Formation is the upper bedrock surface in the northern boundary and northwestern corner of GRC-ATF. The Plum Brook Shale/Prout Limestone are toward the center of GRC-ATF, spanning from central west to the northeast portion of GRC-ATF. The Ohio Shale Formation is the upper bedrock surface in the eastern and southern portions (MK 1994). Figure 3-3 shows the general bedrock geology across the facility, and Figure 3-4 illustrates the bedrock topography for GRC-ATF. Detailed cross-sections, Figures 3-5, 3-6, and 3-7, show a detailed lithology of GRC-ATF. TRBG is located to the west of the southern portion of the north-south cross-section and to the south of the western portion of the east-west cross-section.

3.4.2 Taylor Road Burning Ground

The upper bedrock surface at TRBG is the Devonian Age Plum Brook Shale. Based on soil boring logs completed at the site, depth to black shale bedrock is approximately 6 to 10 feet bgs.

3.5 SOIL

3.5.1 Armstrong Test Facility

Erie County, which is in the eastern part of the Central Lowland Province, consists primarily of lake plain physiography, but till plain physiography occurs in the southeastern part of the county (ODNR 1998). GRC-ATF is in a transition zone between the Erie Lake Section and the Bellevue-Castalia Karst Plain of the Central Lowland Province. The Erie Lake Section, which occurs throughout the central to southeastern portion of GRC-ATF, is characterized by Pleistocene sand, silt, clay, and clay till over Devonian-aged shales. The Bellevue-Castalia Section, which occurs throughout the northern to northwestern portion of GRC-ATF, is characterized by Columbus and Delaware Limestone overlain by thin silty and sandy lacustrine deposits and clay till (ODNR 1998).

The soil is light-textured and often loamy with moderate to slightly acid pH. Primary soil types encountered at GRC-ATF are Elnora loamy fine sand (15 percent), Hornell Silty Clay Loam (14 percent), Fries silty clay loam (11 percent), Colwood loam (11 percent), Kibbie fine sandy loam (9 percent), and Pewamo silty clay loam (5 percent). In addition, approximately 12 percent of GRC-ATF is considered Udorthents, which is urban land consisting of reworked material and fill. Several other minor soil types are also present at GRC-ATF. Figure 3-8 presents a map illustrating the general distribution of soil types at GRC-ATF.

Based on descriptions provided in the *Soil Survey of Erie County, Ohio* (USDA 2006), soil types at GRC-ATF are generally very deep to deep, level to gently sloping, very poorly to somewhat poorly drained soil derived from glacial or lacustrine deposits and limestone or shale bedrock. The thickness and composition of glacial till vary widely within Erie County. Soil formation in the till is generally only a few feet thick. Where these till layers were very thin or eroded away, soil formed in older, harder till. The clay content of the till is highest near Lake Erie and lowest near bedrock areas where glacial ice sheets eroded and transported some of the coarser local material (USDA 2006).

3.5.2 Taylor Road Burning Ground

Soil at TRBG consists largely of Udorthents-disturbed land within the central area of the former Primary Burn Area. Soil surrounding the burn area consists of Dunbridge loamy sand (2 to 6 percent slopes), Marblehead loam (0 to 6 percent slopes), and Hornell silty clay loam (0 to 2 percent slopes) on the northern half of the site, with Elnora loamy fine sand, bedrock stratum (0 to 4 percent slopes) to the southeast of the site, and Fries silty clay loam (0 to 1 percent slopes) to the southwest of the former Primary Burn Area (USDA 2018). Distributions of soil are presented in Figure 3-8.

The Dunbridge loamy sand and Marblehead loam are glaciolacustrine deposits over residuum weathered from limestone. The soil is well drained to somewhat excessively drained and does not exhibit flooding or ponding. The Hornell silty clay loam is a somewhat poorly drained soil that is formed from till over residuum weathered from shale. It is observed in till plains.

The Elnora loamy fine sand consists of loamy fine sand from glaciolacustrine deposits with bedrock typically encountered within 5 feet of the surface. It is moderately well drained and does not exhibit flooding or ponding of surface water.

The Fries silty clay loam is underlaid by clay followed by bedrock. It is a poorly drained soil that may exhibit frequent ponding. Fries silty clay loam is formed from till over residuum weathered from shale and is observed in drainage ways, flats, and depressions on lake plains.

3.6 HYDROGEOLOGY

3.6.1 Armstrong Test Facility

The USACE has produced numerous reports pertaining to their environmental efforts for groundwater at GRC-ATF. Many of the reports describe monitoring of groundwater chemicals, groundwater elevations, and groundwater flows. In general, GRC-ATF has two upper water-bearing zones, one in the overburden/shale and one in the Delaware Limestone bedrock.

The overburden layer consists of discontinuous groundwater seams across the facility that exhibit seasonal variations. The general flow of groundwater in overburden is to the north-northeast toward Lake Erie, largely mirroring surface topography (Figure 3-9). The flow also corresponds somewhat to the topography of the top of the bedrock. In contrast, the Delaware Limestone water-bearing zone is saturated year-round, but also flows to the north-northeast toward Lake Erie (Figure 3-10). The rate of groundwater flow in the bedrock is controlled by the frequency, orientation, density, and connectivity of the fractures.

Data from recent USACE groundwater investigations found that groundwater in the overburden occurs in discontinuous pockets during dry time periods. Connectivity between groundwater in the shallow water-bearing zone and surface water is evident in the spring/wet season at GRC-ATF. The overburden layer's connection to surface water has been demonstrated to be more strongly seasonal and less continuous (Shaw 2005). In general, historical data indicate that groundwater elevations in the overburden/shale fluctuate seasonally, irrespective of the area of GRC-ATF. Data collected from the facility do not show a clear correlation between precipitation rates and water level elevations in site wells (Shaw 2005).

Most residents of Erie County receive water from public utilities whose primary sources are from municipal water derived from Lake Erie. Residences to the north and east of GRC-ATF are connected to city, county, or rural services. Erie County's primary groundwater source is from the limestone and dolomite aquifer in the western end of the county (Shaw 2008). At GRC-ATF, the groundwater has been divided into three zones based on location and yield (Figure 3-11). Zone 1 occurs in the northern and northwestern portion of the station in the limestone formations, which typically occurs in joints and along bedding planes. It has been characterized as yielding from 100 to 500 gallons per minute (gpm) from karstic limestone approximately 100 feet below grade. Zone 2 is in the northern portion of GRC-ATF and has yields of 15 gpm or less from limestone approximately 300 feet below grade. Zone 3 is in the eastern and southern portion of the site in predominantly shale bedrock. In addition to being found in the shale, groundwater is in thin sand and gravel horizons interbedded with silt and clay deposits. Most Zone 3 wells are poor yielding, many of them providing less than 3 gpm (Shaw 2008).

Groundwater at GRC-ATF is not used for drinking water, and no injection wells are onsite. The Erie County Health Department does not allow the use of surface water (e.g., river, stream, creek, drainage ditch) for a private drinking water system, in accordance with Ohio Administrative Code 3701-28; however, a pond, spring, or cistern tank could be used as a source for a private water system. Six known private wells are within 1 mile downgradient from GRC-ATF. The nearest known downgradient private well is approximately 840 feet northeast of the facility boundary.

Leidos completed a review of ODNR's water well records via the Water Wells Viewer (https://gis.ohiodnr.gov/MapViewer/?config=waterwells) on November 11, 2021. The search used a 5,000-foot buffer and 4-mile buffer around the NASA GRC-ATF fence line to identify potable wells registered with ODNR that are located upgradient of and downgradient from GRC-ATF. Twenty-one potential potable wells were identified downgradient from and within 5,000 feet of GRC-ATF. Forty-four potential potable wells were identified upgradient of and within 5,000 feet of GRC-ATF. In addition to the potable wells, the ODNR well search also identified well #9922001, a production well

located in the southern portion of the GRC-ATF property. The well is not currently in use, and it is unknown if this well has been abandoned. Using a 4-mile radius around the GRC-ATF perimeter, the well search identified approximately 912 ODNR registered wells, which is inclusive of wells used for potable and non-potable purposes.

USACE conducted groundwater investigations in connection with site remediation activities such as the red water ponds. NASA and USACE installed approximately 187 monitoring wells. Between 2014 and 2015, USACE abandoned 122 monitoring wells (CB&I 2014 and 2015). Based on an investigation completed in 1997, naturally occurring petroleum was identified in the groundwater, providing further evidence that groundwater at GRC-ATF is unsuitable for potable use (IT 1997). At the time of this report, NASA is working to establish the requirements for a land use control prohibiting groundwater use at GRC-ATF.

3.6.2 Taylor Road Burning Ground

Discontinuous saturated zones in overburden soil were observed at depths ranging from 2.5 to 4.5 feet bgs during the field investigation. During the Phase II RI, five permanent monitoring wells were installed (TRBG-MW01, TRBG-MW02, TRBG-MW03, TRBG-MW04, and TRBG-MW05) with total depths ranging from 5 to 7.5 feet bgs. Monitoring well TRBG-MW04, which is the shallowest well at 5 feet bgs along the top of bedrock/overburden interface and located in the northeastern portion of TRBG, was gauged dry during the May and December 2021 sampling events. Groundwater was observed at 4 feet bgs/1 foot above the bedrock during installation of TRBG-MW04, and groundwater had a thickness of 1.56 feet during well development. The monitoring wells were capable of sustaining low flow sampling (40 to 100 milliliters per minute [mL/min]) during the May 2021 sampling, but significantly less water was present in December 2021 and all wells were bailed dry for sampling.

3.7 DEMOGRAPHY AND LAND USE

U.S. Census Bureau data collected in 2020 for Erie County, Ohio, estimate the 2020 population of Erie County to be 75,622, with 37,897 total housing units (U.S. Census 2020). The population in 2020 was estimated as being 83.0 percent White but not Hispanic, 8.9 percent African American, 4.5 percent Hispanic or Latino, and 3.3 percent two or more races, with the remaining percentage consisting of Native American, Asian, and Native Hawaiian or Pacific Islander. In 2020, the percent of persons under 5 years of age was estimated at 5.3 percent, the percent of persons under 18 years of age was estimated at 20.2 percent, and the percent of persons 65 years or older was estimated at 22.6 percent (U.S. Census 2020).

The average household income for 2015 to 2019 was estimated to be $54,226 annually (U.S. Census 2020). Statistical and demographic data for 2020 published by the U.S. Census Bureau lists the labor force of the county as 38,013 for calendar year 2019, based on the American Community Survey 1-year estimate, with 36,433 employed for an unemployment rate of 4.2 percent (U.S. Census 2020). The services industry employs the most people followed by manufacturing, trade, government, construction, transportation/utilities, finance/insurance/real estate, and agriculture/forestry/fishing and mining.

The location of Erie County next to Lake Erie and the local attractions make the county a high tourist area. The population in the area increases by 50 percent in the summer. Cedar Point Amusement Park alone draws more than 3.6 million visitors each season. The largest city is Sandusky, with a population of approximately 25,000.

Peak NASA employment at GRC-ATF was approximately 600 people in the mid-1960s. Today's total NASA employment is approximately 170. Of these employees, approximately 24 are civil servants and the remainder are contractor employees (Mullenax 2018). Other government agencies have 20 to 30 personnel stationed onsite.

GRC-ATF is not as significant an employer in its region as the Lewis Field site. Other large employers in the area include the Flex-N-Gate (formerly Ford Motor Company), Kyklos Bearing International, Delco-Chassis NDH, Tenneco (formerly Imperial Clevite), Sandusky Plastics, and Sandusky International (Foundry and Machinery) (SAIC 2013b).

NASA's presence in the area nonetheless provides local economic impacts and benefits. A 2021 study found overall economic benefit to the regional economy from NASA GRC to be as follows: total output of $1.8 billion; employment impact of 8,974; and household earnings impact of $805.7 million (Lendel et al. 2021). Most of these benefits are associated with Lewis Field; however, GRC actions are felt throughout Ohio. The 2021 report found that GRC activities in fiscal year (FY) 2020 generated an increased demand for products and services used in northeast Ohio valued at $1.8 billion. In FY 2020, GRC awarded $3.9 million in grants to Ohio academic institutions, 66.7 percent of which went to institutions in northeast Ohio. Northeast Ohio received the greatest share of expenditures from GRC when compared to the rest of the state, 96.1 percent of $303.8 million. The GRC continues to be a significant influence on the economy and labor force in Ohio, particularly for the knowledge-intensive labor force, which helps provide technological advancement for the country, generate local wealth, and attract skilled and knowledgeable workers to reside in Ohio.

3.8 ECOLOGY

GRC-ATF is part of a regional ecosystem encompassing Sandusky, parts of Lake Erie, and several Lake Erie islands. Several natural areas are found in the general vicinity. The Milan State Wildlife Area is located approximately 3 miles to the south. The Erie Sand Barrens SNP is approximately 1,000 feet to the south. The Sheldon Marsh SNP is approximately 4 miles to the northwest, and the Resthaven Wildlife Area is 6 miles to the northwest. Another local natural area is Old Woman Creek, a National Estuarine Research Reserve and SNP, which is east of the city of Huron.

3.8.1 Flora

The ODNR Division of Natural Areas and Preserves (DNAP) conducted a botanical survey of GRC-ATF in 1994. During that survey, 327 species of vascular plants were cataloged, 12 of which were listed by DNAP as Ohio rare species. In 2001, DNAP conducted a follow-up survey in which 312 of the species found in 1994 were identified and 219 new additions were made. During a 2016 field survey, all plant communities previously described throughout 2001 were updated or confirmed to reflect their present ecological condition. The 2016 survey identified 16 formations and 13 alliances at GRC-ATF. Formations and alliances are listed below; descriptions and delineations of the alliances are provided in *Protected Species Management Strategy for NASA Glenn Research Center* (Volume II of EnviroScience 2017). They are identified in Figure 3-12.

Forest Formations

- Formation: I.A.8.N.c. Conical-crowned temperate or subpolar needle-leaved evergreen forest (EFU1)
- Formation: I.B.2.C.b. Orchards and groves (fruit and nut trees) (*eliminated by succession)*
- Formation: I.B.2.N.a. Lowland or submontane cold-deciduous forest
  - *Quercus alba* – (*Quercus rubra*, *Carya* spp.) forest alliance (FU2)
  - *Quercus rubra* – *Acer saccharum* – (*Quercus alba*) forest alliance (FU3)
  - *Quercus velutina* – *Quercus alba* forest alliance (FU4)
  - Mixed (oak-dominated) deciduous successional forest (FU5)
  - Mesic, mixed deciduous successional forest (FU6)
  - Mixed deciduous successional forest (FU7)
  - *Populus deltoides* successional forest (FU8)

- Formation: I.B.2.N.d. Temporarily flooded cold-deciduous forest – successional communities
  - *Fraxinus pennsylvanica – Ulmus americana – Celtis* (*occidentalis, laevigata*) temporarily flooded forest alliance (FL1)
  - *Salix nigra* temporarily flooded forest alliance (FL2)
- Formation: I.B.2.N.e. Seasonally flooded cold-deciduous forest – successional communities
  - *Acer rubrum – Fraxinus pennsylvanica* seasonally flooded forest alliance (FL3)
  - *Quercus palustris* – (*Quercus bicolor*) seasonally flooded forest alliance (FL4)
  - Mixed cold-deciduous seasonally flooded forest (FL5)
- Woodland Formation: Mixed cold-deciduous seasonally flooded woodland (WL1)

Shrubland Formations

- Formation: III.B.2.N.a. Temperate cold-deciduous shrubland – successional communities
  - Dry mid-successional cold-deciduous shrubland (SU1)
- Formation: III.B.2.N.c. Intermittently flooded cold-deciduous shrubland
  - Intermittently flooded mid-successional cold-deciduous shrubland (SL1)
  - Intermittently flooded late-successional cold-deciduous shrubland (SL2)
- Formation: III.B.2.N.f. Semipermanently flooded cold-deciduous shrubland
  - *Cephalanthus occidentalis* semipermanently flooded shrubland alliance (SL3)
- Formation: III.B.2.N.g. Saturated cold-deciduous shrubland
  - *Cornus* spp. - *Salix* spp. saturated shrubland alliance (SL4)

Herbaceous Vegetation Formations

- Formation: V.A.5.C.b. Landscaped urban/suburban/rural (residential yards, nurseries)
  - Landscaped/maintained grounds surrounding buildings (LM)
- Formation: V.A.5.N.c. Medium-tall sod temperate or subpolar grassland
  - Maintained grassland (MG)
- Formation: V.A.5.N.k. Seasonally flooded temperate or subpolar grassland
  - *Phalaris arundinacea* seasonally flooded herbaceous alliance (HL2)
  - *Typha* spp. – (*Scirpus* spp. – *Juncus* spp.) seasonally flooded herbaceous alliance (HL3)
  - *Phragmites australis* seasonally flooded herbaceous alliance (HL4)
- Formation: V.B.2.N.a. Tall temperate or subpolar perennial forb vegetation – successional community
  - Dry early successional herbaceous field (HU1)
- Formation: V.B.2.N.c. Intermittently flooded temperate perennial forb vegetation – successional community
  - Intermittently flooded early successional herbaceous field (HL1)
- Formation: V.C.2.N.a. Permanently flooded temperate or subpolar hydromorphic rooted vegetation
  - *Potamogeton spp.* – *Ceratophyllum* spp. – Elodea spp. permanently flooded herbaceous alliance (HL5)
  - *Nelumbo lutea* permanently flooded herbaceous community (HL6).

Wetlands were formally delineated for all of GRC-ATF in accordance with methods described in the *Corps of Engineers Wetlands Delineation Manual* (USACE 1987) and the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northeast and Northcentral Region* (USACE 2012). A total of 1,050 wetlands totaling 421.958 acres, 373 waterways totaling 308,726 linear feet, and 15 ponds totaling 14.908 acres were delineated.

As part of the wetland delineation effort, 10 upland and wetland vegetative communities were identified at GRC-ATF. Upland and wetland vegetation sample plots were recorded for the delineated wetlands and associated upland areas.

3.8.2 Fauna

Animals censused at GRC-ATF during the 2001 and 2016 surveys for the *Protected Species Management Strategy* (EnviroScience 2017) included birds, amphibians, reptiles, fish, lepidoptera, and bats. One hundred and twenty-five bird species were identified during the 2001 summer birding season at GRC-ATF. This includes 11 species that were considered late migrants through the area and 7 species that were classified as visitors only. A general analysis of the results indicates little change in the species diversity on the station since the 1994 surveys conducted for the *Biological Inventory of Plum Brook Station* (ODNR 1995). The birds identified in the 2016 survey were similar to those identified in 1994 and 2001. One hundred and twenty species were identified, 6 of which were considered visitors and 11 were classified as migrants (EnviroScience 2017).

In 2001, amphibians and/or reptiles were recorded from 115 localities in GRC-ATF. There were 15 localities from 1994 where animals were no longer found, but animals were found at 29 new locations. Twenty-one species have been found, including two salamanders, six frogs, one lizard, five turtles, and seven snakes. Two new native species, the milk snake and blue-tail skink, were found as well as an introduced species, the red-eared slider. The gray tree frog has been deleted from the list. In addition, the area lies within the range of 19 other species, and it is possible that 1 or more of these may yet be discovered here (ODNR 2002). The 2016 survey detected 20 species at more than 200 localities, which includes two salamander species, seven frog species, four turtle species, and seven snake species. Of those 20 species, 2 are listed as species of concern, and 1, the Opheodrys vernalis (Smooth Greensnake), is endangered (Table 3-2).

During the fish survey conducted in support of the 1995 *Biological Inventory of Plum Brook Station* (ODNR 1995), 3,028 individuals, representing 13 species and 1 hybrid, were collected. In 2001, 2,156 individuals, representing 15 species and 1 hybrid, were collected. The small, intermittent nature of the streams in the study area, coupled with extensive channel modifications and habitat degradations, have resulted in a lower species diversity than would be found in more pristine headwater streams of similar size. Except for the brook stickleback, all species captured in this study were common species statewide, exhibiting high degrees of tolerance to habitat and water quality degradations. A small population of sticklebacks was discovered in a small, shallow pool below a culvert in one of the tributary ditches feeding into Pipe Creek in 1993. This population was still there in 2001 but was no longer detected in 2016 (ODNR 2002). The 2017 report confirmed the low fish diversity reported in the 1994 and 2001 reports (EnviroScience 2017).

In a 1994 summer survey of GRC-ATF, 41 species of butterflies were recorded. During the summer of 2001, 53 species of butterflies were recorded. Three species observed in 1994 were not seen in 2001. However, 14 species not recorded in 1994 were found in 2001. As of 2001, the surveys conducted that year raised the number of species recorded from Erie County from 59 to 70 (ODNR 2002). The 2016 survey recorded 45 butterfly species, none of which were listed as Federal- or state-listed rare, threatened, or endangered species. Fourteen species were recorded in either 1994 or 2001 that were not seen in 2016, and three new species were recorded in 2016 (EnviroScience 2017).

After an extensive survey of GRC-ATF during the summer of 2001, 450 species of moths were recorded. A previous survey in 1994 recorded 385 species of moths. At the time of the 2001 moth survey, six species were listed as uncommon, three species were rare, and three species were of special interest. One species on the ODNR Ohio's Endangered Wildlife List was recorded (ODNR 2002). The 2016 survey detected 455 species of moths, 332 of which had been previously detected and 123 that were new to the facility. No Federal- or state-listed rare, threatened, or endangered species were identified during the 2016 survey (EnviroScience 2017).

Distribution, diversity, and relative abundance of the Chiropterans (bats) at GRC-ATF were studied from April through September 2001. Methodology included visual and acoustical surveying of the grounds and buildings; mist netting of wooded, riparian, and open sites; and radio tracking of selected bats within the station. A total of 238 bats, including 8 different species, were captured at 17 of the 21 mist net sites at

GRC-ATF. No evidence of the Indiana bat was found. Several maternity colonies were located and used by three different species (ODNR 2002).

In 2010 and 2012, additional bat mist netting surveys were conducted. In 2010, bats were captured at each of four mist net sites, with five species of bats recorded. The results of this survey were qualitatively similar to the more extensive mist netting survey conducted in 2001 (West 2010) and described above. In 2012, bat mist netting was conducted at eight sites on GRC-ATF; six bat species were captured during the mist netting effort. Acoustic detection of bat calls was also used during the 2012 bat survey. Similar to the 2010 bat survey, the results of the 2012 survey were similar to those of the 2011 bat mist netting survey conducted at GRC-ATF (West 2012).

In 2009 and 2010, various bird surveys were conducted onsite by USDA's Wildlife Services and National Wildlife Research Center (Seamans et al. 2011). As part of this effort, passerine and diurnal raptors were surveyed during their fall (2009) and spring (2010) migratory periods. In the fall of 2009, 40 species of passerines and 10 species of diurnal raptors were identified. In the spring of 2010, 51 species of passerines and 13 species of diurnal raptors were identified. In addition, in 2010, USDA conducted a breeding bird survey, which identified 54 species of such birds at GRC-ATF (Seamans et al. 2011).

In 2012, a survey for a candidate species for the Federal endangered species list, the Eastern Massasauga rattlesnake (*Sistrurus catenatus*), was conducted. The survey sites chosen for this effort were specific to the habitat requirements of the Eastern Massasauga, so it could not be considered a comprehensive snake or reptile survey. However, although no Eastern Massasaugas were found onsite, three species of snakes were recorded during the survey (Lipps 2012).

In 2017, a bee survey was completed in a milkweed field and the adjacent abandoned prairie at the intersection of Taylor and Maintenance Roads. The results identified eight known species of bees. In addition, 18 bees whose species could not be identified were found during the survey (Eppig 2018).

3.8.3 Unique and Important Habitats

GRC-ATF contains vast natural resources in the form of a complex mosaic of plant communities in various successional stages and hydrologic regimes. Much of GRC-ATF is undeveloped natural areas or recovering natural areas previously used for agriculture. The size and diversity of natural habitats at GRC-ATF support many plant and animal species (EnviroScience 2017, ODNR 2002, ODNR 1995). Many of these areas contain rare plants species and rare plant communities, including rare prairie species and remnant oak savannas. The *Protected Species Management Strategy for NASA Glenn Research Center Plum Brook Station Volume II: Plant Community Survey* (EnviroScience 2017) divided significant plant communities into four categories:

- Rare plant community restoration areas,
- Specific rare plant sites,
- Intact rare plant communities, and
- Degraded rare plant communities.

At GRC-ATF, eight core sites containing areas of special vegetation significance were identified as priority areas for management in Volume III of the *Protected Species Management Strategy* (EnviroScience 2017, ODNR 2002). The eight areas are identified in Table 3-3 and Figure 3-13, which shows management areas at GRC-ATF. These include specific sites with identified populations of rare or state-listed plant species as of the species surveys conducted in 2001 and 2016 in support of the *Protected Species Management Strategy* (EnviroScience 2017, ODNR 2002). They can be small and local or somewhat extensive in area, but in all cases their distinguishing characteristic is that they support a growth of rare plants or can be restored to a condition that supports rare plants. The areas are being managed to protect against loss of the most important sites, which would likely mean the irretrievable loss of the local rare plants, many of which are exceptionally rare or state-listed and found nowhere else in the region or state.

Table 3–2. State-listed Animal Species at GRC-ATF (EnviroScience 2017)*

Endangered	Survey Years Located
Bulbulcus ibis (cattle egret)	1994/2001
Opheodrys vernalis (smooth green snake)	1994/2001/2016
Spartiniphaga inops (moth, no common name)	2001
Threatened	
Bartramia longicauda (upland sandpiper)	1994
Emydoidea blandingii (Blanding's turtle)	1994
Nycticorax nycticorax (black-crowned night heron)	1994/2001
Myotis septentrionalis (northern long-eared bat)	2001/2010/2012
Special Interest/Concern	
Accipiter striatus (sharp-shinned hawk)	2016
Ammodramus henslowii (Henslow's sparrow)	2016
Casmerodius albus (great egret)	1994/2001/2016
Cistothorus palustris (marsh wren)	2016
Cistothorus platensis (sedge wren)	1994/2001/2016
Colinus virginianus (northern bobwhite)	2001
Emydoidea blandingii (Blanding's turtle)	1994 (*no longer listed*)
Elaphe vulpine gloydi (eastern fox snake)	1994/2001/2016
Empidonax minimus (least flycatcher)	2001/2016
Eptesicus fuscus (big brown bat)	2001/2010/2012/2016
Haliaeetus leucocephalus (bald eagle)	2002/2016 (*Federal only*)
Lasiurus borealis (eastern red bat)	2001/2010/2012/2016
Lasiurus cinereus (hoary bat)	2001/2010/2012
Myotis lucifugus (little brown bat)	2001/2010/2012
Oporornis philadelphia (mourning warbler)	2001/2016
Pantherophis vulpinus (western foxsnake)	2016
Perimyotis subflavus (tri-colored bat)	2001/2012
Rallus limicola (Virginia rail)	2001/2016
Setophaga cerulean (cerulean warbler)	2016
Setophaga fusca (blackburnian warbler)	2016
Setophaga magnolia (magnolia warbler)	2016
Sphyrapicus varius (yellow-bellied sapsucker)	2016

***Source*:** EnviroScience 2017. *Final Protected Species Management Strategy for NASA Glenn Research Center at Plum Brook Station.* Volume I: Biological Survey. March.

*This table lists fauna that were on Ohio's state-listed protected list at the time they were surveyed at GRC-ATF. Species may be listed in a different category as of 2016, or have been removed from the protected list, and this is reflected in the above table.

