National Aeronautics and
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May 22, 2023

Reply to Attn of: RE-23-092

Mr. Ricardo Maestas, Acting Bureau Chief
New Mexico Environment Department
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

Subject: Response to Approval with Modifications 500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I

NASA White Sands Test Facility (WSTF) received NMED's March 1, 2023, *Approval with Modifications 500 Area Fuel Storage (SWMU 47) Investigation Work Plan (IWP): Phase I*, in which NMED provided three comments related to NASA's June 2021 *Response to Second Disapproval of 500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I*. NMED directed NASA to respond to the Approval with Modifications by May 31, 2023 with a response letter that cross-references where NMED's modifications were addressed, as well as respective replacement and electronic redline-strikeout pages indicating where changes were made.

NASA addressed NMED's comments and provided three additional comments related to site status, potential schedule interferences, and document updates that occurred between NASA's June 2021 *Response to Second Disapproval of 500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I* and NMED's March 1, 2023 Approval with Modifications. NASA cannot accurately forecast distillation operations, fuel transfers, or testing that may be performed in the 300, 400, 500, and 700 Areas at this time, and may propose an alternate schedule in the future if testing impacts the approved investigation field schedule.

This submittal includes a printed response table that cross-references NMED's comments as Enclosure 1. Printed replacement pages for the revised investigation work plan are provided as Enclosure 2. Enclosure 3 provides a CD-ROM that includes the final report, the redline-strikeout report, and response table in electronic form.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

If you have any questions or comments concerning this submittal, please contact Antonette Doherty of my staff at 575-202-5406.

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Timothy J. Davis
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3 Enclosures

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National Aeronautics and Space Administration

500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I

September 2018

Revised November 2019

Revised June 2021

Revised May 2023

NM8800019434

NASA Johnson Space Center White Sands Test Facility

500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I

September 2018

Revised November 2019

Revised June 2021

Revised May 2023

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

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Executive Summary

The NASA JSC (Johnson Space Center) WSTF (White Sands Test Facility) was required by the previous WSTF Hazardous Waste Permit issued by the NMED (New Mexico Environment Department2009) to develop Investigation Work Plans (IWP) for SWMU (solid waste management units) at WSTF. This IWP (investigation work plan) was approved with modifications (NMED, 2023) under Hazardous Waste Permit (NMED, 2016) and will be implemented under the RCRA (Resource Conservation and Recovery Act) Post-Closure Permit (RCRA Permit; NMED, 2023b). Where applicable, references and citations have been updated to the current standards, guidance, and NMED-approved documents. This IWP describes field investigation activities that will be conducted at the 500 Area Fuel Storage (SWMU 47) for this Phase I Investigation.

Eleven proposed primary soil borings will be advanced from ground surface to the alluvium-bedrock interface located at approximately 110 ft (feet) to 225 ft bgs (below ground surface). Up to 15 soil samples will be collected during the advancement of each boring and analyzed for COPC (contaminants of potential concern), which include hydrazine, unsymmetrical dimethylhydrazine, and monomethyl hydrazine, collectively referred to as hydrazines, as well as N-nitrosodimethylamine (a potential oxidation product of some hydrazines), IPA (isopropyl alcohol), and acetone (a potential component of IPA degradation in soil). Up to five of those borings will be advanced into bedrock and groundwater grab samples will be collected (if groundwater is encountered within the borehole). These five borings will be reviewed for groundwater recovery, completed as monitoring wells as appropriate. The completed wells will be incorporated into the WSTF Groundwater Monitoring Plan (NASA, 2018). The results of the soil sample analyses will be compared to SSLs (Soil Screening Levels) in accordance with RCRA Permit Section 3.5.2 (NMED, 2023b, pp28-29) and used to perform a health risk screening for current industrial and construction worker receptors in accordance with the NMED Risk Assessment Guidance for Site Investigations and Remediation, Volume I, Soil Screening Guidance for Human Health Risk Assessments (NMED, 2022), as updated, and provide data for future health and ecological risk assessment in subsequent phases of investigation at SWMU 47 in accordance with RCRA Permit Section 6.5 (NMED, 2023b).

NASA expects to initiate investigation fieldwork approximately four to six months after NMED approval of this IWP, complete fieldwork approximately eight to ten months following initiation, and complete and submit an investigation report to NMED approximately 18 months after NMED approval of this IWP.

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List of Acronyms

ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
DQOs	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ft	Feet
GMP	Groundwater Monitoring Plan
GPS	Global Positioning System
HAZWOPER	Hazardous Waste Operations and Emergency Response
HIS	Historical Information Summary
HSA	Hollow Stem Auger
HTH	Hypochlorite Trihydrate
HWB	Hazardous Waste Bureau
IDW	Investigation-derived waste
in.	Inch(es)
IPA	Isopropyl Alcohol
IWP	Investigation Work Plan
JSC	Johnson Space Center
MMH	Monomethyl Hydrazine
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
OSHA	Occupational Safety and Health Administration
PID	Photoionization Detector
ppb	Parts per billion
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance and Quality Control
RCRA	Resource Conservation and Recovery Act
SAM	San Andres Mountains
SCEM	Site Conceptual Exposure Model
SHP	Safety and Health Plan
SOP	Standard Operating Procedure
SWMU	Solid Waste Management Unit
SWMU 47	500 Area Fuel Storage
TIVC	Total Ionizable Volatile Compounds
UDMH	Unsymmetrical Dimethylhydrazine
USDA SCS	United States Department of Agriculture Soil Conservation Service
VOA	Volatile Organic Analysis
WSTF	White Sands Test Facility

1.0 Introduction

The NASA (National Aeronautics and Space Administration) JSC (Johnson Space Center) WSTF (White Sands Test Facility) is located at 12600 NASA Road in central Doña Ana County, New Mexico. The site is approximately 18 miles northeast of Las Cruces, New Mexico and 65 miles north of El Paso, Texas (Figure 1.1). WSTF has supported testing of space flight equipment and materials since 1964 and continues to operate as a field installation of JSC. The WSTF U.S. EPA (Environmental Protection Agency) Facility Identification Number is NM8800019434.

The WSTF Resource Conservation and Recovery Act Hazardous Waste Permit (Permit), issued by the NMED (New Mexico Environment Department) in November 2009 required the preparation of several IWP (investigation work plans) to assess the potential impact of historical releases of hazardous waste or hazardous constituents (NMED, 2009). The 2009 Permit required NASA to determine whether these releases may have the potential to serve as continuing sources of soil and/or groundwater contamination. Permit Attachment 16 listed the WSTF SWMU (Solid Waste Management Units) and areas of concern that require the submittal of an IWP to the NMED HWB (Hazardous Waste Bureau) for closure and/or investigation (NMED, 2009).

This IWP describes the approach for a planned Phase I Investigation of SWMU 47, as identified in the Hazardous Waste Permit Attachment 16 as the 500 Area Fuel Storage. This IWP was approved with modifications (NMED, 2023) under previous Permit (NMED, 2009) and will be implemented under the RCRA Post-Closure Permit (RCRA Permit; NMED, 2023b). Where applicable, references and citations have been updated to the current standards, guidance, and NMED-approved documents. Figure 1.2 shows the location of the SWMU relative to the industrial areas at WSTF.

1.1 Objectives and Scope

The objective of this investigation is to identify the nature and extent of COPC (contaminants of potential concern) in the vadose zone and potential migration pathways of contaminant releases to the soil and groundwater in the area adjacent to and downgradient of the active portion of SWMU 47. NASA anticipates SWMU 47 will remain active indefinitely, in support of rocket engine testing. Therefore, NASA proposes a phased approach in order to investigate the potential impact of historical releases. The initial phase of this investigation is described in this work plan, which includes soil sampling in 11 borings and the installation of between three and five groundwater monitoring wells. Additional investigation of SWMU 47 will be performed following permanent cessation of fuel storage operations. Follow-on investigation work plans will be prepared in accordance with Section 6.2 of the RCRA Permit (NMED, 2023b, pp81-86). The scope of the initial investigation is limited to the vadose zone and groundwater in the area adjacent to, upgradient, and downgradient of the active portion of SWMU 47 and specific to the known COPCs, determined by historical use of SWMU 47.

NMED's reminder, from Comment 3 of the Second Notice of Disapproval (NMED, 2021), that this is a partial investigation and the unused portion of SWMU 47 cannot be considered for no further investigation induced NASA to reconsider the objectives of this investigation. NASA revisited the objectives and agree that a partial SWMU cannot receive a "no further investigation" determination. Therefore, NASA revised the current scope of the work plan to focus on determining the nature and extent in soils and groundwater, while also considering human health risk evaluations. NASA is reducing the network of soil borings from the original IWP proposed: 16 borings to 11 borings. Reduction in the boring network will allow for the health risk evaluation, while still encompassing a network of borings within SWMU 47 with upgradient and downgradient components. Table 1.1 includes the soil boring reduction rationale.

1.2 Regulatory Requirements

SWMU 47 was originally identified in the Hazardous Waste Permit Attachment 16 with a required IWP submittal date of June 30, 2011. In conjunction with submittal of IWPs, the Hazardous Waste Permit (Section VII.H.1.c) required the submittal of a HIS (historical information summary) to the NMED HWB. In a teleconference on January 6, 2011, NMED proposed that NASA submit a HIS with previous investigation results for SWMU 47 prior to submitting an IWP (NASA, 2011a). In response, NASA submitted the SWMU 47 HIS in conjunction with the IWP and HIS for the 400 Area Closure Investigation on June 27, 2011 (NASA, 2011b). NMED disapproved the 400 Area IWP and stated in Comment 2 that NASA may request to defer further site investigation of SWMU 47 until the area is no longer in use (NMED, 2011). On October 27, 2011 in the reply to the disapproval, NASA stated that a request to defer further site investigations at SWMU 47 would be submitted to NMED in subsequent correspondence (NASA, 2011d). NASA submitted a Class I Permit Modification Request on November 17, 2015 to the NMED HWB to request a new submittal date for the SWMU 47 IWP to “60 days before closure” (NASA, 2015). NMED approved the Permit Modification on December 16, 2015 (NMED, 2015). The approval included NMED modifications indicating that NASA must perform additional investigation of SWMU 47 to fully delineate the contaminant plume identified during previous investigations at SWMU 47. It was unclear if that investigation work was required as part of the SWMU investigation following closure or before closure. NASA evaluated the available options and determined that investigation of SWMU 47, adjacent to, and downgradient of the active portion of the SWMU should be performed prior to closure to determine if there is a continuing source of contamination in the soil. This document was prepared in accordance with the Hazardous Waste Permit and describes the work proposed for that investigation. Deviations from several specific Hazardous Waste Permit requirements for the purpose of this investigation are summarized in Appendix A. Investigation activities will follow those outlined in this NMED-Approved IWP. Permit driven references have been reviewed and, where applicable, references and citations have been updated to the current RCRA Permit (NMED, 2023b).

1.3 Other Considerations

SWMU 47 is an active facility that continues to provide fuel storage for the 300 and 400 Area test operations. The timeframe for future closure of SWMU 47 is unknown and contingent upon current and future test operations within the 300 and 400 Areas. Because SWMU 47 is an active facility at WSTF, NASA will only investigate areas adjacent and downgradient of the active portion of SWMU 47 prior to SWMU closure. The portions of SWMU 47 facility actively being used will be investigated at the time of closure. Due to the nature and stability of the fuels stored at SWMU 47, explosive risk related to drilling vibrations is not anticipated. Mechanical connections, however, may come loose as a result of those vibrations and will require a daily inspection to ensure the safety of all field personnel. In the event that a fuel leak occurs, field activities will be immediately suspended and field personnel will evacuate the area until the leak is resolved and the area is safe to return to active fieldwork. Any leaks that impact continued drilling or boring location will be discussed and resolved with NMED.

Off-specification hydrazine fuel storage for recycling at a distillation unit is in the preliminary planning stages for use at SWMU 47, as initially identified in the April 26, 2019, Request for a "Contained in Determination" for FTU (Fuel Treatment Unit) Debris (NLCID; NASA 2019). The distillation unit has a tentative installation date in 2020 with a tentative concrete pad extension off the north side of the current drum pad area. Figure 1.3 shows the approximate location of the pending distillation pad. The initial phase of this investigation will consider the addition of the planned distillation unit in reference to the placement of wells and concerns with potential active operation interference.

This work plan will be executed in the vicinity of two active test areas: 300 Area and 400 Area (Figure 1.2). There may be periods during which field personnel will not be allowed access to the work area. NASA cannot accurately forecast propulsion testing that may be performed in these two areas at this time but may propose an alternate schedule in the future if testing impacts the field schedule presented in Section 11.0. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

During the interlude from NASA's June 2021 submittal and NMED's March 2023 approval with modifications of this IWP (NMED, 2023a), the previously discussed distillation pad was constructed with a pending start date for off-specification hydrazine recycling in July 2023. The recycling process is scheduled to operate continuously for approximately five years. Due to safety concerns related to the recycling process, the majority of the field area within the vicinity of SWMU 47 may be inaccessible to field personnel during distillation operations and may impede investigation schedules initially proposed in Section 11.0 of this IWP. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

Additionally, the 700 Area High Energy Blast Facility (SWMU 18) is increasing test operations in the area. There may be periods during which field personnel will not be allowed access to the work area related to safety procedures for testing. NASA cannot accurately forecast blast testing that may be performed in the 700 Area at this time but may propose an alternate schedule in the future if testing impacts the field schedule presented in Section 11.0. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

2.0 Background

Historical operations at SWMU 47 are described in the HIS (NASA, 2011b). Additional details regarding SWMU 47 historical operations were also provided by NASA in the *Notice of Disapproval, 400 Area Closure Investigation Work Plan* comment resolutions table (NASA, 2011d).

2.1 Operational History

SWMU 47 was constructed in the mid-1960s for use during the Apollo Space Program testing at WSTF. It contained a 21,000-gallon above-ground steel tank to store hydrazine fuels, overhead fuel distribution lines from the tank to the WSTF testing areas, a low-point stainless steel drain line that extended approximately 350 ft (feet) northwest of the facility, and a Fuel Storage Control Building (Building 501). The fuel tank was built on a concrete pad with a secondary containment concrete pad to the south that sloped into a gunite-lined pond with dimensions of 60 ft x 80 ft. The gunite-lined pond included a sump that terminated approximately 45 ft to the north of the pond via a 4-in. (inch) pipe with a closed check gate. An aerial photograph from 2006 is presented in Figure 2.1 to provide a historical and current overview of significant features associated with SWMU 47. Figure 1.3 shows the complete gunite-lined pond and the sump drain line.

The gunite-lined pond was primarily used to capture fire extinguishment water from testing the Firex®[1] system. According to an interview in the HIS, the gunite-lined pond may have been used to contain any potential fuel spills. The potential spills may have been treated with calcium HTH [hypochlorite trihydrate] for oxidation and left to evaporate (NASA, 2011b; 2011c).

Fuel was historically transferred into the 21,000-gallon tank from tanker trucks (NASA 2011b). Any remaining fuel in the lines was drained using the low-point drain line into a 55-gallon steel open container located at the terminus. The fuel in the container was oxidized with HTH and/or allowed to burn. Use of

[1] Firex is a registered trademark of Walter Kidde Portable Equipment, Inc.

the 21,000-gallon hydrazine tank and steel container ceased in the early to mid-1970s with the conclusion of the Apollo Space Program testing at WSTF (NASA 2011d). Fuel has been stored since the early to mid-1970s in closed-top 55-gallon drums east of the original tank location on the concrete pad under a shelter and occasionally to the south on the secondary containment concrete pad (NASA, 2011b).

Adjacent to SWMU 47, to the east of the parking area, was the historical alcohol storage area. Originally, an aboveground tank stored alcohol (IPA [isopropyl alcohol]) in the 1960s. This tank was removed prior to 1998, and the area is currently not in use (NASA, 2011a).

2.2 Additional Operational History Post-HIS

Historical operations at SWMU 47, described in the HIS (NASA, 2011b), provided operational descriptions and documentation through June 2011. Starting in 2011 through 2012, the fuel distribution lines to the testing areas, the low-point stainless steel drain line, and the 21,000-gallon hydrazines tank were decommissioned. As part of this process, all lines and the tank were triple-rinsed, sampled, and verified that decontamination was successful. The lines and tank were removed and relocated to the WSTF 150 Storage Area.

In 2015, four 3,300-gallon aboveground fuel tanks were installed in the location of the original 21,000-gallon tank (see Figure 2.1). Fuel is stored in these four aboveground tanks and in a mobile tanker truck with a 2,500-gallon capacity on an as-needed basis.

Only one spill was recorded during post-HIS operations at SWMU 47. On April 5, 2016, approximately 0.90 pounds of MMH (monomethyl hydrazine) was noticed on the concrete containment underneath a tank flange. The spill was cleaned up with water and wipes, and drip pans were placed underneath the leaking fittings. The flange was decontaminated with water and wipes which were collected and placed in the area 90-Day Accumulation Area. The flange bolts torque was verified and re-torqued to repair the leak. No MMH was released to soil.

2.3 Previous Investigations

A three-phased soil investigation was conducted at SWMU 47 between July 2000 and May 2001 to evaluate concentrations of NDMA (N-nitrosodimethylamine), the common byproduct of hydrazine fuel oxidation and a current WSTF groundwater contaminant. The results of these investigations are shown in Table 2.1 and were previously provided to NMED in Section 20.35 of the August 8, 2002 RCRA Permit Renewal Application (NASA, 2002) and the May 6, 2004 Notice of Deficiency Response and Submittal of the Revised RCRA Permit Renewal Application Package (NASA, 2004). A brief summary of the soil investigation and historical data is provided in this section. The SWMU 47 HIS (NASA, 2011b) provides additional details. In Phase I, a backhoe was used to collect soil samples at depths of 5 ft and 10 ft bgs (below ground surface) at five locations: one to the west of the gunite-lined pond termed "background;" the low-point drain line terminus; the gunite-lined pond sump drain line terminus; to the north of the hydrazines tank location; and, to the north of the low-point drain line terminus termed "downgradient" (Figure 2.2). NDMA was detected at the 5 ft sampling interval at both the low-point drain line terminus (25.3 ppb [parts per billion]) and north of the tank location (maximum detected was 4.9 ppb).

For Phase II, a HSA (hollow stem auger) drilling rig was used to install 17 soil borings to approximately 30 ft bgs. Locations of the soil borings were: one boring located to the west of the gunite-lined pond termed "background;" one boring at the gunite-lined pond sump drain line terminus; seven borings near the low-point drain line terminus; and, eight borings north of the hydrazines tank location (Figure 2.2). NDMA was detected at two low-point terminus borings (all detected up to 30 ft bgs with a maximum detected concentration of 1.17 ppb) and three borings north of the hydrazines tank (all detected up to 30 ft bgs with a maximum concentration of 14.8 ppb).

Phase III soil borings were located downgradient of Phase II borings to further delineate NDMA in soils at SWMU 47. An HSA drilling rig was used to install nine soil borings to approximately 50 ft bgs. Four borings were located near the low-point drain line terminus, and five borings were located north of the hydrazines tank location (Figure 2.2). NDMA was detected at four low-point drain line terminus borings (all up to 50 ft with a maximum detected concentration of 1.26 ppb) and four borings north of the hydrazines tank (two detected to 50 ft bgs with a maximum detected concentration of 1.59 ppb).

2.4 Current Area Usage

SWMU 47 is currently used for the storage of hydrazine fuels (MMH, hydrazine, and hydrazine blends), with a maximum storage capacity of 19,200 gallons (up to 3,500 gallons within 55-gallon drums, up to 3,300 gallons each in 4 tanks, and up to 2,500 gallons in a mobile tanker). The fuel is stored to support propulsion testing operations, primarily for use in the WSTF 300, 400, and 800 Areas (Figure 1.2).

2.5 Contaminants of Potential Concern

Fuels historically stored at SWMU 47 include hydrazine, 1,1-dimethylhydrazine (UDMH [unsymmetrical dimethylhydrazine]), Aerozine 50 (a 50/50 blend of hydrazine and UDMH), and MMH. The on-site oxidation of fuels may have also resulted in the formation of NDMA, which was detected in soils near SWMU 47 during previous investigations (NASA, 2011b). As previously indicated, there was also an IPA storage tank originally located adjacent to SWMU 47. COPC (contaminants of potential concern) for this investigation therefore comprise hydrazine, UDMH, and MMH, collectively referred to as hydrazines, as well as NDMA, IPA, and acetone (a potential component of IPA degradation in soil). Table 2.2 provides a complete list of COPCs based on the historic operations and documented chemical releases.

2.6 Preliminary Site Conceptual Exposure Model

A preliminary SCEM (site conceptual exposure model) was developed to provide an understanding of the potential for exposure to hazardous constituents at SWMU 47 based on the source of contamination, the release mechanism, the receiving or contact medium, the exposure pathway(s), and the potential receptors(residential, industrial/occupational, construction worker, and soil-to-groundwater) exposure scenarios. Figure 2.3 summarizes and presents the SCEM in diagram form. Incomplete exposure pathways are denoted by dashed lines to potential receptors, and complete exposure pathways are denoted by solid lines.

2.6.1 Contamination Sources

Potential contamination sources are fuels (hydrazines) that may have been spilled or discharged to the environment from historical operations at SWMU 47, NDMA that may have formed or been discharged to the environment from oxidation of fuels, IPA that may have spilled or discharged from the adjacent historical WSTF alcohol storage area, and acetone that may have formed from IPA. During this investigation, the areas adjacent to and downgradient of SWMU 47 will be investigated to determine if any fuels, NDMA, IPA, or acetone are present in soils and groundwater.

2.6.2 Release Mechanisms

Fuels may have been released to the environment through spills from the low-point stainless steel drain line, leaks or spills from the 55-gallon open top barrel at the low-point drain line terminus, leaks from the hydrazines tank, or discharges to grade of treated fuel and water from the gunite-lined pond. NDMA could have formed from oxidation of the fuels through natural exposure or HTH usage. IPA could have been spilled during loading/unloading the alcohol tank and become the breakdown product acetone in the environment.

2.6.3 Exposure Pathways

NASA evaluated seven potential exposure pathways with current conditions at SWMU 47: 1) ingestion (direct and incidental) of soil; 2) dermal contact with soil; 3) inhalation of volatiles and particulate emissions (dust); 4) ingestion of groundwater; 5) dermal contact with groundwater; 6) inhalation of indoor air vapors; and 7) migration of COPCs through soil to underlying potable groundwater. There are no current or future residential land use scenarios anticipated in the vicinity of SWMU 47. WSTF is a controlled test site located on the U.S. Army White Sands Missile Range, and there are no encroaching residential areas. Therefore, there are no complete exposure pathways identified for the residential exposure scenario in the SCEM (Pathways 1 through 6).

SWMU 47 is currently used at WSTF to store fuels and there are no industrial buildings in the area (Pathway 6). Industrial/occupational workers deliver and remove fuel containers for use in propulsion testing performed at other areas at WSTF. If there is any residual surface soil contamination at SWMU 47, workers could come into contact with potentially contaminated wind-blown surface soils during routine working activities. Therefore, inadvertent ingestion or inhalation of, or dermal contact with, contaminated soil may be considered complete exposure pathways (Pathways 1, 2, and 3).

The groundwater underlying much of WSTF is known to be contaminated, and its future use and potential risk to receptors are part of ongoing site-wide evaluation and corrective actions. The only water supply wells for the site are located several miles to the west and down hydraulic gradient from SWMU 47. The supply wells are monitored regularly for the presence of any site-source contaminants. Ingestion of groundwater (Pathway 4) is not considered a completed exposure pathway for the residential, industrial/occupational, or construction worker exposure scenarios.

Environmental Department and subcontractor drilling crews (construction workers) will be performing this investigation, which includes installation of borings that intercept soil and potentially groundwater. A potential exposure pathway exists for that population to ingest, inhale, or come into dermal contact with potentially contaminated soil (Pathways 1, 2 and 3) or come into dermal contact with potentially contaminated groundwater (Pathway 5). This potential exposure will be mitigated by the use of engineering controls and proper use of PPE (personal protective equipment) during the investigation activities.

Pathway 7 represents the soil-to-groundwater pathway, which is a first step to determine if the release is a continuing source for contamination to groundwater. Data collected from this investigation will be evaluated as part of the SWMU 47 Investigation Report. A point-to-point comparison of maximum investigation soil concentrations will be compared to SSLs (soil screening levels). Complete current WSTF exposure pathways (Figure 2.3) will be evaluated per the NMED Risk Assessment Guidance for Site Investigations and Remediation, Volume I, Soil Screening Guidance for Human Health Risk Assessments (RA Guidance; NMED, 2022), as updated.

2.6.4 Potential Receptors

Investigation activities at SWMU 47 will include subsurface investigation that will provide complete release and exposure mechanisms to field personnel and subcontractor crews (site receptors - industrial/occupational and construction workers and potentially groundwater through the soil-to-groundwater pathway). NASA will conduct a risk and hazard evaluation for the potential receptors for complete pathways for receptors as outlined in the SCEM (Figure 2.3) in accordance with the NMED RA Guidance (NMED, 2022), as updated. A summary of the site receptor evaluation will be provided in the SWMU 47 Phase 1 Investigation Report. NASA will utilize procedures detailed in Section 5.5 to mitigate personnel exposure.

3.0 Site Conditions

3.1 SWMU 47 Description

SWMU 47 was built on a concrete pad with a secondary containment concrete pad to the south that sloped into a gunite-lined pond with dimensions of 60 ft x 80 ft. See Section 2.1 and the SWMU 47 HIS (NASA, 2011b) for a more detailed description.

3.2 Surface Conditions

Soil surface conditions at and near SWMU 47 consist of Quaternary piedmont slope facies of the Camp Rice Formation. The Camp Rice Formation represents part of the widespread upper Santa Fe Group alluvium (Seager, 1981) derived from the adjacent SAM (San Andres Mountains) to the east. The piedmont slope deposits comprise coalescent alluvial fans that originated from Bear Canyon, a major east-west-trending transverse canyon in the southern SAM located 1 mile east of SWMU 47. The alluvial fan that houses SWMU 47 has a gentle gradient towards the north indicating any surface flow or drainage would propagate northward and intersect the main arroyo running along the north side of SWMU 47.

Santa Fe Group alluvial deposits comprise variably sized gravel clasts within a sand silt, and clay sized matrix. The alluvium is consolidated to unconsolidated, poorly sorted and locally contains discontinuous cemented caliche horizons a few inches in thickness. The most proximal outcropping lithologic units are located approximately 1 mile to the east in the Bear Canyon area and comprise Pennsylvanian to Permian age limestone, sandstone, siltstone, and shale.

The soil type present at SWMU 47 is the Tencee-Nickel Association, Steep unit ([USDA] United States Department of Agriculture [SCS] Soil Conservation Service, 1976). This soil consists of approximately 45% Tencee Very Gravelly Loam and 40% Nickel Fine Sandy Loam with slopes up to 35% grade. General characteristics of this soil type include moderate permeability, very low water capacity, rapid runoff, severe water erosion capacity, and low probability of generating wind-blown soils. Gravelly soils containing less than 35% coarse fragments, badland, stony rock land, and arroyos are included in this soil type.

3.3 Subsurface Conditions

Unconformably overlying older Santa Fe Group alluvium in the vadose zone is Quaternary alluvium of the Camp Rice Formation and younger piedmont slope alluvium. These younger alluvial units are syntectonic with a period of younger Basin and Range faulting. Several subsurface faults in the vicinity of SWMU 47 have been inferred from seismic and in the adjacent 300, 400, and 700 Areas, well log data (Reynolds, 1988; Maciejewski, 1996).

No monitoring wells have been installed in the 500 Area. However, the adjacent 300, 400, and 700 Areas provide likely analogs to subsurface conditions at SWMU 47. Based on adjacent areas, bedrock lithology in the vicinity of SWMU 47 is expected to consist of Tertiary (Eocene or Oligocene) Orejon Andesite (Seager, 1981) at approximate depths between 110 and 225 ft bgs.

3.3.1 Structure

Two styles of geologic deformation are present in the vicinity of SWMU 47. The oldest and less prevalent deformation consists of west to northwest-trending folding and faulting associated with the Late Cretaceous to Early Tertiary Laramide Orogeny. This compressional deformation style is present east of SWMU 47, exposed along Bear Canyon, and defined by Seager (1981) as the Bear Peak Fold and Thrust Zone. Thrust faults of the Bear Peak Fold and Thrust zone are interpreted to extend northwestward along strike in the subsurface and pass north of SWMU 47. The second more recent and more prevalent deformational style consists of extensional northwest-trending Late Tertiary Basin and Range normal faulting. The local expression of this structural style is the Rio Grande Rift. Basin and Range normal faulting began in the Rio Grande Rift between 26 and 32 million years ago (Seager, 1981).

3.3.2 Hydrogeology

Based on adjacent areas to SWMU 47, the aquifer in the vicinity of SWMU 47 is likely hosted within the Tertiary andesite bedrock, typically at depths of between 121 ft bgs (monitoring well 700-J-200) and 233 ft bgs (monitoring well BW-5-295). The andesite bedrock has little to no primary porosity; therefore, any porosity and groundwater flow is within secondary fractures induced through structural episodes. Groundwater flow in the SWMU 47 vicinity is from east to west based on the latest groundwater depth measurements of monitoring wells in surrounding areas. Groundwater volume is generally restricted based on low hydraulic conductivities within the andesite aquifer determined from slug testing at monitoring wells in surrounding areas.

4.0 Scope of Activities

Investigation activities will be conducted under the supervision of the site supervisor (a qualified engineer, environmental scientist, or geologist) or designated field lead. The following activities will be performed during the investigation of the currently unused portion of SWMU 47 and the area adjacent to and downgradient of the SWMU.

- Field investigation of soil boring and groundwater monitoring locations. These locations will be based on:
  - Information within the SWMU 47 HIS
  - Information collected from previous investigations in the area.
  - Information identified in the field relative to any visible staining of soil or odors detected using portable field monitoring equipment.
- Daily safety and health briefings.
- Field data and GPS (global positioning system) survey data collection.
- Field operations for collection, management, and shipment of soil and groundwater samples (including field quality control samples).
- Laboratory analyses (including laboratory quality control samples), analytical reporting, and data processing using the established WSTF data management system.

- Interpretation of field and analytical data for use in development of an investigation report for the unused portion of SWMU 47.

4.1 Data Quality Objective Process

The investigation methodology was developed based on "Guidance on Systematic Planning Using the DQO [Data Quality Objectives] Process" (USEPA, 2006) and the Corrective Action Site Investigations requirements of the Hazardous Waste Permit (NMED, 2009; Section VII.H). The data acquisition plan (i.e., sampling design) is based on the DQO process and formulated to meet Hazardous Waste Permit requirements.

4.1.1 Problem Statement

The problem statement is summarized in the Hazardous Waste Permit (NMED, 2009; Section VII.H.1.b), which states that the IWP "…shall include schedules for implementation and completion of specific actions necessary to determine the nature and extent of contamination and the potential migration pathways of contaminant releases to the air, soil, surface water, and ground water." The problem statement is further clarified in NMED's December 16, 2015 comment on NASA's November 17, 2015 Permit Modification, which indicated that further delineation of subsurface contamination is required and that NASA "…must either demonstrate that migration of COC (contaminants of concern) to groundwater has not occurred or provide justification showing that COCs in the vadose zone are not a threat to groundwater."

4.1.2 Decision Statement and Alternative Actions

The primary decision is to determine the nature and extent of vadose zone contamination and whether contaminant migration to the groundwater has occurred. Alternative actions for the decisions include:

- If needed, perform further investigation for the site (or portions thereof) to further delineate potential source(s) of continuing contamination.

4.1.3 Decision Inputs

COPC concentrations measured in the vadose zone soil and local groundwater are the primary inputs to the decision. COPCs for this investigation were identified in Section 2.4. This section provides four decision inputs for evaluation of COPCs in soil and groundwater:

- Detailed information pertinent to the establishment and operational history of the 500 Area Fuel Storage as documented in the historical information summaries for SWMU 47 through a variety of historical documents and reports, personnel interviews, and personnel questionnaires.
- Validated analytical results from soil samples collected during the investigation will be compared to all applicable SSL including human health risk and hazard screenings using NMED SSL (NMED, 2022) and EPA's RSL (regional screening levels; November 2019) for analytes not listed in the NMED guidance. Results will also be compared with risk-based and MCL (maximum contaminant level)-based SSLs protective of groundwater for identified complete exposure pathways, in accordance with the NMED Risk Assessment Guidance for Site Investigations and Remediation (RA [Risk Assessment] Guidance; NMED, 2022).
- Validated analytical results from groundwater samples collected during the investigation will be compared to the RCRA Permit Section 3.5.1, Groundwater Cleanup Levels (NMED, 2023b, pp28-29).

- Soil analytical methods selected for this investigation will be used to quantify COPC concentrations at or below NMED SSLs whenever possible (NMED, 2022). Groundwater analytical methods selected for this investigation will be used to quantify COPC concentrations at or below RCRA Permit 3.5.1 cleanup levels whenever possible (NMED, 2023b, pp28-29).

4.1.4 Study Boundaries

The horizontal boundaries of the study represent the known extent of the SWMU as determined by historical research and confirmed by field surveys of the sites. The currently inactive and unused portion of SWMU 47 will be investigated. This investigation addresses and is limited to the upper portion of the vadose zone and groundwater beneath and downgradient of the unused portion of the SWMU. Adjacent areas to be included in the investigation include the upgradient portion of the Fire Break Road and the downgradient portion of the arroyo located to the north of SWMU 47 (Figure 4.1). The vertical boundary is the approximate depth to bedrock (110 ft to 225 ft). However, because groundwater is also of concern, three to five borings are expected to be advanced to groundwater (120 ft to 230 ft bgs), with depths not to exceed 250 ft bgs if groundwater is not encountered.

4.1.5 Study Constraints

One of the primary constraints to drilling and sampling in the 500 Area is related to subsurface geology. Based on previous soil boring and well installations across the site, cobbles and boulders are common within the coarse-grained coalescent alluvial fan deposits. These make collection of representative soil samples difficult, with previously reported soil sample recoveries as low as 20% using hollow stem augers equipped with split spoon samplers (NASA, 1996). Standard coring techniques also typically experience very low recoveries and problems with sidewall sloughing and collapse due to the extremely dry and relatively coarse-grained nature of the alluvium. Rotary techniques have the potential to contaminate samples through the use of drilling fluids or air. Small drill rigs (i.e., direct-push or mini-sonic rigs) are incapable of penetrating the difficult lithologies known to exist near the SAM front beyond a depth of a few feet. During the 600 Area and 300 Area Closure field investigations (performed November 2010 through January 2011), a modified heavy-duty sampling core barrel was used with an air-rotary casing hammer drilling strategy. This boring installation technique allowed for improved soil sample recovery (typically 20 to 50%) with minimal boring collapse. For the 400 Area Closure investigation, a combination of sonic and air rotatory drilling was utilized: sonic – to advance soil borings and collect soil cores within the uncemented alluvium; and rotary – to advancing borings to bedrock or groundwater. It has been concluded that only a limited number of drilling and sample collection approaches can be employed within the WSTF industrialized areas.

Another constraint is related to operations and testing in nearby areas. The proximity of the project area to the active testing and test support facilities also imposes logistical constraints. The active portion of SWMU 47 is currently used for fuel storage. Test support operations, fuel transfers, and other materials transfers (e.g., cryogenics and inert gases) may occur within the 500 area temporarily restricting access to SWMU 47. Current operations at the 300 and 400 Areas include support facilities for propulsion system and components testing. These areas were constructed to perform hazardous testing of hardware safely with access to essential utilities and control facilities. For safety purposes, access to select areas of the investigation site could be periodically restricted during testing and other hazardous operations. Field activities will be closely coordinated with the 300, 400 and 500 Areas in accordance with an internal communications matrix to minimize schedule impacts to testing and investigation activities.

4.2 Sampling Tasks

For the Phase I investigation, 11 soil boring locations (500-SB-01 through 500-SB-11; Figure 4.1) are anticipated to be installed using air rotary or sonic drilling methods. The following sections discuss sampling tasks. Drilling and sampling procedures are discussed in Section 5.0.

4.2.1 Soil Borings

The 11 soil borings are positioned to allow the collection of samples that will characterize the vadose zone below and adjacent to SWMU 47 (Figure 4.1). Table 1.1 provides the rationale for soil boring placement. One boring is planned upgradient of SWMU 47 to the north of the Fire Break Road (500-SB-04). Six borings are located within or immediately adjacent to the current SWMU 47 (Figure 4.2): one at the terminus of the removed low-point drain line (500-SB-02); one at the terminus of the sump drain line (500-SB-03); one at the historical alcohol storage tank (removed prior to 1998) location (500-SB-11); one at the termination of an “unknown” line (500-SB-10); one directly north of the active fuel storage pad (500-SB-09); and, one adjacent to the northeast of the gunite-lined pond (500-SB-08). Two borings will be positioned immediately adjacent to the secondary SWMU 47 fence: one near the northwestern corner of the gunite lined pond (500-SB-01); and, one near the arroyo to the north that originates within the SWMU 47 boundary (500-SB-07). Two borings are positioned downgradient: two borings adjacent to the main arroyo to the north of SWMU 47 (500-SB-05 and 500-SB-06).

Soil borings proposed for the initial investigation are specifically designed to provide the information necessary to characterize the extent of vadose zone contamination beyond the low-point drain line and the sump drain line. Most soil borings will be installed to bedrock in order to fully characterize the vertical extent of potential soil contamination. Three to five of the borings will be advanced into bedrock in an attempt to locate and sample groundwater. These borings will extend to 20 ft below the first encounter of groundwater. Potential boring locations for advancement to groundwater may include borings 500-SB-02, 500-SB-04, 500-SB-05, 500-SB-07, and 500-SB-09. If groundwater is not encountered in at least three of the five borings advanced to the anticipated depth of groundwater, NASA will propose additional locations in the next phased IWP for SWMU 47. Additional information related to groundwater sampling is provided in subsequent sections.

Four soil borings, located by the northwest corner of the gunite-lined pond (500-SB-01), the low-point drain line terminus (500-SB-02), the sump drain line terminus (500-SB-03), and the drum pad area (500-SB-09) will be drilled first in order to obtain representative analytical data for waste characterization according to the investigation-derived waste procedures (Appendix B). The remaining borings will be drilled in numerical order, or as close to numerical order as possible given recognized project constraints. Adjustments to the numerical sequence may be made in order to install borings in a manner that minimizes any disruption of the 500 Area operations and test support activities.

4.2.2 Sampling Design

The sampling design must fulfill the project DQOs, which requires contaminant concentration data from subsurface soil samples and groundwater samples. Sections 4.2.2 through 4.2.4 provide a detailed discussion of the project sampling design for soils and groundwater. Table 4.1 summarizes the sampling and analyses that will be performed during the initial investigation. A detailed discussion of drilling methods proposed for the investigation is provided in Section 5.1.

4.2.3 Soil Sampling Plan

To facilitate the collection of representative soil samples, investigation borings will be installed from ground surface to bedrock (approximately 110 ft to 225 ft bgs) or groundwater (approximately 130 ft to 200 ft bgs) as previously described. Based on drilling experience in similar geological conditions during the 300, 400 and 600 Area Closure Investigations, NASA expects moderate difficulty with the recovery of soil samples during boring installation. NASA plans to collect samples over discrete intervals without the use of drilling fluids. The air rotary drilling and sonic drilling methods, described in Section 5.1, will allow sampling of undisturbed cores over short depth intervals without using drilling fluids that could interfere with the chemical analysis. Additional soil samples may be attempted based on pertinent geological conditions or field observations (discolored soil, revised depth to bedrock, etc.).

To address project DQOs and exposure pathways, soil samples will be collected on 5-ft intervals to 30 ft bgs beginning with a surface sample (0 to 1 ft), on ten-foot intervals from 30 ft to 50 ft bgs, and on 25-ft intervals from 50 ft bgs to the bedrock. The depth to bedrock beneath the 500 Area is expected to vary between approximately 110 ft and 225 ft bgs. The deepest sample will be collected as close to the alluvial bedrock interface as feasible, taking into account issues of sample quality, sample recovery, and the position of the water table if encountered unexpectedly. Sampling procedures are discussed in Section 5.0.

Soil samples collected from the borings will be analyzed for the SWMU 47 COPCs (Table 2.2) using standardized analytical methods approved for use at WSTF. Table 4.1 summarizes planned soil samples and anticipated analytical methods.

NASA suggests conducting an if/then analysis for NDMA due to the unknown nature of the soils at depth, the groundwater in the 500 Area, and in consideration of the health risk requirements. This approach will prevent laboratory calibration blow-out issues as consulted and recommended by analytical laboratory personnel. The historical shallow soil investigations already suggest the presence of NDMA by Method 607, indicating that perspective samples within SWMU 47 could produce qualitative results by NDMA low-level instead of the quantitative results needed to perform health risk calculations. The if/then analysis will be analyzed by Method 607 first. For soil samples analyzed by method 607 in which NDMA is detected, low-level analysis will not be performed. For soil samples analyzed by method 607 in which NDMA is not detected, the low-level method will then be performed at the discretion of the laboratory.

NDMA low-level analyses will be completed using a gas chromatograph and mass spectrometer analytical method developed by Southwest Research Institute (SRI) that can achieve a low-level NDMA RL (reporting limit) and MDL (method detection limit). SRI developed the Test/Analytical Procedure 01-0408-031 (TAP-01-0408-031) to achieve low level (matrix spike) instrumental analytical technique for NDMA analysis. The SRI method is based on EPA Method 607 that SRI has modified to provide for lowest available detection limits. The NDMA low-level MDL of 1.7E-04 mg/kg exceeds the SL-SSL of 2.04E-05 mg/kg.

4.2.4 Groundwater Sampling Plan

NASA does not expect to encounter groundwater above bedrock at SWMU 47. However, per the NMED approved Class 1 Permit Modification Request with Modifications (NMED, 2015), “The Permittee must either demonstrate that migration of COC to groundwater has not occurred or provide justification showing that COC in the vadose zone are not a threat to groundwater.” To fulfill this requirement, three to five of the soil borings will be drilled to the anticipated depth of groundwater (approximately 120 to 230 ft bgs) as indicated in Section 4.2.1. If groundwater is not encountered, the boring will be plugged and abandoned according to RCRA Permit Section 5.3 (pp78-79) and New Mexico Office of the State Engineer Regulations 19.27.4.30.C NMAC.

The closest cross-gradient wells are 300-A-120, 300-A-170, and 700-J-200. These cross-gradient wells encounter groundwater between 120 ft and 130 ft bgs. Downgradient wells BW-5-295 and BW-7-211 encounter groundwater between 190 ft and 235 ft bgs. Groundwater is anticipated under poorly confined to non-confined conditions within the fractured Tertiary Orejon andesite at irregular depths of between 120-240 ft bgs, several tens of feet below the bedrock surface. If groundwater is encountered during drilling, it will be allowed to stabilize overnight. A piezometric level will be recorded the following morning, and a disposable or decontaminated Teflon®[2] bailer will be lowered into the boring and used to collect a grab sample of groundwater. Water quality parameters will be measured and grab samples will be analyzed for the COPC specified in Section 2.4.

If perched groundwater is encountered in the vadose zone above the alluvium/bedrock interface at a sufficient volume to allow for sample collection, drilling will be suspended and groundwater will be allowed to accumulate for sample collection as described in the preceding paragraph.