ATF = Armstrong Test Facility
GRC = John H. Glenn Research Center

Table 3–3. Eight Species Management Areas at GRC-ATF

Area Name	Category	Acreage
East Patrol Road	Rare Prairie Plant Site	78
Magazine Area	Rare Prairie Plant Site	504
Pentolite Area	Native Forests	227
West Area	Native Forest	55
South Patrol Road and Taft Road	Savanna Areas	90
Pentolite Road	Savanna Area	17
Central	Meadows Area	458
Gateway	Meadow Area	99

ATF = Armstrong Test Facility
GRC = John H. Glenn Research Center

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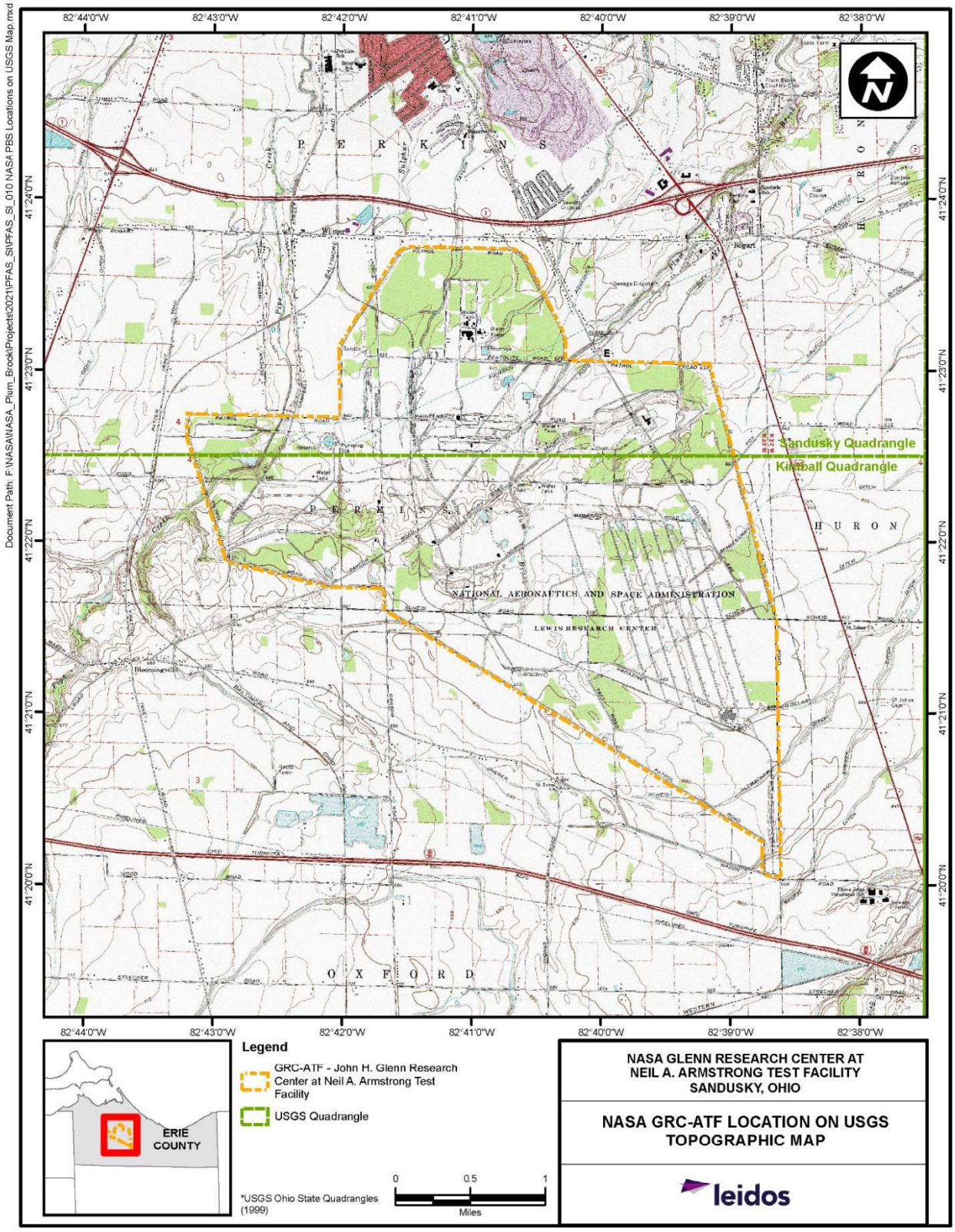

Figure 3–1. GRC-ATF Location on USGS Topographic Map

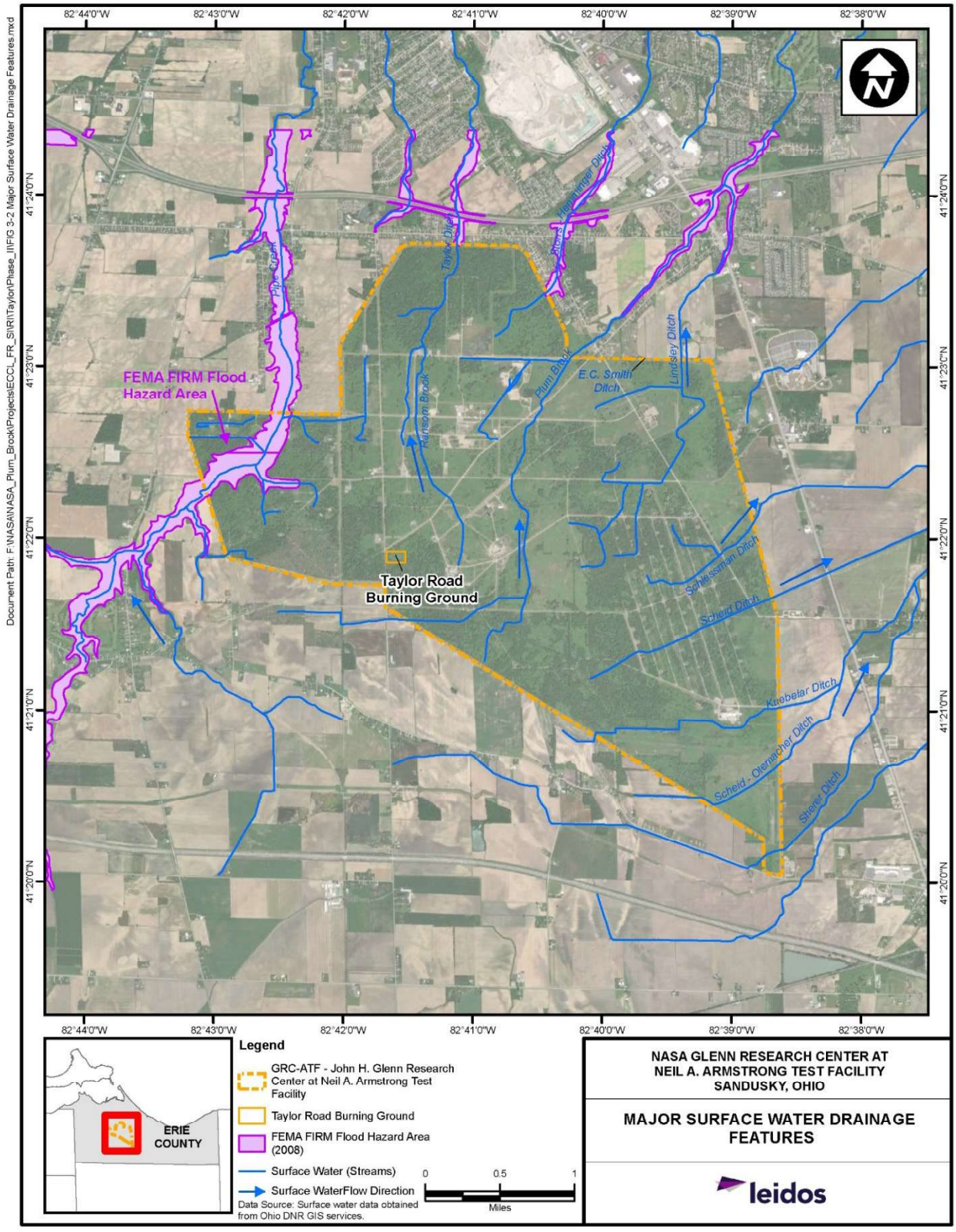

Figure 3-2. Major Surface Water Drainage Features

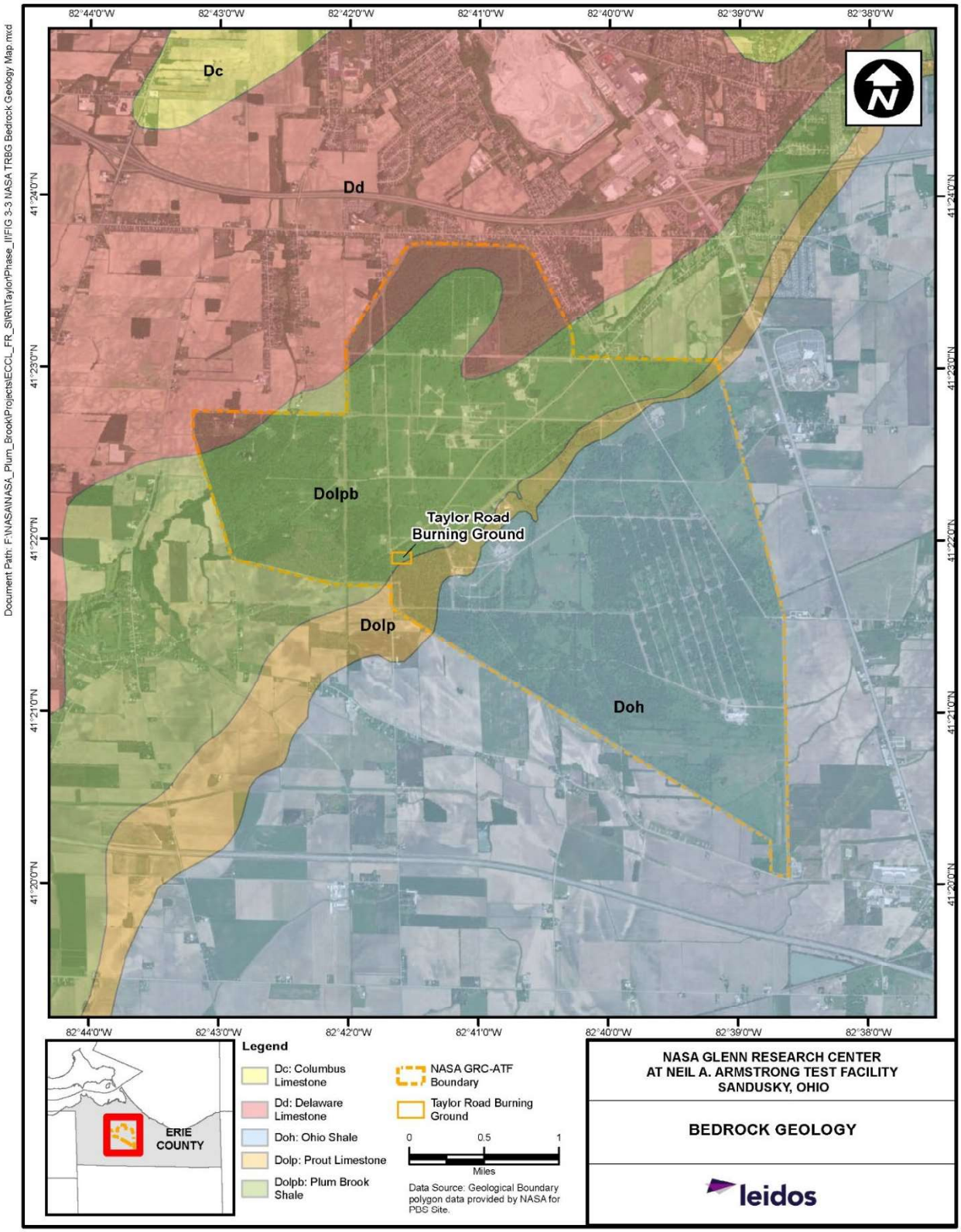

Figure 3-3. Bedrock Geology

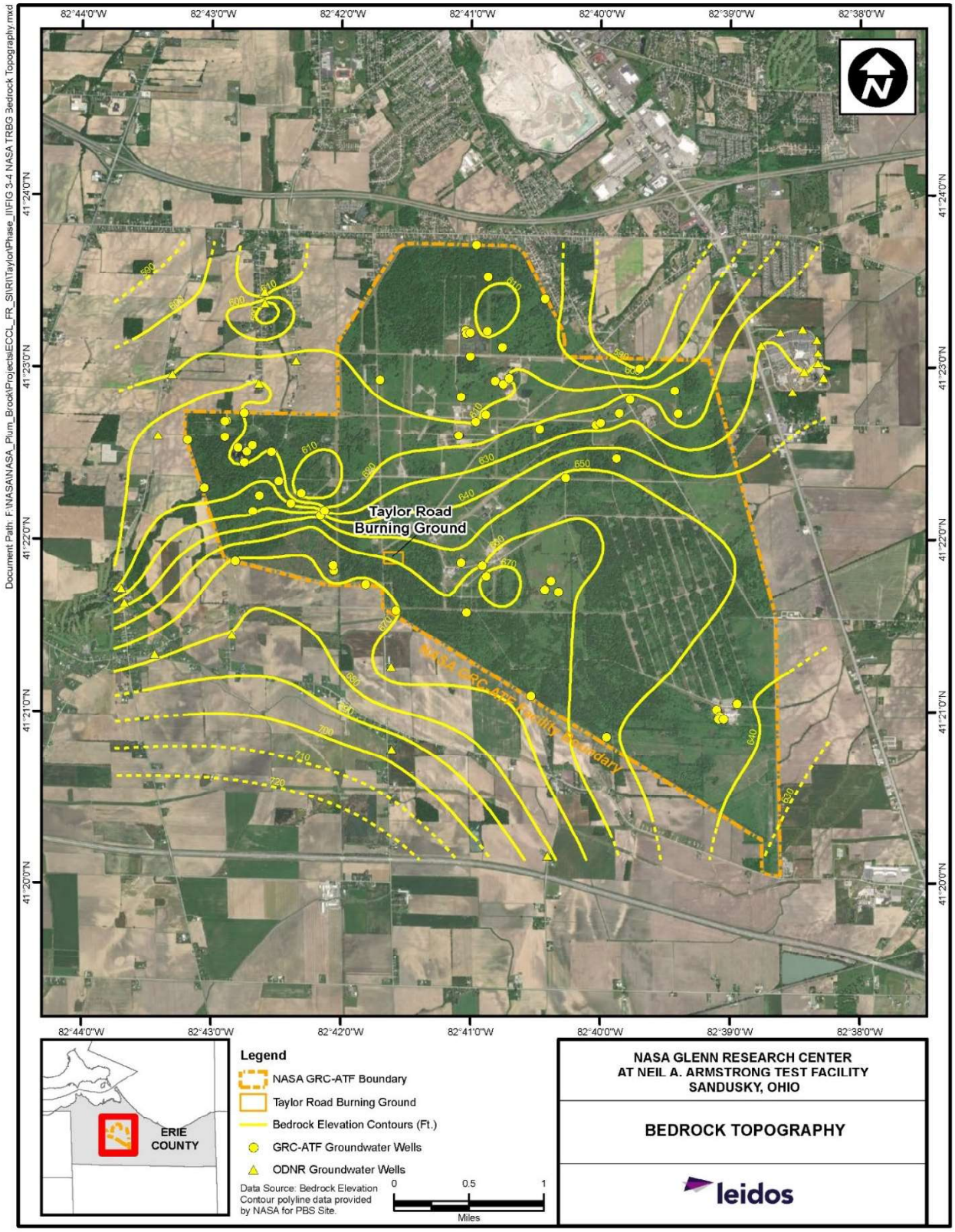

Figure 3-4. Bedrock Topography

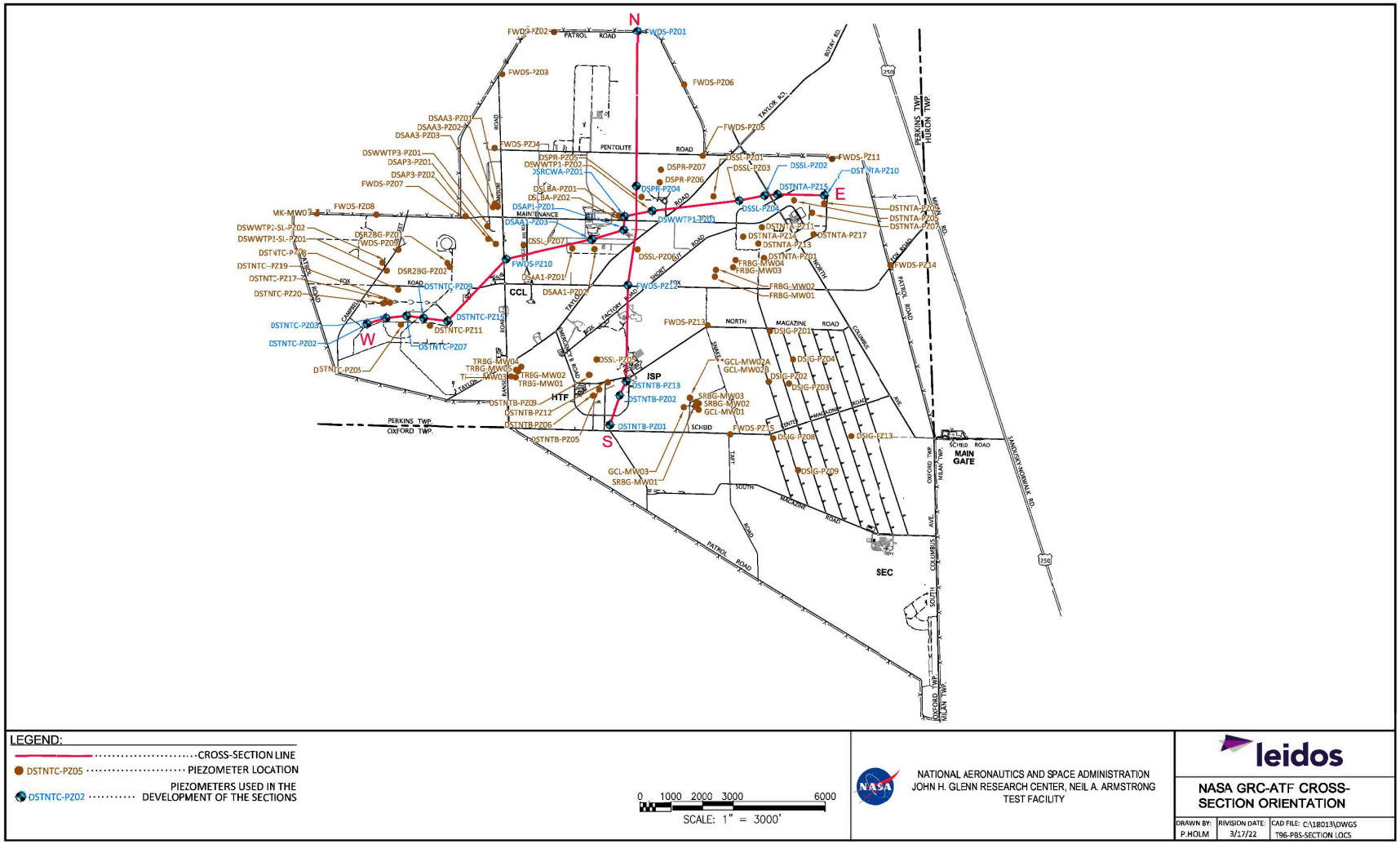

Figure 3–5. NASA GRC-ATF Cross Section Orientation

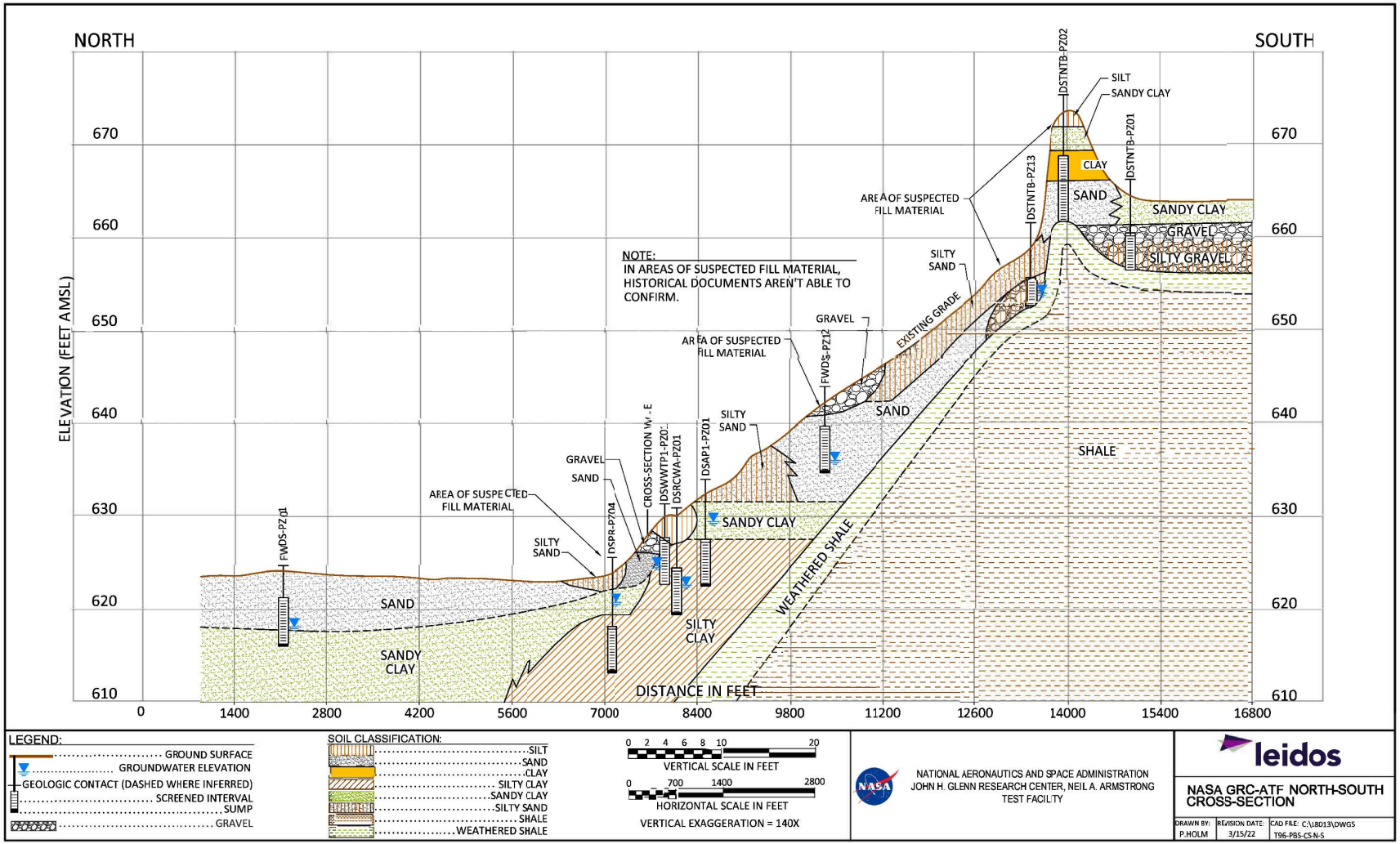

Figure 3-6. NASA GRC-ATF North-South Cross-Section

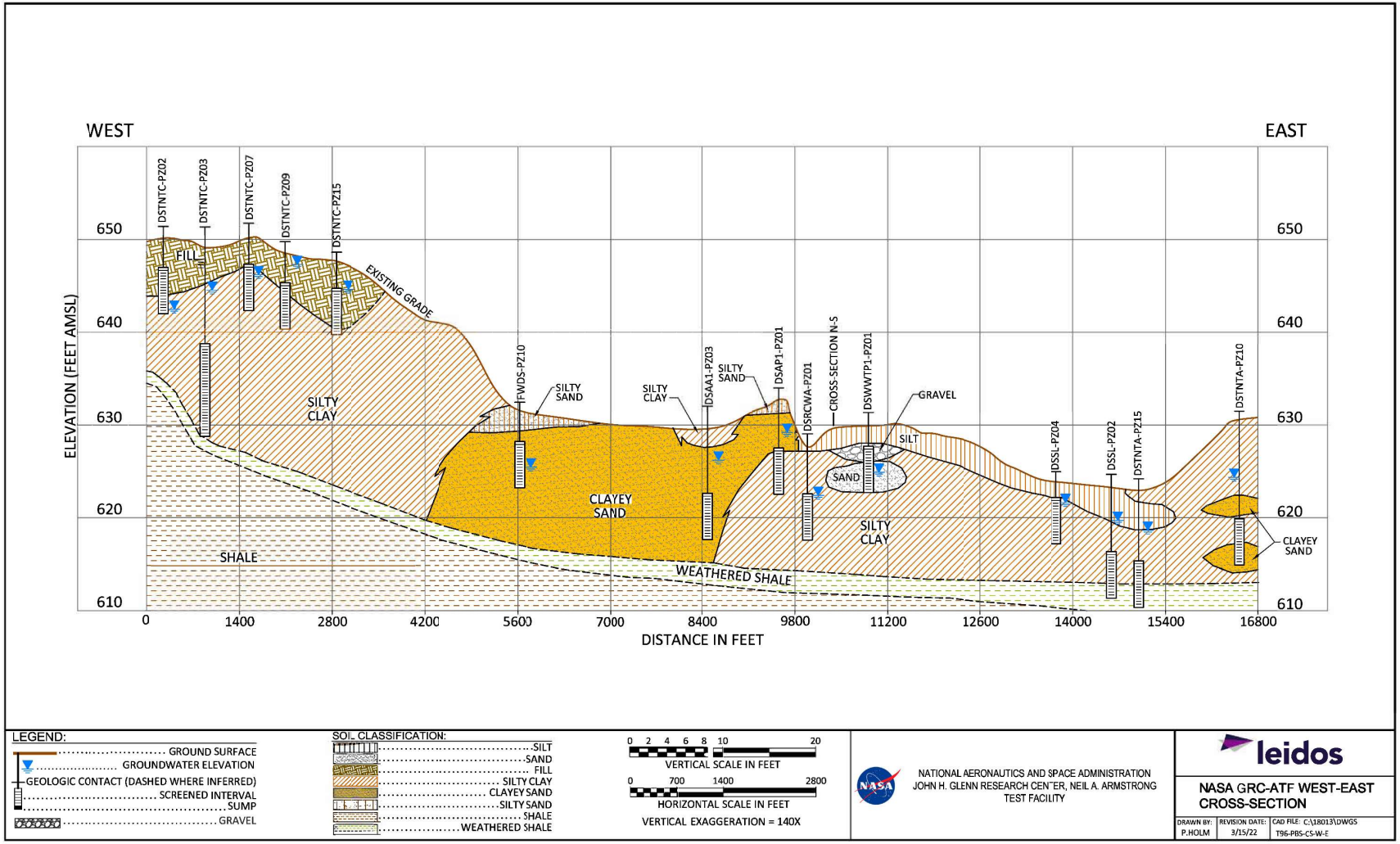

Figure 3-7. NASA GRC-ATF West-East Cross-Section

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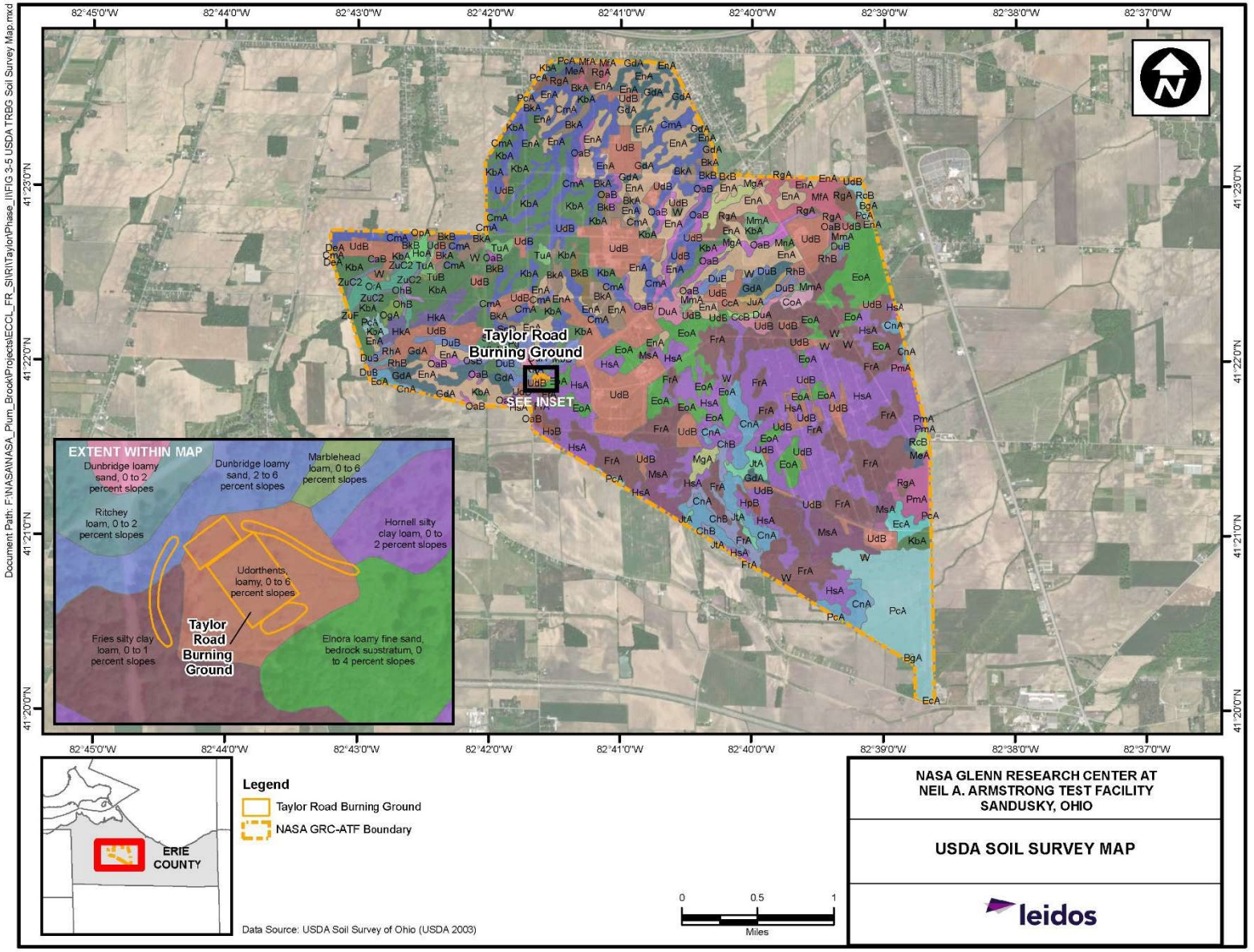

Figure 3-8. USDA Soil Survey Map

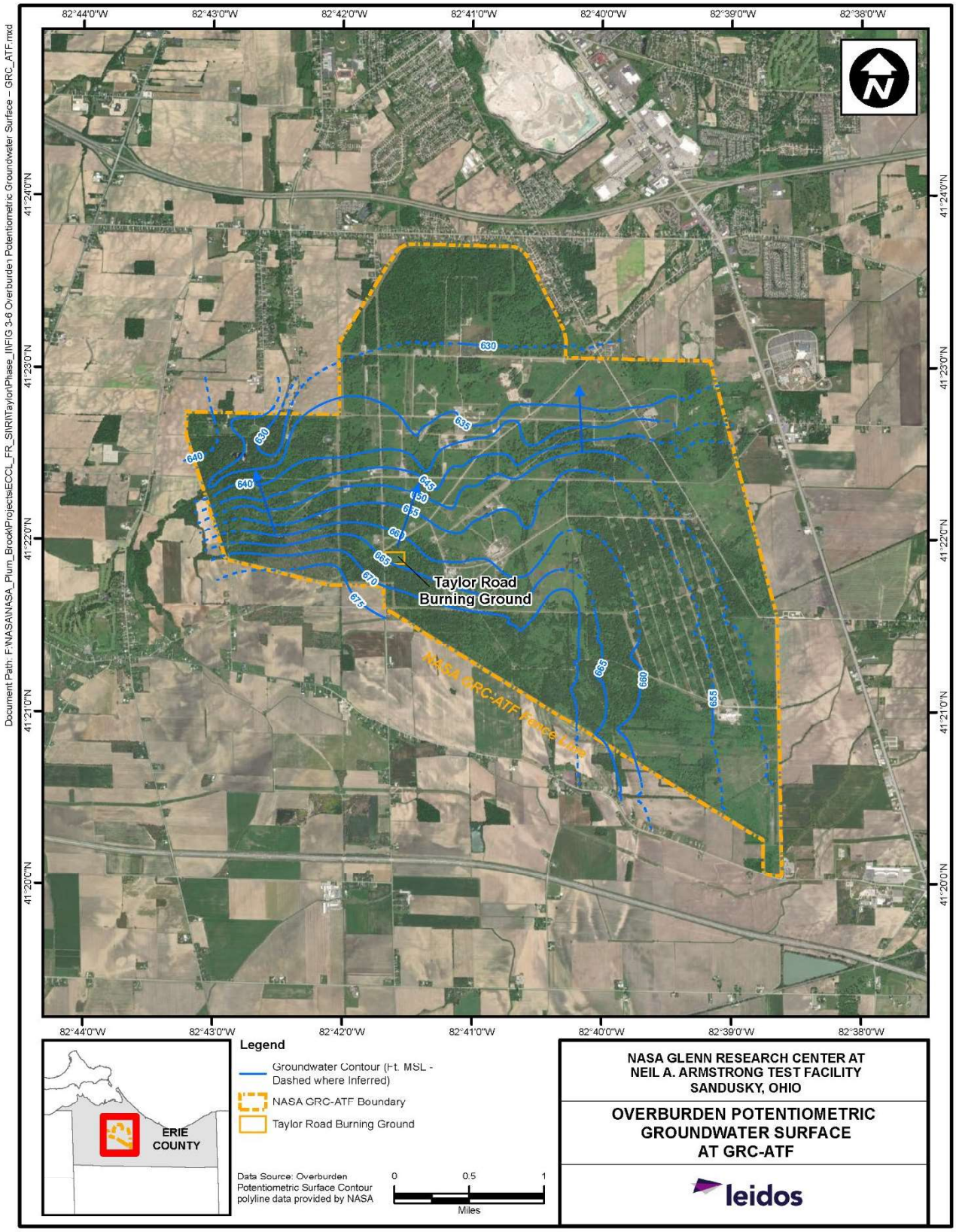

Figure 3-9. Overburden Potentiometric Groundwater Surface at GRC-ATF

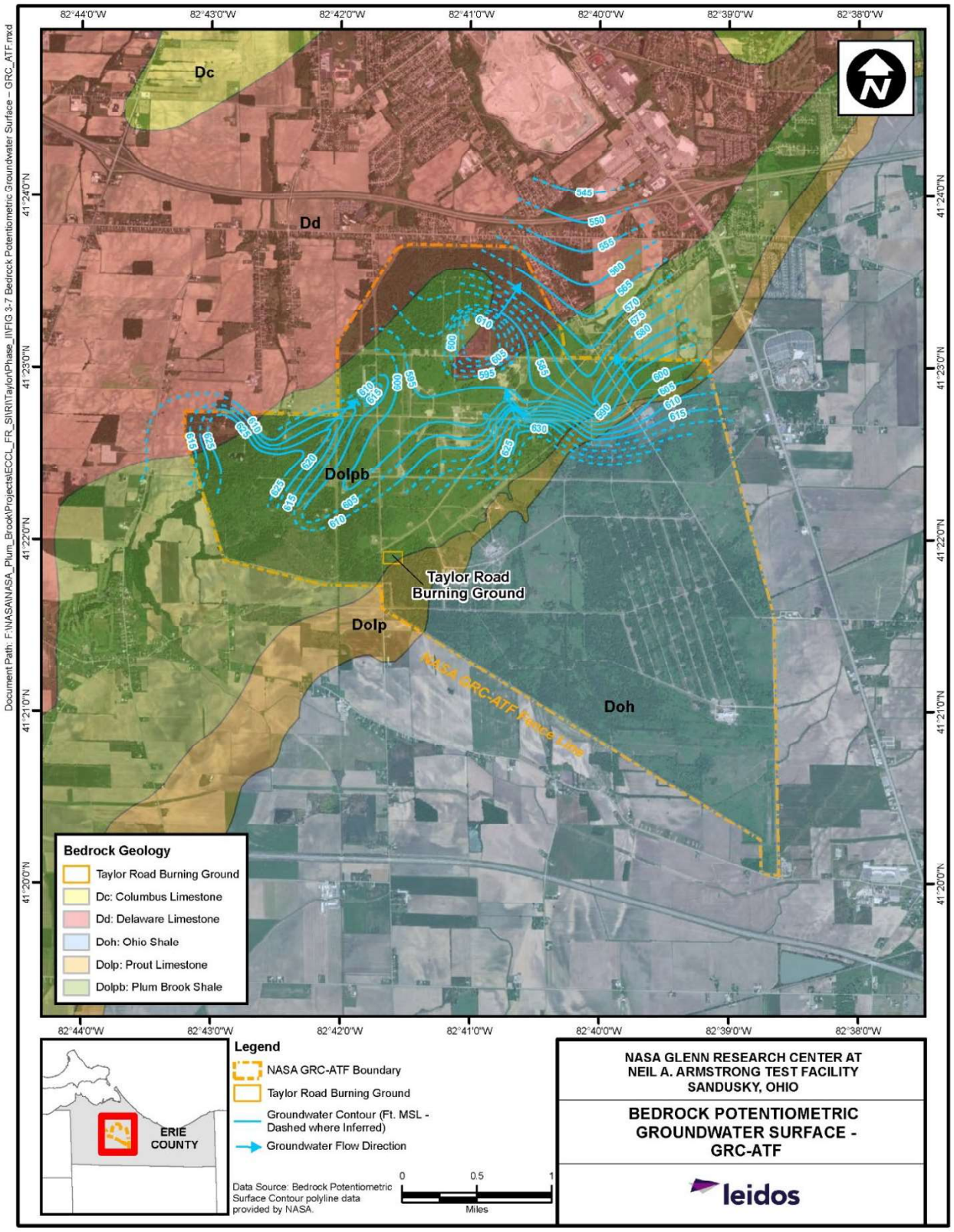

Figure 3-10. Bedrock Potentiometric Groundwater Surface – GRC-ATF

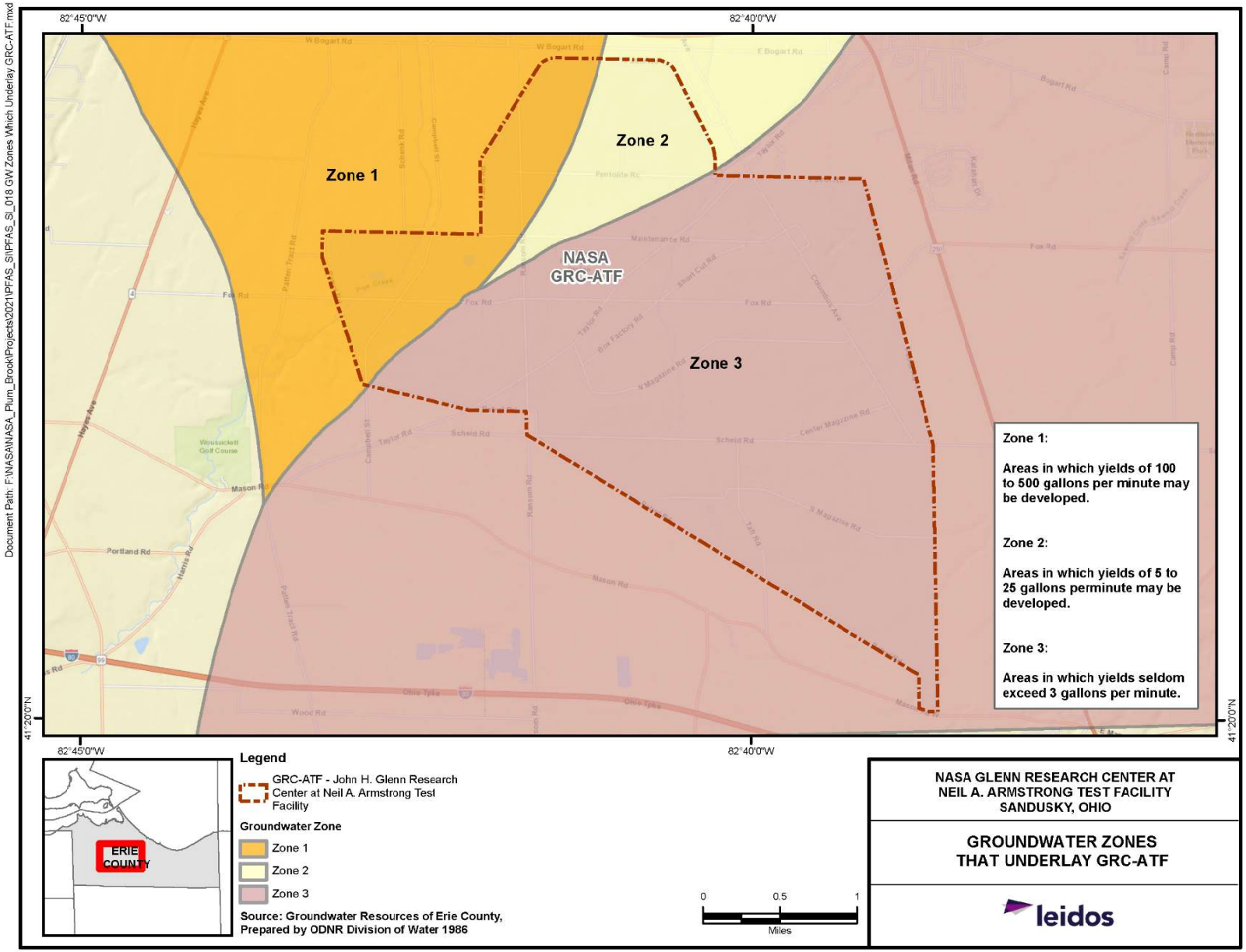

Figure 3-11. Groundwater Zones that Underlay GRC-ATF

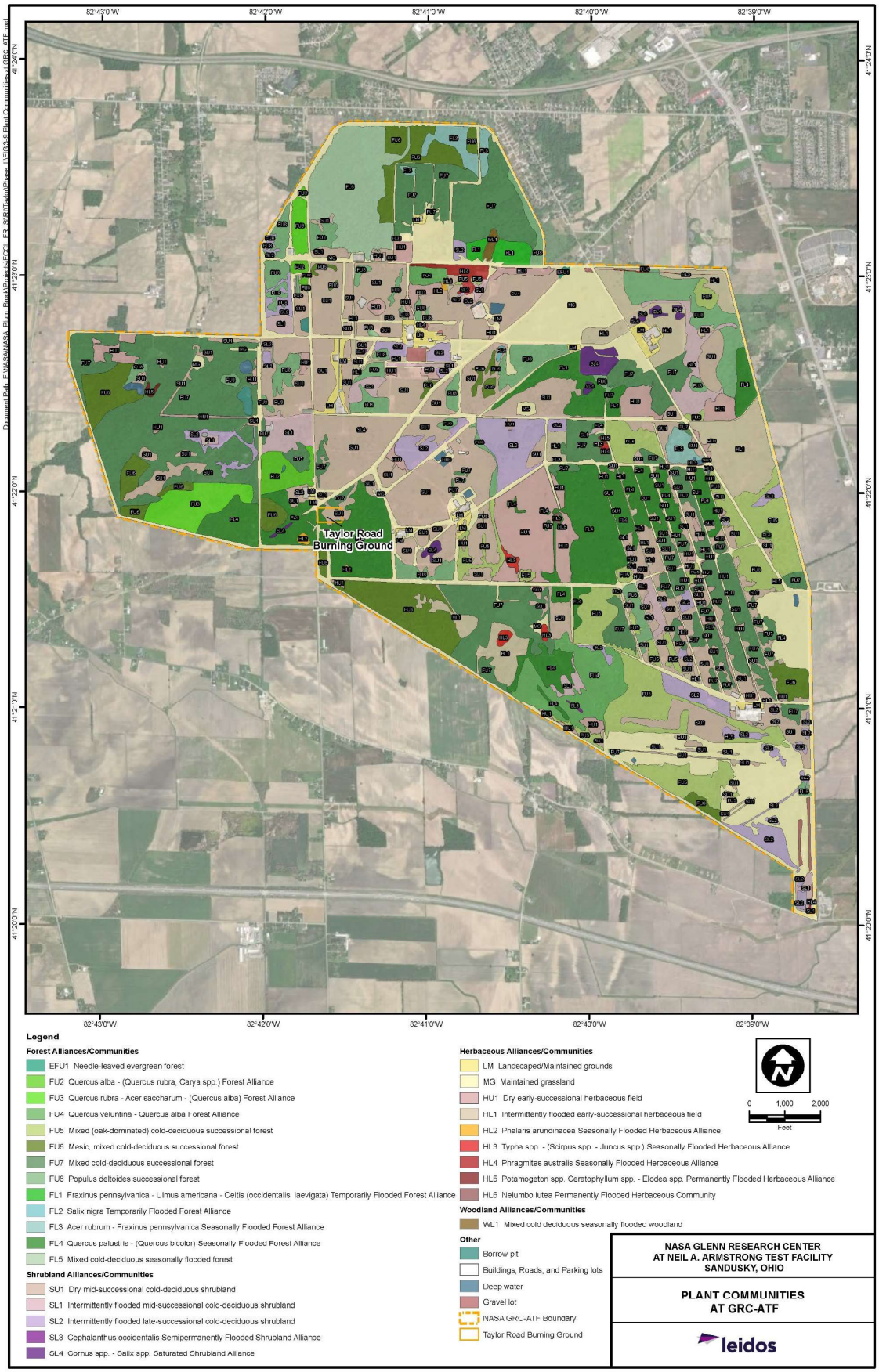

Figure 3-12. Plant Communities at GRC-ATF

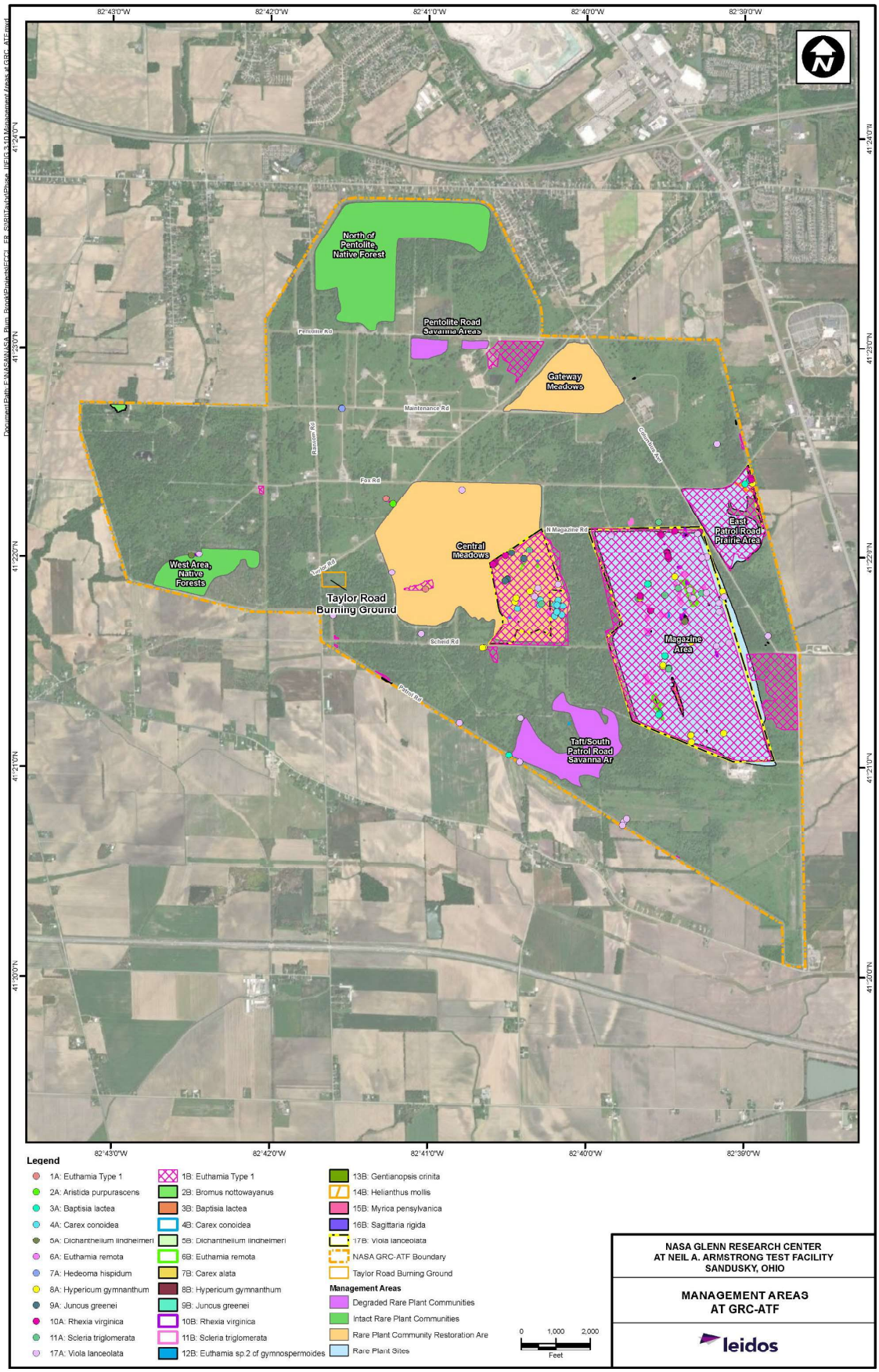

Figure 3-13. Management Areas at GRC-ATF

4. FIELD PROGRAM METHODS

4.1 INTRODUCTION

This section describes the methods used to perform the activities that Leidos completed during the Phase II RI conducted at GRC-ATF in accordance with the CERCLA process. The primary objective of this project was to implement the recommendations of the Phase I RI, which were to complete the Burning Grounds Phase II RI at TRBG, SRBG, and FRBG. The objective of the Phase II RI is to fully characterize the nature and extent and evaluate exposure risk to hazardous substances in groundwater, and if necessary, soil vapor, due to historical activities at the three burning grounds. All field activities were performed in accordance with the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020b).

Leidos conducted the following Phase II RI field activities at TRBG from April through December 2021:

- Utility clearance and general access/mobilization activities;
- Installation and development of five permanent groundwater monitoring wells (TRBG-MW01, TRBG-MW02, TRBG-MW03, TRBG-MW04, and TRBG-MW05);
- Two seasonal groundwater sampling events with each consisting of four of the five groundwater monitoring wells sampled for metals, explosives, VOCs, SVOCs, and PCBs (eight groundwater samples);
- Investigation-derived waste (IDW) management; and
- Civil survey.

4.2 DEVIATIONS FROM THE WORK PLAN

The following items were field-dictated or laboratory conditions that resulted in a deviation from the Phase *II RI Sampling and Analysis Plan* (Leidos 2020b):

- During the first sampling event, TRBG-MW04 was dry upon gauging on May 17, 2021, and again on May 24, 2021. After notifying the Project Manager, samples were not collected at TRBG-MW04.
- During the fall gauging event, TRBG-MW04 was dry and was not sampled during the November and December 2021 sampling activities.
- Tables 5-1 through 5-3 of the Sampling and Analysis Plan (Leidos 2020b) stated that samples were proposed for total metals analysis. Leidos issued a field change request to update the sampling plan to collect both total metals (unfiltered) and field filtered metals samples for analysis due to the turbid nature of the groundwater monitoring wells installed. NASA approved the field change request on May 20, 2021.

4.3 UTILITY LOCATE

Prior to any subsurface investigation, a NASA surveyor located and marked known underground utilities (e.g., water, gas, electric, and telephone). NASA provided an appropriate dig permit prior to the commencement of any intrusive field activities.

Focused geophysical surveys, including ground penetrating radar and ground conductivity meter (e.g., EM-31) were not planned as part of the Phase II RI.

4.4 PERMANENT MONITORING WELL INSTALLATION

During the Phase II RI field activities, five permanent monitoring wells were installed at TRBG. Monitoring well installations were performed in accordance with the Sampling and Analysis Plan (Leidos 2020b) and Ohio EPA's Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring – Chapter 7: Monitoring Well Design and Installation (Ohio EPA 2008). TTL Associates, Inc. conducted all hand augering, hollow-stem auger drilling, and environmental monitoring well installation activities.

The five permanent monitoring wells at TRBG were installed to identify the extent of hazardous substances in groundwater due to the historical activities at the burning ground. All monitoring wells were installed in the uppermost aquifer observed in the overburden. The monitoring wells were installed at each borehole using a Geoprobe® or hollow-stem auger rig with a 4.25-inch inside diameter auger. The wells are composed of pre-cleaned 2-inch-diameter Schedule 40 polyvinyl chloride (PVC) and are protected above ground in a 6-inch-diameter iron/steel casing that extends approximately 3 feet above grade. Well construction details for all monitoring wells are provided in Table 4-1, and the locations of the five wells are depicted in Figure 4-1. Lithology from each location was documented, with boring logs and well construction details being provided in Appendix A.

4.5 MONITORING WELL DEVELOPMENT

All five permanent monitoring wells were developed using the pump and surge method no sooner than 48 hours after the well installation. Each well was developed to ensure that fine-grained particles were removed from the well per Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring – Chapter 8: Monitoring Well Development, Maintenance, and Redevelopment* (Ohio EPA 2009b). Well development proceeded until all criteria outlined in the *Burning Grounds Phase II Remedial Investigation Sampling and Analysis Plan* (Leidos 2020b) were achieved. Final water quality parameters associated with groundwater monitoring well development are detailed in Table 4-2, and well development forms are included in Appendix A.

4.6 WATER LEVEL MEASUREMENT

Due to naturally occurring petroleum at portions of GRC-ATF, static water level measurements were made using an electronic oil-water interface probe. The depth to groundwater and petroleum (if any) were measured from a consistent measuring point, which were surveyed and permanently marked on each monitoring well. Since all probe cords used for measurement are incrementally marked at 0.01-foot intervals, water level measurements were recorded to the nearest 0.01 foot. The proper method for water level measurements were followed in accordance with the Phase II RI Sampling and Analysis Plan (Leidos 2020b). Groundwater elevations were measured to the nearest 0.01 foot in each monitoring well prior to sampling and during well purging. Comprehensive groundwater level measurements were collected at TRBG on May 17, and November 23, 2021. No petroleum was measured at the site. Groundwater elevation data are provided in Table 4-3. The groundwater potentiometric elevations for the November 2021 event are depicted in Figure 4-2. Groundwater flow at the site flows northeastward across the site. This is consistent with general groundwater flow direction at GRC-ATF.