4.2.5 Monitoring Well Installation

Each of the borings planned for advancement to groundwater (borings 500-SB-02, 500-SB-04, 500-SB-05, 500-SB-07, and 500-SB-09) is a candidate for the installation of a groundwater monitoring well. Following contact with groundwater in these borings, if it occurs, each boring will be reviewed for monitoring well installation. Recharge, groundwater quality parameters, location, and long-term support for the WSTF groundwater assessment program as described in the GMP (Groundwater Monitoring Plan; NASA, 2022) will be considered as factors for well installation. Based on experience gained from monitoring wells installed in the 400 Area, there is a minimum amount of recharge required to obtain representative samples of approximately 0.5 gpm. In addition, there must be sufficient water in the well to purge the proposed sampling system (pump and tubing) and the well. This can be as much as 8 to 10 gallons. Additionally, potential low-flow bladder pumps must be submerged in the water to function properly, Therefore, the completed well must have at least 10 ft of groundwater. If the borings do not meet these minimum criteria, they will not be considered for well installation.

Investigation groundwater monitoring wells will be constructed in accordance with the requirements stated in Section 5.2.2 of the RCRA Permit (NMED, 2023b) with nominal 4 in. Schedule 80 PVC (polyvinyl chloride) casing and screen. Each groundwater monitoring well will include a 15 ft (0.010-in. slot) screen straddling the water table, with 5 ft of screen above the water table and 10 ft below the water table. The annular seal for the screened sampling zones will be comprised of bentonite chips or pellets. A generalized construction design for groundwater monitoring wells is presented in Figure 4.3. NASA will provide final monitoring well location, rationale, and proposed well construction details (i.e., well design, sampling system, etc.) to NMED for each well prior to construction for review and approval. In the event that a proposed location is determined to be insufficient for monitoring well installation, NASA will provide an email notification to NMED.

Annular materials will be emplaced using a minimum 1.5-in. ID tremie pipe. A 10/20 or similar silica sand filter pack will be placed to a height of 2 ft above and below the monitoring screen. Three feet of fine silica sand, such as 30/70 or similar, will be used to grade from the sand pack to a 5-ft bentonite seal composed of hydrated bentonite chips or pellets. Materials above the bentonite seal will be comprised of bentonite grout with at least 20% solids. The upper 10 ft of the borehole and well pad will be completed

[2] Teflon is a registered trademark of The Chemours Company FC, LLC.

with Type I Portland concrete. Figure 4.3 provides a diagram of the general well design with annular materials.

A 4-ft square (1.5 square miles) concrete pad that slopes away from the well will be constructed at ground level and surrounded by bollards. In locations where well stick-up and bollards may cause concern for traffic or safety, a flush well head design may be considered as an alternative. Final well design will be provided to NMED for approval prior to installation. A brass cap will be installed in the concrete well pad at each well. A survey will be conducted in accordance with the requirements for surveying monitoring wells listed in RCRA Permit Section 4.2.7 (NMED, 2023b, pp51-52). Coordinates and elevation will be recorded in the applicable well files. A permit application will be submitted to the New Mexico Office of the State Engineer to provide a record for each monitoring well.

Several types of dedicated and non-dedicated well sampling systems are used at WSTF due to the variability of sampling conditions encountered. A low-flow bladder pump sampling system or an appropriate alternative NMED-approved purging and sampling method capable of providing representative groundwater samples, for long-term support of the WSTF Groundwater Monitoring Program, will be considered for each of the proposed monitoring wells. In accordance with Section 5.1 (Conventional Monitoring Wells) of the approved GMP (NASA, 2022), the sampling system will be selected based on factors such as the depth to water, volume of water to be purged, water recovery rate, frequency of sampling, overall integrity of the well casing, and the cost of system installation.

Groundwater monitoring wells will be developed following the completion of the last well or boring installation for the project and then allowed to equilibrate for four weeks before commencing groundwater sampling activities. Samples will be collected as described in Section 5.3. As part of this initial investigation, a single set of groundwater samples will be collected, analyzed for investigation COPCs, and evaluated. Subsequent groundwater monitoring will be performed in accordance with the GMP (NASA, 2022).

For NDMA analysis, groundwater samples will be analyzed by an if/than approach similar to the NDMA soil samples. Groundwater samples analyzed by method 607 in which NDMA is detected, low-level analysis will not be performed. For groundwater samples analyzed by method 607 in which NDMA is not detected, the specific monitoring well will be resampled and analyzed for low-level NDMA.

5.0 Investigation Methods

This section addresses activities related to the acquisition and evaluation of field data. The drilling, sampling, and QA/QC (quality assurance/quality control) procedures required to achieve the project DQOs are presented in this section.

5.1 Drilling Procedures

Drilling will be conducted with methods selected to enhance the ability to collect representative soil samples, optimize the potential for completion of the wells without the use of drilling additives, and complete the wells to the targeted depth. The methods that will be considered, in order of preference based on cost, time, and capability of reaching the target depths, are air rotary and rotosonic (sonic). NASA also expects to consider the use of other technically acceptable methods proposed by potential drilling subcontractors.

5.1.1 Air Rotary Drilling

The air rotary drilling (e.g., ARCH [air rotary casing advance] drilling, Stratex™ drilling, etc) method uses compressed air as the fluid to clean the borehole of cuttings during advancement of the bit followed by 9 5/8-in. diameter casing used to prevent borehole collapse. Because cuttings will be a combination of chips from the bottom of the borehole and slough from above the bit, they will not be entirely representative of the specific bit depth at sample collection. Lithologic logs recorded for the borehole will include as much detail as is feasible.

In order to collect samples at specific depths, the borehole will be cleaned of cuttings and a sampling core barrel (e.g., modified sonic core barrel) will be driven 2 to 5 ft into the undisturbed formation at the bottom of the open borehole using a pneumatic driver head or drop hammer. The percentage of sample recovery will depend on the coarseness of the formation, which can impede or altogether prevent advancement of the core barrel.

Given that drilling conditions in the 500 Area are expected to be similar to those in the 300 and 400 Areas, split-spoon sampling tubes will not be used because of the high probability of sample refusal and equipment damage.

5.1.2 Sonic Drilling

The sonic drilling method involves driving a core barrel using vibration, rotation, and a downward force to collect soil core samples. The drilling rig has a hydraulically powered oscillator, which generates adjustable high-frequency vibrational forces. The sonic head is attached directly to the drill pipe or outer casing, sending vibrations down through the drill pipe to the bit. The core barrel will be advanced using vibration, rotation, and downward force to collect soil cores from the undisturbed formation. Once the core barrel has been advanced, a secondary casing will be advanced down to the same depth as the inner core barrel. The over-ride casing keeps the borehole from collapsing. Once the core barrel is removed, the core barrel will be retrieved to the surface and the soil core will be extruded from the core barrel through the use of gravity-aided vibration, into chemically-resistant containers (e.g. sampling sleeves, stainless steel troughs), minimizing the disturbance of the soil core and ensuring the collection of a representative soil sample.

Sonic drilling was successfully used during the 400 Area Closure Investigation and the continuous coring allowed for the entire volume of lithologic material in the boring to be captured for more complete downhole interpretation (NASA, 2017b). The continuous coring was also useful in determining specific depths for the well designs during the 400 Area Investigation. Sonic coring methods, however, have historically had difficulty advancing through bedrock at WSTF. Due to the improved representativeness of samples collected during the recent 400 Area Closure Investigation, sonic drilling will be considered in addition to the air rotary method.

5.2 Rig Access Procedures

Overhead lines, underground utilities, and equipment access to the SWMU 47 boring locations will be surveyed and evaluated following NMED approval of the proposed soil boring locations. The site inspection will include a review of the most current updated utility maps of the area to ensure that proposed sampling locations are not coincident with the location of known underground utilities and an evaluation to establish appropriate setback distance between equipment and any overhead lines.

The drilling subcontractor will provide specific drilling rig information prior to mobilization to WSTF in order to ensure that potential access issues can be resolved in advance. Upon arrival at WSTF, the drilling subcontractor is required to submit all drilling and related equipment to a detailed safety inspection prior to admission to the specific soil boring locations. Any concerns regarding the condition or performance of drilling equipment are resolved prior to proceeding to the first soil boring location. Equipment unloading and rigging up will take place at or near the exact soil boring location that it will occupy during operations.

5.3 Sampling Procedures (Collection, Management, Shipment) and Requirements

5.3.1 Soil Samples

Soil collected for analysis will be transferred from the sampler or sample collection tool using decontaminated stainless steel or polyethylene spatulas or spoons and placed directly into clean sample containers provided by the laboratory contracted to analyze the investigation samples. Excess soil around the top of the sample container will be removed to ensure proper lid fit and container closure. Disposable gloves will be worn to collect soil samples and changed between sampling intervals within each boring. Gloves and other disposable materials contacting the samples will be collected and managed in accordance with the SWMU 47 IDW (Investigation-Derived Waste) Management Plan in Appendix B.

5.3.2 Field Screening Procedures

During borehole installation activities, soil vapors derived from soil samples will be analyzed via the headspace method for TIVC (total ionizable volatile compounds) with a PID (portable photoionization detector) and total hydrazines with a Dräger®[3] vapor monitor. The PID and Dräger will be calibrated according to manufacturer’s instructions.

Using the headspace method, a representative soil sample will be immediately placed in an airtight plastic zip bag. The soil will be agitated and left in the bag for a minimum of five minutes, after which the headspace soil vapors in the bag will be measured for TIVC and total hydrazines. Each meter’s readings will be recorded in the field logbook. Headspace readings from soil samples may be used to assist with the selection of soil chemical samples as applicable.

5.3.3 Groundwater Sampling Procedures

Groundwater grab samples will be collected during drilling activities, for informational purposes, from boreholes that intercept groundwater. Groundwater will be collected using a decontaminated or disposable Teflon bailer. Grab samples will be dispensed from the bailer into appropriate laboratory-provided containers in accordance with site-specific procedural documentation and the GMP (NASA, 2022). Groundwater samples will also be collected following development, purging, and equilibration activities for up to five monitoring wells installed as described in Sections 4.2.4 and 4.2.5. The installed groundwater monitoring wells will be allowed to equilibrate for four weeks after the last well is fully developed for groundwater monitoring zones. Groundwater sample collection and management activities performed after well equilibration will be conducted in accordance with the GMP (NASA, 2022).

5.3.4 Sample Containers, Volume, and Preservation

Appropriately prepared and preserved (if required) sample containers for all sample media will be procured. Chemical samples will be containerized and preserved according to the instructions provided by

[3] Dräger is a registered trademark of Draegerwerk AG & Co. KGaA.

the analytical laboratory selected during the competitive procurement process planned following approval of this work plan. Geotechnical samples will be collected in clean plastic sealable bags or buckets.

5.3.5 Field Quality Control Samples

Field quality control samples will be collected as required in Part 4 of the RCRA Permit to ensure high quality data are generated during the investigation (NMED, 2023b). Field quality control samples will be collected as indicated below.

- Field blanks will be collected for each investigation medium (soil or groundwater) at a rate of one per sampling day.
- Field rinsate (equipment) blanks are typically collected from the sampling tooling at the onset of the project prior to sampling activities and if the sampling tooling is required to leave the project site prior to completion of the project. In addition, field rinsate blanks will be collected at a rate of 10% of investigation samples or one per sampling day if disposable sampling equipment is used.
- Field duplicate samples will be collected at a rate of 10% of investigation samples at select sampling locations. Duplicate samples will be analyzed for the same parameters as the primary samples.
- Five percent matrix spike/matrix spike duplicate MS/MSD (matrix spike/matrix spike duplicate) samples will be collected for specified analyses.
- Trip blanks will accompany VOA (volatile organic analysis) samples at a rate of one for each shipping container.

NASA has developed comprehensive internal procedures for sample collection, shipping, and management. These procedures provide specific information on sample management and related documentation, including instructions for sample custody (internal to NASA and external during shipment), storage, packaging, shipment, delivery tracking, and related recordkeeping. These procedures will be utilized during this project to ensure appropriate sample management.

5.4 Analytical Tasks

NASA contracts services from off-site, accredited analytical laboratories to support program and project needs, as required by the Section 4.5 of the RCRA Permit (NMED, 2023b, p61). Laboratories considered to support this project must conduct all sample analysis quality assurance and quality control in accordance Permit Section 4.5.1, Laboratory QA/QC Requirements, (NMED, 2023b, p61). The analytical tasks required to achieve the project objectives will be awarded to the off-site laboratory that is successful in the competitive procurement process. Potential laboratories must respond to a comprehensive statement of work developed to meet the project objectives defined in this IWP. Analytical SOP (standard operating procedures), laboratory quality manuals, and other laboratory-specific documentation are provided by the analytical laboratory following award of the contract and are not available in advance. These documents are retained in the project record and will be available for NMED review as required.

The overall objective for laboratory analysis is to produce data of known and sufficient quality to support project decision-making. Appropriate procedures and quality checks will be used so that known and acceptable levels of accuracy and precision are maintained for each data set. All samples will be analyzed by a fully qualified laboratory in accordance with the laboratory’s quality plan, which ensures that the contract laboratory adheres to standardized analytical protocols and reporting requirements and is capable of producing accurate analytical data.

As part of the competitive procurement process for analytical services, NASA requests that contracted laboratories achieve low MDLs. However, laboratories report that MDL can vary by several orders of magnitude for various analyses dependent on properties such as low-level calibration issues and matrix interference. The lowest possible MDL may not be achievable for every analysis. This is the case with hydrazines; WSTF soils have a history of matrix interference and do not always achieve the lowest MDL. In order to limit this occurrence, NASA will request laboratory analysis of hydrazines by EPA Method 8315 using liquid chromatography with tandem mass spectrometry (LC/MS/MS). Analyses that consistently produce an MDL above NMED and EPA screening levels will be discussed in the investigation report.

Method blanks and laboratory QC samples are prepared and analyzed in accordance with the laboratory's method-specific SOPs. The analytical results of method blanks shall be reviewed to evaluate the possibility of contamination caused by analytical procedures. At a minimum, the laboratory will analyze method blanks and laboratory control samples at a frequency of 1 in 20 for all batch runs.

5.5 Safety and Health

Field activities will be conducted in accordance with requirements of OSHA (Occupational Safety and Health Administration) Standards for HAZWOPER (Hazardous Waste Operations and Emergency Response, 29 CFR 1910.120 [b] – [o], 2013). The WSTF environmental contractor's SHP (Safety and Health Plan) will be augmented with site-specific Job Hazard Analyses to address potential hazard foreseeable for the project; and, will be followed in accordance with applicable requirements of the standards. The augmented SHP will address safety and health issues pertaining to work activities, including known and reasonably anticipated hazards associated with project scope of work as well as contingencies for unexpected conditions. The requirements of the SHP will apply to prime and sub-tier contractors as well as personnel requesting access to controlled areas of the investigation site. Project field personnel are required to be current in HAZWOPER training. In the event that new hazards are encountered that are not addressed by the SHP, the field team will stop work and coordinate with contractor health and safety experts to develop additional guidance on means to eliminate or mitigate any new hazards. As required by the Hazardous Waste Operations and Emergency Response (2013), the SHP and related project-specific safety documents will address:

- A safety and health risk or hazard analysis for each site task and operation found in this work plan.
- Employee training assignments.
- PPE to be used by employees for each of the site tasks and operations being conducted.
- Medical surveillance and fitness for duty requirements (based on nature of the project scope and COC).
- Frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used, including methods of maintenance and calibration of monitoring and sampling equipment to be used.
- Site control measures in accordance with the site control program.
- Decontamination procedures.
- An emergency response plan for safe and effective responses to emergencies, including the necessary PPE and other equipment.
- Confined space entry procedures.

- A spill containment program.
- Pre-entry briefing. The SHP shall provide for pre-entry briefings to be held prior to initiating any site activity, and at such other times as necessary to ensure that employees are apprised of the SHP and that this plan is being followed.
- Inspections shall be conducted by a recognized competent person is knowledgeable in occupational safety and health at WSTF.

During the project, subcontractors must comply with OSHA and EPA standards applicable to this IWP, the SHP, and any related area-specific (SWMU 47) safety documentation. Project subcontractor field personnel are required to be current in HAZWOPER training required under Hazardous Waste Operations and Emergency Response (29 CFR 1910.120 [b] – [o], 2013).

Safety professionals, or their designees, will inspect subcontractor equipment prior to the commencement of work. Any significant safety and health concerns will be identified, and the subcontractor will be allowed to address the concerns. If significant concerns cannot be rectified, this may be cause for termination of the subcontract.

5.6 Final Site Restoration and Grading

Final restoration and grading activities at the investigation site will commence after the completion of investigation field activities, receipt of the final analytical results, submittal of the investigation report to NMED, and receipt of concurrence from NMED. Soils characterized as non-hazardous will be spread to grade in the vicinity of the soil boring locations following NMED approval of a “no longer contained in” determination. All site grading will be completed to prevent ponding of water at the site location. Site restoration and grading activities may also include the installation of best management controls (e.g., diversion culverts, temporary berms, silt fences, etc.) to direct storm water away from the site locations to prevent storm water runoff impacts. Site restoration activities will not include any efforts to reseed the areas. Vegetation will be allowed to return naturally in the 500 Area.

6.0 Decontamination

All equipment, including drilling equipment, must be decontaminated prior to commencement of investigation activities at WSTF. All sampling and soil boring equipment will be decontaminated after completion of each sampling event and drilling equipment will be decontaminated prior to leaving the investigation site. General decontamination guidance available in ASTM International D5088-15a (ASTM, 2015) will be followed for this project.

Decontamination procedures will be performed by 40-hour HAZWOPER trained personnel wearing appropriate PPE. The decontamination of the drilling rig will be performed by the drilling subcontractor under the supervision of the site supervisor or their designee.

6.1 Decontamination Area

Initial decontamination of large equipment is expected to be performed at the existing concrete decontamination pad in the 600 Area. In addition, at least one decontamination area is expected to be established at a central location in the 500 Area. Individual smaller-scale decontamination pads may be constructed adjacent to individual boing locations to collect and contain soil brushed from the sampling equipment. All contamination reduction or decontamination activities will be performed over a properly designed pad or containment device that will retain any waste generated during the decontamination process. Waste generated during the decontamination process will be managed in accordance with the SWMU 47 IDW Management Plan provided in Appendix B. In the event that the decontamination pad requires any repairs to effectively contain decontamination fluids, activities that require decontamination will be halted until the decontamination pad is repaired.

Safeguards will be implemented to ensure no cross-contamination occurs between other projects that may be simultaneously conducted with this investigation. The decontamination area will be established within the contamination reduction zone in order to prevent any transport of contamination outside the investigation area. The decontamination area will be located away from the potential influence of the active 500 Area operations. Best practices will be employed to maintain the integrity of the decontamination process and protect the area from dust-producing site operations that could contaminate the equipment. Sampling and decontamination operations may be modified or delayed during dusty conditions, if necessary.

6.2 Decontamination Methods

6.2.1 Contamination Reduction

Drilling activities (if required subsequent to initial soil sampling) will be performed using an air-rotary or sonic drill rig without the application of drilling fluids (dry drilling). Adherence of the soil to the downhole equipment as well as production of liquid waste will be kept to a minimum with these methods. Soil will be removed from drilling equipment and sampling equipment using wire brushes and scraping tools such as spatulas or paint stirring sticks. Removal of solids will be performed over or inside an open-top 55-gallon drum or other suitable container using underlying plastic sheeting, or over plastic sheeting, to collect any soils.

6.2.2 Decontamination

Following the contamination reduction described above, decontamination will be performed to minimize the potential for cross-contamination between location and samples. Any tools or drilling equipment will be required to undergo contamination reduction and decontamination prior to exiting the area in order to ensure potentially contaminated soil or liquid is contained within the work area. Decontamination utilizes steam cleaning or pressurized heated water and/or detergent in conjunction with brushes, sprayers (as required), and a final rinse with purified water.

Equipment will be decontaminated between boreholes if it is to be reused at different sampling locations. All non-disposable equipment will be decontaminated at the end of the project or before leaving WSTF for any reason. The drilling rig, downhole equipment, and other reusable equipment that will not directly contact soil samples will be decontaminated using a steam cleaner or high-pressure heated water wash followed by thorough rinsing with WSTF potable water. Hand augers, core barrels, and other reusable equipment that will contact soil samples will be decontaminated by first, hand washing the item with non-phosphate detergent such as Alconox®[4] or by using a steam cleaner or high pressure heated water wash, then by rinsing with WSTF potable water, and finally by rinsing with purified water.

6.3 Decontamination of Field Screening Instruments

In the event field screening instruments are used to monitor the condition of the soil, dry decontamination followed by an alcohol-free moist wipe will be used for moisture sensitive equipment such as a PID.

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[4] Alconox is a registered trademark of Alconox, Inc.

Solid waste materials removed from the equipment and the wipes used will be disposed of as IDW and managed as indicated in Appendix B.

7.0 Field Documentation Procedures

The site supervisor will ensure that details of all activities related to this investigation are documented using a field logbook, field data records, and/or any required site-specific procedural documentation. Logbook entries will include, as applicable, information such as:

- Standard Daily Header – project name, logbook number, date, weather conditions, team members present and their affiliations (including subcontractors), sample location identification, day's task(s), daily safety meeting topics, PPE to be used, equipment in use, and any calibration information, if applicable.
- Daily activities (time and observations recorded) – site arrival and departure, visitors and the purpose of their visit, sampling information, soil type, soil conditions, decontamination (i.e., method, equipment cleaned), reference data sheets or maps, if applicable.
- Daily summary – action items, materials used, changes or deviations made from planned protocol, plan for next day.
- Signatures (field personnel and logbook reviewer).

At a minimum, field records will include observations of soil conditions, location surveys using GPS, and sample documentation. For analytical samples, the date, location, depth, sample type, collection method, identification number, sampler, and any circumstances, events, or decisions that could impact sample quality will be documented by the site supervisor in the project field logbook. Even though each case may be unique, the site supervisor's decision must be documented as to conditions that precipitated any decisions for the unsuitability of samples for analyses. In addition to the field logbook notes for sampling events, chain-of-custody forms will be completed for analytical samples and maintained with project documentation.

Evidential records for the entire project will be maintained in hard copy or electronic form and will consist of:

- Project IWP with any deviations redlined.
- Site-specific internal procedural documentation or plans.
- Project logbooks.
- Field data records (i.e., surveyed site location).
- Sample chain-of-custody forms.
- Correspondence with NMED.
- Final analytical data packages.
- Reports.
- Miscellaneous related records such as photos, maps, drawings, etc.

8.0 Investigation-Derived Waste Management Plan

As required in Hazardous Waste Permit Attachment 20 (Section 20.2.13), the IDW Management Plan is provided as Appendix B. The IDW Management Plan provides a description of the potential wastes that will be generated from the SWMU 47 investigation as well as procedures for waste management, waste characterization, and waste disposition. Wastes that may be generated as part of the investigation include: soil in the form of soil cuttings or remnants from sample collection; used sampling equipment; PPE; plastic sheeting; rags; miscellaneous debris contaminated by boring soil or fluids; and, water and soap solutions used for equipment decontamination.

9.0 Data Management Tasks

Data management tasks include project documentation and data review and assessment. The details related to these tasks are outlined below.

9.1 Project Documentation and Records

All facets of this investigation will be documented in detail by the responsible project personnel. Records are retained in the WSTF Operating Record and can be accessed at any time by authorized WSTF personnel.

9.1.1 Sample Collection and Field Measurements Data

Sample information and field measurements are recorded in the field logbook by the responsible project field personnel. These are reviewed by knowledgeable project personnel on a regular basis during the investigation and are retained in the project file. They are ultimately archived in the WSTF Records Management System as part of the Operating Record. As required for reporting, these data are also transferred to and archived in operational and historical databases.

9.1.2 Off-site Laboratory Data

Data packages from off-site analytical laboratories will consist of two primary components: comprehensive reports, to be submitted as Adobe PDF (portable document files) for review and archiving; and electronic data deliverable files to facilitate transfer of chemical analytical data into WSTF's analytical database(s). The PDF report will include a variety of information, including laboratory name, report date, sample-specific information, analyte names and Chemical Abstract Service numbers, analytical results, QC sample results, data qualifiers and narratives, pertinent analytical notes, laboratory reviewer signatures, and a variety of other information specific to the laboratory and analytical method. The electronic data deliverable will include the associated electronic data and follow the same review and approval cycle as the paper report.

9.2 Data Assessment and Review Procedures

A QA/QC specialist will evaluate the sample data, field, and laboratory QC results for acceptability with respect to the project quality objectives. Chemical analytical data will be compared with the project quality objectives and evaluated using the data validation guidelines contained in EPA guidance documents, the latest version of SW-846 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods and industry-accepted QA/QC methods and procedures (USEPA, n.d.).

9.3 Assessment and Response Actions

The conformance of investigation activities to the IWP will be evaluated on an ongoing basis while field activities are in progress. Additional verification will be provided through oversight of the field activities by the site supervisor or other responsible personnel. If a sample cannot be collected as planned, the site supervisor will be notified and, if possible, an alternate location or sampling method may be selected.

Significant deviation from the number and locations of samples indicated in the IWP will be discussed with NMED for concurrence. The assessment process will include immediate evaluation of any change to the sampling plan so that, if necessary, an alternate field procedure may be quickly established. Daily quality field assessments may be conducted during drilling and sampling activities. Field assessments will be performed by environmental professionals who are not immediate members of the field team. Following completion of field activities, a final review of field activities will be performed. Any deviations from the IWP or procedures will be documented and noted in the investigation report.

The contract laboratory will be required to notify NASA of significant data quality exceptions within one business day of discovery. Sample re-analysis will be performed, if possible. NASA will contact NMED as soon as practical to discuss any data quality exceptions that may affect the ability to meet the objectives of the investigation.

9.4 Data Review Process

A comprehensive review of sample analytical data will be conducted. Prior to conducting the review, the following information (where required and applicable) will be compiled and provided for the review.

- The NMED-approved IWP.
- Field sampling records and other pertinent field records.
- Laboratory reports.
- Statements of work and the laboratory Quality Management Plan.
- Electronic Data Deliverable Files.
- Standard Operating Procedures.
- Database tools.

9.5 Data Review Elements

Step I: Verification – Verification (review for completeness) is the confirmation by examination and provision of objective evidence that the specified requirements (sampling and analytical) have been completed (USEPA, 2005).

Data verification is the process of determining whether data have been collected or generated as required by the project documents. The process consists of the following categories: 1) verifying that field sampling operations were performed as outlined in the IWP; 2) verifying that the data collection procedures and protocols were followed; 3) verifying completeness to establish that sufficient data necessary to meet project objectives have been collected; and 4) checking that QC sample results meet control limits defined in the analytical methods.

Step II: Validation – Validation is the confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. Validation is a sampling and analytical process that includes evaluating compliance with method, procedure, or contract requirements and extends to evaluating against criteria based on the quality objectives developed (USEPA, 2005).

The purpose of validation is to assess the performance of the sampling and analysis processes to determine the quality of specified data. Data validation consists of the following objectives: 1) verifying that measurements (field and laboratory) meet the user's needs; 2) providing information to the data user regarding data quality by assignment of individual data qualifiers based on the associated degree of variability; and 3) determining whether project quality objectives were met. Data management personnel will perform data validation in accordance with the requirements in this IWP and existing WSTF procedures.

Step III: Usability Assessment – Usability assessment is the determination of the adequacy of data, based on the results of validation and verification, for the decisions being made. The usability process involves assessing whether the process execution and resulting data meet project quality objectives (USEPA, 2005).

The goal of the usability assessment is to determine the quality of each data point and to identify data that are not acceptable to support project quality objectives. Data may be qualified as being unusable or R (rejected), as based on established quality review protocols. Data qualified as J (estimated) are less precise, or less accurate, than unqualified data but are still acceptable for use. The data users, with support from the contractor environmental data management staff, are responsible for assessing the effect of the inaccuracy or imprecision of the qualified data on statistical procedures and other data uses. The data reporting will include a discussion of data limitations and their effect on data interpretation activities.

10.0 Current Monitoring and Sampling Programs

The most significant current monitoring program that contributes to this investigation is WSTF's ongoing groundwater assessment program. Though there are few groundwater monitoring wells in proximity to SMWU 47, there are several downgradient wells and cross-gradient wells (Figure 1.2). NASA relies on the data generated from groundwater monitoring to provide input for the development of IWPs. NASA routinely collects groundwater samples from a comprehensive network of monitoring wells at WSTF in accordance with the NMED-approved GMP (NASA, 2022). Groundwater samples are collected for the analysis of the following primary constituents: VOAs, NDMA, bromacil, and metals. In addition to routine groundwater samples required by the GMP, samples for other chemical analyses are frequently collected at many of the groundwater monitoring wells. Because these samples are not a direct requirement of the GMP, the results of these analyses are provided in the appropriate project-specific report.

11.0 Schedule

This investigation consists of three primary phases: 1) pre-investigation planning and preparation; 2) execution of the field investigation activities; and 3) data assessment and preparation of the investigation report detailing the findings of the investigation. The schedule for these activities is presented below.

11.1 Planning and Preparation

In addition to NMED review of this IWP, NASA must complete several important activities prior to the initiation of field activities. Resource requirements must be clearly identified and scheduled using the established NASA process for planning, funding, and executing work at WSTF. In addition, off-site resources must be coordinated. NASA expects these activities to require four to six months after NMED approval of this plan.

11.2 Field Investigation

Field activities for the initial investigation at SWMU 47 will be executed in the vicinity of a fuel storage area and active testing facilities. As a result, there may be periods during which field personnel will not be allowed access to the work area. NASA cannot accurately forecast distillation operations, fuel transfers, or testing that may be carried out in the 300, 400, 500, and 700 Areas at this time, and may propose an alternate schedule in the future if testing impacts the field schedule. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

Investigation of SWMU 47 is expected to be completed approximately eight to ten months after initiation. Unforeseen field conditions, such as access issues mentioned above, off-site resource availability, delays in approval of this IWP, or other complications possibly impacting this schedule will be discussed with NMED as they arise to determine the best resolution.

Field lithologic information, a revised well construction diagram, and any pertinent borehole details will be provided to NMED via email to expedite the review process after completion of any soil boring that is advanced to groundwater (Figure 4.3). NMED review and approval of the proposed well construction diagram is required prior the specific well installation. Expedited turnaround from NMED will be required in order to avoid short-term (or potentially longer term) standby delays.

11.3 Data Assessment and Reporting

Chemical analytical data from samples collected during the investigation should be fully available for verification and validation by NASA scientists within one month of the completion of field activities. These data will be evaluated as previously described, a process that typically requires up to two months. NASA will report non-detect values as less than the laboratory detection limit (e.g., groundwater NDMA-LL non-detect will be "<0.0022 µg/L"). Data that does not meet RCRA Permit requirements of 20 percent of the cleanup, screening, or background levels will be identified (NMED, 2023b, p61). Additional resources, guidance, or supporting data will also be assessed and utilized to support the investigation. NASA will include a risk and hazard evaluation based on complete exposure pathways in the SCEM (Figure 2.3) to support the conclusions and recommendations in the Phase I SWMU 47 Investigation Report in accordance with the NMED RA Guidance (NMED, 2022), current version. The results of these evaluations will be incorporated into a final report for submittal to NMED approximately 18 months following NMED approval of this work plan. Unforeseen delays in the completion of field investigation activities or data evaluation may adversely impact the completion of the report on this schedule and will be discussed with NMED as soon as possible upon NASA becoming aware of a problem.

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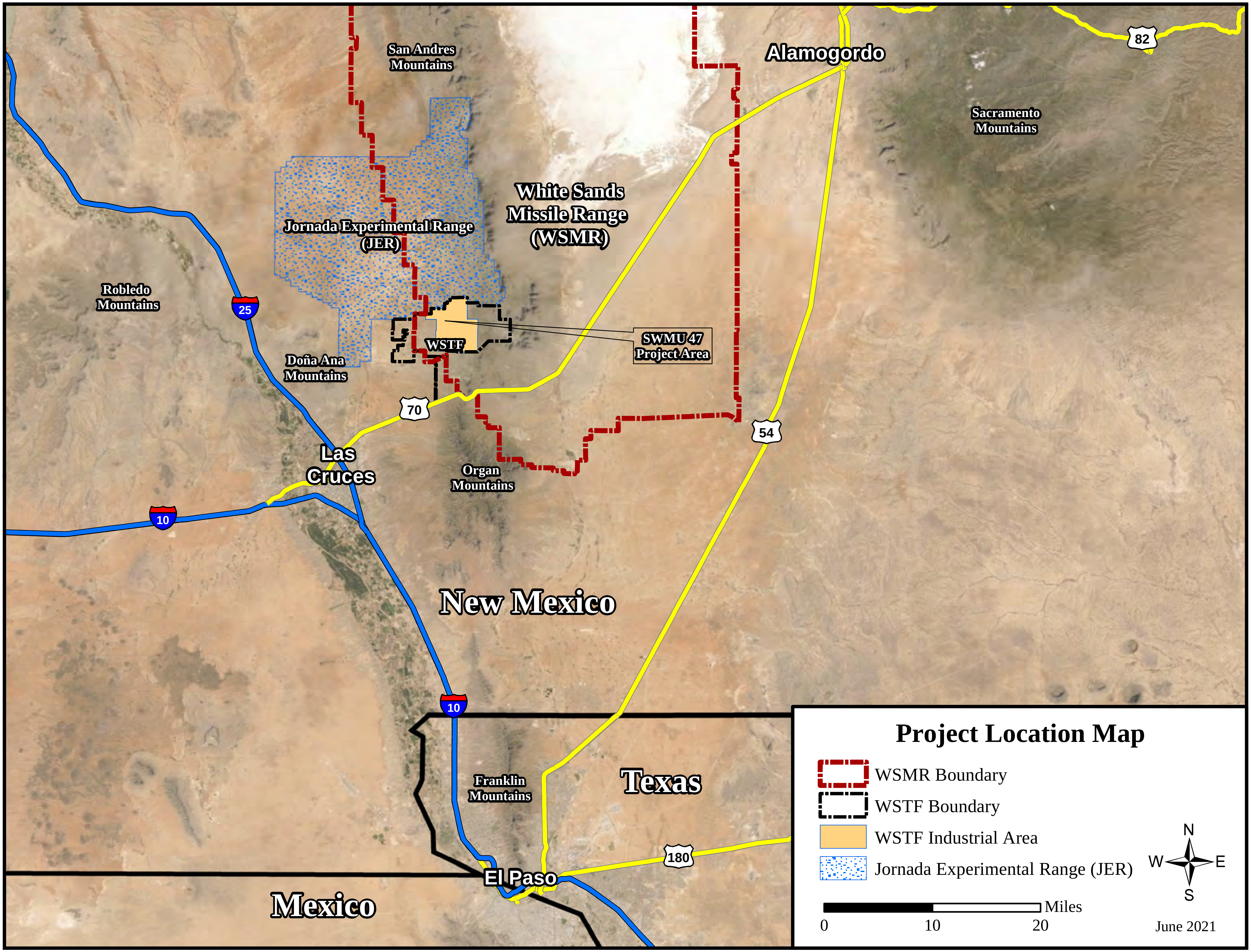
Figures

Figure 1.1 **WSTF Location**

(SEE NEXT PAGE)


San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
SWMU 47 Project Area
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
Project Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
N
W
E
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Miles
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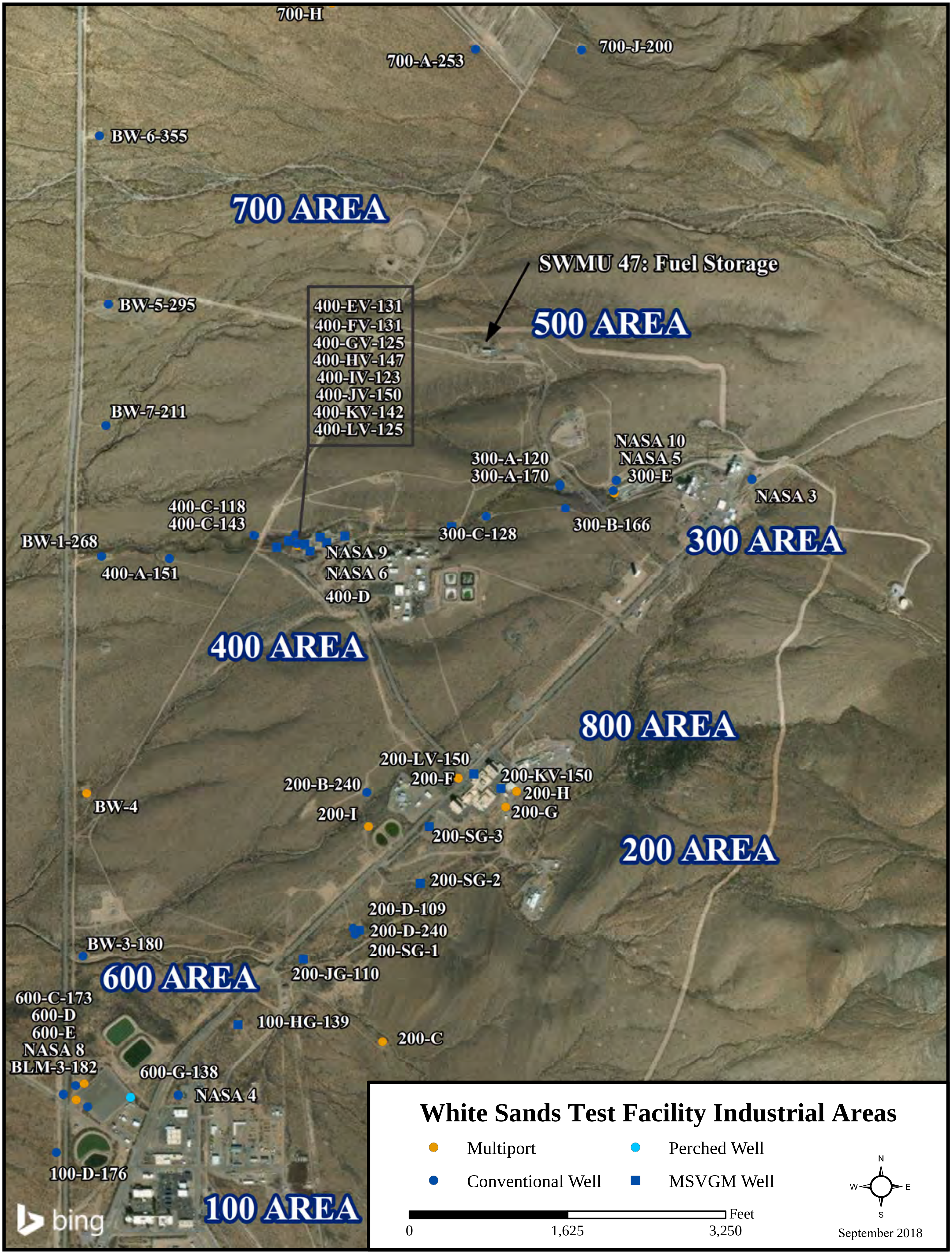
10
20
June 2021

Figure 1.2 **WSTF Industrial Areas**

(SEE NEXT PAGE)



700-H
700-A-253
700-J-200
BW-6-355
700 AREA
SWMU 47: Fuel Storage
500 AREA
BW-5-295
400-EV-131
400-FV-131
400-GV-125
400-HV-147
400-IV-123
400-JV-150
400-KV-142
400-LV-125
BW-7-211
NASA 10
NASA 5
300-E
300-A-120
300-A-170
NASA 3
400-C-118
400-C-143
300-B-166
300-C-128
BW-1-268
NASA 9
NASA 6
400-A-151
400-D
300 AREA
400 AREA
800 AREA
200-LV-150
200-F
200-KV-150
200-B-240
200-H
BW-4
200-G
200-I
200-SG-3
200 AREA
200-SG-2
200-D-109
200-D-240
200-SG-1
BW-3-180
600 AREA
200-JG-110
600-C-173
600-D
600-E
NASA 8
BLM-3-182
100-HG-139
200-C
600-G-138
NASA 4
100-D-176
100 AREA
bing
White Sands Test Facility Industrial Areas
Multiport
Perched Well
Conventional Well
MSVGM Well
N
W
E
S
Feet
0
1,625
3,250
September 2018

Figure 1.3 **WSTF 500 Area SWMU 47**

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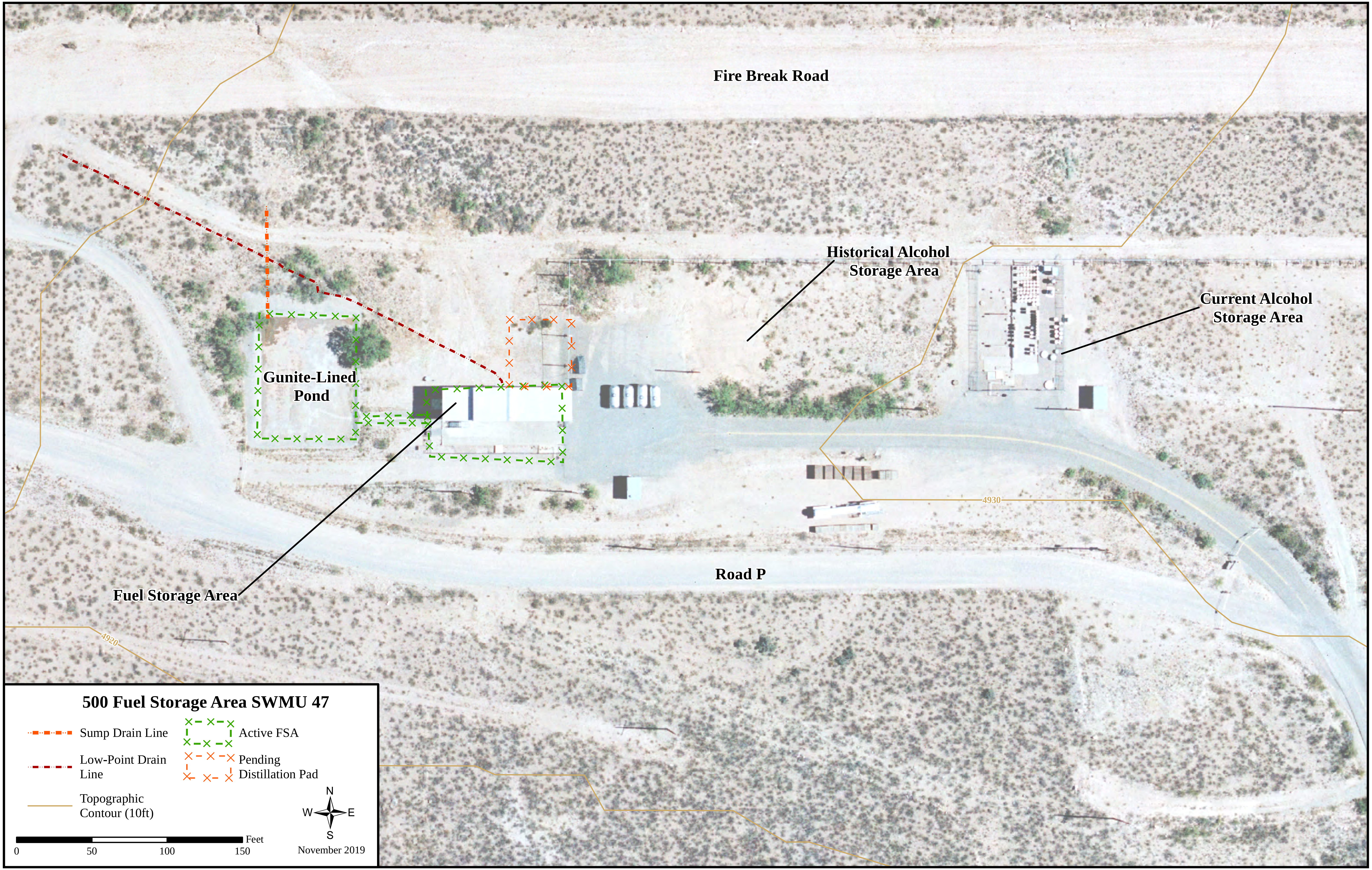