Table 4–1. Monitoring Well Construction Details

Monitoring Well Identifier	Casing Type	Installation Date	Northing (ft)	Easting (ft)	Top of Casing Elevation (ft AMSL)	Casing Material	Screen Material	Filter Pack	Total Depth (ft bgs)	Screen Depth (ft bgs)
TRBG-MW01	Stick-up	5/3/21	618599.20	1915324.76	675.22	2-inch PVC	10 slot	#5 Sand	7.4	4.3 – 7.3
TRBG-MW02	Stick-up	4/30/21	618795.42	1915399.71	674.69	2-inch PVC	10 slot	#5 Sand	6.0	3.9 – 5.9
TRBG-MW03	Stick-up	5/3/21	618627.78	1915176.20	674.73	2-inch PVC	10 slot	#5 Sand	6.3	4.2 – 6.2
TRBG-MW04	Stick-up	4/29/21	618937.22	1915503.52	672.02	2-inch PVC	10 slot	#5 Sand	5.0	2.9 – 4.9
TRBG-MW05	Stick-up	4/29/21	618840,67	1915338.01	674.89	2-inch PVC	10 slot	#5 Sand	6.5	3.4 – 6.4

Notes: Horizontal datum: Ohio State Plane Coordinate System, using North American Datum of 1983 with units of English feet.
Vertical datum: North American Vertical Datum of 1988 with units of English feet.

AMSL = Above Mean Sea Level
bgs = Below Ground Surface
ft = feet
PVC = Polyvinyl Chloride

Table 4–2. Well Development Final Water Quality Parameters

Monitoring Well Identifier	Development Date[b]	Volume Purged (gal)	Temperature (°C)	Specific Conductivity (mS/cm)	pH (S.U.)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	ORP (mV)
TRBG-MW01	5/11/21	5.0	8.62	0.502	7.96	800	2.06	1
TRBG-MW02	5/11/21	2.0	9.27	0.410	7.55	637	4.44	207
TRBG-MW03[a]	5/11/21	1.0	8.89	3.42	7.93	800	3.3	126
TRBG-MW04	5/10/21	1.75	12.46	0.314	8.02	458	4.08	86
TRBG-MW05	5/10/21	5.75	9.75	0.168	7.27	1,000	2.98	148

[a]Well frequently went dry; sediment removed and a minimum of five well volumes purged; well is considered developed per the Sampling and Analysis Plan.
[b]Dates shown are inclusive of all dates during well development; measurements are from final well development measurement.

NTU = Nephelometric Turbidity Unit
ORP = Oxidation-Reduction Potential
NTU = Nephelometric Turbidity Unit
ORP = Oxidation-Reduction Potential
S.U. = Standard Unit

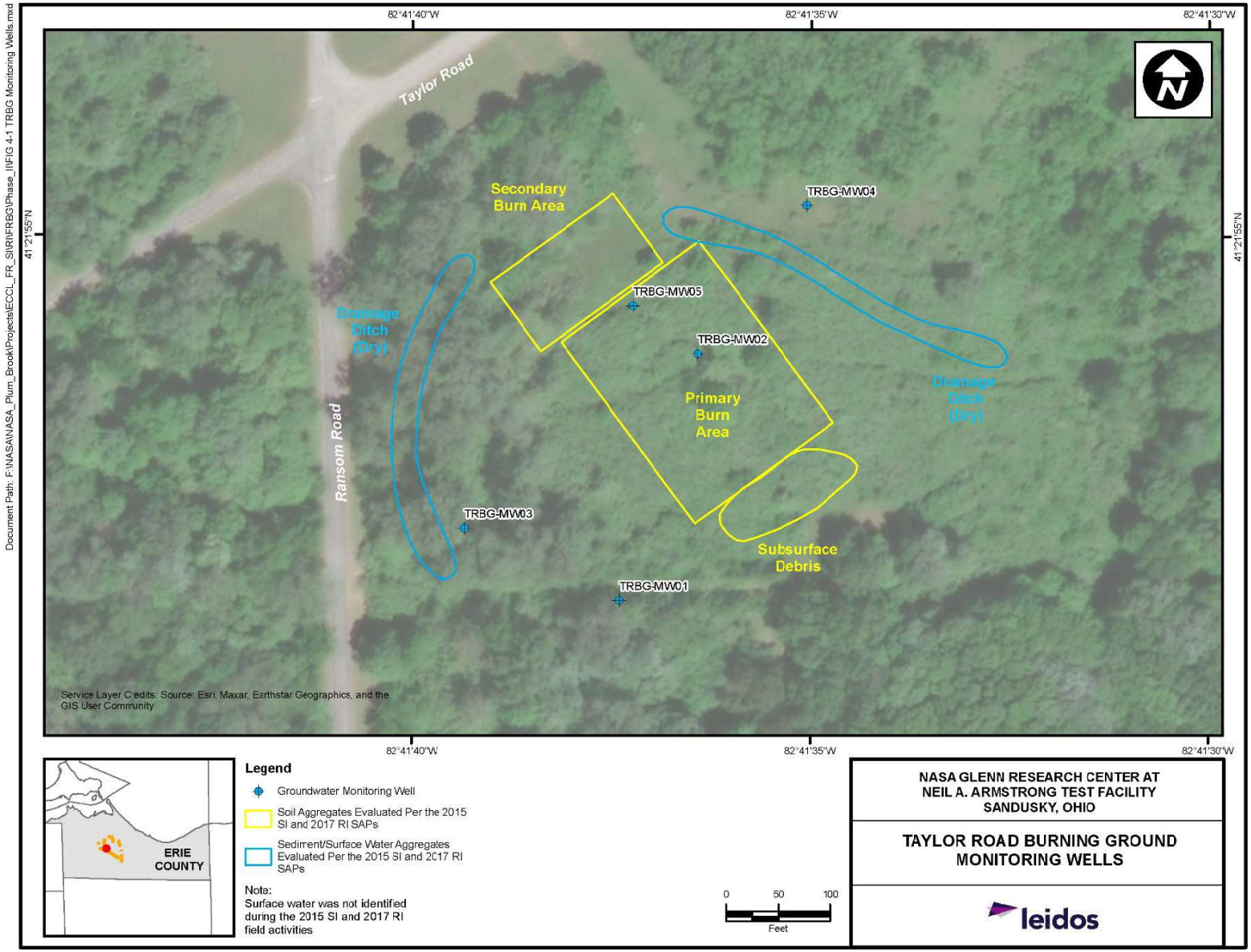

Figure 4–1. Taylor Road Burning Ground Monitoring Wells

Table 4–3. Groundwater Elevation Data

Monitoring Well Identifier	TOC Elevation (ft AMSL)	Depth to Water (ft BTOC)		Groundwater Elevation (ft AMSL)	
Date		**5/17/21**	**11/23/21**	**5/17/21**	**11/23/21**
TRBG-MW01	675.22	5.55	7.90	669.67	667.32
TRBG-MW02	674.69	4.84	7.33	669.85	667.36
TRBG-MW03	674.73	4.55	6.64	670.18	668.09
TRBG-MW04	672.02	DRY	DRY	DRY	DRY
TRBG-MW05	674.89	5.21	7.71	669.68	667.18

Notes: Vertical datum: North American Vertical Datum of 1988 with units of English feet.

AMSL = Above Mean Sea Level
BTOC = Below Top of Casing
ft = feet
TOC = Top of Casing

4.7 GROUNDWATER SAMPLING

Groundwater monitoring wells were sampled using the low-flow drawdown method in accordance with Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring – Chapter 10: Ground Water Sampling* (Ohio EPA 2012). The purpose of the low-flow sampling procedure is to obtain groundwater samples that are representative of the source from which they are collected and to minimize sampler exposure to potential groundwater contaminants as well as minimize the volume of IDW.

Prior to purge and sample activities, static water level measurements were made using an oil-water interface probe using procedures outlined in Section 4.6. Each monitoring well was purged using low-flow techniques prior to sample collection using a bladder pump. Teflon® materials were not used in low-flow sampling (i.e., tubing, bladder) as the groundwater monitoring wells may be used for future sampling that is sensitive to the use of fluoro-polymer products. The pump intake was positioned near the middle of the screened interval of the well to ensure that standing water is removed and fresh formation water is drawn into the well. Low-flow purging techniques were used in conjunction with a flow-through cell to measure the following water quality parameters: pH, temperature, specific conductivity, dissolved oxygen (DO), oxidation reduction potential (ORP), and turbidity. Water quality measurements and water level drawdown were recorded every 5 minutes. A flow rate that ensures minimal drawdown of the water level is typically 100 to 500 mL/min but was adjusted accordingly to minimize drawdown. Purging was considered complete when the indicator parameters of pH, temperature, conductivity, DO, ORP, and turbidity have stabilized for three successive measurements. Final water quality parameters associated with groundwater monitoring well sampling are detailed in Table 4-4. Copies of the groundwater purge and sample forms are provided in Appendix A.

Following completion of monitoring well purging and stabilization, samples were collected in laboratory-supplied containers using clean, disposable nitrile gloves and immediately cooled with ice to 4°C (±2°C). The samples were submitted to Eurofins/Test America Laboratory in Canton, Ohio for total and dissolved metals VOCs, SVOCs, and PCBs analyses. Explosives samples were submitted to Eurofins/Test America Laboratory in Denver, Colorado.

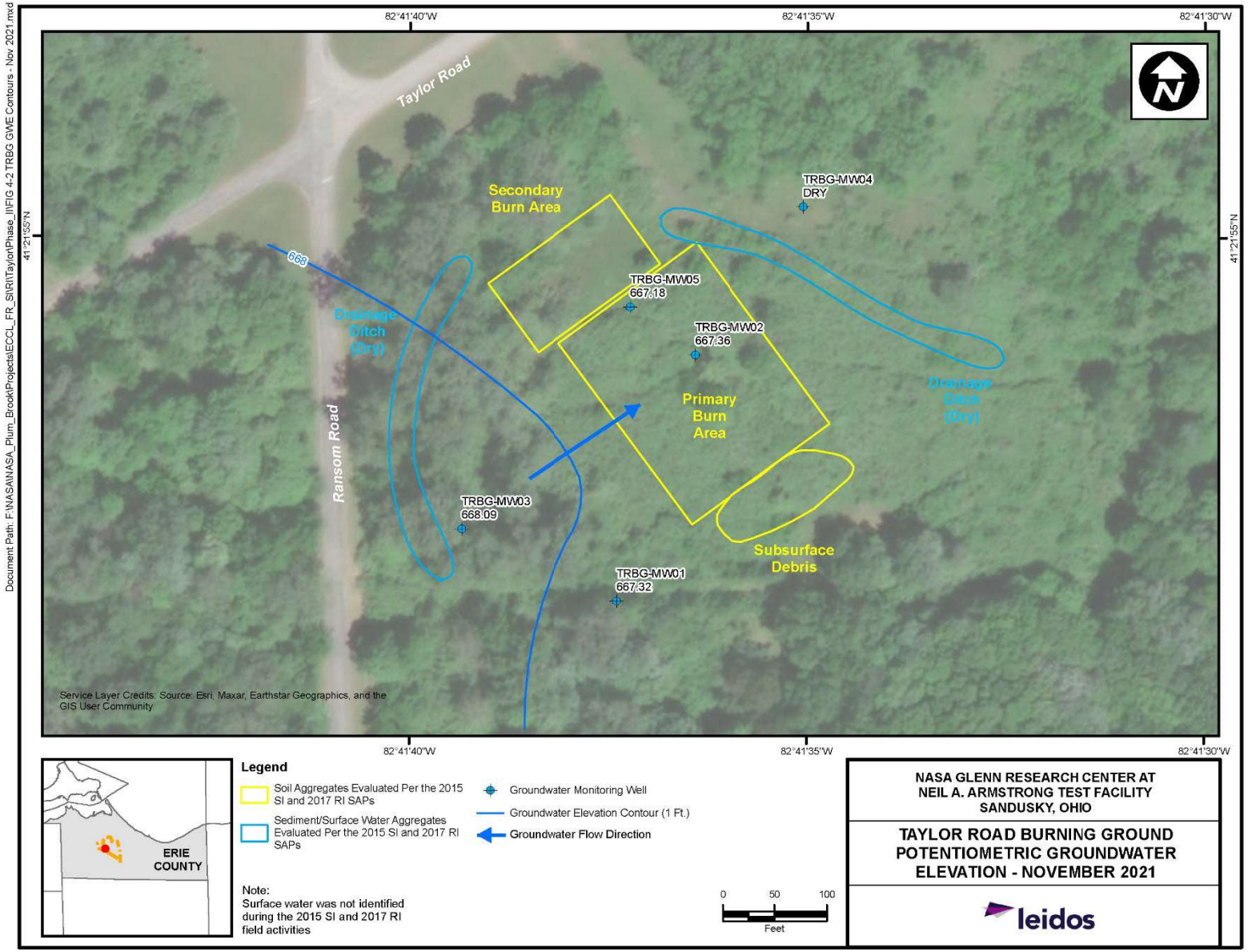

Figure 4–2. TRBG Potentiometric Groundwater Elevation – November 2021

Table 4–4. Monitoring Well Sampling Final Water Quality Stabilization Parameters

Monitoring Well Identifier	Sampling Date	ORP (mV)	Temperature (°C)	pH (S.U.)	Specific Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Turbidity (NTU)
TRBG-MW01	5/25/21	-77	17.17	7.16	0.659	0.91	137
TRBG-MW02	5/24/21	175	20.97	6.92	0.404	2.98	141
TRBG-MW03	5/25/21	-33	14.2	7.85	3.33	2.81	2.2
TRBG-MW05	5/24/21	121	20.27	6.83	0.079	5.06	88.7
TRBG-MW01[a]	12/1/21	-5	10.73	7.06	0.487	4.36	>1,000
TRBG-MW02[a]	12/1/21	189	12.08	6.58	0.461	6.06	>1,000
TRBG-MW03[a]	11/29/21	112	8.77	7.09	3.25	4.78	>1,000
TRBG-MW05[a]	12/1/21	42	9.44	7.02	0.160	6.46	>1,000
Resample (6/29/21)							
TRBG-MW01	6/29/21	-101	18.31	7.5	0.465	0.8	28.5
TRBG-MW02	6/29/21	206	21.56	6.6	0.475	1.64	29
TRBG-MW03	6/29/21	-59	19.82	7.44	3.51	1.81	7.2
TRBG-MW05	6/19/21	80	29.28	6.18	0.124	0.73	37.1

[a]Well was purged dry and sample was collected within 24 hours; water quality parameters are from the last measurement before dryness.
[b]TRBG-MW04 was dry for both sampling events.

NTU = Nephelometric Turbidity Unit
ORP = Oxidation-Reduction Potential
S.U. = Standard Unit

4.8 DECONTAMINATION

Equipment and sample collection tools used during sampling activities were decontaminated to prevent potential chemical cross-contamination. Decontamination of drill rig equipment was conducted within a temporary decontamination pad designed so that all decontamination liquids were contained from the surrounding environment and could be recovered for disposal as IDW per the Sampling and Analysis Plan (Leidos 2020b). Decontamination of stainless-steel tools and equipment used during sampling activities (i.e., water level, bladder pump) were completed per the Sampling and Analysis Plan (Leidos 2020b).

4.9 CIVIL SURVEY

Leidos coordinated a survey of the groundwater monitoring wells with NASA's state licensed surveyor. The surveyor provided horizontal and vertical coordinates for site monitoring wells. The horizontal coordinates were surveyed to within 0.1 foot. Horizontal coordinates are in the Ohio State Plane coordinate system. The vertical coordinates are based on North American Datum of 1983 (NAD 83) (elevation) and were surveyed to within 0.01 foot for well casings. The well coordinates of the five new wells are detailed in Table 4-1, and the survey report is provided in Appendix B.

4.10 INVESTIGATION-DERIVED WASTE MANAGEMENT

IDW generated during performance of the investigation were containerized, managed, and disposed of in accordance with the Sampling and Analysis Plan (Leidos 2020b). The final waste manifests for the solid IDW generated during well installation and the liquid IDW generated during the fall 2021 groundwater sampling event are provided in Appendix C.

Eleven drums of liquid IDW were generated during the May/June 2021 SRBG, TRBG, and FRBG RIs and GRC-ATF PFAS SI field activities. Per direction of NASA GRC-ATF Waste Management, all IDW drums were transported to the designated drum staging area located at Building 9206. The liquid IDW was

classified as non-hazardous, non-regulated waste. Following NASA Headquarters guidance, liquid IDW was treated with a granulated activated carbon (GAC) treatment system on November 11, 2021. Confirmation samples were collected post-treatment to confirm that the treatment was successful in removing PFAS contamination. On December 2, 2021, the city of Sandusky and Erie County provided NASA approval to discharge the post-treatment water to sanitary sewer. On December 3, 2021, NASA and Waste Management completed discharge of the post-treatment water to sanitary sewer. A post-treatment confirmation sample was collected from the spent GAC. The post treatment GAC sample exhibited four minor PFAS detections; all other PFAS were non-detect. Currently, NASA has eight 55-gallon drums of spent GAC onsite at Building 9206. NASA plans to use the spent GAC for future treatment events at GRC-ATF.

5. DATA EVALUATION

5.1 DATA USE

The Phase II RI/FS Sampling and Analysis Plan (Leidos 2020b) implemented USEPA's DQO process to ensure that, upon completion of this RI, enough data of sufficient quality and usability would be collected to support the groundwater nature and extent of contamination and HHRA.

RI analytical data were sampled, analyzed, verified, and validated in accordance with the protocols specified in the Phase II Sampling and Analysis and Uniform Federal Policy-Quality Assurance Project Plan (Leidos 2020b). Table 5-1 lists the samples collected during the Phase II RI and how they are used in this RI Report. The data quality assessment for the RI data is included in Appendix F and documents the quality and usability of the RI analytical data. The assessment noted that some data were flagged or qualified due to minor analytical issues, but this had limited impact on the data quality. In conclusion, the results are considered usable to support evaluations in this RI, including the nature and extent evaluation and HHRA.

5.2 ENVIRONMENTAL MEDIA

5.2.1 Groundwater

The scope of the Phase II RI Report includes a full evaluation of groundwater. Five permanent monitoring wells were installed in April to effectively characterize the downgradient and source area groundwater conditions. During the spring sampling event, four groundwater samples were collected and analyzed for metals, explosives, PCBs, SVOCs, and VOCs. Four groundwater samples were collected for the fall sampling event, testing for metals, explosives, PCBs, SVOCs, and VOCs. Due to the low groundwater yield during the sampling event, the samples volume of the entire analytical suite was collected on two separate days for TRBG-MW02, TRBG-MW03, and TRBG-MW05. Well TRBG-MW04 was not sampled in both the spring and fall due to insufficient groundwater for sample collection. Groundwater data are evaluated site wide and not by EUs like the soils data.

5.2.2 Soil Vapor

Due to the nature of the site (former burning ground), Ohio EPA correspondence stated that if VOCs were not detected as potential COCs for the site, then assessing the soil vapor pathway would not be triggered (Ohio EPA 2019). Vapor-forming chemicals were not detected in subsurface soils at TRBG as part of the Phase I RI. Groundwater tested in Phase II of the RI showed different results. All four monitoring wells samples had low concentrations of VOCs. A desktop evaluation determined that installation of vapor points and collection of soil vapor samples were not warranted at TRBG.

5.3 DATA QUALITY

The data used in this Phase II RI Report were verified and validated using the methodology described in the Sampling and Analysis Plan (Leidos 2020b). Analytical results were loaded into a database. Data qualified during the validation as rejected ("R") were not used in the risk assessments. During the spring sampling event, metals were requested to be analyzed by analytical method SW846 6020, but the laboratory analyzed the metals by analytical method SW846 6010. Total metals were reanalyzed by analytical method SW846 6020, but the filtered metals could not be reanalyzed by analytical method SW846 6020 and results were reported from analytical method SW846 6010. In addition, during the spring sampling event, all explosive samples and the VOC sample for TRBG-MW03 were not analyzed within the sampling method holding time. The samples were recollected on June 29, 2021, for the specific analysis and analyzed.

However, some compounds were not reported in the second analysis; therefore, results for the missing compounds were reported from the samples analyzed out of holding time (initial sample). All results were properly flagged. Complete data quality assessments are provided in Appendix F.

5.3.1 Background Evaluation

Background screening levels for naturally occurring inorganics from the *2004 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio* (Shaw 2005; herein referred to as the 2004 Groundwater Data Summary Report) was used for comparison for determining site-related chemicals (SRCs). An analyte was considered an SRC only if its maximum concentration exceeded the background level.

5.3.2 Risk-Based Comparison

Data screening consisted of comparing site concentrations to risk-based values. The results of the data screens were used to evaluate the nature and extent of site-related contamination and for HHRA. Data are compared to the most recent (May 2022) USEPA tap water RSLs available at the time of this report submission at a target risk (TR) equal to 1E-06 and a hazard quotient (HQ) equal to 0.1. Data were also compared to the most current MCL if available.

Table 5–1. Data Use Table

Sample Location	Sample ID	Date	Sampling Event	QC	N&E	F&T	HHRA	ERA	Analysis Suite
TRBG-MW01	TRBGGW1001	05/25/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered, PCBs, SVOCs, VOCs
TRBG-MW01	TRBGGW1001-R	06/29/2021	2021 Phase II RI Resample	--	X	X	X	--	Explosives
TRBG-MW02	TRBGGW1002	05/24/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered, PCBs, SVOCs, VOCs
TRBG-MW02	TRBGGW1002-R	06/29/2021	2021 Phase II RI Resample	--	X	X	X	--	Explosives
TRBG-MW03	TRBGGW1003	05/25/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered, PCBs, SVOCs, VOCs
TRBG-MW03	TRBGGW1003-R	06/29/2021	2021 Phase II RI Resample	--	X	X	X	--	Explosives, VOCs
TRBG-MW05	TRBGGW1005	05/24/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered, PCBs, SVOCs, VOCs
TRBG-MW05	TRBGGW1005-R	06/29/2021	2021 Phase II RI Resample	--	X	X	X	--	Explosives
TRBG-MW01	TRBGGW1006	12/01/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
TRBG-MW02	TRBGGW1007A	12/01/2021	2021 Phase II RI	--	X	X	X	--	PCBs, SVOCs, VOCs
TRBG-MW02	TRBGGW1007B	12/02/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered), Explosives
TRBG-MW03	TRBGGW1008	11/30/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered), Explosives, PCBs, SVOCs, VOCs
TRBG-MW05	TRBGGW1010A	12/01/2021	2021 Phase II RI	--	X	X	X	--	PCBs, SVOCs, VOCs
TRBG-MW05	TRBGGW1010B	12/02/2021	2021 Phase II RI	--	X	X	X	--	TAL Metals (Filtered and unfiltered), Explosives

Note:
Quality control samples are field duplicates

ERA = Ecological Risk Assessment
F&T = Fate and Transport
HHRA = Human Health Risk Assessment
ID = Identification
N&E = Nature and Extent
PCB = Polychlorinated Biphenyl
QC = Quality Control
RI = Remedial Investigation
SVOC = Semivolatile Organic Compound
TAL = Target Analyte List
VOC = Volatile Organic Compound

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6. NATURE AND EXTENT OF CONTAMINATION

This section evaluates the nature and extent of groundwater contamination at TRBG. The evaluation discusses the nature and extent of SRCs in groundwater at TRBG, using analytical data results obtained during the 2021 Phase II RI. Nature and extent of soil contamination at TRBG is presented in the Phase I RI Report (Leidos 2018a).

6.1 CONTAMINANT EVALUATION METHODOLOGY

The following subsections describe the methodology to screen available data from groundwater to determine the SRCs.

6.1.1 Site-Related Chemical Evaluation

The purpose of selecting SRCs is to identify those chemicals that may be present as a result of past site activities and may be of concern to human health. The first step in SRC identification involves evaluating the quality of the analytical data to ensure their acceptability for use. Additional steps involve eliminating chemicals that are considered essential nutrients and comparing the analytical concentrations to GRC-ATF background concentrations.

Identification of SRCs begins with all chemicals detected in an exposure medium (e.g., groundwater). Detected chemicals are eliminated as SRCs based on the following criteria.

Data Quality Assessment – Analytical results were reported by the laboratory in electronic form and loaded into a database. Site data were then extracted from the database so that only one result is used for each station and depth sampled. If laboratory reanalysis or dilutions are performed, only the one appropriate result is used based on data review and validation. Quality control (QC) data, such as sample splits, are not included in the determination of SRCs. However, if a field duplicate was collected, the field duplicate result was averaged with the primary result to provide the one result. Samples rejected in the validation process are excluded from the data set.

Essential Nutrients – Chemicals that are considered essential nutrients (i.e., calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the human food supply and are often added to foods as supplements. USEPA recommends these chemicals not be evaluated provided they are present at low concentrations (i.e., only slightly above naturally occurring levels) and toxic only at high doses (i.e., much higher than those that could be associated with contact at the site) (USEPA 1989). Essential nutrients were not carried forward as SRCs.

Background – Background screening levels for naturally occurring inorganics are from the 2004 Groundwater Data Summary and Evaluation Report (Shaw 2005). An analyte was considered an SRC only if its maximum concentration exceeded the background level.

To support the evaluation of nature and extent of contamination, SRC concentrations were compared to the tap water RSL at a target HQ of 0.1 or TR of 1E-06. Appendix E contains analytical data from the 2021 Phase II RI. Table 6-1 presents the data summary tables of detected chemicals in groundwater. If a chemical is not detected, it is not presented in the summary table. Figure 6-1 presents chemicals that exceed background concentrations or tap water RSLs of an HQ of 0.1 and a TR of 1E-06. If a chemical did not have a background concentration or screening level, the chemical was not presented in Figure 6-1. The following subsections discuss the exceedances.

6.1.2 Chemical Contamination

Eight groundwater samples were collected at TRBG: four during the spring sampling event and four during the fall sampling event. The sampling suite associated with groundwater included TAL metals (filtered and unfiltered), explosives, VOCs, SVOCs, and PCBs.

In groundwater, 22 metals, 5 SVOCs (1-methylnaphthalene; 2-methylnaphthalene; bis[2-ethylhexyl]phthalate; caprolactam; and naphthalene), and 7 VOCs (acetone; 1,1,1-trichloroethane (TCA); methylene chloride; tetrachloroethene [PCE]; toluene; trichloroethene[TCE]; and cis-1,2-dichloroethene [DCE]) were detected. No explosives or PCBs were detected. Table 6-1 presents the data screening results for groundwater at TRBG.

Only one of the five SVOCs (bis[2-ethylhexyl]phthalate) and 12 of the 22 metals detected in ground at TRBG exceeded their respective background concentrations and/or the tap water RSL at an HQ of 0.1 and a TR of 1E-06.

Aluminum – Total aluminum was detected in six of the eight samples and exceeded the tap water RSL of 2,000 micrograms per liter (µg/L) at all four locations during the fall sampling event; TRBG-MW01 (5,400 µg/L), TRBG-MW02 (18,000 µg/L), TRBG-MW03 (14,000 µg/L), and TRBG-MW05 (19,000 µg/L). Dissolved aluminum was detected in only three of the eight samples, and all concentrations were below the tap water RSL and background concentration.

Antimony – Total antimony was detected in four of the eight samples and exceeded the tap water RSL of 0.78 µg/L at three locations during the fall sampling event. All results were estimated concentrations and included TRBG-MW02 (1.2 µg/L), TRBG-MW03 (1.5 µg/L), and TRBG-MW05 (1.9 µg/L). All detections were below the USEPA MCL of 6.0 µg/L. Only one of the eight sample results had an estimated detected concentration (TRBG-MW03 at 0.75 µg/L in fall 2021) for dissolved aluminum, and the concentration was below the tap water RSL; however, the detections limits were above the tap water RSL.

Arsenic – Total arsenic was detected in five of the eight samples and exceeded the tap water RSL of 0.052 µg/L at all locations; however, only two locations were higher than the background screening level of 7.4 µg/L and the MCL of 10.0 µg/L: TRBG-MW02 (15 µg/L) and TRBG-MW05 (19 µg/L). Dissolved arsenic was not detected, but the detection limit was higher than the tap water RSL.

Cadmium – Total cadmium was detected in three of the eight samples and exceeded the tap water RSL of 0.18 µg/L during the winter sampling event at TRBG-MW02 (0.44 µg/L), TRBG-MW03 (0.51 µg/L), and TRBG-MW05 (0.77 µg/L). All detects were below the USEPA MCL of 5.0 µg/L. After filtration, cadmium was detected in only one sample, and the detected cadmium concentration also exceeded the tap water RSL at 0.2 µg/L for TRBG-MW03. In the samples where total or dissolved cadmium was not detected, the detection limit was greater than the tap water RSL.

Cobalt – Total cobalt was detected in all eight samples, and six results exceeded the tap water RSL of 0.6 µg/L. Total cobalt only exceeded the background concentration of 12.1 µg/L during the winter sampling event at TRBG-MW02 (23 µg/L), TRBG-MW03 (15 µg/L), and TRBG-MW05 (18 µg/L). All detects were below the USEPA MCL of 5.0 µg/L. After filtration, none of the sample results exceeded the background concentration.

Copper – Total copper was detected in all eight samples and exceeded the background concentration of 19.8 µg/L in three samples; however, only one sample exceeded the tap water RSL of 80 µg/L during the winter sampling event at TRBG-MW03 (81 µg/L). All detects were below the USEPA MCL of 1,300 µg/L.

After filtration, only three samples had detected concentrations of copper; all were below the background concentration.

Iron – Total iron was detected in six of the eight samples and exceeded the tap water RSL of 1,550 µg/L in five samples: TRBG-MW01 (1,900 µg/L in May 2021 and 12,000 µg/L in December 2021); TRBG-MW02 (34,000 µg/L in December 2021), TRBG-MW03 (15,000 µg/L in November 2021), and TRBG-MW05 (49,000 µg/L) in December 2021. After filtration, iron was detected in seven samples. Only TRBG-MW01 exceeded the tap water RSL at 2,100 µg/L in May and 1,600 µg/L in December 2021.

Lead – Total lead was detected in six of the eight samples and exceeded the background concentration and MCL of 15 µg/L in three of those samples. Exceedances were found in TRBG-MW02 (30 µg/L), TRBG-MW03 (20 µg/L), and TRBG-MW05 (25 µg/L) during the fall sampling event. None of the dissolved lead sample results exceeded screening criteria.

Manganese – Total manganese was detected in seven of the eight samples. Six of the detects exceeded the tap water RSL of 10 µg/L, and three (TRBG-MW01 at 650 µg/L, TRBG-MW02 at 2,000 µg/L, and TRBG-MW05 at 1,100 µg/L in December 2021) exceeded the background concentration of 636 µg/L. After filtration, eight samples detected manganese, with six exceeding the tap water RSL, but only one (TRBG-MW02 at 1,100 µg/L) exceeded the background concentration.

Nickel – Total nickel was detected in seven of the eight samples. Five of the detections exceeded the background concentration of 8.6 µg/L, but only three locations (TRBG-MW02 at 69 µg/L, TRBG-MW03 at 51 µg/L, and TRBG-MW05 at 56 µg/L) during the fall sampling event exceeded the tap water RSL pf 39 µg/L. After filtration, nickel was detected in six samples; however, none exceeded the tap water RSL.

Thallium – Total thallium was detected in three of the eight samples, and all exceeded the tap water RSL of 0.02 µg/L. The three sample locations included TRBG-MW01 (0.49 µg/L), TRBG-MW02 (0.62 µg/L), and TRBG-MW05 (0.78 µg/L) and all occurred in the fall sampling event. None of the spring 2021 sample results exceeded the tap water RSLs; however, the detection limit was greater than the tap water RSL. Thallium was not detected in any of the filtered samples, but the detection limit was greater than the tap water RSL of 0.02 µg/L.

Vanadium – Total vanadium was detected in six of the eight samples, and four samples had concentrations higher than the tap water RSL of 8.6 µg/L. The four samples included TRBG-MW01 at 15 µg/L, TRBG-MW02 at 41 µg/L, TRBG-MW03 at 33 µg/L, and TRBG-MW05 at 44 µg/L during the fall sampling event. Vanadium was not detected in any of the filtered samples, but the detection limit was greater than the tap water RSL of 8.6 µg/L.

Bis(2-ethylhexyl)phthalate – Bis(2-ethylhexyl)phthalate was only detected in one of the eight samples (TRBG-MW03) at a concentration of 19 µg/L in November 2021 and exceeds the tap water RSL of 5.6 µg/L.

Methylene Chloride – Methylene chloride was detected in three of the eight samples with a maximum concentration of 22 µg/L. All three detections during the spring sampling event at TRBG-MW01 (22 µg/L), TRBG-MW02 (14 µg/L), and TRBG-MW05 (22 µg/L) exceed the tap water RSL of 11 µg/L and MCL of 5 µg/L.

PCE – PCE was only detected at TRBG-MW01 during both sampling events at concentrations of 3.3 and 5 µg/L. Only the fall concentration of 5 µg/L exceeded the tap water RSL of 4.1 µg/L but is at the MCL of 5 µg/L.

TCE – TCE was detected in three of the eight samples; all three detections were from the spring sampling event. The three TCE detections at TRBG-MW01 (0.3 µg/L), TRBG-MW02 (0.46 µg/L), and TRBG-MW05 (0.31 µg/L) exceeded the tap water RSL of 0.28 µg/L but not the MCL of 5 µg/L.

cis-1,2-DCE – cis-1,2-DCE was only detected in one of the eight samples at TRBG-MW02 in the fall sampling event at a concentration of 6.6 µg/L and exceeds the tap water RSL of 3.6 µg/L but not the MCL of 70 µg/L.

6.2 CONCLUSIONS

During the Phase I RI for TRBG, the site was divided into four EUs to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the Primary Burn Area, Secondary Burn Area, Drainage Area, and Debris Area. The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the EU source area. Conservative transport modeling indicated 10 chemicals may be present in the groundwater table beneath their respective sources at concentrations exceeding MCLs/RSLs. However, after a qualitative assessment of the sample results, it was concluded that two contaminant migration chemicals of concern (CMCOCs) would first be assessed at the site. The two initial CMCOCs included hexachloroethane and naphthalene. Hexachloroethane was not detected in groundwater at TRBG; however, the detection limits (1.0 and 1.1 µg/L) were greater than the tap water RSL of 0.33 µg/L. Naphthalene was only detected in one sample at an estimated concentration of 0.12 µg/L at TRBG-MW001 in the fall of 2021.

Only 3 of the 12 metals (cadmium, iron, and manganese) exceeded their respective background concentrations and/or the tap water RSL in groundwater at TRBG in both the total and dissolved samples. Cadmium only exceeded the screening criteria for both total and dissolved cadmium at one location in the fall of 2021 at TRBG-MW03. Total and dissolved iron exceeded screening criteria at TRBG-MW01 at concentrations of 2,100 µg/L in May and 1,600 µg/L in December 2021. Only one sample exceeded the screening criteria in the fall sampling event at TRBG-MW02 at a concentration of 1,100 µg/L. The metal detections appear to be seasonal since most screening criteria exceedances occurred in the fall when less groundwater was available.

Bis(2-ethylhexyl)phthalate was the only SVOC detected above the screening criteria in the November 2021 sample from TRBG-MW03. VOCs detected above screening levels were limited to the chlorinated solvents PCE; TCE; cis-1,2-DCE; and methylene chloride. Of the four VOCs, only methylene chloride exceeded both its tap water RSL and MCL at TRBG-MW01, TRBG-MW02, and TRBG-MW05.

The groundwater in the overburden is in discontinuous pockets during dry time periods, as evidenced by TRBG-MW04 being dry during both sampling events. During wet periods, the general flow direction in the overburden water-bearing zone is to the north-northeast, largely mirroring surface topography (Shaw 2005). Since the majority of the SRCs were detected at TRBG-MW01, TRBG-MW02, and TRBG-MW03 located in or upgradient of the soil contamination requiring remedial action and TRBG-MW-04 is dry in the downgradient direction, it appears the extent of the contaminants in the TRBG groundwater is adequately characterized. In addition, none of the CMCOCs identified in the Phase I RI were detected in the groundwater above screening criteria.

Table 6–1. Data Screening Table – Groundwater

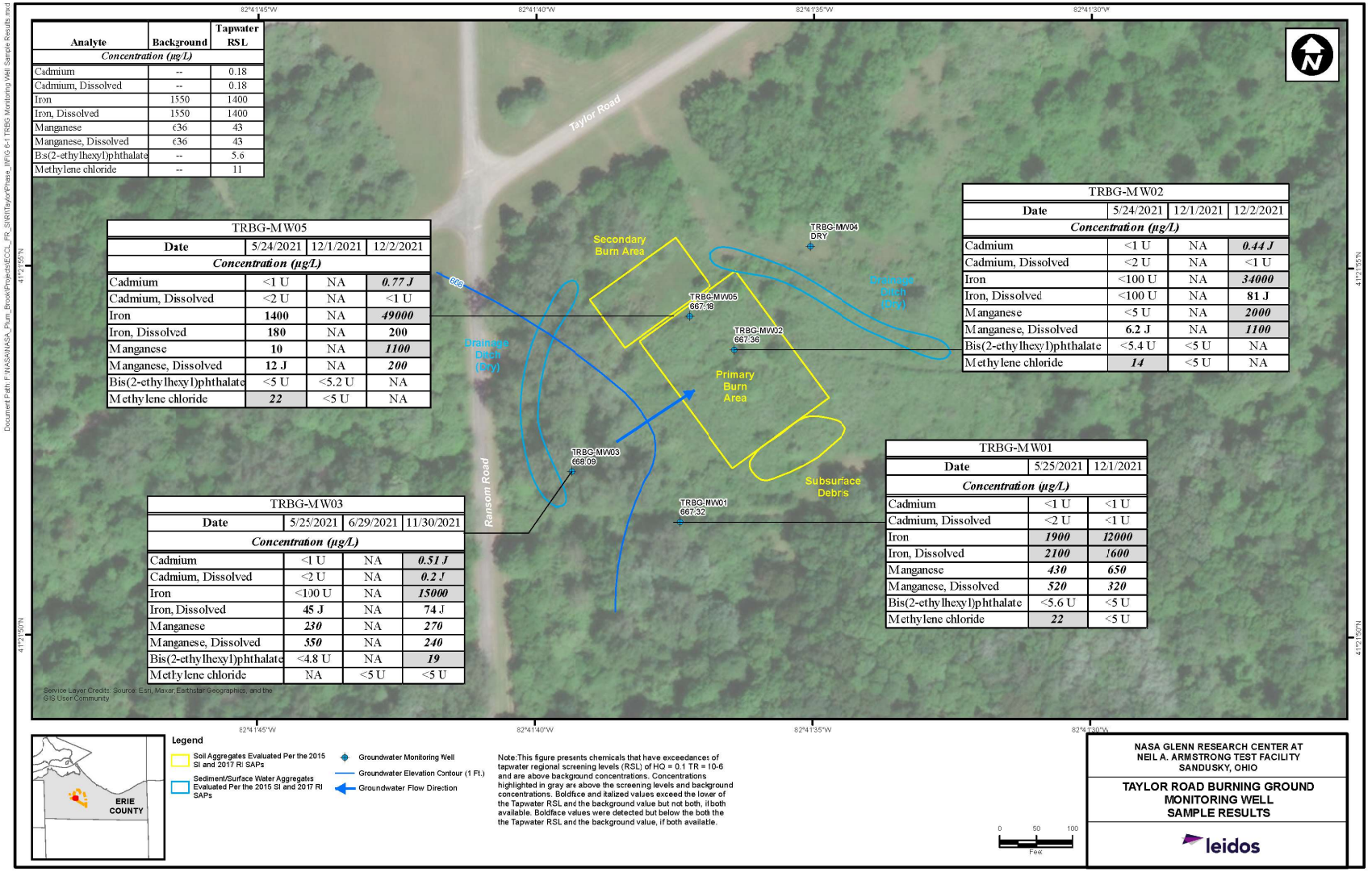
Analysis Type	Analyte (µg/L)	CAS Number	Freq of Detect	Minimum Detect (µg/L)	Maximum Detect (µg/L)	Average Result (µg/L)	Background Criteria (µg/L)	Maximum Exceeds Background?	Number > BKG	Tap Water RSL May 2022 (µg/L)	RSL Type	Maximum Exceeds RSL?	Number > RSL	USEPA MCL (µg/L)	Maximum Exceeds MCL?	Number > MCL	Exceedance Justification
Metals, Total	Aluminum	7429-90-5	6/8	900	19000	7410	309	Yes	6	2000	n	Yes	4	--	--	--	Exceeds screening level
Metals, Total	Antimony	7440-36-0	4/8	0.73	1.9	1.17	--	--	--	0.78	n	Yes	3	6	No	0	Exceeds screening level
Metals, Total	Arsenic	7440-38-2	5/8	1.5	19	7.05	7.4	Yes	2	0.052	c	Yes	5	10	Yes	2	Exceeds screening level
Metals, Total	Barium	7440-39-3	8/8	11	430	143	11800	No	0	380	n	Yes	1	2000	No	0	Below background
Metals, Total	Beryllium	7440-41-7	3/8	0.76	1.3	0.691	--	--	--	2.5	n	No	0	4	No	0	Below risk screening criteria
Metals, Total	Cadmium	7440-43-9	3/8	0.44	0.77	0.528	--	--	--	0.18	n	Yes	3	5	No	0	Exceeds screening level
Metals, Total	Calcium	7440-70-2	8/8	15000	470000	166000	316000	Yes	2	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Chromium	7440-47-3	7/8	1.2	24	9.38	--	--	--	2200	n	No	0	100	No	0	Below risk screening criteria
Metals, Total	Cobalt	7440-48-4	8/8	0.21	23	8.22	12.1	Yes	3	0.6	n	Yes	6	--	--	--	Exceeds screening level
Metals, Total	Copper	7440-50-8	8/8	1.9	81	24.1	19.8	Yes	3	80	n	Yes	1	1300	No	0	Exceeds screening level
Metals, Total	Iron	7439-89-6	6/8	1400	49000	14200	1550	Yes	5	1400	n	Yes	5	--	--	--	Exceeds screening level
Metals, Total	Lead	7439-92-1	6/8	1	30	10.9	--	--	--	15	MCL	Yes	3	15	Yes	3	Exceeds screening level
Metals, Total	Magnesium	7439-95-4	8/8	2500	270000	77700	217000	Yes	2	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Manganese	7439-96-5	7/8	10	2000	587	636	Yes	3	43	n	Yes	6	--	--	--	Exceeds screening level
Metals, Total	Nickel	7440-02-0	7/8	2.6	69	26.4	8.6	Yes	5	39	n	Yes	3	--	--	--	Exceeds screening level
Metals, Total	Potassium	7440-09-7	8/8	560	9900	3380	116000	No	0	--	--	--	0	--	--	--	Essential nutrient
Metals, Total	Selenium	7782-49-2	4/8	2.2	10	3.63	--	--	--	10	n	No	0	50	No	0	Below risk screening criteria
Metals, Total	Silver	7440-22-4	3/8	0.078	0.41	0.386	--	--	--	9.4	n	No	0	--	--	--	Below risk screening criteria
Metals, Total	Sodium	7440-23-5	7/8	2100	59000	17000	1390000	No	0	--	--	--	0	--	--	--	Essential Nutrient
Metals, Total	Thallium	7440-28-0	3/8	0.49	0.78	0.522	--	--	--	0.02	n	Yes	3	2	No	0	Exceeds screening level
Metals, Total	Vanadium	7440-62-2	6/8	2.3	44	17.9	--	--	--	8.6	n	Yes	4	--	--	--	Exceeds screening level
Metals, Total	Zinc	7440-66-6	4/8	66	170	68.3	507	No	0	600	n	No	0	--	--	--	Below background
Metals, Dissolved	Aluminum, Dissolved	7429-90-5	3/8	35	120	71.4	--	--	--	2000	n	No	0	--	--	--	Below risk screening criteria
Metals, Dissolved	Antimony, Dissolved	7440-36-0	1/8	0.75	0.75	2.97	--	--	--	0.78	n	No	0	6	No	0	Below risk screening criteria
Metals, Dissolved	Barium, Dissolved	7440-39-3	8/8	4.7	220	78.8	--	--	--	380	n	No	0	2000	No	0	Below risk screening criteria
Metals, Dissolved	Cadmium, Dissolved	7440-43-9	1/8	0.2	0.2	0.713	--	--	--	0.18	n	Yes	1	5	No	0	Exceeds screening level
Metals, Dissolved	Calcium, Dissolved	7440-70-2	8/8	14000	520000	169000	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Cobalt, Dissolved	7440-48-4	6/8	0.39	7.8	3.06	--	--	--	0.6	n	Yes	4	--	--	--	Exceeds screening level
Metals, Dissolved	Copper, Dissolved	7440-50-8	3/8	3.5	10	5.95	--	--	--	80	n	No	0	1300	No	0	Below risk screening criteria
Metals, Dissolved	Iron, Dissolved	7439-89-6	7/8	45	2100	541	--	--	--	1400	n	Yes	2	--	--	--	Exceeds screening level
Metals, Dissolved	Magnesium, Dissolved	7439-95-4	8/8	2100	290000	78600	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Manganese, Dissolved	7439-96-5	8/8	6.2	1100	369	--	--	--	43	n	Yes	6	--	--	--	Exceeds screening level
Metals, Dissolved	Nickel, Dissolved	7440-02-0	6/8	1.5	11	8.91	--	--	--	39	n	No	0	--	--	--	Below risk screening criteria
Metals, Dissolved	Potassium, Dissolved	7440-09-7	6/8	590	7200	2490	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Selenium, Dissolved	7782-49-2	2/8	1.5	7.8	5.54	--	--	--	10	n	No	0	50	No	0	Below risk screening criteria
Metals, Dissolved	Sodium, Dissolved	7440-23-5	7/8	1900	58000	16900	--	--	--	--	--	--	0	--	--	--	Essential nutrient
Metals, Dissolved	Zinc, Dissolved	7440-66-6	1/8	24	24	19.3	--	--	--	600	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	1-Methylnaphthalene	90-12-0	1/8	0.16	0.16	0.111	--	--	--	1.1	c	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	2-Methylnaphthalene	91-57-6	1/8	0.25	0.25	0.122	--	--	--	3.6	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	Bis(2-ethylhexyl)phthalate	117-81-7	1/8	19	19	4.63	--	--	--	5.6	c	Yes	1	6	Yes	1	Exceeds screening level
Organics-Semivolatile	Caprolactam	105-60-2	7/8	2	82	19.5	--	--	--	990	n	No	0	--	--	--	Below risk screening criteria
Organics-Semivolatile	Naphthalene	91-20-3	1/8	0.12	0.12	0.106	--	--	--	0.12	c	No	0	--	--	--	Below risk screening criteria

Table 6–1. Data Screening Table – Groundwater (Continued)

Analysis Type	Analyte (µg/L)	CAS Number	Freq of Detect	Minimum Detect (µg/L)	Maximum Detect (µg/L)	Average Result (µg/L)	Background Criteria (µg/L)	Maximum Exceeds Background?	Number > BKG	Tap Water RSL May 2022 (µg/L)	RSL Type	Maximum Exceeds RSL?	Number > RSL	USEPA MCL (µg/L)	Maximum Exceeds MCL?	Number > MCL	Exceedance Justification
Organics-Volatile	1,1,1-Trichloroethane	71-55-6	1/8	0.55	0.55	0.506	--	--	--	800	n	No	0	200	No	0	Below risk screening criteria
Organics-Volatile	Acetone	67-64-1	3/8	16	26	11.3	--	--	--	1800	n	No	0	--	--	--	Below risk screening criteria
Organics-Volatile	Methylene chloride	75-09-2	3/8	14	22	8.81	--	--	--	11	n	Yes	3	5	Yes	3	Exceeds screening level
Organics-Volatile	Tetrachloroethene	127-18-4	2/8	3.3	5	1.41	--	--	--	4.1	n	Yes	1	5	No	0	Exceeds screening level
Organics-Volatile	Toluene	108-88-3	2/8	0.14	0.14	0.41	--	--	--	110	n	No	0	1000	No	0	Below risk screening criteria
Organics-Volatile	Trichloroethene	79-01-6	3/8	0.3	0.46	0.446	--	--	--	0.28	n	Yes	3	5	No	0	Exceeds screening level
Organics-Volatile	cis-1,2-Dichloroethene	156-59-2	1/8	6.6	6.6	1.26	--	--	--	3.6	n	Yes	1	70	No	0	Exceeds screening level

Notes:
Average Result was calculated using 0.5 times the detection limit for non-detect results.
USEPA MCL -US Environmental Protection Agency maximum contaminant level, May 2022 (USEPA 2022a).
RSL-USEPA Regional Screening Level for tap water for HQ=0.1 and TR=1E-6 May 2022 update (USEPA 2022a).
Background Criteria from 2004 Groundwater Data Summary and Evaluation Report, Former Plum Brook Ordnance Works, Sandusky, Ohio (Shaw 2005).

-- = The screening value is does not exist for the chemical
µg/L = Micrograms per kilogram
BKG = Background
Freq = Frequency
MCL = Maximum Contaminant Level
RSL = Regional screening level, types are c=carcinogenic, n=non-carcinogenic, and MCL=lead model



Analyte	Background	Tapwater RSL
Concentration (µg/L)		
Cadmium	--	0.18
Cadmium, Dissolved	--	0.18
Iron	1550	1400
Iron, Dissolved	1550	1400
Manganese	€36	43
Manganese, Dissolved	€36	43
Bis(2-ethylhexyl)phthalate	--	5.6
Methylene chloride	--	11

TRBG-MW05			
Date	5/24/2021	12/1/2021	12/2/2021
Concentration (µg/L)			
Cadmium	<1 U	NA	***0.77 J***
Cadmium, Dissolved	<2 U	NA	<1 U
Iron	**1400**	NA	***49000***
Iron, Dissolved	**180**	NA	**200**
Manganese	**10**	NA	***1100***
Manganese, Dissolved	**12 J**	NA	***200***
Bis(2-ethylhexyl)phthalate	<5 U	<5.2 U	NA
Methylene chloride	***22***	<5 U	NA

TRBG-MW02			
Date	5/24/2021	12/1/2021	12/2/2021
Concentration (µg/L)			
Cadmium	<1 U	NA	***0.44 J***
Cadmium, Dissolved	<2 U	NA	<1 U
Iron	<100 U	NA	***34000***
Iron, Dissolved	<100 U	NA	**81 J**
Manganese	<5 U	NA	***2000***
Manganese, Dissolved	**6.2 J**	NA	***1100***
Bis(2-ethylhexyl)phthalate	<5.4 U	<5 U	NA
Methylene chloride	***14***	<5 U	NA

TRBG-MW01		
Date	5/25/2021	12/1/2021
Concentration (µg/L)		
Cadmium	<1 U	<1 U
Cadmium, Dissolved	<2 U	<1 U
Iron	***1900***	***12000***
Iron, Dissolved	***2100***	***1600***
Manganese	***430***	***650***
Manganese, Dissolved	***520***	***320***
Bis(2-ethylhexyl)phthalate	<5.6 U	<5 U
Methylene chloride	***22***	<5 U

TRBG-MW03			
Date	5/25/2021	6/29/2021	11/30/2021
Concentration (µg/L)			
Cadmium	<1 U	NA	***0.51 J***
Cadmium, Dissolved	<2 U	NA	***0.2 J***
Iron	<100 U	NA	***15000***
Iron, Dissolved	**45 J**	NA	**74 J**
Manganese	***230***	NA	***270***
Manganese, Dissolved	***550***	NA	***240***
Bis(2-ethylhexyl)phthalate	<4.8 U	NA	***19***
Methylene chloride	NA	<5 U	<5 U

Figure 6–1. Chemical Exceedances of Background and RSL (HQ of 0.1, TR of 1E-06) in Groundwater

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7. CONTAMINANT FATE AND TRANSPORT

The properties of chemicals and the environment are used to understand and predict chemical fate and transport. An understanding of the fate and transport is part of the overall assessment of the potential for a chemical to cause an adverse human health or environmental effect. This section provides an overview of the fate and transport properties of chemicals previously identified as SRCs in groundwater at TRBG. Based on groundwater sample results discussed in the previous section, the main SRCs that occur in groundwater at TRBG are metals.

Section 7.1 describes physical and chemical properties of SRCs found in soil and groundwater at the site. Section 7.2 presents chemical transport mechanisms. The Phase I RI presented a soil screening analysis to identify the soil SRCs with the potential to migrate from soil to groundwater as initial contaminant migration chemicals of potential concern (CMCOPCs), described fate and transport modeling of final CMCOPCs, and provided an evaluation of the identified initial CMCOCs.

7.1 CHEMICAL MOBILITY AND PERSISTENCE

The mobility and persistence of potential contaminants are determined by their physical, chemical, and biological interaction with the environment. Mobility is the potential for a chemical to migrate from a site, and persistence is a measure of how long a chemical will remain in the environment. Some of the mechanisms controlling mobility and persistence are described as follows:

- *Volatilization* occurs when a compound transfers from the aqueous phase to the gas phase. Measures of a chemical's tendency to volatilize from water and soil moisture include its vapor pressure and Henry's law constant (K_h). Volatilization tends to occur more readily from surface water, sediment, or shallow soil than from deeper soil or groundwater.
- *Sorption* occurs when a constituent adheres to and becomes associated with solid particles. The soil and sediment media likely to sorb chemicals are clays and organic matter. The conventional measure of sorption is the distribution coefficient (K_d). The K_d for organic chemicals is typically the product of the soil organic carbon partition coefficient (K_{oc}) of the chemical and the fraction of organic carbon in the soil. Metals sorption potential is a complex function of pH, organic content, oxide coatings, and other factors; therefore, K_d is not easily estimated by methods other than site-specific testing (USEPA 2010). Generally, metals adsorption increases with pH and they most often sorb to clay minerals, organic matter, and iron and manganese oxyhydroxides.
- *Solubility* is a measure of the degree to which a constituent will dissolve in water. Highly soluble chemicals are more likely to be leached from soil by precipitation or runoff that infiltrates into the subsurface.
- *Degradation* is the deterioration or destruction of a chemical, either biologically (through biodegradation) or abiotically (through such processes as abiotic reduction, hydrolysis, and photolysis). Biodegradation of chemicals by microbial organisms occurs through metabolic or enzymatic processes. The rate of degradation is dependent on the chemical, biological, and physical conditions of the medium in which the contaminant is located.
- *Transformation* occurs when the valence state of metals is increased (oxidation) or decreased (reduction). It can be caused by changes in oxidation potential or pH and by microbial or nonmicrobial (abiotic) processes. Transformation may have a significant effect on the mobility of a metal, either increasing or decreasing it.

7.1.1 Explosives

Several explosive compounds were detected in soil at TRBG but not in the groundwater. The nitro groups of TNT are the most prevalent explosives in soils at the site. TNT can be aerobically biodegraded, reduced by hydrogen under anaerobic conditions, or degraded by biotic cometabolism. TNT can also be degraded abiotically by hydrolysis or reduced by iron.