Fire Break Road
Historical Alcohol Storage Area
Current Alcohol Storage Area
Gunite-Lined Pond
Road P
Fuel Storage Area
4930
4920
500 Fuel Storage Area SWMU 47
Sump Drain Line
Low-Point Drain Line
Topographic Contour (10ft)
Active FSA
Pending Distillation Pad
N
W
E
S
0
50
100
150
Feet
November 2019

Figure 2.1 **WSTF 500 Area – View to the North**

(SEE NEXT PAGE)

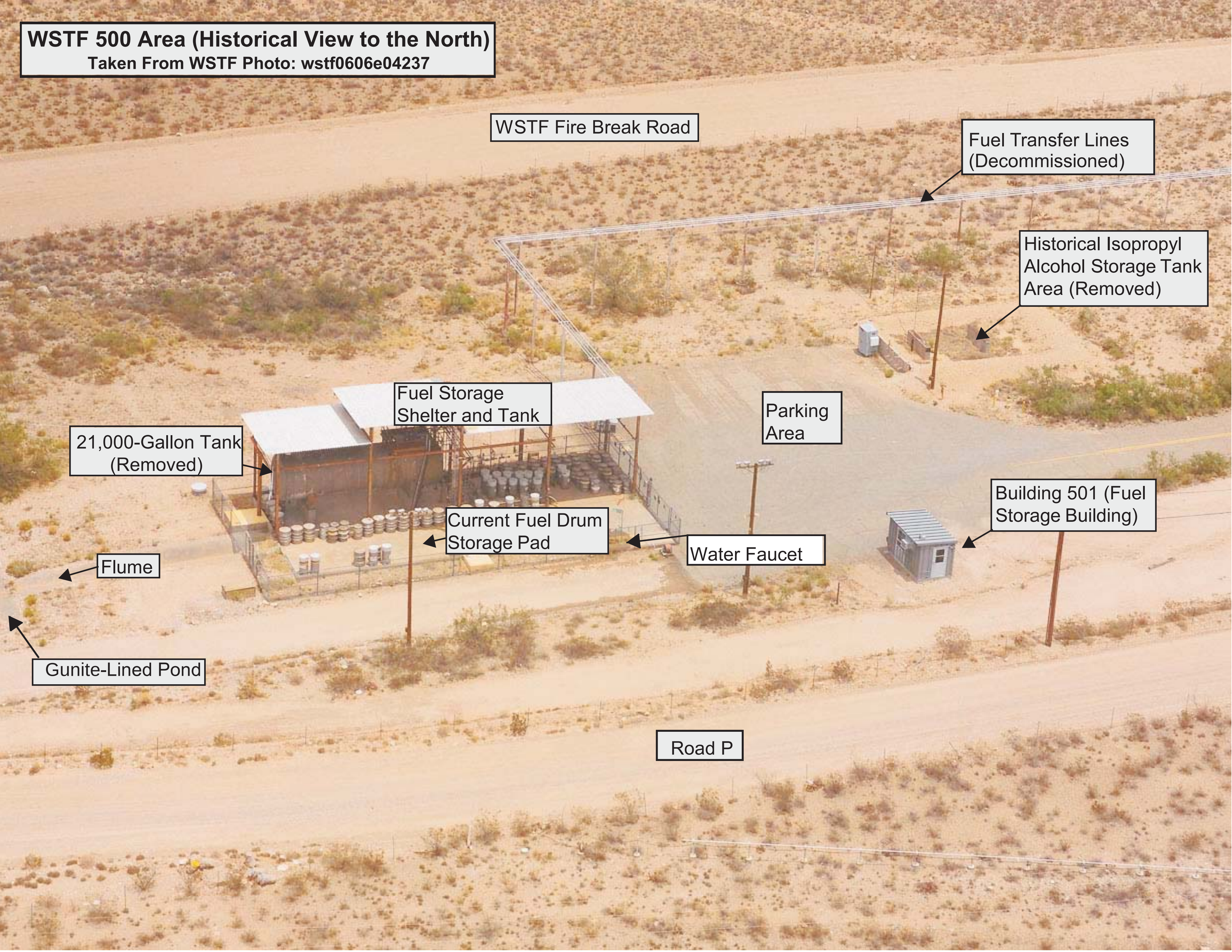

WSTF 500 Area (Historical View to the North)
Taken From WSTF Photo: wstf0606e04237
WSTF Fire Break Road
Fuel Transfer Lines (Decommissioned)
Historical Isopropyl Alcohol Storage Tank Area (Removed)
Fuel Storage Shelter and Tank
Parking Area
21,000-Gallon Tank (Removed)
Building 501 (Fuel Storage Building)
Current Fuel Drum Storage Pad
Water Faucet
Flume
Gunite-Lined Pond
Road P

Figure 2.2 500 Area Fuel Storage Previous Sampling Events

(SEE NEXT PAGE)

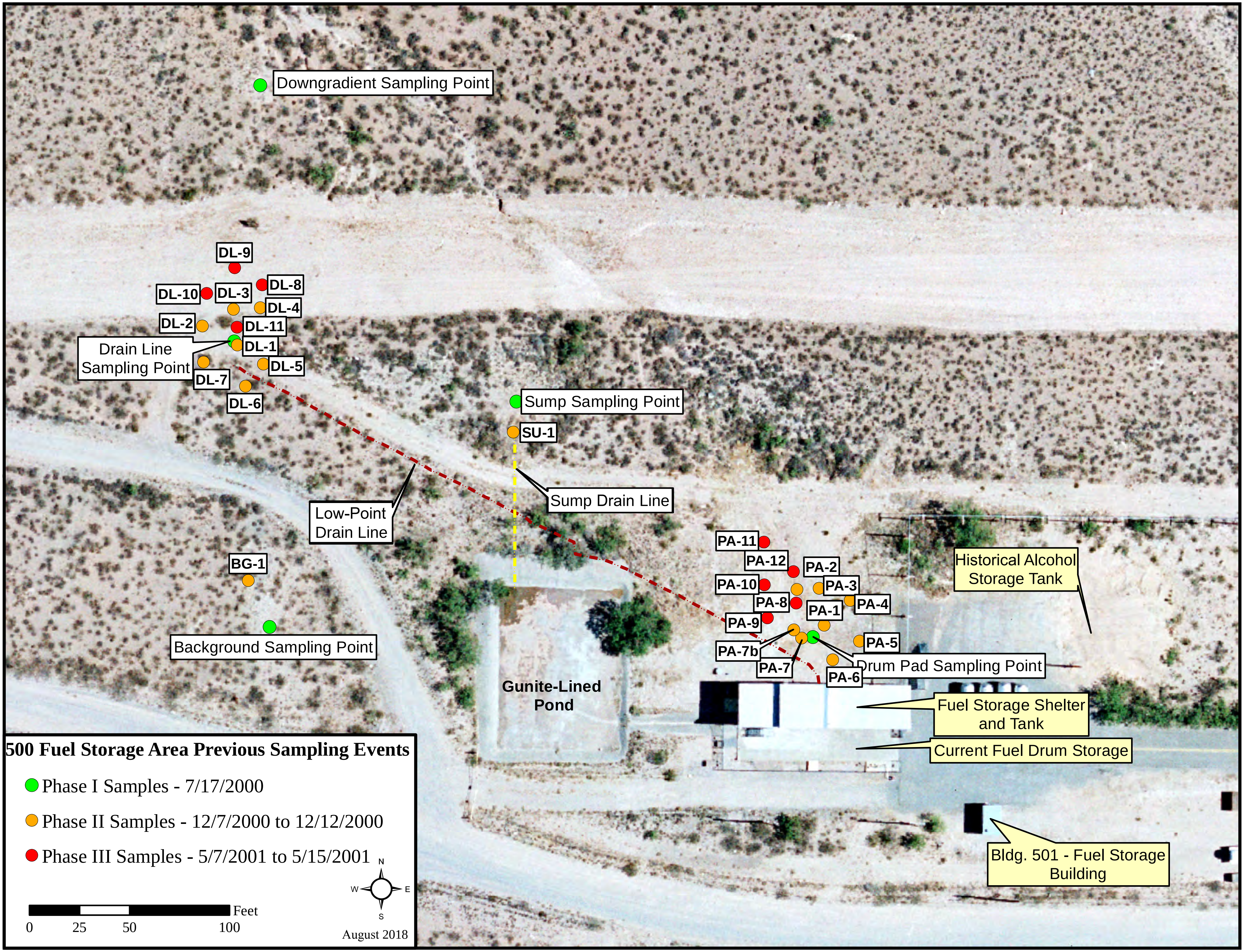

Downgradient Sampling Point
DL-9
DL-8
DL-10
DL-3
DL-4
DL-2
DL-11
Drain Line Sampling Point
DL-1
DL-5
DL-7
DL-6
Sump Sampling Point
SU-1
Sump Drain Line
Low-Point Drain Line
BG-1
Background Sampling Point
Gunite-Lined Pond
PA-11
PA-12
PA-2
PA-10
PA-3
PA-8
PA-4
PA-1
PA-9
PA-5
PA-7b
PA-7
PA-6
Drum Pad Sampling Point
Historical Alcohol Storage Tank
Fuel Storage Shelter and Tank
Current Fuel Drum Storage
Bldg. 501 - Fuel Storage Building
500 Fuel Storage Area Previous Sampling Events
Phase I Samples - 7/17/2000
Phase II Samples - 12/7/2000 to 12/12/2000
Phase III Samples - 5/7/2001 to 5/15/2001
N
W
E
S
Feet
0
25
50
100
August 2018

Figure 2.3 Preliminary Site Conceptual Exposure Model

(SEE NEXT PAGE)

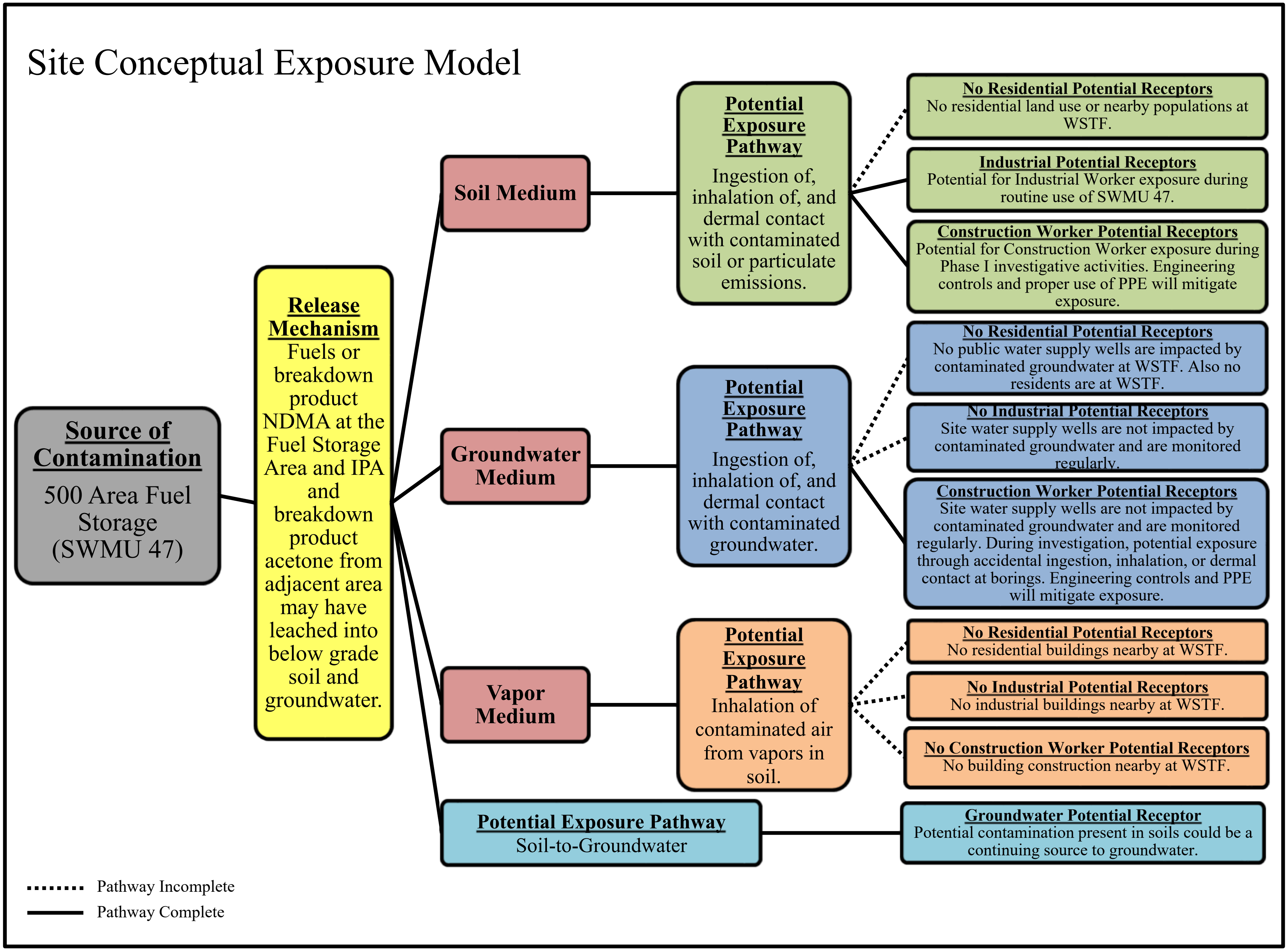
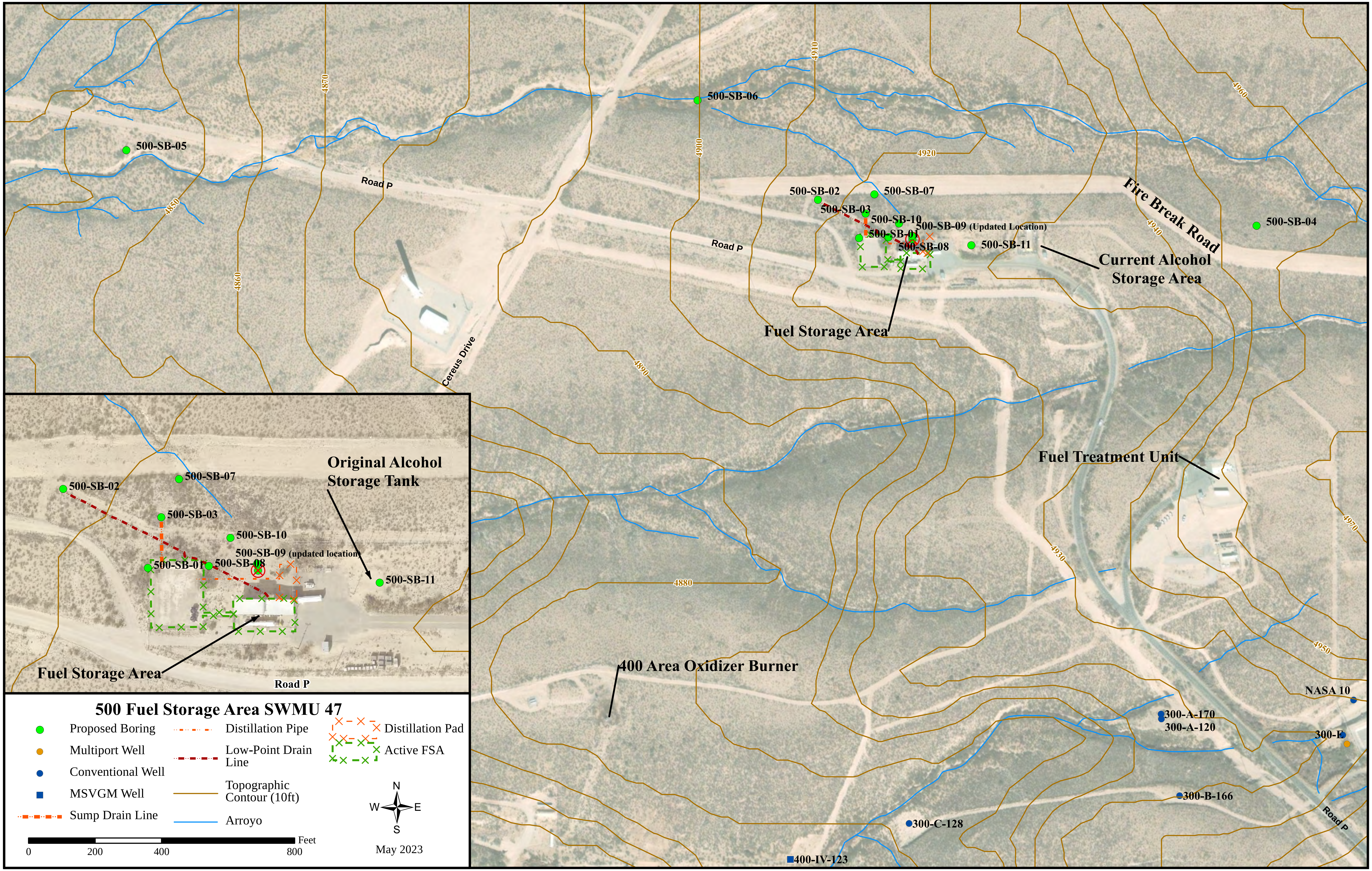

Site Conceptual Exposure Model
Source of Contamination
500 Area Fuel Storage (SWMU 47)
Release Mechanism
Fuels or breakdown product NDMA at the Fuel Storage Area and IPA and breakdown product acetone from adjacent area may have leached into below grade soil and groundwater.
Soil Medium
Groundwater Medium
Vapor Medium
Potential Exposure Pathway
Ingestion of, inhalation of, and dermal contact with contaminated soil or particulate emissions.
Potential Exposure Pathway
Ingestion of, inhalation of, and dermal contact with contaminated groundwater.
Potential Exposure Pathway
Inhalation of contaminated air from vapors in soil.
Potential Exposure Pathway
Soil-to-Groundwater
No Residential Potential Receptors
No residential land use or nearby populations at WSTF.
Industrial Potential Receptors
Potential for Industrial Worker exposure during routine use of SWMU 47.
Construction Worker Potential Receptors
Potential for Construction Worker exposure during Phase I investigative activities. Engineering controls and proper use of PPE will mitigate exposure.
No Residential Potential Receptors
No public water supply wells are impacted by contaminated groundwater at WSTF. Also no residents are at WSTF.
No Industrial Potential Receptors
Site water supply wells are not impacted by contaminated groundwater and are monitored regularly.
Construction Worker Potential Receptors
Site water supply wells are not impacted by contaminated groundwater and are monitored regularly. During investigation, potential exposure through accidental ingestion, inhalation, or dermal contact at borings. Engineering controls and PPE will mitigate exposure.
No Residential Potential Receptors
No residential buildings nearby at WSTF.
No Industrial Potential Receptors
No industrial buildings nearby at WSTF.
No Construction Worker Potential Receptors
No building construction nearby at WSTF.
Groundwater Potential Receptor
Potential contamination present in soils could be a continuing source to groundwater.
Pathway Incomplete
Pathway Complete

Figure 4.1 **SWMU 47 Proposed Borings**

(SEE NEXT PAGE)



500-SB-06
500-SB-05
500-SB-02
500-SB-07
500-SB-03
500-SB-10
500-SB-09 (Updated Location)
500-SB-01
500-SB-08
500-SB-11
500-SB-04
Road P
Fire Break Road
Current Alcohol Storage Area
Fuel Storage Area
Cereus Drive
Fuel Treatment Unit
400 Area Oxidizer Burner
NASA 10
300-A-170
300-A-120
300-B-166
300-C-128
400-IV-123
4850
4860
4870
4880
4890
4900
4910
4920
4930
4940
4950
4960
4970
Original Alcohol Storage Tank
500-SB-09 (updated location)
500 Fuel Storage Area SWMU 47
Proposed Boring
Multiport Well
Conventional Well
MSVGM Well
Sump Drain Line
Distillation Pipe
Low-Point Drain Line
Topographic Contour (10ft)
Arroyo
Distillation Pad
Active FSA
N
W
E
S
Feet
0
200
400
800
May 2023

Figure 4.2 Proposed Borings Within and Adjacent to the SWMU 47 Boundary

(SEE NEXT PAGE)