7.1.2 Organic Chemicals

Organic chemicals, such as SVOCs or VOCs, may be transformed or degraded in the environment by processes including hydrolysis, oxidation/reduction, photolysis, volatilization, biodegradation, or biotransformation. The half-life of organic chemicals in transport media can vary from minutes to years, depending on environmental conditions and chemical structures. Some types of organic chemicals are stable, and degradation rates can be slow. Organic degradation may either enhance (by producing more toxic byproducts) or reduce (reducing concentrations) the toxicity of a chemical in the environment.

7.1.3 Inorganic Chemicals

Due to the complexity of inorganic chemicals, specifically metals, and their variable forms in the environment, predicting their chemical mobility and persistence can be difficult. Typically, they are not volatile under normal temperature and pressure conditions. Their sorption potential is a complex function of pH, organic content, oxide coatings, and other factors; therefore, K_d is not easily estimated by methods other than site-specific testing (USEPA 2010). Generally, metal adsorption increases with pH. Metals most often sorb to clay minerals, organic matter, and iron and manganese oxyhydroxides. Metals may be sorbed on the surface of the soil or fixed to the interior of the soil, where they are unavailable for release to groundwater. After available sorption sites are filled, most metals are incorporated into the structures of major mineral precipitates as coprecipitates (ERG 2005).

The solubilities of metals are also dependent on several factors. In general, solubility is highly dependent on the oxidation state of the metal. The solubility of cations (positively charged ions) decreases as pH increases. Some cations may complex with oxygen and hydroxide, forming insoluble oxyhydroxides, or with phosphate, sulfate, and carbonate, forming insoluble mineral precipitates. Metal sulfide complexes, which form in reducing environments, are extremely insoluble and tend to reduce the total metals concentrations (ERG 2005).

The solid forms of iron (iron hydroxides) and manganese (manganese oxides) are present in the natural soil matrix. If insufficient amounts of oxygen and nitrate are present in the subsurface, iron hydroxides and manganese oxides will be used as electron acceptors during metabolic activity and dissolve under reducing conditions into soluble forms. Sulfides present in groundwater can also result in the dissolution of iron hydroxides. Several metals, such as arsenic, tend to sorb to these iron hydroxides and manganese oxides. If these iron and manganese compounds are dissolved, the metals that are bound to these hydroxides and oxides, such as chromium and arsenic, will also be released. Iron also becomes more soluble as pH decreases below 7 (ERG 2005).

Subsurface conditions are likely to become more reduced in areas that have substantial carbon available. Several metabolic processes can use naturally occurring organic carbon or anthropogenic organic compound contamination as an electron donor or electron acceptor. Metal concentrations, in particular iron and manganese and those metals that tend to desorb from iron and manganese oxyhydroxides when they are reduced to their more soluble forms, are also frequently higher in areas of organic contamination (such as explosives or VOC plumes) because of the reducing conditions that are created during biodegradation of these chemicals (USEPA 2017).

7.2 CHEMICAL TRANSPORT

Contamination at TRBG is attributed primarily to historical usage as a disposal site and the burning of disposed of materials. The primary source of contamination includes contaminated wastes, including explosives, waste oil, solvents, asbestos, and acids. Except for some scattered debris, the site has no more primary source material.

Migration pathways for potential contaminants at TRBG are further discussed below in the context of their location (i.e., unsaturated zone and saturated zone migrations).

7.2.1 Unsaturated Zone Migration

Contaminants released to the ground surface migrated through the unsaturated zone, as controlled by the chemical and physical differences between the contaminants and the surrounding media, gravity, and pressure (head). Once in the unsaturated zone, contaminants may have sorbed to soil or organic matter, become trapped in residual pore spaces, or continued to leach to the saturated zone. Although the explosives and VOCs have lower K_{oc} values, the contaminants could still sorb to soil in areas of higher clay or total organic carbon content. The high-molecular-weight PCBs have a strong tendency for sorption. Once in the soil, contaminants can enter the gas phase through volatilization of soil contaminants. Higher soil temperatures in the upper few feet of soil occur during the summer and can lead to increased volatilization. Constituents sorbed or complexed to surface soil may be transported to sediment via surface water runoff.

The entire TRBG site is vegetated, and there is little to no restriction for infiltration. VOCs and SVOCs have leached from the unsaturated zone to groundwater. In contrast, due to the high sorption potential and low water solubility of PCBs, these contaminants are largely immobile in the unsaturated zone and unlikely to appreciably leach to groundwater. Based on their moderate volatility, PCBs may evaporate into soil gas and then into the atmosphere.

Most metals at TRBG are likely naturally occurring in the environment and not associated with a CERCLA release. The mobility of metals in the unsaturated zone is highly dependent on the subsurface conditions. Surface soil and shallow subsurface soil (within the top 2 feet of the ground surface) exist under more oxidizing conditions due to the proximity to outdoor air; therefore, aluminum, manganese, and iron will tend to be in their immobile forms of aluminum hydroxides, manganese oxides, and iron hydroxides. In oxidizing environments, arsenic and chromium are typically present in forms that are more mobile. However, these metals, along with lead, thallium, and zinc, will potentially sorb or complex with clays, organic material, iron hydroxides, or manganese oxides, limiting their mobility.

7.2.2 Saturated Zone Migration

Contaminants have entered groundwater at TRBG primarily by leaching through unsaturated zone soil. A description of regional and site-specific hydrology is provided in Section 3.6 and summarized below:

- The general groundwater flow direction across TRBG is to the northeast (Figure 4-2). The approximate hydraulic gradient is 0.00457 ft/ft.
- The upper bedrock surface at TRBG is the Devonian Age Ohio Shale. Based on soil boring logs completed at the site for the wells sampled, depth to bedrock 6.0 to 7.0 feet bgs.
- Based on the 2001 Groundwater RI (USACE 2002), depth to water at TRBG fluctuates throughout the year between approximately 1.5 and 7 feet bgs. During the Phase II RI field investigation, groundwater in the overburden soil was observed at depth ranging from 2.1 to 3.1 feet bgs in May 2021 and 4.2 to 5.4 feet bgs in November 2021.

Contaminants typically will not move as rapidly as groundwater because of retardation, or the adsorption of the contaminant to the solid media. Retardation can be a significant factor for groundwater COPCs within the overburden aquifer, which is composed primarily of clays and silts.

As previously mentioned, organic contamination in groundwater is composed primarily of SVOCs and VOCs. The SVOCs and VOCs in groundwater may volatilize into soil gas overlying the water table. These constituents also have high to moderate aqueous solubilities and have the potential to migrate once dissolved in groundwater. All of the organic groundwater COPCs are subject to biodegradation. This is evident by the presence of PCE and its daughter products TCE and cis-1,2-DCE.

Transport and partitioning of metals in water is dependent on the oxidation state of the metal and on interactions with other materials present. Under reducing conditions, iron and manganese would be expected to be transformed into more soluble forms. Any metals (such as arsenic), which may be naturally bound to iron hydroxides and manganese oxides, can also become more mobile. Arsenic can also coprecipitate in groundwater.

7.3 SUMMARY AND CONCLUSIONS

The Phase I RI fate and transport evaluation identified hexachloroethane and naphthalene for future groundwater evaluation to assess the modeling results. Hexachloroethane was not detected in groundwater at TRBG during the Phase II RI. Naphthalene was detected in only one groundwater sample at an estimated concentration equal to the tap water RSL of 0.12 µg/L.

Based on the information presented above, contaminant leaching from soil to the water table (vertical migration) and mixing with groundwater beneath the source is the contaminant release mechanism identified at TRBG.

One of the principal migration pathways at the site is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). The rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Once the contaminant leachate percolates through the soil and reaches the water table, it mixes with groundwater beneath the source. The potential receptor location would be a hypothetical domestic water well located beneath the site. However, because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. In addition, the CMCOCs identified in the Phase I RI were not detected in groundwater above screening criteria. The presence of the inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring.

8. HUMAN HEALTH RISK ASSESSMENT

This HHRA documents the potential health risks to humans resulting from exposure to groundwater contamination within TRBG.

The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance and technical information sources, which include:

- USEPA guidance found in the Risk Assessment Guidance for Superfund Part A (USEPA 1989);
- USEPA guidance regarding evaluation of dermal exposure and toxicity from the Risk Assessment Guidance for Superfund Part E (USEPA 2004);
- Ohio EPA Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for the Division of Environmental Response and Revitalization (DERR) Remedial Response Program (Ohio EPA 2009a);
- Toxicity values from the USEPA RSL table (USEPA 2022a); and
- VISLs (USEPA 2022b).

The HHRA consists of four steps:

- Data evaluation,
- Exposure assessment,
- Toxicity assessment, and
- Risk characterization.

The following sections describe the methods and assumptions used to conduct the HHRA as well as the results of the HHRA.

Section 8.1, Site Background and History. Describes the physical characteristics of the site, its current and plausible future uses, and potential sources of contamination.

Section 8.2, Data Evaluation. Describes data sources, data quality and usability, and selection of COPCs.

Section 8.3, Exposure Assessment. Describes the exposure scenarios and rationale by which plausible receptors are selected, the routes by which receptors may be exposed, the calculation of exposure point concentrations (EPCs) for each COPC, and the estimated dose or contact rates for each COPC.

Section 8.4, Toxicity Assessment. Evaluates the potential for COPCs to cause adverse health effects in exposed individuals. Where possible, it provides an estimate of the relationship between the intake or dose of a COPC and the likelihood or severity of adverse health effects resulting from that exposure.

Section 8.5, Risk Characterization. Quantitative risk estimates are calculated for each complete exposure pathway by combining the toxicity values from Section 8.4 with the chemical dose or contact rates estimated in Section 8.3.

Section 8.6, Uncertainty Analysis. This section presents the uncertainties associated with the various assumptions and parameters used in the HHRA; their potential effects on the HHRA and its interpretation are addressed qualitatively.

Section 8.7, Summary and Recommendations. This section provides a summary and discussion focused on those results and issues that are most directly relevant to the risk assessment conclusions for TRBG, including any COCs identified by the HHRA.

8.1 SITE BACKGROUND AND HISTORY

A detailed description of the site and its history is provided in Section 1.2. Sufficient information is summarized below to support this HHRA.

TRBG is in the west-central portion of GRC-ATF, southeast of the intersection of Taylor and Ransom Roads (Figure 1-2). As noted in the 1995 Records Review Report, the TRBG configuration (per a 1944 historical drawing No. 1669-T-603-9-1/2) was approximately 300 feet southeast of Taylor Road and 300 feet east of Ransom Road. An access road from Taylor Road was built to the burn area, which had a northwest-southeast orientation and measured approximately 100 140 feet.

TRBG was one of the burning grounds that the Army and NASA used for destroying hazardous and non-hazardous material. These burning grounds are considered potential sources of environmental contamination because they were disposal sites for contaminated wastes. The contaminants included explosives, acids, asbestos, waste oil, and solvents. TRBG was used for destroying combustible wastes that were not contaminated with acids or explosives. Surface soil in the burning area was excavated and used to construct a 3-foot-high earthen embankment surrounding the burn area. Eight-inch-diameter drainage tiles were installed throughout the embankment at natural low points. A mesh chicken wire fence was installed on top of the embankment.

The 2015 SI established three contiguous areas, as presented in Figure 1-2, for investigation at TRBG based on available historical information: the Primary Burn Area, Secondary Burn Area, and Debris Area. The Primary Burn Area was identified using a 1960 aerial photograph. A Secondary Burn Area was identified in a map from the 1994 SI Report. In addition, the Debris Area was defined as the area to the southeast of the Primary Burn Area that was discovered to contain buried metal debris.

TRBG is currently surrounded by shrub and a forested area with a wetland present on the western portion of the site. The habitat at TRBG is dominated by shrubland surrounded by forested area. Two ephemeral drainage ditches exist at the site, one west of the burn area and the other northeast of the burn area (Figure 1-2). The area encompassing the former burning ground is at a slightly higher elevation than the surrounding terrain, and the embankment mentioned above is no longer present. Buried construction debris has been observed in the southwestern portion of the area.

TRBG currently has no structures. However, as discussed in subsequent sections, debris was identified at the site. Metal fragments, debris, and piping were identified southeast of the Primary Burn Area, and ACM identified as white, cementitious material was identified in the Primary Burn Area.

8.2 DATA EVALUATION

8.2.1 Data Sets

Data collected at TRBG from the two rounds of groundwater sampling in 2021 (May/June and November/December) were used in this HHRA. All groundwater data were aggregated into a single EU due to well locations in the unconsolidated aquifer and the potential to be affected by site activities. Samples included in the HHRA data set are listed in Table 8-1. Groundwater samples were analyzed for TAL metals (filtered and unfiltered), explosives, PCBs, VOCs, and SVOCs.

Only groundwater is included in this HHRA.

8.2.2 Identification of Chemicals of Potential Concern

The purpose of selecting COPCs is to identify those chemicals that may be present resulting from past site activities that may be of concern to human health.

8.2.2.1 COPCs – Approach

The first step in COPC identification involves evaluating the quality of the analytical data to ensure their acceptability for use in the HHRA (USEPA 1989). Additional steps involve eliminating chemicals that are considered essential nutrients, comparing the analytical concentrations to background concentrations, and comparing the analytical concentrations to risk-based screening concentrations. This selection process is intended to identify those chemicals presumed to be site-related (i.e., present due to inadvertent or intentional site activity) and determine if those chemicals are potentially harmful to human health.

The selection of COPCs begins by identifying all chemicals detected in at least one sample in a given exposure medium (i.e., groundwater). Detected chemicals are eliminated as COPCs based on the criteria below.

Data Quality Assessment – The data used in the risk assessment were verified and validated using the methodology described in the data quality assessment (Appendix F). Analytical results were reported by the laboratory in electronic form and loaded into a database. Site data were then extracted from the database so that only one result is used for each station and depth sampled. If laboratory reanalysis or dilutions were performed, only the appropriate result is used based on data review and validation. QC data, such as sample splits, are not included in the determination of COPCs for this risk assessment. Data qualified during the validation as rejected ("R") were not used in the risk assessment. Field duplicate results were averaged with the primary result (if both results were detected or not detected). If only one of the duplicate pair had a detectable concentration, just the detected result was used. Data qualified as estimated ("J") are retained and used in the risk assessment.

Essential Nutrients – Chemicals that are considered essential nutrients (i.e., calcium, chloride, iodine, iron, magnesium, potassium, phosphorus, and sodium) are an integral part of the human food supply and are often added to foods as supplements. USEPA recommends these chemicals not be evaluated provided they are present at low concentrations (i.e., only slightly above naturally occurring levels) and toxic only at high doses (i.e., much higher than those that could be associated with contact at the site) (USEPA 1989). Essential nutrients were not carried forward as COPCs.

Background – Background screening levels for naturally occurring inorganics are from the 2004 Groundwater Summary Report (Shaw 2005).

Risk-Based Screening – The objective of this evaluation is to identify COPCs that may pose a potentially significant risk to human health. The risk-based screening values are conservative values published by USEPA. The maximum detected concentration (MDC) of each chemical was compared to appropriate screening values. Chemicals detected below these screening values were screened from further consideration. The risk-based screening values are the most current residential tap water RSLs taken from the May 2022 RSL tables (USEPA 2022a). To account for the potential effects of multiple chemicals, a target HQ of 0.1 was used for RSLs based on non-cancer endpoints and a target cancer risk of 1E-06 was used. These screening values are considered conservative.

Specific details concerning use of the RSLs are described below:

- **Chromium –** Detected concentrations were reported by the laboratory for total chromium. RSLs are available for trivalent and hexavalent chromium. There is no known source of hexavalent chromium at TRBG; therefore, chromium was assumed to be represented primarily by the more environmentally stable trivalent form.

- **Manganese –** The RSL for non-diet manganese was used in the screening process to select the groundwater COPCs (USEPA 2022a).

The MDCs for detected organic compounds were compared with screening levels calculated using the USEPA VISL calculator (USEPA 2022b). The calculator provides media-specific, risk-based screening-level concentrations for groundwater and other media. The primary objective of risk-based screening is to identify sites or buildings unlikely to pose a health concern through the soil gas intrusion pathway. Generally, at properties where subsurface concentrations of vapor-forming chemicals, such as VOCs in groundwater, fall below the recommended screening levels (i.e., VISLs), NFA or no further study is warranted. The calculator uses the same database of toxicity values, chemical parameters, and inhalation exposure equations as the RSLs.

8.2.2.2 COPCs – Results

The COPC screening results are presented in Appendix G. This table includes frequency of detection, range of detected concentrations, and comparison to RSLs and background concentrations (where applicable). All detected chemicals and those selected as COPCs are shown in Table 8-2.

Thirty-four chemicals were detected at least once in the groundwater samples: 22 metals, 5 SVOCs, and 7 VOCs. Twelve metals (aluminum, antimony, arsenic, cadmium, cobalt, copper, iron, lead, manganese, nickel, thallium, and vanadium), one SVOC (bis[2-ethylhexyl]phthalate), and four VOCs (cis-1,2-DCE; methylene chloride; PCE; and TCE) were selected as COPCs in groundwater. Table 8-3 presents statistics and EPCs for the COPCs.

For metals, human health risks were calculated using unfiltered groundwater data as opposed to filtered (i.e., dissolved) data. The dissolved metals results are used as a weight-of-evidence tool to distinguish between metals dissolved in the groundwater versus metals that are in particulate form that are typically eliminated by filtration, and to aid in the selection of COCs.

The VISL screening results also are presented in Appendix G. Of the 12 detected organic compounds, VISLs could be derived for six (methylene chloride; naphthalene; toluene; PCE; TCE; and 1,1,1-TCA). The MDCs for these six compounds were less than the VISLs. VISLs could not be derived for acetone, cis-1,2-DCE, 1-methylnapthalene, or 2-methylnaphthalene because inhalation toxicity values are not available. Nevertheless, the chemicals are not expected to be a concern because cis-1,2-DCE; 1-methylnapthalene; and 2-methylnaphthalene were only detected once in the eight samples at relatively low concentrations, and acetone, which could be a laboratory blank contaminant, was detected in three of eight samples at a concentration well below the RSL for drinking water. VISLs were not derived for bis(2-ethylhexyl)phthalate and caprolactam because they are not considered to be volatile compounds. Thus, based on the VISL screening and evaluation of other factors, no COPCs are identified for the vapor intrusion pathway.

8.3 EXPOSURE ASSESSMENT

The objectives of the exposure assessment are to estimate the magnitude, frequency, and duration of potential human exposure to COPCs. The four primary steps of the exposure assessment are:

1. Characterize the exposure setting, including identification of contaminant sources, release mechanisms, and migration and identification of current and future land use;
2. Identify potentially exposed populations, exposure media, and exposure pathways;
3. Calculate EPCs; and
4. Estimate each receptor's potential intake of each COPC.

Steps 1 and 2 are summarized in the conceptual site exposure model (CSEM) summarized in Section 8.3.1 and Figure 1-3. Steps 3 and 4 are described in Sections 8.3.2 and 8.3.3, respectively. The output of the exposure assessment is used in conjunction with the output of the toxicity assessment (Section 8.4) to quantify risks and hazards to receptors in the risk characterization (Section 8.5).

8.3.1 Conceptual Site Exposure Model

The CSEM provides the basis for identifying and evaluating potential risks to human health in the HHRA. The CSEM identifies the receptors appropriate to all plausible site use scenarios and the potential exposure pathways through which the receptors may be exposed to contaminated media. The CSEM includes all sources, release and transport pathways, and exposure routes, thus facilitating a consistent and comprehensive evaluation of risk to human health and preventing potential pathways from being overlooked. The elements of the CSEM include the following:

- Source (i.e., initially contaminated environmental media) and contaminant release mechanism;
- Contaminant migration pathways and media;
- Exposure media;
- Receptors; and
- Routes of exposure (e.g., ingestion, inhalation, and dermal).

A receptor may come into direct contact with a contaminated source medium, in which case the source medium and exposure medium are identical. Figure 1-3 shows the CSEM for TRBG.

8.3.2 Contaminant Sources, Release Mechanisms, Migration Pathways, and Exposure Media

TRBG is considered a potential source of environmental contamination at GRC-ATF due to historical usage as a disposal site and burning ground. While historical documents suggest that NASA used TRBG for burning combustible wastes that were not contaminated with acids or explosives, the previous use by the Army specific to TRBG is not as certain. Consequently, TRBG is assumed to have the same primary source of contamination as the other burning grounds (e.g., SRBG and FRBG) that include contaminated wastes, including explosives, waste oil, solvents, asbestos, and acids. Except for some scattered debris, the site has no more primary source material. The source medium or secondary source is surface soil and subsurface soil that were potentially contaminated from burning of the primary source material.

Releases to soil and sediment were discussed and evaluated in the Phase I RI (Leidos 2018b). Sources of contamination at TRBG may include releases to surface and subsurface soil from the burning of contaminated debris and residual debris following removal and disposal of contaminated surface and subsurface soil. Contaminants released to surface soil also may migrate to the Drainage Ditch via surface runoff and to air via volatilization and fugitive dust. These releases were discussed and evaluated in the Phase I RI. In addition, contaminants released to soil may reach the groundwater through the process of infiltration to the groundwater, which is the focus of this risk assessment.

8.3.3 Receptor Scenarios and Exposure Routes

TRBG and GRC-ATF, including their physical setting, historical and current use, topography, and demographics of the area, are described in Sections 1.0 and 3.0. An estimated 75 percent of NASA's property at GRC-ATF is considered unused. The remaining land is used for offices, test facilities, roads, and infrastructure. Public access is restricted at GRC-ATF. An 8-foot security fence surrounds approximately 5,000 acres of GRC-ATF, and access to the site is gained through the security office located on East Scheid Road. The main gate and security office are staffed by armed guards 24 hours per day. During each 8-hour shift, a security guard patrols the inside perimeter road (Patrol Road) of the facility.

Persons gain access to the station by showing the guard a badge that authorizes entry. GRC-ATF is expected to remain under NASA's control for the foreseeable future.

Groundwater at GRC-ATF is not used for drinking water. The GRC Master Plan (NASA 2008) states the following: *"Groundwater underlying PBS shall not be extracted or used for any purpose, potable or otherwise, except for investigation, monitoring or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities."*

Although it is unlikely that TRBG will be developed for residential purposes and/or that the groundwater will be used as a source of potable water, a hypothetical onsite residential scenario is evaluated to assess the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction. Relevant pathways for groundwater exposure are ingestion, dermal contact, and inhalation of VOCs (during household use of water). The resident is assumed to be exposed 350 days/year for 26 years (20 years as an adult and 6 years as a child).

The groundwater receptor scenarios evaluated in the HHRA are summarized in the CSEM (Figure 1-3). Note this figure also includes exposures to soil by other receptors, such as groundskeepers and hunters (from the Phase I RI).

8.3.4 Exposure Point Concentrations

This HHRA evaluates the reasonable maximum exposure (RME) of receptors to groundwater contaminants at TRBG. The RME is an estimate of the highest exposure reasonably expected to occur at the site. The EPC is the single concentration used to represent the RME for each COPC in an environmental medium. Per USEPA recommendations, the smaller of the 95 percent upper confidence limit (UCL) or the MDC is used to estimate groundwater EPCs (USEPA 2002). The 95 percent UCLs were calculated using ProUCL Version 5.1.002 (USEPA 2016). ProUCL outputs are provided in Appendix G. The EPC for lead is the calculated average concentration as recommended by USEPA (USEPA 2021a). The statistical summary of groundwater data (including MDCs, averages, and UCLs) is provided in Table 8-3 for all COPCs.

8.3.5 Quantification of Chemical Intake

The magnitude of human exposure to chemicals in environmental media is described differently for each of the primary intake pathways in terms of the average daily intake for ingestion exposure, inhalation exposure concentration, and dermal absorbed dose (DAD). This HHRA used standard intake equations along with default exposure assumptions for a resident from the USEPA RSL User's Guide (USEPA 2022a). The exposure assumptions are shown in Table 8-4, and the equations are included in Appendix G.

Lead exposures are assessed using models specific to the complex nature of lead partitioning and toxicity within the human body. USEPA has developed the Integrated Exposure Uptake Biokinetic (IEUBK) model (USEPA 2021b), which is used to estimate blood-lead levels in resident children Adult exposure to lead in groundwater was not evaluated because the Adult Lead Model (also developed by USEPA) is used to evaluate exposure to lead only in soil. USEPA has not developed a model to evaluate adult exposure to lead in groundwater or other media.

This HHRA evaluates the RME of receptors to contaminants at TRBG. The intent of the RME is to estimate the highest exposure level that could reasonably be expected to occur but not the worst possible case (USEPA 1989). Exposure parameters selected for a baseline RME scenario for intake rate, exposure frequency, and exposure duration are generally upper bounds. Other variables (e.g., body weight and lifespan) are generally central or average values. The resulting exposure rate, once the components are multiplied, represents a conservative estimate of actual exposure.

8.4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to evaluate the potential for COPCs to cause adverse health effects in exposed individuals. Where possible, it provides an estimate of the relationship between the intake or dose of a COPC and the likelihood or severity of adverse health effects resulting from that exposure. USEPA has extensively evaluated toxic effects. This section provides the results of the USEPA evaluation of the chemicals identified as groundwater COPCs at TRBG.

For carcinogens, risks are estimated as the probability that an individual will develop cancer over a lifetime resulting from exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as excess or incremental cancer risk, which is cancer occurrence in addition to normally expected rates of cancer development. The numeric descriptor of carcinogenic potency for oral and dermal exposures is the cancer slope factor (CSF) expressed in units of milligrams per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$. The numeric descriptor of carcinogenic potency for inhalation exposures is the inhalation unit risk (IUR) expressed in units of milligrams per cubic meter (mg/m^3). The CSF and IUR are defined as plausible upper-bound estimates of the probability of a response (i.e., cancer) per unit intake of a chemical over a lifetime (USEPA 1989).

Non-carcinogenic effects are evaluated by comparing an exposure or intake/dose with a reference dose (RfD) expressed in units of mg/kg-day for oral and dermal exposure and reference concentration (RfC) expressed in units of mg/m^3 for inhalation exposure. The RfDs and RfCs are determined using available dose-response data for individual chemicals. Scientists determine the exposure concentration or intake/dose below which no adverse effects are seen and add a safety factor (from 10 to 1,000) to determine the RfD or RfC. RfDs and RfCs are identified by scientific committees supported by USEPA. RfDs and RfCs are route- and duration-specific. Toxic effects are diverse and measured in various target body organs (e.g., they range from eye irritation to kidney or liver damage). USEPA is currently reviewing methods for accounting for the difference in severity of effects; however, existing RfDs and RfCs do not address this issue.

8.4.1 Oral and Inhalation Toxicity Values

The cancer and non-cancer toxicity values for evaluating risks from oral (ingestion) and inhalation exposures are identified based on the following three-tiered hierarchy of sources as recommended by USEPA:

- Tier 1 - USEPA's Integrated Risk Information System (IRIS) database.
- Tier 2 - National Center for Environmental Assessment (NCEA) provisional peer-reviewed toxicity values.
- Tier 3 - In the case where NCEA cannot provide any provisional toxicity values, the following resources may be used with priority given to the source providing the most current peer-reviewed information, available to the public, and transparent in the methods and processes used to develop the value:
    - U.S. Centers for Disease Control and Prevention – Agency for Toxic Substances and Disease Registry toxicological profiles.
    - USEPA criteria documents (criteria documents, such as drinking water criteria documents, drinking water health advisory summaries, ambient water quality criteria documents, and air quality criteria documents, may be consulted in the event none of the above sources contain appropriate information).

- California Environmental Protection Agency Office of Environmental Health Hazard Assessment toxicity criteria database.
- Screening toxicity values presented in an appendix to a provisional peer-reviewed toxicity values assessment.
- Health Effects Assessment Summary Table values (the values found in this table are still applicable in cases where the sources listed in the hierarchy above do not contain toxicity values for a constituent).

This is the hierarchy used in the USEPA May 2022 RSL tables.

8.4.2 Dermal Toxicity Values

Because no toxicity values are specific to dermal exposure, USEPA recommends oral toxicity values be used to assess risks from dermal exposure. However, oral toxicity factors relate toxic response to the administered dose of a chemical, only some of which may be absorbed by the body, whereas chemical intake from dermal contact is estimated as an absorbed dose using chemical-specific permeability constants for absorption from water (USEPA 2004). To ensure that dermal toxicity is not underestimated, USEPA recommends adjusting oral toxicity factors by chemical-specific gastrointestinal absorption fractions (GIABS) if the USEPA-recommended GIABS is less than 50 percent. Oral toxicity criteria are adjusted to generate dermal toxicity criteria, as shown in the equation below:

$$CSF_d = \frac{CSF_o}{GIABS} \quad \text{and} \quad RfD_d = RfD_o \times GIABS$$

Where:

CSF_d = cancer slope factor for dermal pathway (mg/kg-day)-1,
CSF_o = cancer slope factor for oral pathway (mg/kg-day)-1,
GIABS = gastrointestinal absorption factor (unitless),
RfD_d = reference dose for dermal pathway (mg/kg-day), and
RfD_o = reference dose for oral pathway (mg/kg-day)

The GIABSs for five COPCs (antimony, cadmium, manganese, nickel, and vanadium) were less than 50 percent. As a result, the RfD_o was multiplied by the GIABS to generate the RfD_d.

When the USEPA-recommended GIABS is greater than 50 percent, USEPA recommends using oral CSFs and RfDs without adjustment to assess potential dermal risks. The GIABS for all other COPCs are 100 percent; therefore, oral CSF and RfD values were used to evaluate dermal exposure for these COPCs without adjustment.

Toxicity values for the COPCs are summarized in Table 8-5.

8.4.3 Chemicals Without USEPA Toxicity Values

No suitable dose-response values exist for assessing the risks associated with exposure to lead. USEPA has identified a blood-lead level of 10 µg/dL as a level of concern. According to USEPA, no child should have more than a 5 percent probability of having a blood lead level greater than 10 micrograms per deciliter (µg/dL). USEPA has developed the IEUBK model (USEPA 2021b), which is used to estimate blood-lead levels in children.

8.5 RISK CHARACTERIZATION

The purpose of the risk characterization is to evaluate the information obtained through the exposure and toxicity assessments to estimate potential risks and hazards. Potential carcinogenic effects are characterized by using projected intakes and chemical-specific, dose-response data (i.e., CSFs and IURs) to estimate the probability that an individual will develop cancer over a lifetime. Potential non-carcinogenic effects are characterized by comparing projected intakes of contaminants to toxicity values (i.e., RfDs and RfCs). The numerical risk and hazard estimates presented in this section must be interpreted in the context of the uncertainties and assumptions associated with the risk assessment process and with the data upon which the risk estimates are based. Some chemicals may induce both cancer and non-cancer effects; however, the risks for each endpoint are calculated separately.

Except for lead, risks for the resident receptor were calculated using the USEPA RSL calculator (USEPA 2022a). This tool was used because it is a standardized and widely accepted method. The RSL calculator calculates risks for adults and children exposed to chemicals in water that are delivered into a residence from groundwater. Ingestion of drinking water is an appropriate pathway for all chemicals. The inhalation exposure route is only calculated for volatile compounds. Activities such as showering, laundering, and dish washing contribute to contaminants in the air for inhalation. Dermal contact with tap water is also considered for applicable chemicals.

8.5.1 Risk Characterization Methods

8.5.1.1 Carcinogenic Risk Characterization

For carcinogens, risk is expressed as the probability that an individual will develop cancer over a lifetime resulting from exposure to the carcinogen. Cancer risk from exposure to contamination is expressed as the incremental lifetime cancer risk (ILCR), or the increased chance of cancer above the normal background rate of cancer. In the United States, the background chance of contracting cancer is a little more than 3 in 10 for women and a little less than 5 in 10 for men, or 3E-01 to 5E-01 (American Cancer Society 2015). The calculated ILCRs are compared to the range specified in the NCP of 1E-06 to 1E-04, or 1 in 1 million to 1 in 10,000 exposed persons developing cancer (USEPA 1990). ILCRs below 1E-06 are considered acceptable; ILCRs above 1E-04 are considered unacceptable. The range from 1E-06 to 1E-04 is of concern, and any decisions to address ILCRs further in this range, either through additional study or engineered control measures, should account for the uncertainty in the risk estimates. The Ohio EPA DERR program has adopted a human health cumulative ILCR goal within this range of 1E-05 to be used as the level of acceptable excess cancer risk and for developing remediation goals. The DERR notes that the defined risk goal should be applied as a goal, recognizing the need to retain flexibility during the evaluation and selection of remedial alternatives.

For each carcinogenic COPC, the ILCR is calculated by multiplying the average daily exposure of the chemical, for each route of exposure, by the appropriate cancer toxicity measure for the chemical/route, as follows:

$$ILCR = Exposure \times Toxicity\ Value$$

Where:

ILCR	=	incremental lifetime cancer risk (unitless);
Exposure	=	daily intake (mg/kg-day), DAD (mg/kg-day), or exposure concentration (mg/m^3) of chemical; and
Toxicity Value	=	oral or dermal CSF $(mg/kg\text{-}day)^{-1}$, or IUR (mg/m^3).

For a given exposure pathway, the total risk to a receptor exposed to several carcinogenic COPCs is the sum of the ILCRs for each carcinogen, as shown below:

$$ILCR_{total} = \Sigma ILCR_i$$

Where:

$ILCR_{total}$ = total probability of cancer incidence associated with all carcinogenic COPCs; and

$ILCR_i$ = ILCR for the i^{th} COPC.

In addition to summing risks across all carcinogenic COPCs, risks are summed across all exposure pathways for a given environmental medium (e.g., ingestion, inhalation, and dermal contact).

8.5.1.2 Non-Carcinogenic Risk Characterization

In addition to developing cancer from exposure to contaminants, an individual may experience other toxic effects. The term "toxic effects" is used here to describe a wide variety of systemic effects ranging from minor irritations, such as eye irritation and headaches, to more substantial effects, such as kidney or liver disease and neurological damage. The risks associated with toxic (i.e., non-carcinogenic) chemicals are evaluated by comparing an estimated exposure (i.e., intake or dose) from site media to an acceptable exposure expressed as an RfD or RfC. The RfD/RfC is the threshold level below which no toxic effects are expected to occur in a population, including sensitive subpopulations. The ratio of intake over the RfD or RfC is the HQ (USEPA 1989) and is calculated by dividing the estimated exposure of the constituent over a specific time period by the appropriate non-cancer toxicity value for that constituent, derived for a similar exposure period as follows:

$$HQ = \frac{\text{Exposure}}{\text{Toxicity Value}}$$

Where:

HQ = hazard quotient (unitless);

Exposure = daily intake (mg/kg-day), DAD (mg/kg-day), or exposure concentration (mg/m^3) of chemical; and

Toxicity Value = oral or dermal RfD (mg/kg-day) or inhalation RfC (mg/m^3).

The HQs for each COPC are summed to obtain a hazard index (HI), as shown below:

$$HI = \Sigma HQ_i$$

Where:

HI = hazard index for all toxic effects; and

HQ_i = hazard quotient for the i^{th} COPC.

An HI greater than 1 has been defined as the level of concern for potential adverse non-carcinogenic health effects (USEPA 1989).

Non-cancer risks have been calculated only for the resident child because the child HIs are greater than the resident adult HIs.

8.5.1.3 Evaluation of Lead

No suitable dose-response values exist for assessing the risks associated with exposure to lead. USEPA has developed the IEUBK model, which is used to estimate blood-lead levels in children 1 to 7 years old following exposure to lead in various environmental media (USEPA 2021b). USEPA has identified a blood-lead level of 10 µg/dL as a level of concern that should be avoided. Because children are the most sensitive receptors, blood-lead levels calculated for children are used as a point of comparison. If the blood-lead levels for children are less than 10 µg/dL, it can be inferred that there is no substantial risk for older receptors; therefore, blood-lead levels resulting from children being exposed to lead in environmental media are calculated. The technical review workgroup for lead strongly recommends using the IEUBK with default input values; therefore, per this guidance, model defaults are used along with the site-specific EPCs for groundwater and soil (the soil concentration is from the Phase I RI). In accordance with USEPA guidance, the site-specific EPC for lead is the arithmetic mean concentration (USEPA 2021a). Therefore, the arithmetic mean concentrations for lead in soil and water were used. Resident child exposures to lead are presented as predicted blood-lead levels and the probability of exceeding a blood-lead level of 10 µg/dL in the modeled population. According to USEPA, no child should have more than a 5 percent probability of exceeding a blood lead level of 10 µg/dL.

8.5.2 Risk Characterization Results

Detailed hazard and risk results are presented in Appendix G for residents exposed to groundwater. Output files for the IEUBK model also are provided in Appendix G. Risk results are summarized in Table 8-6 and the following section.

The hypothetical future onsite resident may be exposed to groundwater via incidental ingestion, dermal contact, and inhalation (while using water for household purposes). Risks are reported for unfiltered groundwater. Dissolved metal concentrations and their potential effect on the risk results are discussed in Section 8.7.

The HI for groundwater exposure by a resident child is 15, which is greater than the target of 1. Because the HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1:

- The target organ HI of 3 for nervous system effects exceeds the target of 1 (due to manganese [2] and aluminum [0.7]).
- The target organ HI of 6 for dermal effects exceeds the target of 1 (due to thallium [4] and arsenic [2]).
- The target organ HI of 2 for gastrointestinal effects exceeds the target of 1 (due to iron [2])
- The target organ HI of 2 for endocrine system effects exceeds the target of 1 (due to cobalt [2]).

The total ILCR for groundwater exposure of 2E-04 is at the upper bound of the target cancer risk range and is associated almost entirely with arsenic.

The geometric mean blood-lead concentration for a child resident of 12 to 72 months is 3.1 µg/dL, and the probability that the blood-lead concentration of a child resident would exceed the target of 10 µg/dL is 0.7 percent, which is less than the target (5 percent).

8.6 UNCERTAINTY ANALYSIS

This section qualitatively discusses the sources of uncertainty in this HHRA and their effect on the risk estimates. Uncertainty is a factor in each step of the exposure and toxicity assessments presented in the preceding sections.

8.6.1 Types of Uncertainty

Generally, risk assessments are influenced by two types of uncertainty:

- Measurement uncertainty, and
- Uncertainty arising from data gaps.

Measurement uncertainty includes the usual variance that accompanies scientific measurements (e.g., instrument uncertainty – accuracy and precision) associated with contaminant concentrations and the heterogeneity of the data.

A second type of uncertainty stems from data gaps (i.e., additional information needed to complete the database for the assessment). The data gap is often significant, such as the absence of information on the effects of human exposure to a chemical or the biological mechanism of action of an agent. Models are often used to fill data gaps because they represent a level of understanding to address certain exposure parameters that are impractical or impossible to measure. Assumptions represent an educated estimate of information that is not available (e.g., additivity of non-cancer effects).

Reliance on a simplified numerical presentation of dose and risk without consideration of uncertainties, limitations, and assumptions inherent in the assessment process can be misleading. For example, an ILCR of 1E-06 may be calculated for a given exposure scenario. However, if the uncertainty in this estimate is several orders of magnitude, then the real risk may be higher than the risk from another scenario that has a calculated ILCR of 1E-05 but a smaller degree of uncertainty. Alternatively, an ILCR of 1E-03 may be calculated and appears to represent an unacceptable risk. The actual risk, however, may be orders of magnitude smaller. Situations like this occur because the estimated risk reflects conservative assumptions on lifestyles and site use scenarios, maximum or near-maximum values for many modeling and exposure variables, and the derivation of toxicity values.

8.6.2 Sources of Uncertainty

The sources of uncertainty, as well as the bias they impart to the risk assessment (i.e., whether conservatism is increased or decreased), are discussed below.

8.6.2.1 Sampling Limitations

It is impossible to completely characterize the nature and extent of contamination at any site. Uncertainties arise from limits on the media sampled, the total number and specific locations that can be sampled, and the parameters chosen for analysis to characterize the site. Sampling limitations may result in underestimating or overestimating true risk.

8.6.2.2 Estimation of EPCs

Generally, the UCL on the arithmetic mean is adopted as the EPC and is considered to represent a conservative estimate of the average concentration. This imparts a small but intentional conservative bias to this HHRA, provided the sampling captured the most highly contaminated areas. In cases where the UCL

exceeded the MDC or not enough samples were detected to calculate a UCL, the MDC was used as the EPC. This is generally a conservative estimate of the actual concentration to which receptors are exposed to this HHRA.

8.6.2.3 Selection of Hypothetical Receptors and Potential Exposure Pathways

The hypothetical residential receptor and associated exposure pathways were chosen to represent an unrestricted use scenario. The onsite resident is not a likely receptor for TRBG and is evaluated in this assessment for the additional information it provides. Inclusion of the onsite resident overestimates the risk that may be experienced by actual receptors in the future because groundwater underlying the site is not used as a source of drinking water.

8.6.2.4 Quantification of Intakes

Ingestion rates, exposure durations, and exposure factors used in the RSL calculator are based on upper bound values (USEPA 2022a), even though it is likely that serial multiplication of conservative variable values leads to overestimation of COPC intake rates (Cogliano 1997). Input parameter values used in the IEUBK model have been selected based on extensive research by USEPA to derive an estimate of average exposure by a child.

8.6.2.5 Toxicity Assessment

Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose response) evaluations of a toxicity assessment. Positive animal cancer test data suggest that humans also contain tissue(s) that may manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of non-cancer effects, positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans (USEPA 1989). Uncertainty decreases when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose-related; when toxicokinetic data indicate a similar fate in animals and humans; when postulated mechanisms of toxicity are similar for humans and animals; and when the COPC is structurally similar to other chemicals for which the toxicity is more completely characterized.

Many sources of uncertainty exist in the dose-response evaluation for cancer (i.e., computation of a slope factor) and non-cancer effects (i.e., computation of an RfD). First, there is uncertainty regarding interspecies (animal-to-human) extrapolation, which, in the absence of quantitative toxicokinetic, dosimetric, or mechanistic data, is usually based on consideration of interspecies differences in the basal metabolic rate. Second, there is uncertainty regarding intraspecies, or individual, variation. Most toxicity experiments are performed with animals that are similar in age and genotype so that intragroup biological variation is minimal; however, the human population of concern may reflect wide heterogeneity, including unusual sensitivity to the COPC. Even toxicity data from human occupational exposure reflect a bias because only those individuals who are sufficiently healthy to attend work regularly and those not unusually sensitive to the COPC are likely to be occupationally exposed. Third, uncertainty arises from the quality of the key study (from which the quantitative estimate is derived) and the database. For cancer effects, the uncertainty associated with some study quality factors (e.g., test group size) is expressed within the 95 percent upper bound of the slope factor. For non-cancer effects, additional uncertainty factors may be applied in deriving the RfD to reflect poor quality of the key study or gaps in the database.

A further source of uncertainty for non-cancer effects arises from the use of a lowest observed adverse effect level in estimating an RfD or an RfC because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an additional uncertainty factor is

usually applied to estimate a no-observable-adverse-effect level (NOAEL) from a lowest-observable-adverse-effect level (LOAEL). Additional uncertainty arises from estimating RfD values for chronic exposure from less-than-chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the NOAEL in the less-than-chronic study.

Another source of uncertainty regarding quantitative risk estimation for carcinogenicity is the method by which data from high dose rates in animal studies are extrapolated to the low dose rate range expected for environmentally exposed humans. The linearized multi-stage model that is used in most quantitative estimates of human cancer risk from animal data is based on a non-threshold assumption of carcinogenesis. An impressive body of evidence, however, suggests that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are non-carcinogenic (USEPA 2005); therefore, the use of the linearized multi-stage model is ultraconservative for chemicals that exhibit a threshold for carcinogenicity.

In summary, the USEPA methodology for both cancer and non-cancer toxicity evaluations is intentionally designed to be protective. However, the extent to which toxicity values may overestimate toxicity is not clear, and it is possible that the toxicity values for some compounds may not be adequately protective.

Significant uncertainty regarding toxicity information for this risk assessment arises in the use of provisional toxicity values (e.g., the RfDs for aluminum, iron, and thallium are provisional toxicity values). The significance of findings based on provisional toxicity values should be tempered by the understanding that the provisional value represents a lower level of review and certainty than USEPA-verified toxicity values and may not provide an adequate basis for decision making. The use of such toxicity values may either overestimate or underestimate actual risk.

There is added uncertainty for thallium because the RfD is a supplemental screening toxicity value developed in an appendix to a provisional toxicity assessment. For thallium, insufficient data were available to develop a verified toxicity value or to support the derivation of a provisional toxicity value under current guidelines; however, information was available "…which may be of limited use to risk assessors" (USEPA 2012). Although this toxicity value receives external peer review, there is even more uncertainty than that associated with a provisional toxicity value.

Note the oral RfD for vanadium is derived from the IRIS oral RfD for Vanadium Pentoxide by factoring out the molecular weight (MW) of the oxide ion (USEPA 2022). This adds uncertainty to the risk estimate for vanadium because the toxicity value used may not accurately reflect the form of vanadium at TRBG.

8.6.2.6 Risk Characterization

Risk characterization is the process of quantifying the cancer risk due to exposure to carcinogens, as well as quantitatively evaluating hazards potentially posed by non-cancer effects. Cancer risk is assumed to be additive for all carcinogens. Non-cancer risk is assumed to be additive for chemicals with similar sites of toxicological action. If any combination of these chemicals results in synergistic effects, risk might be underestimated. Conversely, the assumption of additivity would overestimate risk if a combination of these chemicals acted antagonistically. It is unclear whether the potential for chemical interaction has been inadvertently understated or overstated. It seems unlikely that the potential for chemical interaction contributes significant uncertainty to this HHRA.

8.7 SUMMARY AND RECOMMENDATIONS

The HHRA documents the potential health risks to humans resulting from exposure to groundwater underlying TRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance.

Groundwater data collected at TRBG and used in this HHRA were aggregated into a single EU. GRC-ATF is expected to remain under NASA's control for the foreseeable future. Although it is unlikely that TRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to evaluate the upper bound for long-term exposure and represent an unrestricted reuse scenario. Sites that "pass" a residential risk assessment can be released for use without restriction. TRBG is best classified as an inactive area, and plausible receptors include groundskeepers. Hunting is not currently permitted in this area, although hunting is permitted in other areas within GRC-ATF. Neither groundskeepers nor hunters use the groundwater because access is restricted.

Lead exposures were assessed using a model specific to the complex nature of lead partitioning and toxicity within the human body. USEPA has developed the IEUBK model, which is used to estimate blood-lead levels in children. This model was used to evaluate exposure to lead in groundwater. Note the average soil lead concentration from the Phase I RI was used in the model.

The results of the HHRA for hypothetical residential land use are summarized in Table 8-6. For non-cancer effects, His were calculated only for the resident child because the child His are greater than the resident adult His. The total resident child HI for groundwater (15) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ His exceed the target of 1: the HI of 2 for nervous system effects (due to manganese [2] and aluminum [0.7]), the HI of 6 for dermal effects (due to arsenic [2], and thallium [4]), the HI of 2 for gastrointestinal effects (due to iron [2]), and the HI of 2 for endocrine system effects (due to cobalt [2]). The total ILCR of 2E-04 for groundwater exposure exceeds the upper bound of the target cancer risk range and is associated entirely with arsenic. The lead model results for the resident child show that the probability the blood-lead concentration would exceed the level of concern is less than the target.

Upon further evaluation of the risk assessment results, no COCs were identified in groundwater, as discussed below:

- Aluminum was not identified as a COC in groundwater because of significantly lower concentrations detected seasonally in the well with the highest concentration (i.e., 19,000 µg/L in December versus 1,900 µg/L in May 2021) and significant reduction in the filtered groundwater sample (representing dissolved metals) associated with the maximum detect (i.e., 66 µg/L). This dissolved aluminum concentration is more than two orders of magnitude less than the MDC in unfiltered groundwater. Typically, groundwater used as a source of potable water would be filtered, which would result in reduction of the EPC and a corresponding reduction in risk. Aluminum concentrations did not exceed the RSL based on the filtered data. In addition, uncertainty is associated with the provisional toxicity value used to calculate non-cancer risk. Moreover, turbidity readings collected at the time of sampling indicated the samples collected in December 2021 (values greater than 1,000 nephelometric turbidity units [NTUs]) were much higher than those detected in May 2021 (2.2 to 141 NTUs). For these reasons, aluminum was not selected as a COC at TRBG.
- Although the MDC of arsenic at TRBG (19 µg/L) exceeds an HQ of 1, arsenic was not detected in any filtered samples. The MDC of arsenic was detected in a sample collected in December 2021,

at which time the turbidity readings were elevated (greater than 1,000 NTUs). Arsenic was only detected in one of the samples collected in May 2021 (TRBGGW1001 at an estimated concentration of 1.5 µg/L). For these reasons, arsenic was not identified as a groundwater COC at TRBG.

- Cobalt was not identified as a COC in groundwater because it was detected in filtered groundwater samples at concentrations (up to 7.8 µg/L), which were substantially lower than the concentrations detected in unfiltered samples (up to 23 µg/L). The MDC in filtered samples was less than the background screening value of 12.1 µg/L. The unfiltered MDC of cobalt was detected in a sample collected in December 2021, at which time the turbidity readings were elevated (greater than 1,000 NTUs). The EPC for the dissolved cobalt concentration (as well as the EPCs for dissolved cadmium, iron, and manganese) were run in the USEPA RSL calculator (see Appendix G). The resulting HQ (0.8) was less than 1. For these reasons, cobalt was not identified as a COC at TRBG.
- Iron was not identified as a COC in groundwater because it was detected in filtered groundwater samples at concentrations (up to 2,100 µg/L) that were substantially lower than the concentrations detected in unfiltered samples (up to 49,000 µg/L). The MDC of iron was detected in a sample collected in December 2021, at which time the turbidity readings were elevated (greater than 1,000 NTUs). The EPC for the dissolved iron was run in the USEPA RSL calculator (see Appendix G). The resulting HQ (0.15) was less than 1. For these reasons, iron was not identified as a COC at TRBG.
- Manganese was not identified as a COC in groundwater due to reduced concentrations in the filtered samples. The filtered HQ is 1 (rounded down from 1.4). The HQ associated with unfiltered samples was only 2.0. The concentrations of manganese were higher in the unfiltered samples collected in December 2021, when the turbidity levels were elevated (greater than 1,000 NTUs). The EPC for the filtered concentrations (608 µg/L) (Appendix G) is less than the background screening value (636 µg/L). In addition, manganese was not identified as a COPC in the risk assessment for soil.
- Thallium was not identified as a COC in groundwater because it was not detected in filtered groundwater samples. The MDC of thallium (0.78 µg/L) was detected in a sample collected in December 2021, at which time the turbidity readings were elevated (greater than 1,000 NTUs). Thallium, however, was not detected in any of the samples collected in May 2021. For this reason, thallium was not identified as a COC at TRBG. In addition, the MDC was less than the MCL of 2 µg/L.

The results of the lead modeling show that the blood lead levels for the resident child are below the USEPA target (i.e., the probability that the blood-lead concentration of a child resident would exceed the target of 10 µg/dL is 0.4 percent, which is less than the target of 5 percent). Therefore, lead was not identified as a COC in groundwater.

The MDCs of chemicals also were compared to their respective MCLs (Appendix G). Arsenic (in two samples), bis(2-ethylhexyl)phthalate (in one sample), and methylene chloride (in three samples) were detected in unfiltered samples at concentrations greater than applicable MCLs. Arsenic, however, was not detected in any filtered samples, and none of the other chemicals in filtered samples were detected at concentrations greater than MCLs. Methylene chloride is an organic chemical commonly used in the laboratory and may be introduced into a sample from laboratory cross-contamination, which may explain its detection. Lead was detected in three unfiltered samples at concentrations greater than the action level (15 µg/L). All three of these detections were in samples collected in December 2021 when turbidity readings were elevated. The higher turbidity may have been a result of the purge and sample process being completed with a bailer in December 2021 due to insufficient volume for low-flow sampling. Lead was not detected in any of the unfiltered samples collected in May 2021 or any filtered samples at concentrations greater than the action level.

In summary, no organic chemicals or metals were identified as COCs for groundwater hypothetical future residential land use of TRBG.

Table 8–1. Groundwater Samples Included in the HHRA for Taylor Road Burning Ground

Station	Sample ID	Date Collected
TRBG-MW01	TRBGGW1001	5/25/2021
TRBG-MW01	TRBGGW1001-R	6/29/2021
TRBG-MW01	TRBGGW1006	12/1/2021
TRBG-MW02	TRBGGW1002	5/24/2021
TRBG-MW02	TRBGGW1002-R	6/29/2021
TRBG-MW02	TRBGGW1007A	12/1/2021
TRBG-MW02	TRBGGW1007B	12/1/2021
TRBG-MW03	TRBGGW1003	5/25/2021
TRBG-MW03	TRBGGW1003-R	6/29/2021
TRBG-MW03	TRBGGW1008	11/30/2021
TRBG-MW05	TRBGGW1005	5/24/2021
TRBG-MW05	TRBGGW1005-R	6/29/2021
TRBG-MW05	TRBGGW1000A	12/1/2021
TRBG-MW05	TRBGGW1000B	12/2/2021

ID = Identifier

Table 8–2. COPCs in Groundwater at Taylor Road Burning Ground

Detected Chemical	COPC
Metals*	
Aluminum	X
Antimony	X
Arsenic	X
Barium	
Beryllium	
Cadmium	X
Calcium	
Chromium	
Cobalt	X
Copper	X
Iron	X
Lead	X
Magnesium	
Manganese	X
Nickel	X
Potassium	
Selenium	
Silver	
Sodium	
Thallium	X
Vanadium	X
Zinc	
SVOCs	
1-Methylnaphthalene	
2-Methylnaphthalene	
Bis(2-ethylhexyl)phthalate	X
Caprolactam	
Naphthalene	
VOCs	
1,1,1-Trichloroethane	
Acetone	
Methylene Chloride	X
Tetrachloroethylene	X
Toluene	
Trichloroethene	X
cis-1,2-Dichloroethene	X

*Arsenic, beryllium, lead, nickel, silver, thallium, and vanadium were not detected in any of the filtered samples.