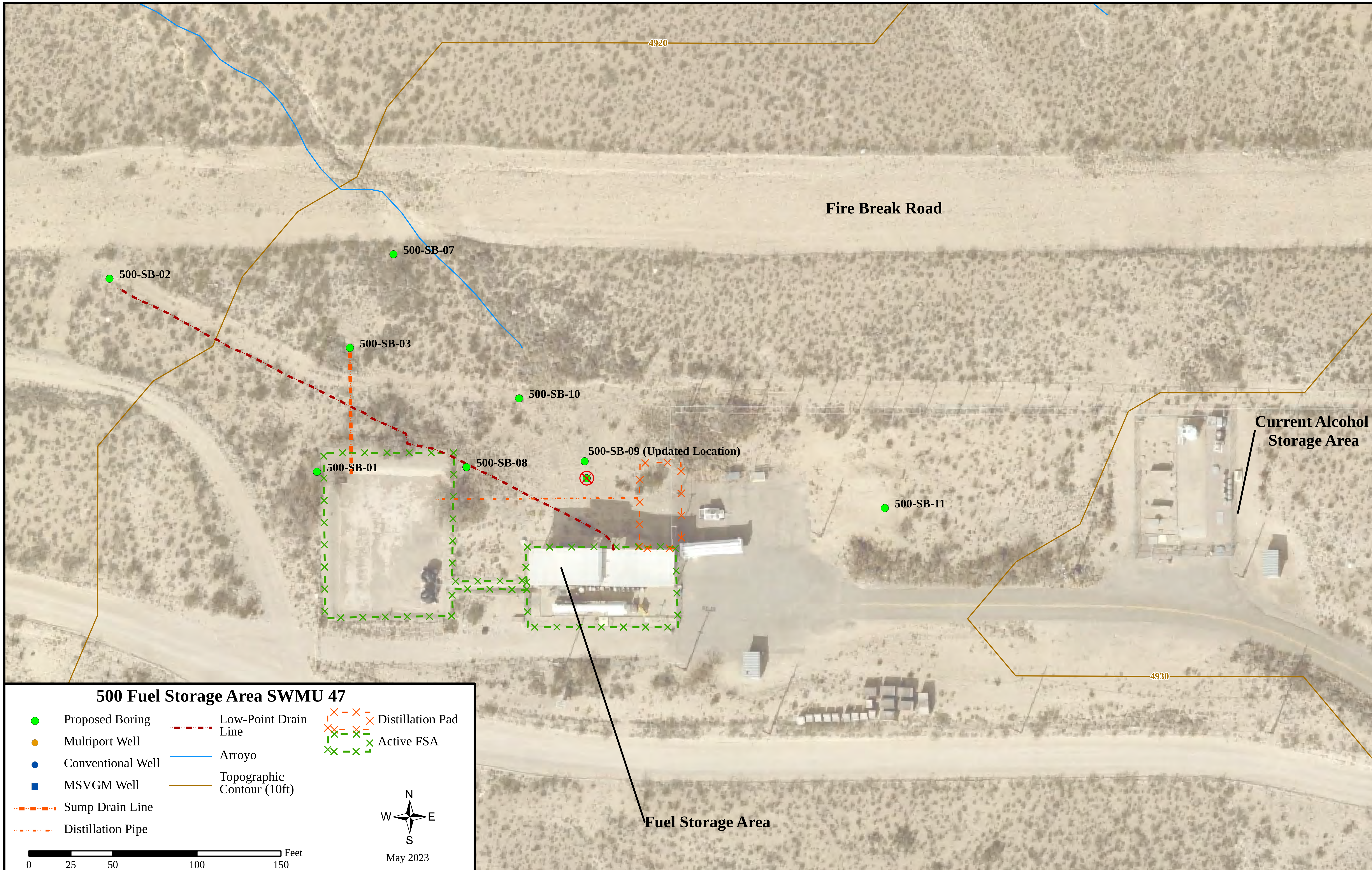
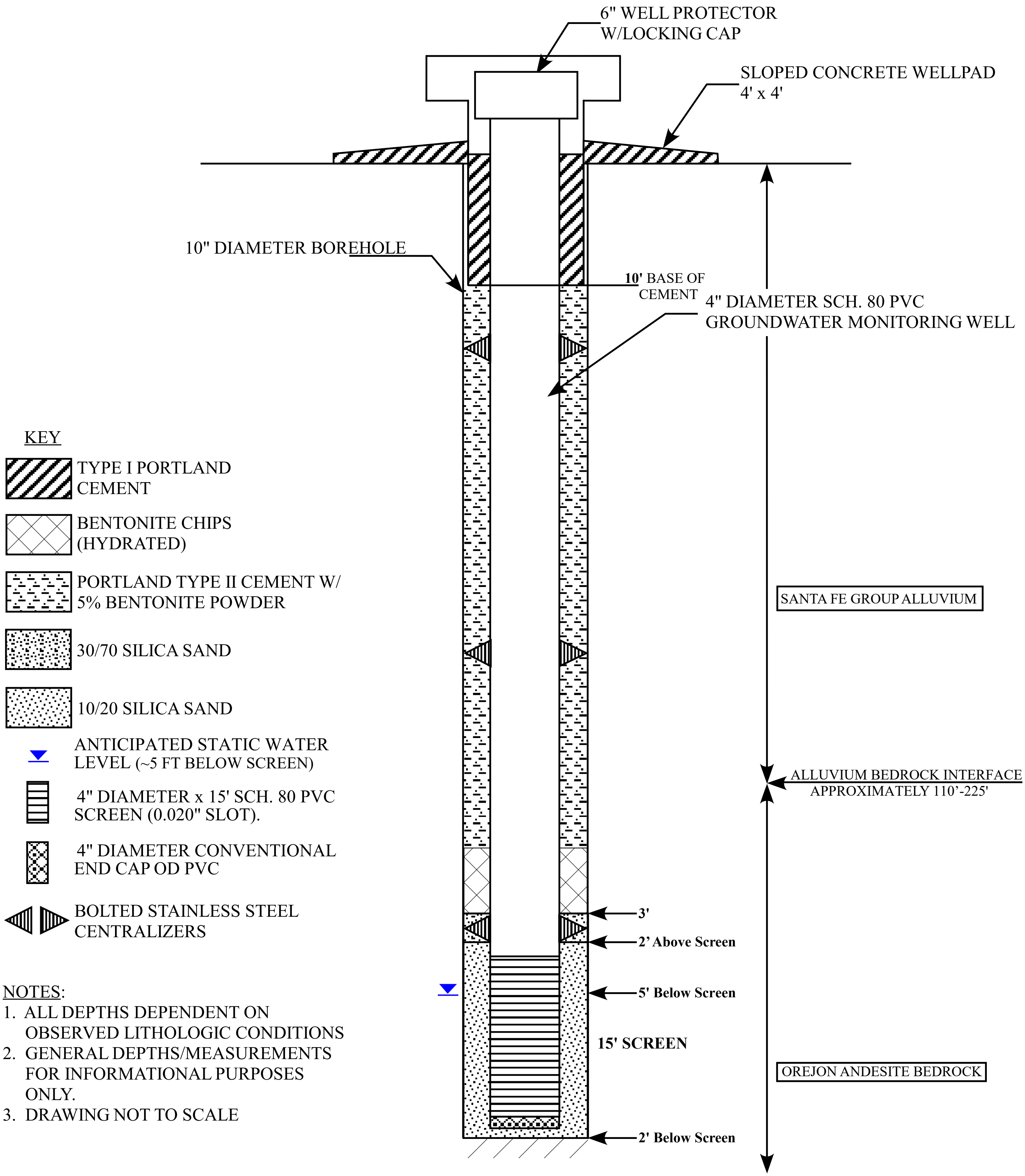

4920
Fire Break Road
500-SB-07
500-SB-02
500-SB-03
500-SB-10
500-SB-09 (Updated Location)
500-SB-08
500-SB-01
500-SB-11
Current Alcohol
Storage Area
4930
Fuel Storage Area
500 Fuel Storage Area SWMU 47
Proposed Boring
Multiport Well
Conventional Well
MSVGM Well
Sump Drain Line
Distillation Pipe
Low-Point Drain Line
Arroyo
Topographic Contour (10ft)
Distillation Pad
Active FSA
N
W
E
S
Feet
0
25
50
100
150
May 2023

Figure 4.3 General Monitoring Well Construction Diagram

(SEE NEXT PAGE)



GENERAL CONSTRUCTION DIAGRAM FOR 500 AREA GROUNDWATER MONITORING WELLS

Tables

Table 1.1 Soil Boring Rationale

Original Name	2nd NOD Proposed Name	Proposed Status	Location	Rational to Keep or Remove Proposed Soil Boring for Phase I
500-SB-01	500-SB-01	Keep	Immediately adjacent to SWMU 47, adjacent to northwest corner of gunite-lined pond, and the ponds low-point	Propose to keep due to the downgradient side of the gunite-lined pond. If hypothetical contaminants/wastewater were released to the pond, this location is the closest spot to drill where they would have pooled without compromising the existing structure.
500-SB-02	500-SB-02	Keep	SWMU 47, terminus of the removed low-point drain line	Propose to keep due to the terminus of the removed low-point drain line and historical detections of NDMA at this location. This is also a proposed well location due to its historical detections and its potential for soil-to-groundwater health risk evaluations.
500-SB-03	500-SB-03	Keep	SWMU 47, terminus of the gunite-lined pond sump drain line	Propose to keep due to the terminus of the gunite-lined pond sump drain line. If hypothetical contaminants/wastewater in the pond were released to grade, this location is a site of potential infiltration.
500-SB-04	500-SB-04	Keep	Upgradient, North of Fire Break Rd	Propose to keep due to the upgradient location. This location is assumed to be clean and would provide baseline data for comparisons. This is also a proposed well location for the same reasons.
500-SB-05	500-SB-05	Keep	Downgradient, 500 Area main arroyo, mid-way from SWMU 47 to BW-5-295	Propose to keep due to the downgradient location. This is also a proposed well location that is mid-way between SWMU 47 and BW-5- 295 and would potentially fill a data gap that exists between the two locations.
500-SB-06	500-SB-06	Keep	Downgradient, 500 Area main arroyo, NW of SWMU 47	Propose to keep due to the downgradient location. This location is where runoff waters from SWMU 47 join the main arroyo.

Original Name	2nd NOD Proposed Name	Proposed Status	Location	Rational to Keep or Remove Proposed Soil Boring for Phase I
500-SB-07	500-SB-07	Keep	Immediately adjacent to SWMU 47, 500 feed arroyo drains to the N of SWMU 47	Propose to keep due to the surface gradient within SWMU 47. This is a proposed well location and marks the beginning of the feed arroyo for SWMU 47 runoff waters.
500-SB-08		Remove	Adjacent to SWMU 47, 500 feed arroyo drains N of SWMU 47 and N of Fire Break Rd	Propose to remove due to the proximity to 500-SB-07. This location is where runoff waters from the Fire Break Road join SWMU 47 feed arroyo and drains to the north.
500-SB-09		Remove	Adjacent to SWMU 47, 500 Area feed arroyo drains NW of SWMU 47 & N of Fire Break Rd	Propose to remove due to the proximity to 500-SB-02. This location is where runoff waters from the Fire Break Road drains north toward the feed arroyo.
500-SB-10		Remove	Immediately adjacent to SWMU 47, Adjacent to southwest corner of gunite-lined pond	Propose to remove due to the gradient of the gunite-lined pond. If hypothetical contaminants/wastewater were released to the pond, would have pooled on the north side of the structure.
500-SB-11	500-SB-08	Keep	SWMU 47, adjacent to the NE of the gunite-lined pond	Propose to keep due to the gradient of the gunite-lined pond. If hypothetical contaminants/wastewater were released to the pond, would have pooled on the north side of the structure. This location is staged adjacent to the northeast of the pond and beneath the removed drain line.
500-SB-12	500-SB-09	Keep	SWMU 47, directly north of the active fuel storage pad	Proposed to keep due to the historical NDMA detections. This is also a proposed well location due to its historical detections and its potential for soil-to-groundwater health risk evaluations.
500-SB-13	500-SB-10	Keep	SWMU 47, termination of an "unknown" line	Propose to keep due to the "unknown" nature of the line.

Original Name	2nd NOD Proposed Name	Proposed Status	Location	Rational to Keep or Remove Proposed Soil Boring for Phase I
500-SB-14	500-SB-11	Keep	SWMU 47, historical location of alcohol storage tank, E of parking lot	Propose to keep due to the historical location of alcohol storage tank and the spills noted in the HIS.
500-SB-15		Remove	Upgradient, South of Fire Break Rd	Propose to remove due to its proximity to 500-SB-04, the location is on a steeper slope than 500-SB-04 increasing safety risks, and only one upgradient location is needed for comparison.
500-SB-16		Remove	Downgradient, 500 Area feed arroyo drains to the south of SWMU 47	Propose to remove due to the natural surface gradient of SWMU 47 to the north. This feed arroyo drains from Road P and not directly from SWMU 47.

Red text = Soil borings NASA proposes for removal.

Table 2.1 Historical 500 Area Fuel Storage Soil Sampling Results

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
Background	07/17/00	007170840	5	< 0.3	< 0.3	0.3	0.2
Downgradient	07/17/00	007170910	5	< 0.3	< 0.3	0.3	0.2
	07/17/00	007170920	10	< 0.3	< 0.3	0.3	0.2
Drain Line	07/17/00	007171000	5	**25.3**	**1.3**	0.3	0.2
	07/17/00	007171020	10	< 0.3	< 0.3	0.3	0.2
Sump	07/17/00	001711210	5	< 0.3	< 0.3	0.3	0.2
	07/17/00	001711220	10	< 0.3	< 0.3	0.3	0.2
Drum Pad	07/17/00	007171240	5	**4.9**	**1.2**	0.3	0.2
	07/17/00	007171250	10	**1.5**	**0.5**	0.3	0.2
BG-1	12/11/00	0012111440	1	< 0.33	< 0.33	0.33	0.17
SU-1	12/07/00	0012071209	2	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071217	5	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071333	13	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071409	20	< 0.33	< 0.33	0.33	0.17
DL-1	12/07/00	0012071533	1	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071615	6	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071633	10	**0.18 J**	< 0.33	0.33	0.17
	12/08/00	0012080926	20	**0.69**	< 0.33	0.33	0.17
	12/08/00	0012080928	20 Dup	**0.6**	< 0.33	0.33	0.17
	12/08/00	0012081010	30	**0.21 J**	< 0.33	0.33	0.17
DL-2	12/08/00	0012081116	5	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081132	10	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081154	20	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081226	30	< 0.33	< 0.33	0.33	0.17
DL-3	12/08/00	0012081406	5	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081418	10	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081446	20	**0.88**	< 0.33	0.33	0.17
	12/08/00	0012081512	30	**1.17**	< 0.33	0.33	0.17
DL-4	12/08/00	0012081542	5	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081544	5 Dup	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081608	10	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081630	20	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081656	30	< 0.33	< 0.33	0.33	0.17
DL-5	12/09/00	0012090840	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012090850	10	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012090910	20	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012090940	30	< 0.33	< 0.33	0.33	0.17

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
DL-6	12/09/00	0012091040	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091042	5 Dup	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091050	10	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091210	20	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091234	30	< 0.33	< 0.33	0.33	0.17
DL-7	12/09/00	0012091420	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091428	10	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091450	20	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091508	30	< 0.33	< 0.33	0.33	0.17
PA-1	12/09/00	0012091610	1	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091620	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091654	10	**14.8**	**1.51**	0.33	0.17
	12/10/00	0012100900	20	**13.7**	**0.76**	0.33	0.17
	12/10/00	0012100950	30	**7.92**	**0.33 J**	0.33	0.17
	12/10/00	0012100952	30 Dup	**7.41**	**0.29 J**	0.33	0.17
PA-2	12/10/00	0012101032	5	**1.75**	< 0.33	0.33	0.17
PA-2	12/10/00	0012101040	10	**2.13**	< 0.33	0.33	0.17
	12/10/00	0012101250	20	**1.08**	< 0.33	0.33	0.17
	12/10/00	0012101316	30	**0.19 J**	< 0.33	0.33	0.17
PA-3	12/10/00	0012101430	5	< 0.33	< 0.33	0.33	0.17
	12/10/00	0012101440	10	< 0.33	< 0.33	0.33	0.17
	12/10/00	0012101500	20	< 0.33	< 0.33	0.33	0.17
	12/10/00	0012101536	30	< 0.33	< 0.33	0.33	0.17
PA-4	12/11/00	0012110828	5	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012110840	10	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012110910	20	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012110944	30	< 0.33	< 0.33	0.33	0.17
PA-5	12/11/00	0012111030	5	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111040	10	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111042	10 Dup	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111101	20	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111200	30	< 0.33	< 0.33	0.33	0.17
PA-6	12/11/00	0012111402	5	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111408	10	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111450	20	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111530	30	< 0.33	< 0.33	0.33	0.17

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
PA-7	12/12/00	0012120816	5	**1.16**	**0.30 J**	0.33	0.17
	12/12/00	0012120830	10	**0.32 J**	< 0.33	0.33	0.17
PA-7B	12/12/00	0012121110	20	**0.66**	< 0.33	0.33	0.17
	12/12/00	0012121112	20	**0.66**	< 0.33	0.33	0.17
BG-1	05/07/01	0105071340	1	< 0.33	< 0.33	0.33	0.17
DL-8	05/07/01	0105071130	5	< 0.33	< 0.33	0.33	0.17
	05/07/01	0105071140	10	< 0.33	< 0.33	0.33	0.17
	05/07/01	0105071215	20	< 0.33	< 0.33	0.33	0.17
	05/07/01	0105071250	30	**0.27 J**	< 0.33	0.33	0.17
	05/08/01	0105080820	40	**0.46**	< 0.33	0.33	0.17
DL-9	05/08/01	0105081020	5	< 0.33	**4.66**	0.33	0.17
	05/08/01	0105081040	10	**0.37**	< 0.33	0.33	0.17
	05/08/01	0105081150	30	**1.26**	< 0.33	0.33	0.17
	05/08/01	0105081315	40	**0.58**	< 0.33	0.33	0.17
	05/08/01	0105081545	50	**0.34**	< 0.33	0.33	0.17
DL-10	05/09/01	0105091010	5	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091015	5 Dup	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091025	10	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091050	20	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091115	30	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091145	40	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091245	50	**0.17 J**	< 0.33	0.33	0.17
DL-11	05/09/01	0105091500	5	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091515	10	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091550	20	**0.43**	< 0.33	0.33	0.17
	05/09/01	0105091630	30	**0.52**	< 0.33	0.33	0.17
	05/09/01	0105091730	40	**0.93**	< 0.33	0.33	0.17
	05/09/01	0105091735	40	**0.85**	< 0.33	0.33	0.17
	05/09/01	0105091820	45	**0.48**	< 0.33	0.33	0.17
PA-8	05/10/01	0105100920	5	< 0.33	< 0.33	0.33	0.17
	05/10/01	0105100940	10	**0.57**	< 0.33	0.33	0.17
	05/10/01	0105101010	20	**0.8**	< 0.33	0.33	0.17
	05/10/01	0105101050	30	**1.1**	< 0.33	0.33	0.17
	05/10/01	0105101140	40	< 0.33	< 0.33	0.33	0.17
	05/10/01	0105101240	50	**0.48 T**	< 0.33 T	0.33	0.17
PA-9	05/10/01	0105101505	5	< 0.33 T	< 0.33 T	0.33	0.17
	05/10/01	0105101520	10	< 0.33 T	< 0.33 T	0.33	0.17

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
PA-9	05/10/01	0105101550	20	< 0.33 T	< 0.33 T	0.33	0.17
PA-10	05/11/01	0105110845	5	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105110905	10	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105110907	10 Dup	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105110935	20	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105111035	32	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105111120	40	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105111235	50	**0.18 J**	< 0.33	0.33	0.17
PA-11	05/11/01	0105111430	5	**0.81**	< 0.33	0.33	0.17
	05/11/01	0105111500	10	**0.57**	< 0.33	0.33	0.17
	05/11/01	0105111545	20	**1.59**	< 0.33	0.33	0.17
PA-11	05/15/01	0105151400	30	**0.21 J**	< 0.33	0.33	0.17
	05/15/01	0105151530	40	< 0.33	< 0.33	0.33	0.17
	05/15/01	0105151610	50	< 0.33	< 0.33	0.33	0.17
	05/15/01	0105151612	50 Dup	< 0.33	< 0.33	0.33	0.17
PA-12	05/15/01	0105151800	5	< 0.33	< 0.33	0.33	0.17
	05/15/01	0105151815	10	**0.91**	< 0.33	0.33	0.17
	05/15/01	0105151835	20	**0.92**	< 0.33	0.33	0.17
	05/15/01	0105151905	30	< 0.33	< 0.33	0.33	0.17
	05/16/01	0105161105	40	< 0.33	< 0.33	0.33	0.17
	05/16/01	0105161205	50	< 0.33	< 0.33	0.33	0.17

Data is taken from the RCRA Permit Renewal Application (NASA, 2002)
Unless otherwise indicated, the sample is a soil matrix.
Samples analyzed by Modified EPA Method 607.
BG – Background; SU – Sump; DL – Drain Line; PA – Drum Pad
Dup – Duplicate Sample
J – The result is an estimated value less than the quantitation limit, but greater than or equal to the detection limit.
T – Samples were received at the laboratory outside of acceptable holding temperature.

Table 2.2 List of Historically Identified COCs for the 500 Area Vadose Zone Investigation

Constituent	CAS Number	Target Detection Limits for Soil Samples (mg/kg)	Target Detection Limits for Aqueous Samples (ug/L)	Sample Suite Type	Anticipated Method
N-Nitrosodimethylamine*	62-75-9	1.60E-01/1.70E-04	4.80E-03/2.20E-04	Nitrosamines	Modified Method 607/NDMA Low-level
Isopropyl Alcohol (2-Propanol)	67-63-0	3.30E-02	1.30E-00	VOA	Method 8260B
Acetone	67-64-1	1.70E-03	1.74E+00	VOA	Method 8260B
Hydrazine	302-01-2	2.0E-01	4.40E-03	Hydrazines	Modified Method 8315
UDMH (Unsymmetrical Dimethylhydrazine)	57-14-7	1.22E+00	4.40E-03	Hydrazines	Modified Method 8315
MMH (Monomethyl Hydrazine)	60-34-4	5.00E-02	4.40E-03	Hydrazines	Modified Method 8315

* N-Nitrosodimethylamine analysis will be conducted using an if/then approach. A sample will first be analyzed by Method 607. If this sample returns a non-detect result, then a second sample will be analyzed by NDMA low-level.