COPC = Chemical of Potential Concern
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound

Table 8–3. Statistical Summary and Exposure Point Concentrations for Groundwater COPCs at Taylor Road Burning Ground

COPC	CAS Number	Freq of Detect	Minimum Detect	Average Result[a]	Maximum Detect	Dist.	ProUCL Method	95% UCL from ProUCL	EPC	EPC Basis
Aluminum	7429-90-5	6/8	900	7410	19000	N	95% KM (t) UCL	13100	13100	Pro UCL
Antimony	7440-36-0	4/8	0.73	1.17	1.9	N	95% KM (t) UCL	1.8	1.8	Pro UCL
Arsenic	7440-38-2	5/8	1.5	7.05	19	N	95% KM (t) UCL	11.5	11.5	Pro UCL
Cadmium	7440-43-9	3/8	0.44	0.528	0.77	N	95% KM (t) UCL	0.764	0.764	Pro UCL
Cobalt	7440-48-4	8/8	0.21	8.22	23	N	95% Student's-t UCL	14.3	14.3	Pro UCL
Copper	7440-50-8	8/8	1.9	24.1	81	N	95% Student's-t UCL	43.2	43.2	Pro UCL
Iron	7439-89-6	6/8	1400	14200	49000	N	95% KM (t) UCL	26700	26700	Pro UCL
Lead	7439-92-1	6/8	1.0	10.9	30	N	95% KM (t) UCL	19.4	10.9	Average[b]
Manganese	7439-96-5	7/8	10	587	2000	N	95% KM (t) UCL	1040	1040	Pro UCL
Nickel	7440-02-0	7/8	2.6	26.4	69	N	95% KM (t) UCL	45.2	45.2	Pro UCL
Thallium	7440-28-0	3/8	0.49	0.522	0.78	N	95% KM (t) UCL	0.733	0.733	Pro UCL
Vanadium	7440-62-2	6/8	2.3	17.9	44	N	95% KM (t) UCL	30.6	30.6	Pro UCL
Bis(2-ethylhexyl)phthalate	117-81-7	1/8	19	4.64	19	D	Number of Detects<3	--	19	MDC
Methylene Chloride	75-09-2	3/8	14	8.81	22	N	95% KM (t) UCL	16.4	16.4	Pro UCL
Tetrachloroethylene	127-18-4	2/8	3.3	1.41	5	D	Number of Detects<3	--	5	MDC
Trichloroethene	79-01-6	3/8	0.3	0.446	0.46	N	95% KM (t) UCL	0.455	0.455	Pro UCL
cis-1,2-Dichloroethene	156-59-2	1/8	6.6	1.26	6.6	D	Number of Detects<3	--	6.6	MDC

Notes:
All units are micrograms per liter (µg/L)
[a]Average calculated using one-half the detection limit for non-detect results
[b]The EPC for lead is the calculated average concentration in as recommended by USEPA (USEPA 2021a)

-- = No value available
CAS = Chemical Abstract Service
COPC = Chemical of Potential Concern
EPC = Exposure Point Concentration
MDC = Maximum Detected Concentration
UCL = 95% Upper Confidence Limit of the mean

Dist.:
D = too few detects
N = normal distribution

Table 8–4. Exposure Assumptions for HHRA at Taylor Road Burning Ground

Exposure Factor	Assumed Value for Resident	
	Adult	Child
Chemical concentration in groundwater (Cgw) (µg/L)	Chemical-specific	
Ingestion rate of groundwater (IR) (L/day)	2.5	0.78
Skin surface area exposed to groundwater (SA) (cm^2)	19,652	6,365
Permeability coefficient (Kp) (cm/hr)	Chemical-specific	
Exposure frequency (EF) (days/year)	350	350
Exposure duration (ED) (years)	20	6
Exposure time (ET) (hours/event)	0.71	0.54
Inhalation exposure time (hours/day)	24	24
Events (EV) (events/day)	1	1
Body weight (BW) (kg)	80	15
Averaging time – non-cancer (Atn)	NA	2,190
Averaging time – cancer (Atc) (days)	25,550	25,550

Note: Conversion factors are included in the Appendix B equations

µg = Microgram
cm = Centimeter
HHRA = Human Health Risk Assessment
Hr = Hour
kg = Kilogram
L = Liter
NA = Not Applicable
m = Meter

Table 8–5. Chemical-Specific Exposure and Toxicity Factors

COPC	Kp (cm/hr)	Mutagen	GIABS	SFo $(mg/kg\text{-}day)^{-1}$	RfDo[a] (mg/kg-day)	Critical Effect/System for RfDo	IUR[b] $(\mu g/m^3)^{-1}$	RfC[b] (mg/m^3)	Critical Effect/System for RfC[b]
Aluminum	1.00E-3	No	1	--	1.0	Nervous system	--	--	--
Antimony	1.00E-3	No	0.15	--	4.0E-4	Hematologic	--	--	--
Arsenic	1.00E-3	No	1	1.5	3.0E-4	Cariovascular, Dermal	--	--	--
Cadmium	1.00E-3	No	0.05	--	1.0E-4	Urinary	--	--	--
Cobalt	4.00E-4	No	1	--	3.0E-4	Endocrine system	--	--	--
Copper	1.00E-3	No	1	--	4.0E-2	Gastrointestinal	--	--	--
Iron	1.00E-3	No	1	--	7.0E-1	Gastrointestinal	--	--	--
Lead	--	--	--	--	--	--	--	--	--
Manganese	1.00E-3	No	0.04	--	2.4E-2	Nervous System	--	--	--
Nickel	2.00E-4	No	0.04	--	2.0E-2	Decreased body and organ weights	--	--	--
Thallium	1.00E-3	No	1	--	1.0E-5	Decreased hair follical cystine	--	--	--
Vanadium	1.00E-3	No	0.026		5.04E-3	Urinary	--	--	--
Bis(2-ethylhexyl)phthalate	1.13E+0	No	1	1.40E-2	2.0E-2	Hepatic	2.4E-6	--	--
Methylene Chloride	3.54E-4	Yes	1	2.0E-3	6.0E-3	Hepatic	1.0E-8	6.0E-1	Hepatic
Tetrachloroethylene	3.34E-2	No	1	2.1E-3	6.0E-3	Nervous system, Ocular	2.6E-7	4.0E-2	Nervous, Ocular
Trichloroethene	1.16E-2	Yes	1	4.6E-2	5.0E-4	Developmental, Immune	4.1E-6	2.0E-3	Developmental, Immune
cis-1,2-Dichloroethene	1.10E-2	No	1	--	2.0E-3	Urinary	--	--	--

Notes:
All values are from U.S. Environmental Protection Agency (USEPA) regional screening level (RSL) table dated May 2022 unless otherwise noted
[a]RfD_o adjusted based on GIABS to derive RfDd.
[b]Provided only for the organic COPCs that are evaluated in the RSL calculator for inhalation

-- = No value available
cm/hour = Centimeters per Hour
COPC = Chemical of Potential Concern
GIABS = Gastrointestinal Absorption Factor
IUR = Inhalation Unit Risk
Kp = Permeability Coefficient
mg/kg-day = Milligrams per Kilogram per day
NA = Not Applicable
RfC=Reference Concentration
RfD = Reference Dose
SF = Cancer Slope Factor

Table 8–6. Risk Characterization for Groundwater at Taylor Road Burning Ground
Future Hypothetical Resident

COPC	EP (µg/L)	Total HQ	Total ILCR Across All Pathways	Selected as COC
Aluminum	13100	0.7	--	No, Not a COPC based on filtered data
Antimony	1.8	0.2	--	No, HQ less than 1
Arsenic	11.5	2	2E-4	No, Not detected in filtered samples
Cadmium	0.764	0.4	--	No, HQ less than 1
Cobalt	14.3	2	--	No, HQ for filtered data less than 1
Copper	43.2	0.05	--	No, HQ less than 1
Iron	26700	2	--	No, HQ for filtered data less than 1
Lead	19.4	---	--	No, IEUBK model results meet protective goals
Manganese	1040	2	--	No, HQ = 1 based on filtered data
Nickel	45.2	0.1	--	No, HQ less than 1
Thallium	0.733	4	--	No, Not detected in filtered samples
Vanadium	30.6	0.4	--	No, HQ less than 1
Bis(2-ethylhexyl)phthalate	19	0.05	3E-6	No, HQ less than 1
Methylene Chloride	16.4	0.2	1E-6	No, HQ less than 1
Tetrachloroethylene	5	0.1	4E-7	No, HQ less than 1
Trichloroethene	0.455	0.2	9E-7	No, HQ less than 1
cis-1,2-Dichloroethene	6.6	0.2	--	No, HQ less than 1
Total All Chemicals		**15**	**2E-4**	

-- = No value available
µg/L = Micrograms per Liter
COC = Chemical of Concern
COPC = Chemical of Potential Concern
EP = Exposure Point
HQ = Hazard Quotient
IEUBK = Integrated Exposure Uptake Biokinetic
ILCR = Incremental Lifetime Cancer Risk

9. ECOLOGICAL RISK ASSESSMENT

An ERA was completed in the Phase I RI Report. TRBG is approximately 5.2 acres and is vegetated with shrubland surrounded by forested area, with a wetland present on the western boundary of the site. Wetlands are considered important ecological resources, and there is soil documentation of contamination at TRBG, so further analysis was conducted in a Level II ERA. Soil data was collected, but no sediment or surface water was found at the site during the Phase I RI. Surface soil data were screened against ESVs recommended in Ohio EPA guidance, and preliminary COPECs were identified for each EU. Preliminary COPECs were further analyzed to determine if ecological risk was probable with the information available, and exposure pathway analysis was completed on the wetland. Frequency of detection, average concentration, sample location, migration to wetlands, and impact of recommended human health remediation were considered as applicable for each EU. Using this combination of factors, it was determined that there are no final COPECs at TRBG. Consequently, the ERA for TRBG concluded with a Level II Screening ERA, NFA was recommended to be protective of important ecological resources. (Leidos 2018b).

Ecological receptors are not typically exposed to groundwater except for caves and when groundwater daylights to surface water. No known caves are present at NASA, and this site does not contain surface water bodies. As a result, ecological exposures to chemicals in the groundwater are not a concern.

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10. CONCLUSIONS

This Phase II RI Report for TRBG presents a detailed analysis of historical site operations and environmental data to assess environmental groundwater impacts of these historical operations. The following sections summarize the site history and description and the major findings of the nature and extent of contamination, contaminant fate and transport, HHRA, and ERA.

A CSM incorporating all pertinent information is presented. The CSM denotes, based on current data, where source areas occur, the mechanisms for contaminant migration from source areas to receptor media (e.g., groundwater), exit pathways from the site, and if COCs occur that may require further evaluation in an FS. This section concludes with recommendations for any further characterization under the RI phase of work and, for groundwater evaluated in this Phase II RI, whether to proceed to the FS phase of the RI/FS process.

10.1 SITE HISTORY AND DESCRIPTION

The Army and NASA have used burning grounds for destroying both hazardous and non-hazardous material. These burning grounds are considered potential sources of environmental contamination because they were disposal sites for contaminated wastes, including explosives, acids, asbestos, waste oil, and solvents.

TRBG is located in the west-central portion of PBS, southeast of the intersection of Taylor and Ransom Roads. When used in the 1950s and 1960s, the TRBG configuration was approximately 300 feet southeast of Taylor Road and 300 feet east of Ransom Road. An access road from Taylor Road was built to the burn area, which had a northwest-southeast orientation and measured approximately 100 by 140 feet. Surface soil in the burning area was excavated and used to construct a 3-foot-high earthen embankment surrounding the burn area. Eight-inch-diameter drainage tiles were installed throughout the embankment at natural low points. A mesh chicken wire fence was installed on top of the embankment. Historical records indicate that TRBG was not used after 1965.

TRBG is composed primarily of field and a few soil piles, surrounded by shrub and a forested area with a wetland on the western and southern portions of the site. The habitat at TRBG is dominated by shrubland surrounded by forested area. Two ephemeral drainage ditches exist at the site, one west of the former burn area and the other northeast of the former burn area. TRBG currently has no structures.

10.2 SUMMARY OF PREVIOUS INVESTIGATIONS AND DATA USE

10.2.1 Remedial Investigations

The following assessments and evaluations included TRBG:

- 1990 Contamination Evaluation (IT Corporation 1990), which identified TRBG as the Rubbish Burning Grounds;
- 1991 PA (SAIC 1991), which included TRBG as part of the OU4 Burning Grounds evaluation;
- 1994 SI (MK 1994), which included TRBG as part of PMU 2 Ransom Ditch/Brook; and.
- 1995 Records Review Report (DM 1995), which provided the site history, potential sources, and environmental investigations of TRBG.

The GRC-ATF Multi-Site SI was conducted in August 2015. The SI activities at TRBG included 11 soil borings, 11 surface soil samples, 18 subsurface samples, and 8 sediment samples. Samples were analyzed for VOCs, SVOCs, herbicides, pesticides, PCBs, TAL metals, explosives, and asbestos (0- to 2-foot bgs interval only). In addition, a site walk was performed to identify any painted debris; however, no painted debris was identified. An Asbestos Hazard Evaluation Specialist also performed a site assessment, which included collecting 19 soil samples to analyze asbestos content and identifying one piece of ACM. Two of the 19 soil samples contained chrysotile and/or amosite asbestos at concentrations greater than 1 percent. The white, cementitious ACM was considered friable and contained 20 percent chrysotile (Leidos 2016b).

To supplement the 2015 SI, a Phase I RI was conducted in January 2017 to complete a data set that fully characterizes the nature and extent of contamination, assesses potential impacts soil may have on groundwater, and provides data to update and complete the HHRA and ERA. Six surface soil samples and four subsurface soil samples were collected from six locations (TR-1 to TR-6). Five surface water and sediment samples were planned for collection around (upgradient or downgradient) the two drainage ditches identified at the site. Consistent with the observations during the 2015 SI, surface water was not present in the drainage ditches. As a result, surface water samples were not collected, and the sediment samples collected were included in the soil medium. TRBG was divided into four EUs for evaluation to allow for refined evaluation of potential chemical contamination and potential exposure. These EUs were the Primary Burn Area, Secondary Burn Area, Drainage Areas, and Debris Area. Data collected at TRBG were aggregated by environmental medium (e.g., surface soil and subsurface soil).

Based on the Phase I RI results, TRBG was adequately characterized, and further investigation was not warranted to complete the RI for surface and subsurface soil. The nature and extent of potentially impacted media has been sufficiently characterized, and no ecological risk was identified. However, the HHRA identified the following EUs, sample locations, and COCs that required assessment in an FS:

- Primary Burn Area at sample locations TR-6, TRBG-SL-002, and TRBG-SL-001 to address PCBs (1254 and 1260) in surface soil and PCB-1254 in subsurface soil; and
- Drainage Area at sample location TRBG-SDSW-004 to address PCB-1254 in surface soil.

It was concluded that remediation of these locations will also address the three surface soil sample locations (TRBG-SL-001, TRBG-SL-002, and TRBG-SDSW-004) that had detectable asbestos, as well as the area that contained the one piece of ACM (white cementitious material at TRBG-SL-001). Sample location TRBG-SDSW-004 had less than 1 percent asbestos. Sample location TRBG-SL-001 had 3.5 percent chrysotile in the soil. This location also had co-located ACM identified as white, cementitious material that contained 20 percent chrysotile which, given the size, was presumed to be removed during sampling activities. Sample location TRBG-SL-002 had 1.75 percent chrysotile in the soil.

In addition, metal fragments, debris, and piping were identified in the Debris Area. Although this area was not identified as having chemical contamination posing a risk to human health or the environment, it was recommended that the removal and disposal of this debris be included in site remedial activities.

10.3 SUMMARY OF NATURE AND EXTENT OF CONTAMINATION

A total of eight groundwater samples were collected at TRBG: four from the spring sampling event and four from the fall sampling event to adequately characterize TRBG groundwater. Section 6.0 summarizes the nature and extent of contamination. Ten groundwater samples were planned (five during each event), but one of the five monitoring wells installed was dry during both events.

In groundwater, 22 metals, five SVOCs (1-methylnaphthalene; 2-methylnaphthalene; bis[2-ethylhexyl]phthalate; caprolactam; and naphthalene), and seven VOCs (acetone, 1,1,1-TCA;

methylene chloride; PCE; toluene, TCE; and cis-1,2-DCE) were detected. No explosives or PCBs were detected. Only 12 of the 22 metals detected in groundwater at TRBG exceeded their respective background concentrations and/or the tap water RSL at an HQ of 0.1 and a TR of 1E-06.

The sampling rationale for each groundwater sampling location was to assess potential impacts to overburden groundwater within or downgradient from the soil EU source area. Conservative transport modeling indicated 10 chemicals may be present in the groundwater table beneath their respective sources at concentrations exceeding MCLs/RSLs. However, after a qualitative assessment of the sample results, it was concluded that two CMCOCs would first be assessed at the site. The two initial CMCOCs included hexachloroethane and naphthalene. Hexachloroethane was not detected in groundwater at TRBG; however, the detection limit was greater than the tap water RSL. Naphthalene was only detected in one sample at an estimated concentration of 0.12 µg/L at TRBG-MW001 in the fall of 2021.

Only 3 of the 12 metals (cadmium, iron, and manganese) exceeded their respective background concentrations and/or the tap water RSL in groundwater at TRBG in both the total and dissolved samples. Cadmium only exceeded the screening criteria for both total and dissolve cadmium at one location in the fall of 2021 at TRBG-MW03. Total and dissolved iron exceeded screening criteria at TRBG-MW01 at concentrations of 2,100 µg/L in May and 1,600 µg/L in December 2021. Only one sample exceeded the screening criteria during the fall sampling event at TRBG-MW02 at a concentration of 1,100 µg/L. Bis(2-ethylhexyl)phthalate was the only SVOC detected above the screening criteria in the November 2021 sample from TRBG-MW03. VOCs detected above screening levels were limited to the chlorinated solvents PCE; TCE; cis-1,2-DCE; and methylene chloride. Of the four VOCs, only methylene chloride exceeded both its tap water RSL and MCL at TRBG-MW01, TRBG-MW02, and TRBG-MW05.

The groundwater in the overburden is in discontinuous pockets during dry time periods, as evidenced by TRBG-MW04 being dry during both sampling events. Based on groundwater elevations measured at the site, the general flow direction in the overburden water-bearing zone is to the north-northeast. Since the majority of the SRCs were detected at TRBG-MW01, TRBG-MW02, and TRBG-MW03 located in or upgradient of the soil contamination requiring remedial action and TRBG-MW-04 is dry in the downgradient direction, it appears the extent of the contaminants in the TRBG groundwater has been adequately characterized. In addition, none of the CMCOCs identified in the Phase I RI were detected in the groundwater above screening criteria.

10.4 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

During the Phase I RI, SRCs were evaluated through the stepwise fate and transport evaluation. Evaluation of modeling results identified the following initial CMCOCs for soil: selenium; silver; 2,4,6-TNT; 2,4-DNT; 4-amino-2,6-DNT; benzaldehyde; hexachloroethane; naphthalene; beta-hexachlorocyclohexane; and dalapon. These chemicals were predicted to exceed the screening criteria in groundwater beneath the source area. The qualitative assessment eliminated selenium; silver; 2,4,6-TNT; 2,4-DNT; 4-amino-2,6-DNT; benzaldehyde; beta-hexachlorocyclohexane; and dalapon as final CMCOCs. The other two initial CMCOCs (hexachloroethane and naphthalene) were retained for consideration, and groundwater sampling was recommended to fully characterize TRBG (Leidos 2018b). Hexachloroethane was not detected in groundwater at TRBG; however, the detection limit was greater than the tap water RSL. Naphthalene was only detected in one sample at an estimated concentration of 0.12 µg/L at TRBG-MW001 in the fall of 2021.

One of the principal migration pathways at the site is percolation through the unsaturated soil to the water table (i.e., vertical leaching of contaminants from soil into groundwater). The rate of percolation is controlled by soil cover, ground slope, saturated conductivity of the soil, and meteorological conditions. Once the contaminant leachate percolates through the soil and reaches the water table, it mixes with

groundwater beneath the source. The potential receptor location would be a hypothetical domestic water well located beneath the site. However, because of the heterogeneous nature of the unconsolidated glacial material, groundwater flow patterns within unconsolidated soil are difficult to predict. In addition, the CMCOCs identified in the Phase I RI were not detected in groundwater above screening criteria except for naphthalene. The presence of the inorganics above screening levels in groundwater either leached from soil prior to previous investigations or are naturally occurring. The organics appeared to have leached from the soil into the overburden groundwater, and only bis(2-ethylhexyl)phthalate and methylene chloride exceeded screening levels. The other chlorinated solvents, PCE and its daughter products, had concentrations below screening levels and were isolated, indicating migration is minimal and natural degradation is occurring.

10.5 SUMMARY OF HUMAN HEALTH RISK ASSESSMENT

The HHRA documents the potential health risks to humans resulting from exposure to groundwater contamination within TRBG. The HHRA was performed consistent with previous GRC-ATF HHRAs and is based on USEPA and Ohio EPA guidance.

GRC-ATF is expected to remain under NASA's control for the foreseeable future. Although it is unlikely that TRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to represent unrestricted use and evaluate the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction. TRBG is best classified as an inactive area and plausible receptors include groundskeepers and hunters. No groundwater at GRC-ATF is used for drinking water under current or planned future use. The GRC Master Plan (NASA 2008) states the following: *"Groundwater underlying PBS shall not be extracted or used for any purpose, potable or otherwise, except for investigation, monitoring or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities."*

The groundwater exposure routes evaluated in the HHRA include ingestion, dermal contact, and inhalation (for certain organic compounds). Risks were calculated for both cancer and non-cancer effects using the USEPA RSL calculator. Lead exposures were evaluated for the resident child using USEPA's IEUBK model, which is used to predict the relative increase in blood lead concentration that might result from environmental exposure.

For hypothetical residential land use, the total resident child HI for groundwater (15) exceeds the target of 1. Because the total HI exceeds 1, the chemicals were segregated according to target organ or system and an HI was calculated for each target organ. The following target organ HIs exceed the target of 1 for the resident child: the HI of 2 for nervous system effects (due to manganese [2] and aluminum [0.7]), the HI of 6 for dermal effects (due to arsenic [2], and thallium [4]), the HI of 2 for gastrointestinal effects (due to iron [2]), and the HI of 2 for endocrine system effects (due to cobalt [2]). The total ILCR of 2E-04 for groundwater exposure is above the upper bound of the target cancer risk range and is associated almost entirely with arsenic. The lead model results for the resident child show that the probability the blood-lead concentration would exceed the level of concern is less than the USEPA target.

After further evaluation of the data for filtered groundwater samples, no organic chemicals or metals were identified as COCs. Arsenic, aluminum, cobalt, iron, manganese, and thallium were eliminated as COCs because they were either not detected in filtered samples or detected at concentrations for which the calculated HQ was equal to or less than 1. Note the high turbidity associated with the November/December samples (>1,000 NTUs), which helps account for the decrease in concentrations generally seen in both the filtered samples and in the May/June samples.

10.6 SUMMARY OF ECOLOGICAL RISK ASSESSMENT

An ERA was completed in the Phase I RI Report. TRBG is approximately 5.2 acres and is vegetated with shrubland surrounded by forested area, with a wetland on the western boundary of the site. Wetlands are considered important ecological resources, and there is soil documentation of contamination at TRBG, so further analysis was conducted in a Level II ERA. It was determined that there are no final COPECs at TRBG. Consequently, the ERA for TRBG concluded with a Level II Screening ERA, and NFA was recommended to be protective of important ecological resources (Leidos 2018b).

Ecological receptors are not typically exposed to groundwater except for caves and when groundwater daylights to surface water. No known caves are at GRC-ATF, and this site does not contain surface water bodies. As a result, ecological exposures to chemicals in the groundwater are not a concern.

10.7 CONCEPTUAL SITE MODEL

Section 1.3 presents the CSM associated with this site, including the contamination sources, exposure pathways, human receptors, and ecological resources. In addition, Figure 1-3 provides the pathway network receptor diagram to support the groundwater HHRA. This section updates the CSM and discusses potential risk identified, data gaps, and uncertainties.

10.7.1 Groundwater Contaminant Migration Pathways and Exit Points

The general flow of groundwater in overburden is to the north-northeast toward Lake Erie, largely mirroring surface topography. The flow also corresponds somewhat to the topography of the top of the bedrock. In contrast, the Delaware Limestone water-bearing zone is saturated year-round but also flows to the north-northeast toward Lake Erie. Saturated soil occurs within unconsolidated glacial overburden at a depth range of 2.0 to 5.4 feet bgs. Groundwater discharge to surface water features (e.g., via base flow to streams or springs) does not occur within the site boundary.

Contaminant leaching pathways from soil to the water table are through silty clay loam and loamy sand unconsolidated soil. Groundwater sampling results indicated that one of the two initial CMCOCs (hexachloroethane) was not detected in groundwater above screening criteria and the other initial CMCOC (naphthalene) was only detected in one sample at an estimated concentration and did not exceed the tap water RSL.

Only three metals (cadmium, iron, and manganese) exceeded their respective background concentrations and/or the tap water RSL in groundwater at TRBG in both the total and dissolved samples. Bis(2-ethylhexyl)phthalate was the only SVOC and methylene chloride was the only VOC detected above the screening criteria.

10.7.2 Potential Receptors

GRC-ATF is expected to remain under NASA's control for the foreseeable future. Although it is unlikely that TRBG will be developed for residential purposes, a hypothetical onsite residential scenario was included to evaluate the upper bound for long-term exposure. Generally, sites that "pass" a residential risk assessment can be released for use without restriction.

The site has no streams or ponds. Surface water in the ditches was not present during the 2015 SI, 2017 Phase I RI, or 2021 Phase II RI.

Groundwater at GRC-ATF is not used for drinking water, and no injection wells are onsite. The Erie County Health Department does not allow the use of surface water as private drinking water. The GRC Master Plan (NASA 2008) states that groundwater underlying GRC-ATF shall not be extracted or used for any purpose, potable or otherwise, except for investigation, monitoring or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities. Prior to transfer or conveyance of GRC-ATF or any portion thereof, the General Services Administration and NASA shall ensure that the prospective purchaser or transferee: i) is aware of the environmental conditions of the property; and ii) agrees, as a condition of the purchase/transfer, to enter into an environmental covenant with the State of Ohio prohibiting the extraction or use of groundwater underlying GRC-ATF for any purpose, potable or otherwise, except for investigation, monitoring or remediation of groundwater, or in conjunction with construction or excavation activities or maintenance of subsurface utilities.

10.7.3 Uncertainties

Uncertainties are inherent in the CSM depending on the density and availability of data. The CSM for TRBG groundwater is overall well defined using existing data, and major data gaps do not remain to be resolved. However, some uncertainties for the CSM for TRBG include some SRCs were identified due to the lack of background concentration data available or having limited or slight exceedances of established background concentrations.

10.8 EMERGING CONTAMINANTS

As presented in Section 2.4, TRBG was one of the eight AOPCs at GRC-ATF where NASA is assessing potential PFAS contamination. The assessment is being conducted under a separate investigation; therefore, a PFAS evaluation is not included in this RI. The results of the investigation can be viewed in the PFAS SI Report (Leidos 2022).

10.9 RECOMMENDATIONS OF THE REMEDIAL INVESTIGATION

This Phase II RI only evaluated groundwater at TRBG as soil was evaluated in the Phase I RI. Based on the Phase II RI investigation results, TRBG groundwater has been adequately characterized, and further investigation is not warranted to complete the RI for groundwater. The nature and extent of potentially impacted media has been sufficiently characterized.

The HHRA did not identify any COCs with residential use of groundwater at TRBG. Ecological exposures to chemicals in the groundwater are not a concern. NFA is required to address chemical contamination within groundwater at TRBG.

An FS addressing soil contamination at TRBG was prepared in 2018 (Leidos 2018c). The recommended alternative was excavation and offsite disposal of approximately 2,824 cubic yards of contaminated soil. Since no COCs were identified with residential use of groundwater at TRBG, no additional recommendations are warranted for the FS for groundwater. However, it is recommended that the soil RSLs used the Phase I RI be compared to current RSLs to determine if any additional COCs are present in surface and subsurface soils and if the remedial cleanup goals in the FS need to be updated.

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