Table 4.1 Sampling and Analysis for the SWMU 47 Investigation

Soil Boring ID and Location[1]	Borehole Depth*	Analytical Parameters	Sample Collection Summary (Estimated Number of Samples)					
			Soil Chemical[2]	Soil Geotech[3]	Ground-water Chemical[4]	Duplicates[5]	Spikes[5]	Potential Blanks[6]
500-SB-01	Bedrock	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
500-SB-02	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
		Parameters: IPA, Acetone, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-03	Bedrock	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
500-SB-04	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA/DMN	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				

Soil Boring ID and Location[1]	Borehole Depth*	Analytical Parameters	Sample Collection Summary (Estimated Number of Samples)					
			Soil Chemical[2]	Soil Geotech[3]	Ground-water Chemical[4]	Duplicates[5]	Spikes[5]	Potential Blanks[6]
		Parameters: IPA, Acetone, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-05	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
		Parameters: IPA, Acetone, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-06	Bedrock	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
500-SB-07	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
		Parameters: IPA, Acetone, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-08	Bedrock	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	

Soil Boring ID and Location[1]	Borehole Depth*	Analytical Parameters	Sample Collection Summary (Estimated Number of Samples)					
			Soil Chemical[2]	Soil Geotech[3]	Ground-water Chemical[4]	Duplicates[5]	Spikes[5]	Potential Blanks[6]
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				Field, Rinsate, Trip
500-SB-09	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
		Parameters: IPA, Acetone, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-10	Bedrock	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
500-SB-11	Bedrock	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				

<table>
<tr><th rowspan="2">Soil Boring ID and Location[1]</th><th rowspan="2">Borehole Depth*</th><th rowspan="2">Analytical Parameters</th><th colspan="6">Sample Collection Summary (Estimated Number of Samples)</th></tr>
<tr><th>Soil Chemical[2]</th><th>Soil Geotech[3]</th><th>Ground-water Chemical[4]</th><th>Duplicates[5]</th><th>Spikes[5]</th><th>Potential Blanks[6]</th></tr>
<tr><td colspan="3">Maximum Sample Totals:
Soil Chemical Parameters: IPA (110-165 samples), Acetone (110-165 samples), Hydrazines (110-165 samples), NDMA (110-165 samples)
Soil Geotech Parameters: Soil Classification (11-33 samples), Particle Size (11-33 samples), Gravimetric Moisture Content (11-33 samples), Bulk Density (11-33 samples), Porosity (11-33 samples), Saturated Hydraulic Conductivity (11-33 samples), Unsaturated Hydraulic Conductivity (11-33 samples), and Organic Carbon (11-33 samples)
Groundwater Chemical Parameters: IPA (1-21 samples), Acetone (1-21 samples), Hydrazines (1-21 samples), and NDMA/DMN (1-21 samples)</td><td colspan="6">Sample Blank/Duplicate Totals:
1 x trip blank (VOAs) for each soil boring (estimated 11 samples)
1 x field blank per day (estimated 11 samples)
1 x rinsate blank or field blank per groundwater well (estimated 5 samples)
Field Duplicates + Matrix Spikes Samples:
Soil Chemical Parameters: IPA (11-33 + 6-17 samples), Acetone (11-33 + 6-17 samples), Hydrazines (11-33 + 6-17 samples), NDMA (11-33 + 6-17 samples)
Groundwater Chemical Parameters: IPA (1 + 1 samples), Acetone (1 + 1 samples), Hydrazines (1 + 1 samples), and NDMA/DMN (1 + 1 samples)</td></tr>
</table>

Notes:

* Soil borings to be drilled to bedrock or groundwater. Bedrock depths vary from 110 ft to 225 ft. Groundwater depths vary from 120 ft to 235 ft.

[1] Refer to Figure 4.1 for soil boring locations.

[2] Samples to be collected: on 5-ft intervals to 30 ft bgs, on 10-ft intervals from 30 ft to 50 ft bgs, and on 25-ft intervals from 50 ft to the bedrock. Anticipated order, preparation, and analytical methods: IPA – SW-846 Method 8260C; Acetone – SW-846 Method 8260C; hydrazines – SW-846 Method 8315; NDMA – If/Then Modified EPA Method 607/NDMA low-level analysis.

[3] Minimum one geotechnical sample per soil boring. Geotechnical samples will be collected for each primary lithologic change up to a maximum of three. Geotechnical samples will be collected for: soil classification and particle size distribution by laser analysis; volumetric moisture content; bulk density; porosity; saturated hydraulic conductivity; organic carbon content; and unsaturated hydraulic conductivity.

[4] Samples to be collected as groundwater grab samples and monitoring samples. Anticipated order, preparation, and analytical methods: IPA – SW-846 Method 8260B; Acetone – SW-846 Method 8260B; hydrazines – SW-846 Method 8315; NDMA – If/Then Modified EPA Method 607 /NDMA low-level analysis. Note: Grab samples will be taken for engineering purposes, and turbidity issues may preclude the collection of a sample meeting laboratory criteria for analysis.

[5] Duplicates and Spikes: 1 x field duplicate per 10 samples, 1 x matrix spike per 20 samples.

[6] Blanks: 1 x soil field blank per day on days when soil is sampled; 1 x trip blank for each shipment of groundwater samples; 1 x aqueous field blank per day on days when groundwater is sampled.

Appendix A
Investigation Work Plan Deviations

Investigation Work Plan Deviations

The Permit states in Section VII.H.1.b Investigation Work Plan Requirements: "The Permittee shall provide sufficient written justification for any omissions or deviations from the minimum requirements specified in Permit Attachment 20 (Reporting Requirements)" (NMED, 2016). According to the requirements established in Attachment 20.2 Investigation Work Plan, this IWP (investigation work plan) fulfills the general requirements.

The Permit provides a number of detailed requirements related to the IWP process aside from the reporting requirements in Attachment 20.2. Some of these requirements include, but are not limited to: drilling methods, sampling methods, chemical analysis, background data requirements, etc. (Attachment 17); and monitoring well installation (Attachment 19; NMED, 2016). Omissions or deviations related to these attachments are provided for NMED review and approval. Below is a summary of the specific requirements from the Permit with a discussion of how each requirement is implemented in this IWP.

Reference

NMED Hazardous Waste Bureau. (2016, November 10). Administrative Completeness and Fee Assessment Transmittal of Class 1 Permit Modification Without Prior Approval. Santa Fe, NM.

Table B.1 Permit Requirements and Implementation in the IWP

Permit Specification		Implementation in IWP
Attachment 17.2.2.b.i	Hollow-stem auger or DPT drilling methods are preferred if vapor-phase or VOC contamination is known or suspected to be present. Air rotary drilling is preferred for borings intersecting the regional aquifer.	The methods that will be considered, in order of preference based on cost, time, and capability of reaching the target depths, are air rotary and rotosonic (sonic). NASA concludes that hollow-stem auger or DPT do not have the capabilities to reach the target sample depths based on previous investigations during which these technologies yielded poor sample recovery and boring refusal.
Attachment 17.2.2.b.i	…the borings shall be advanced to the following minimum depths: 1. In all borings, 25 feet (ft) below the deepest detected contamination based on field screening, laboratory analyses, and/or previous investigations at the site; 2. Twenty ft below the base of disposal units if contamination is not detected; 3. Five ft below the base of shallow structures such as piping or building sumps, or other building structures; and 4. Depths specified by NMED based on regional or unit specific data needs.	The vertical boundary of the investigation is the approximate depth to bedrock (110 ft to 225 ft). However, because groundwater is also of concern, one to five borings are expected to be installed to groundwater (120 ft to 230 ft bgs), not to exceed 250 ft bgs if groundwater is not encountered.
Attachment 17.2.2.b.i	The drilling and sampling shall be accomplished under the direction of a qualified engineer or geologist who shall maintain a detailed log of the materials and conditions encountered in each boring.	The drilling and the sampling shall be accomplished under the direction of a qualified and experienced engineer, environmental scientist, or geologist. A detailed field record will be maintained for all investigation fieldwork.
Attachment 17.2.2.b.i.i	Generally, the samples shall be collected at the following intervals and depths:	Soil samples will be collected on five-foot intervals to 30 ft bgs, on ten-foot intervals from 30 ft to 50 ft bgs, and on 25-foot intervals from 50 ft bgs to bedrock.

Permit Specification		Implementation in IWP
Attachment 17.2.2.b.ii (cont.)	1. At five-ft intervals, ten-ft intervals, continuously, or as approved by NMED; 2. At the depth immediately below the base of the disposal unit or facility structure; 3. At the maximum depth of each boring; 4. At the depths of contacts or first encounter, observed during drilling, with geologic units of different lithology, structural or textural characteristics, or of relatively higher or lower permeability; 5. Of soil or rock types relatively more likely to sorb or retain contaminants than surrounding lithology; 6. At the depth of the first encounter, during drilling, with shallow or intermediate saturated zones; 7. At intervals suspected of being source or contaminated zones; 8. At the top of the aquifer; and 9. At other intervals approved or required by NMED.	The deepest sample will be collected as close to the alluvial bedrock interface as feasible, taking into account issues of sample quality, sample recovery, and the position of the water table if encountered unexpectedly.
Attachment 17.2.2.b.ii	A decontaminated split-barrel sampler lined with brass sleeves, a coring device, or other method approved by NMED shall be used to obtain samples during the drilling of each boring.	Given that drilling conditions in the 500 Area are expected to be similar to those in the 300 and 400 Areas, split-spoon sampling tubes will not be used because of the high probability of sample refusal and equipment damage. Instead, a modified heavy-duty sampling core barrel may be used with an air-rotary drilling or a sonic core barrel may be used with a sonic drilling. This equipment has been used successfully at WSTF during previous investigations.
Attachment 17.2.2.b.ii	Upon recovery of the sample, one or more brass sleeves shall be removed from the split barrel sampler and the open ends of the sleeves covered with Teflon tape or foil and sealed with plastic caps fastened to the sleeves with tape for shipment to the analytical laboratory.	For air rotary drilling: A sampling core barrel (e.g., modified sonic core barrel) will be driven 2 to 5 ft into the undisturbed formation at the bottom of the open borehole using a pneumatic driver head or drop hammer For sonic drilling: The soil core will be extruded from the core barrel through the use of gravity-aided vibration, into chemically-resistant containers (e.g. sampling sleeves, stainless steel troughs), minimizing the disturbance of the soil core and ensuring the collection of a representative soil sample. Soil collected for analysis will be transferred from the sampler into clean sample containers provided by the laboratory contracted to analyze the investigation samples.
Attachment 17.2.2.c	Detailed logs of each boring shall be completed in the field by a qualified engineer or geologist.	Detailed logs for each boring will be completed by a qualified engineer, environmental scientist, or geologist and reviewed by a qualified geologist for inclusion in the investigation report.

Permit Specification		Implementation in IWP
Attachment 17.2.2.d	The primary screening methods to be used shall include: 1) visual examination; 2) headspace vapor screening for VOCs; and 3) metals screening using X-ray fluorescence (XRF). Additional screening for site- or release-specific characteristics such as pH, High Explosives (HE), Total Petroleum Hydrocarbons (TPH) or for other specific compounds using field test kits shall be conducted where appropriate.	For site-specific COPCs (hydrazines, NDMA, IPA, and acetone), headspace vapor will be screened using a PID and Dräger vapor monitor.
Attachment 17.2.2.g	Samples of subsurface vapors shall be collected from vapor monitoring points from both discrete zones, selected based on investigation and field screening results, and as total well subsurface vapor samples where required by NMED.	Due to the nature of the site-specific COCs and available historical information on the FSA, monitoring of subsurface vapors is not anticipated for this investigation.
Attachment 17.2.2.i.ii	All purged groundwater and decontamination water transported to ETU shall be temporarily stored at satellite accumulation areas or transfer stations in labeled 55-gallon drums, less-than-90-day storage areas or other containers approved by NMED until proper characterization and disposal can be arranged.	One or more Central Accumulation Areas will be established in the field adjacent to SWMU 47 within the perimeter of the investigation area to manage IDW. Purged groundwater and decontamination water will be managed in DOT-compliant containers, such as 55-gallon drums
Attachment 19.3.5	Newly installed monitoring wells shall not be developed for at least 48 hours after the outer protective casing is installed.	Wells will be developed following the completion of the last well or boring installation for the project.

Appendix B
Investigation-Derived Waste Management Plan

National Aeronautics and Space Administration

500 Area Fuel Storage (SWMU 47)
Investigation-Derived Waste Management Plan

September 2018

Revised November 2019

Revised June 2021

NM8800019434

NASA Johnson Space Center White Sands Test Facility

500 Area Fuel Storage (SWMU 47)
Investigation-Derived Waste Management Plan

September 2018

Revised November 2019

Revised June 2021

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

TIMOTHY DAVIS Digitally signed by TIMOTHY DAVIS
Date: 2023.05.22 07:56:50 -06'00'

Timothy J. Davis
Chief, NASA Environmental Office

See Electronic Signature
Date

National Aeronautics and Space Administration

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List of Acronyms

CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
IDW	Investigation-Derived Waste
IWP	Investigation Work Plan
MMH	Monomethylhydrazine
MPITS	Mid-plume Interception and Treatment System
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMED	New Mexico Environment Department
RCRA	Resource Conservation and Recovery Act
SSL	Soil Screening Level
SWMU	Solid Waste Management Unit
SWMU 47	500 Area Fuel Storage
TSDF	Treatment, Storage, and Disposal Facility
UDMH	Unsymmetrical Dimethylhydrazine
WSTF	White Sands Test Facility

1.0 Waste Generating Activity and Description

The investigation of SWMU (Solid Waste Management Unit) 47 – 500 Area Fuel Storage will require soil boring installations, well installations, and associated sample collection activities. IDW (investigation-derived waste) generated during the investigation of SWMU 47 will include: saturated and unsaturated soil generated during the drilling and sampling process (soil cuttings or soil cores); used disposable sampling equipment; personal protective equipment (i.e., nitrile gloves); plastic sheeting, rags, and other debris that is contaminated by soil or fluids; groundwater, and decontamination water and soap solutions.

2.0 Waste Characterization Procedures

2.1 Preliminary Waste Characterization

Historical documentation indicates that MMH (monomethylhydrazine), hydrazine, UDMH (unsymmetrical dimethylhydrazine), and Aerozine 50 fuels were stored within SWMU 47. Off-specification hydrazine based fuel may have been treated in the SWMU 47 containment pond and subsequently released to grade (NASA, 2018). Previous investigation results indicates that NDMA (N-Nitrosodimethylamine) is present in soils adjacent to the active portions of SWMU 47 (NASA, 2018). The investigation location is outside of the known boundary of the WSTF groundwater contamination plume, but there are no groundwater monitoring wells in the immediate area of SWMU 47 that can be sampled to confirm groundwater in this area is not contaminated. Because of the lack of groundwater data in the area, it is assumed that the WSTF groundwater COCs (contaminants of concern), NDMA, trichloroethylene, tetrachloroethene, CFC-11 (chlorofluorocarbon), and CFC-113 may be found in groundwater and saturated environmental media during the SWMU 47 investigation. Trichloroethylene, tetrachloroethene, CFC-11, and CFC-113 originate from other WSTF SWMUs and are not a CoC for SWMU 47 investigation.

Discarded commercial chemical products, off-specification species, container residues, and spill residues of materials identified in and meeting the conditions of 40 CFR § 261.33 are listed hazardous wastes. When discarded, hydrazine, MMH, and UDMH are listed hazardous wastes with EPA (Environmental Protection Agency) waste codes U133, P068, U098, respectively. Groundwater extracted from the WSTF groundwater contamination plume has been previously characterized as F001 and F002 listed hazardous waste. This characterization will also be used for this project. Any waste generated with these waste codes are also subject to §268.40 land disposal restriction treatment standards. NDMA was present as an impurity in the hydrazine based fuels and likely also formed as an oxidation byproduct during treatment of the fuels. The P082 EPA waste code is not applicable to waste generated during this project because the NDMA, if present, does not meet the listing description of a hazardous waste per §261.33. No characteristic hazardous waste is expected to be generated during this project.

The EPA has established that groundwater and soil are environmental media that is not solid waste, but is subject to regulation as if it were hazardous waste when it contains listed waste (EPA, 1991). This is commonly referred to as the Contained-In Policy. Through application of this policy, soil and groundwater that may contain listed hazardous waste constituents must be managed as hazardous waste. Groundwater within the WSTF contaminated groundwater plume is characterized as listed hazardous waste with the EPA waste codes F001 and F002, which are associated with trichloroethylene, tetrachloroethene, and CFC-11, and CFC-113 releases from other WSTF SWMUs. Though the location of SWMU 47 is located outside of the current boundaries of the WSTF groundwater plume, there are no available groundwater analytical data within the immediate investigation area. To address this issue, NASA will conservatively manage IDW generated below the water table as carrying the F001 and F002 EPA waste codes in addition to the U133, P068, and U098 codes associated with the investigation CoCs.

Other materials that come into contact with or is mixed with environmental media characterized as hazardous waste is regulated under the EPA's "mixture rule" (§261.3(a)(2)(iv)). This waste could include hazardous debris, such as, spent personal protective equipment, contaminated sampling supplies, and plastic sheeting. Decontamination water and other material that has come into contact with contaminated media must also be regulated as hazardous waste.

The initial waste characterization for specific waste streams that will be generated during this project is provided in Table 2.1.

Table 1 Initial Waste Characterization

Waste	Waste Characterization	EPA Waste Codes
Environmental Media – Unsaturated Soil and Soil Cuttings	Hazardous Waste	U133, U098, P068
Environmental Media – Saturated Soil and Drill Cuttings	Hazardous Waste	U133, U098, P068, F001, F002
Environmental Media - Groundwater	Hazardous Waste	U133, U098, P068, F001, F002
Hazardous Debris Generated Above the Water Table	Hazardous Waste	U133, U098, P068
Hazardous Debris Generated Below the Water Table	Hazardous Waste	U133, U098, P068, F001, F002
Decontamination Water Generated from Equipment Used Above the Water Table	Hazardous Waste	U133, U098, P068
Decontamination Water Generated from Equipment Used Below the Water Table	Hazardous Waste	U133, U098, P068, F001, F002

2.2 Investigation Derived Waste Characterization

Thorough characterization will be performed on the waste generated during this investigation in accordance with the applicable sections of Attachment 12: *Waste Analysis Plan* of the WSTF Hazardous Waste Permit (2016) and 40 CFR Parts 260 and 261. Waste characterization for IDW may be based on the analytical data received for the primary investigation samples (i.e., samples soil collected from the boreholes), or from specific samples collected from the as-generated waste. For environmental media that are identified as containing listed wastes per 40 CFR 261 Subpart D, a request for a no longer contained-in determination may be submitted to the NMED Hazardous Waste Bureau, if waste characterization sample analytical results support such a request.

3.0 Waste Management Procedures

In accordance with the initial waste characterization, all IDW generated during this project will be initially managed as hazardous waste. IDW will be accumulated and placed into appropriate containers and will be managed in accordance with 20.4.1.300 NMAC and 40 CFR 262.17 (2017). This includes, but is not limited to requirements for accumulation start dates, hazardous waste labels, and container specifications.

One or more Central Accumulation Areas will be established in the field adjacent to SWMU 47 within the perimeter of the investigation area to manage IDW. The accumulation area(s) will adhere to the requirements of 20.4.1.300 NMAC and 40 CFR 262.17 (2017). The following waste accumulation and management strategies will be implemented during this project:

- Unsaturated soil and drill cuttings will be containerized in DOT (U.S. Department of Transportation)-compliant containers, such as 55-gallon drums or bulk containers (i.e., 1-CY intermediate bulk container or roll-off). Produced liquids from drilling returns may be decanted off and accumulated in separate DOT compliant containers.
- Saturated soil and drill cuttings will be containerized in DOT-compliant containers, such as 55-gallon drums or bulk containers (i.e., covered roll-off). Produced liquids from drilling returns may be decanted off and accumulated in separate DOT-compliant containers.
- Hazardous debris consisting of used personal protection equipment, plastic sheeting, and other contaminated items will be containerized in DOT-compliant containers, such as 55-gallon drums.
- Decontamination fluids will be managed in DOT-compliant containers, such as 55-gallon drums.
- Wastes typically associated with equipment maintenance (e.g., grease, contaminated rags, oil, penetrating oil, diesel, soil contaminated with hydraulic fluids, etc.) may also be generated and will be managed in a DOT compliant container as hazardous waste pending a full waste characterization.
- Any inadvertent spills of IDW onto the soil will be immediately addressed and containerized as hazardous waste in DOT compliant containers.

4.0 Waste Disposition Procedures

NASA may request a contained-in determination from the NMED if analytical data indicates environmental media IDW does not contain listed hazardous waste or exhibit characteristics of a hazardous waste. A partial contained-in determination may be requested if the analytical data from aqueous IDW, such as contaminated groundwater or decanted water from saturated drill cuttings, does not indicate the presence of U133, P068, or U098 listed waste, but F001 and F002 constituents are present. Should such an instance occur, NASA would request a contained-in determination from NMED to remove the U133, P068, and U098 listing designations from the waste. The waste would continue to carry the F001 and F002 listed hazardous waste codes and would continue to be managed as hazardous waste. This waste would then be transferred to the MPITS (Mid-plume Interception and Treatment System) for storage, treatment, and discharge. The MPITS was designed with provisions for the storage and treatment of IDW (NASA, 2008). If the analytical data indicate the presence of U133, P068, or U098 listed waste or the waste exhibits characteristics of a hazardous waste, the waste will be properly treated and disposed of at a RCRA permitted TSDF (treatment, storage, and disposal facility).

A table listing summarizing chemical analytical data for the waste, applicable treatment standards found in 40 CFR Part 268.40 (2003), NMED SSL (soil screening levels; NMED, 2017), and the concentrations listed in 40 CFR Part 261.24 Subpart C (Table 1; 2012) will be provided to NMED with the contained-in determination request. If NMED finds contaminant concentrations do not pose an unacceptable risk, then NMED may allow the wastes included in the request to be managed as non-hazardous solid waste that no longer contains listed waste and do not exhibit the characteristic of hazardous waste. A letter from NMED will be required to document such a determination.

IDW soil or drill cuttings that do not meet the definition of a hazardous waste, and do not contain hazardous constituents at concentrations above residential SSLs, will be spread on the ground within the project site with NMED approval. IDW soil that does not meet the definition of a hazardous waste but does contain hazardous constituents above residential SSLs, will be properly managed as non-hazardous solid waste and properly disposed of at a RCRA Resource Conservation and Recovery Act) Subtitle D landfill. IDW debris that is determined to be non-hazardous waste will also be disposed of as non-hazardous solid waste. Soil samples sent to the analytical laboratories will be disposed of by the laboratories as environmental samples in accordance with each individual laboratory's procedure.

For materials that are characterized as hazardous waste, land disposal restriction notifications, disposal facility profiles, and hazardous waste manifests will be completed as required. Waste will be transported for treatment and disposal at a permitted RCRA TSDF. Any wastewater generated during the investigation that only carries the F001 and F002 hazardous waste codes will be treated MPITS. If that system is not capable of receiving the waste, it will be disposed of at a permitted RCRA TSDF.

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Standards Applicable to Generators of Hazardous Waste, 40 C.F.R. § 262 (2017). Retrieved from http://www.ecfr.gov/

Comments for Approval with Modifications of the 500 Area Fuel Storage (SWMU 47) IWP

<table>
<tr><th>NMED Comment Number</th><th>NMED Comments</th><th>NASA Revisions/Responses/Discussion</th></tr>
<tr><td>1. Section 4.2.5, Monitoring Well Installation, Pages 12 and 13</td><td>Permittee Statement: "Based on experience gained from monitoring wells installed in the 400 Area, there is a minimum amount of recharge required to obtain representative samples of approximately 0.5 gpm [gallons per minute]. In addition, there must be sufficient water in the well to purge the sampling system (pump and tubing) and the well. This can be as much as 8 to 10 gallons. Additionally, the low-flow bladder pumps must be submerged in the water to function properly. Therefore, the completed well must have at least 15 ft of groundwater. If the borings do not meet these minimum criteria, they will not be considered for well installation."

NMED Comment: In a following paragraph, a statement proposes that "[e]ach groundwater monitoring well will include a 15 ft [foot] (0.010-in. [inch] slot) screen straddling the water table, with 5 ft of screen above the water table and 10 feet below the water table." This statement contradicts the criteria above for completing a boring as a monitoring well and sampling with a low-flow bladder pump because it proposes 10 feet of screened water column for sampling rather than 15 feet.

If groundwater is encountered at a boring location, the boring must be advanced to a depth in the aquifer that allows for the long-term collection of representative groundwater samples with a bladder pump. Furthermore, as an alternative, NMED-approved 2022 Groundwater Monitoring Plan, Section 5.1, Conventional Monitoring Wells, also allows for groundwater monitoring well purging with a non-dedicated pump and subsequent collection of groundwater samples with a bailer, if necessary.</td><td>NASA statement “Therefore, the completed well must have at least 15 ft of groundwater.” has been revised to state “Therefore, the completed well must have at least 10 ft of groundwater.” to remain consistent with the proposed 15-ft screen straddling the water table. Figure 4.3 has been revised accordingly.

Groundwater recovery in the proposed well locations will ultimately determine the outcome of proposed monitoring well design, installation, and any subsequent sampling system. Factors based on recharge, groundwater quality parameters, location, and long-term support for the WSTF groundwater assessment program will be evaluated. NASA will provide final monitoring well location, rationale, and proposed well construction details (i.e., well design, sampling system, etc.) to NMED for each well prior to construction for review and approval.

NASA added text to Section 4.2.5 stating “A low-flow bladder pump sampling system or an appropriate alternative NMED-approved purging and sampling method capable of providing representative groundwater samples, for long-term support of the WSTF Groundwater Monitoring Program, will be considered for each of the proposed monitoring wells. In accordance with Section 5.1 (Conventional Monitoring Wells) of the approved GMP (2022), the sampling system will be selected based on factors such as the depth to water, volume of water to be purged, water recovery rate, frequency of sampling, overall integrity of the well casing, and the cost of system installation.”</td></tr>
</table>

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
	The Work Plan must be revised to propose an adequate groundwater monitoring well completion design that allows for the collection of representative groundwater samples with a low-flow bladder pump sampling system or an appropriate alternative NMED- approved purging and sampling method. The Work Plan must be revised accordingly, and replacement pages and figures must be provided.	
2. Section 11.2, Monitoring Well Installation, Page 24	**Permittee Statement:** "Field lithologic information and a revised well construction diagram will be provided to NMED after completion of any soil boring that is planned to deviate from the general well design. NMED review and approval of the revised well construction diagram is required prior to specific well installation. Expedited turnaround from NMED will be required in order to avoid short-term (or potentially longer term) standby delays." **NMED Comment:** All monitoring well completions must be submitted to NMED for review and concurrence with all supporting information and proposed well completion diagrams. To expedite this process, this information may be submitted to NMED via email. Revise the section discussion to specify this requirement and provide a replacement page.	NASA revised the section to include approval for all proposed monitoring well designs advanced to groundwater: "Field lithologic information, a revised well construction diagram, and any pertinent borehole details will be provided to NMED via email to expedite the review process after completion of any soil boring that is advanced to groundwater (Figure 4.3). NMED review and approval of the proposed well construction diagram is required prior the specific well installation. Expedited turnaround from NMED will be required in order to avoid short-term (or potentially longer term) standby delays."
3. Table 4.1, Sampling and Analysis Plan for the SWMU 47 Investigation, Pages 46 through 49	**NMED Comment:** The following issues must be addressed: a. Soil boring locations 500-SB-01 and 500-SB-06 have been designated as bedrock only borings; however, the sampling schedule includes the collection of groundwater samples at these locations. Revise the table to resolve the sample schedule discrepancies and provide a replacement table.	NASA corrected Table 4.1 to address discrepancies with bedrock/groundwater depth designations and groundwater chemical sample collections to match the boring advancement to groundwater discussions in Section 4.2.1 (Soil Borings) and Section 4.2.5 (Monitoring Well Installation) of the IWP. a. Groundwater samples at soil boring locations 500-SB-01 and 500-SB-06 have been removed.

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
	b. Soil boring locations 500-SB-02 and 500-SB-09 have been designated as potential groundwater monitoring well locations; however, the sampling schedule does not include the collection of groundwater samples at these boring locations. Revise the table to resolve the sampling schedule discrepancies and provide a replacement table.	b. Groundwater samples at soil boring locations 500-SB-02 and 500-SB-09 have been added. NASA also revised the VOC analysis designation in Table 4.1 to specify the specific volatile organic compounds listed in Table 2.2, in accordance with Section 4.2.3 (Soil Sampling Plan) of the IWP.
N/A		NASA added information related to the newly constructed distillation pad and associated piping in Section 1.3 and Figures 4.1 and 4.2. The completed structure piping is approximately 10 feet from boring 500-SB-09. Due to the nature of distillation operations and safety concerns related to proximity of the piping, NASA relocated boring 500-SB-09 approximately 10 feet to the north of its approved location. Figures 4.1 and 4.2 show the approved location (struck-out) and relocation 500-SB-09. Text discussing the location of boring 500-SB-09 (Section 4.2.1 – Soil Borings and Table 1.1 – Soil Boring Rational) is still valid and no text changes were made associated with the 10-ft step-off to the north.
N/A		NASA added information related to increased operations at 500 Area FSA (SWMU 47) and 700 Area High Energy Blast Facility (SWMU 18) in Section 1.3 – Other Considerations that may have additional impacts on the field schedule. NASA cannot accurately forecast distillation operations, fuel transfers, or testing that may be performed in the 300, 400, 500, and 700 Areas at this time, and may propose an alternate schedule in the future if testing impacts the investigation field schedule. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
N/A		NASA updated permit references in the IWP to reflect the current RCRA Permit, which became effective in April 2023.

National Aeronautics and Space Administration

500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I

September 2018

Revised November 2019

Revised June 2021

Revised May 2023

NM8800019434

NASA Johnson Space Center White Sands Test Facility

500 Area Fuel Storage (SWMU 47) Investigation Work Plan: Phase I

September 2018

Revised November 2019

Revised June 2021

Revised May 2023

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Timothy J. Davis Chief, NASA Environmental Office	Date

National Aeronautics and Space Administration

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Executive Summary

The NASA JSC (Johnson Space Center) WSTF (White Sands Test Facility) ~~is~~ was required by the previous WSTF Hazardous Waste Permit issued by the NMED (New Mexico Environment Department~~;~~ 2009~~16~~) to develop Investigation Work Plans (IWP) for SWMU (solid waste management units) at WSTF. This IWP (investigation work plan) was approved with modifications (NMED, 2023) under Hazardous -Waste Permit (NMED, 2016) and will be implemented under the RCRA (Resource Conservation and Recovery Act) Post-Closure Permit (RCRA Permit; NMED, 2023b). Where applicable, references and citations have been updated to the current standards, guidance, and NMED-approved documents. This IWP describes field investigation activities that will be conducted at the 500 Area Fuel Storage (SWMU 47) for this Phase I Investigation.

Eleven proposed primary soil borings will be advanced from ground surface to the alluvium-bedrock interface located at approximately 110 ft (feet) to 225 ft bgs (below ground surface). Up to 15 soil samples will be collected during the advancement of each boring and analyzed for COPC (contaminants of potential concern), which include hydrazine, unsymmetrical dimethylhydrazine, and monomethyl hydrazine, collectively referred to as hydrazines, as well as N-nitrosodimethylamine (a potential oxidation product of some hydrazines), IPA (isopropyl alcohol), and acetone (a potential component of IPA degradation in soil). Up to five of those borings will be advanced into bedrock and groundwater grab samples will be collected (if groundwater is encountered within the borehole). These five borings will be reviewed for groundwater recovery, completed as monitoring wells as appropriate. The completed wells will be incorporated into the WSTF Groundwater Monitoring Plan (NASA, 2018). The results of the soil sample analyses will be compared to SSLs (Soil Screening Levels) in accordance with RCRA Permit ~~Attachment 15~~ Section 3.5.2 (NMED, 2023b, pp28-29) and used to perform a health risk screening for current industrial and construction worker receptors in accordance with the NMED Risk Assessment Guidance for Site Investigations and Remediation, Volume I, Soil Screening Guidance for Human Health Risk Assessments (NMED, ~~2019~~2022), as updated, and provide data for future health and ecological risk assessment in subsequent phases of investigation at SWMU 47 in accordance with RCRA Permit ~~Attachment 17~~Section 6.5 (NMED, ~~2017, 2019, 2016~~2023b).

NASA expects to initiate investigation fieldwork approximately four to six months after NMED approval of this IWP, complete fieldwork approximately eight to ten months following initiation, and complete and submit an investigation report to NMED approximately 18 months after NMED approval of this IWP.

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List of Acronyms

ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
DQOs	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ft	Feet
GMP	Groundwater Monitoring Plan
GPS	Global Positioning System
HAZWOPER	Hazardous Waste Operations and Emergency Response
HIS	Historical Information Summary
HSA	Hollow Stem Auger
HTH	Hypochlorite Trihydrate
HWB	Hazardous Waste Bureau
IDW	Investigation-derived waste
in.	Inch(es)
IPA	Isopropyl Alcohol
IWP	Investigation Work Plan
JSC	Johnson Space Center
MMH	Monomethyl Hydrazine
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
OSHA	Occupational Safety and Health Administration
PID	Photoionization Detector
ppb	Parts per billion
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance and Quality Control
RCRA	Resource Conservation and Recovery Act
SAM	San Andres Mountains
SCEM	Site Conceptual Exposure Model
SHP	Safety and Health Plan
SOP	Standard Operating Procedure
SWMU	Solid Waste Management Unit
SWMU 47	500 Area Fuel Storage
TIVC	Total Ionizable Volatile Compounds
UDMH	Unsymmetrical Dimethylhydrazine
USDA SCS	United States Department of Agriculture Soil Conservation Service
VOA	Volatile Organic Analysis
WSTF	White Sands Test Facility

1.0 Introduction

The NASA (National Aeronautics and Space Administration) JSC (Johnson Space Center) WSTF (White Sands Test Facility) is located at 12600 NASA Road in central Doña Ana County, New Mexico. The site is approximately 18 miles northeast of Las Cruces, New Mexico and 65 miles north of El Paso, Texas (Figure 1.1). WSTF has supported testing of space flight equipment and materials since 1964 and continues to operate as a field installation of JSC. The WSTF U.S. EPA (Environmental Protection Agency) Facility Identification Number is NM8800019434.

The WSTF Resource Conservation and Recovery Act Hazardous Waste Permit (Permit), issued by the NMED (New Mexico Environment Department) in November 2009 requireds the preparation of several IWP (investigation work plans) to assess the potential impact of historical releases of hazardous waste or hazardous constituents (NMED, 201609). The 2009 Permit requireds NASA to determine whether these releases may have the potential to serve as continuing sources of soil and/or groundwater contamination. Permit Attachment 16 listeds the WSTF SWMU (Solid Waste Management Units) and areas of concern that require the submittal of an IWP to the NMED HWB (Hazardous Waste Bureau) for closure and/or investigation (NMED, 200916).

This IWP describes the approach for a planned Phase I Investigation of SWMU 47, as identified in the Hazardous Waste Permit aAttachment 16 as the 500 Area Fuel Storage. This IWP was approved with modifications (NMED, 2023) under previous Permit (NMED, 2009) and will be implemented under the RCRA Post-Closure Permit (RCRA Permit; NMED, 2023b). Where applicable, references and citations have been updated to the current standards, guidance, and NMED-approved documents. Figure 1.2 shows the location of the SWMU relative to the industrial areas at WSTF.

1.1 Objectives and Scope

The objective of this investigation is to identify the nature and extent of COPC (contaminants of potential concern) in the vadose zone and potential migration pathways of contaminant releases to the soil and groundwater in the area adjacent to and downgradient of the active portion of SWMU 47. NASA anticipates SWMU 47 will remain active indefinitely, in support of rocket engine testing. Therefore, NASA proposes a phased approach in order to investigate the potential impact of historical releases. The initial phase of this investigation is described in this work plan, which includes soil sampling in 11 borings and the installation of between three and five groundwater monitoring wells. Additional investigation of SWMU 47 will be performed following permanent cessation of fuel storage operations. Follow-on investigation work plans will be prepared , in accordance with Section 6.2 of the RCRA Permit (NMED, 2023b, pp81-86). The scope of the initial investigation is limited to the vadose zone and groundwater in the area adjacent to, upgradient, and downgradient of the active portion of SWMU 47 and specific to the known COPCs, determined by historical use of SWMU 47.

NMED's reminder, from Comment 3 of the Second Notice of Disapproval (NMED, 2021), that this is a partial investigation and the unused portion of SWMU 47 cannot be considered for no further investigation induced NASA to reconsider the objectives of this investigation. NASA revisited the objectives and agree that a partial SWMU cannot receive a "no further investigation" determination. Therefore, NASA revised the current scope of the work plan to focus on determining the nature and extent in soils and groundwater, while also considering human health risk evaluations. NASA is reducing the network of soil borings from the original IWP proposed: 16 borings to 11 borings. Reduction in the boring network will allow for the health risk evaluation, while still encompassing a network of borings within SWMU 47 with upgradient and downgradient components. Table 1.1 includes the soil boring reduction rationale.

1.2 Regulatory Requirements

SWMU 47 was originally identified in the Hazardous Waste Permit Attachment 16 with a required IWP submittal date of June 30, 2011. In conjunction with submittal of IWPs, the Hazardous Waste Permit (Section VII.H.1.c) requireds the submittal of a HIS (historical information summary) to the NMED HWB. In a teleconference on January 6, 2011, NMED proposed that NASA submit a HIS with previous investigation results for SWMU 47 prior to submitting an IWP (NASA, 2011a). In response, NASA submitted the SWMU 47 HIS in conjunction with the IWP and HIS for the 400 Area Closure Investigation on June 27, 2011 (NASA, 2011b). NMED disapproved the 400 Area IWP and stated in Comment 2 that NASA may request to defer further site investigation of SWMU 47 until the area is no longer in use (NMED, 2011). On October 27, 2011 in the reply to the disapproval, NASA stated that a request to defer further site investigations at SWMU 47 would be submitted to NMED in subsequent correspondence (NASA, 2011d). NASA submitted a Class I Permit Modification Request on November 17, 2015 to the NMED HWB to request a new submittal date for the SWMU 47 IWP to “60 days before closure” (NASA, 2015). NMED approved the Permit Modification on December 16, 2015 (NMED, 2015). The approval included NMED modifications indicating that NASA must perform additional investigation of SWMU 47 to fully delineate the contaminant plume identified during previous investigations at SWMU 47. It was unclear if that investigation work was required as part of the SWMU investigation following closure or before closure. NASA evaluated the available options and determined that investigation of SWMU 47, adjacent to, and downgradient of the active portion of the SWMU should be performed prior to closure to determine if there is a continuing source of contamination in the soil. This document is was prepared in accordance with the Hazardous Waste Permit and describes the work proposed for that investigation. Deviations from several specific Hazardous Waste Permit requirements for the purpose of this investigation are summarized in Appendix A. Investigation activities will follow those outlined in this NMED-Approved IWP. Permit driven references have been reviewed and, where applicable, references and citations have been updated to the current RCRA Permit (NMED, 2023b).

1.3 Other Considerations

SWMU 47 is an active facility that continues to provide fuel storage for the 300 and 400 Area test operations. The timeframe for future closure of SWMU 47 is unknown and contingent upon current and future test operations within the 300 and 400 Areas. Because SWMU 47 is an active facility at WSTF, NASA will only investigate areas adjacent and downgradient of the active portion of SWMU 47 prior to SWMU closure. The portions of SWMU 47 facility actively being used will be investigated at the time of closure. Due to the nature and stability of the fuels stored at SWMU 47, explosive risk related to drilling vibrations is not anticipated. Mechanical connections, however, may come loose as a result of those vibrations and will require a daily inspection to ensure the safety of all field personnel. In the event that a fuel leak occurs, field activities will be immediately suspended and field personnel will evacuate the area until the leak is resolved and the area is safe to return to active fieldwork. Any leaks that impact continued drilling or boring location will be discussed and resolved with NMED.

Off-specification hydrazine fuel storage for recycling at a distillation unit is in the preliminary planning stages for use at SWMU 47, as initially identified in the April 26, 2019, Request for a "Contained in Determination" for FTU (Fuel Treatment Unit) Debris (NLCID; NASA 2019). The distillation unit has a tentative installation date in 2020 with a tentative concrete pad extension off the north side of the current drum pad area. Figure 1.3 shows the approximate location of the pending distillation pad. The initial phase of this investigation will consider the addition of the planned distillation unit in reference to the placement of wells and concerns with potential active operation interference.

This work plan will be executed in the vicinity of two active test areas: 300 Area and 400 Area (Figure 1.2). There may be periods during which field personnel will not be allowed access to the work area. NASA cannot accurately forecast propulsion testing that may be performed in these two areas at this time but may propose an alternate schedule in the future if testing impacts the field schedule presented in Section 11.0. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

During the interlude from NASA's June 2021 submittal and NMED's March 2023 approval with modifications of this IWP (NMED, 2023a), the previously discussed distillation pad was constructed with a pending start date for off-specification hydrazine recycling in July 2023. The recycling process is scheduled to operate continuously for approximately five years. Due to safety concerns related to the recycling process, the majority of the field area within the vicinity of SWMU 47 may be inaccessible to field personnel during distillation operations and may impede investigation schedules initially proposed in Section 11.0 of this IWP. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

Additionally, the 700 Area High Energy Blast Facility (SWMU 18) is increasing test operations in the area. There may be periods during which field personnel will not be allowed access to the work area related to safety procedures for testing. NASA cannot accurately forecast blast testing that may be performed in the 700 Area at this time but may propose an alternate schedule in the future if testing impacts the field schedule presented in Section 11.0. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

2.0 Background

Historical operations at SWMU 47 are described in the HIS (NASA, 2011b). Additional details regarding SWMU 47 historical operations were also provided by NASA in the *Notice of Disapproval, 400 Area Closure Investigation Work Plan* comment resolutions table (NASA, 2011d).

2.1 Operational History

SWMU 47 was constructed in the mid-1960s for use during the Apollo Space Program testing at WSTF. It contained a 21,000-gallon above-ground steel tank to store hydrazine fuels, overhead fuel distribution lines from the tank to the WSTF testing areas, a low-point stainless steel drain line that extended approximately 350 ft (feet) northwest of the facility, and a Fuel Storage Control Building (Building 501). The fuel tank was built on a concrete pad with a secondary containment concrete pad to the south that sloped into a gunite-lined pond with dimensions of 60 ft x 80 ft. The gunite-lined pond included a sump that terminated approximately 45 ft to the north of the pond via a 4-in. (inch) pipe with a closed check gate. An aerial photograph from 2006 is presented in Figure 2.1 to provide a historical and current overview of significant features associated with SWMU 47. Figure 1.3 shows the complete gunite-lined pond and the sump drain line.

The gunite-lined pond was primarily used to capture fire extinguishment water from testing the Firex®[1] system. According to an interview in the HIS, the gunite-lined pond may have been used to contain any potential fuel spills. The potential spills may have been treated with calcium HTH [hypochlorite trihydrate] for oxidation and left to evaporate (NASA, 2011b; 2011c).

Fuel was historically transferred into the 21,000-gallon tank from tanker trucks (NASA 2011b). Any remaining fuel in the lines was drained using the low-point drain line into a 55-gallon steel open container located at the terminus. The fuel in the container was oxidized with HTH and/or allowed to burn. Use of

[1] Firex is a registered trademark of Walter Kidde Portable Equipment, Inc.

the 21,000-gallon hydrazine tank and steel container ceased in the early to mid-1970s with the conclusion of the Apollo Space Program testing at WSTF (NASA 2011d). Fuel has been stored since the early to mid-1970s in closed-top 55-gallon drums east of the original tank location on the concrete pad under a shelter and occasionally to the south on the secondary containment concrete pad (NASA, 2011b).

Adjacent to SWMU 47, to the east of the parking area, was the historical alcohol storage area. Originally, an aboveground tank stored alcohol (IPA [isopropyl alcohol]) in the 1960s. This tank was removed prior to 1998, and the area is currently not in use (NASA, 2011a).

2.2 Additional Operational History Post-HIS

Historical operations at SWMU 47, described in the HIS (NASA, 2011b), provided operational descriptions and documentation through June 2011. Starting in 2011 through 2012, the fuel distribution lines to the testing areas, the low-point stainless steel drain line, and the 21,000-gallon hydrazines tank were decommissioned. As part of this process, all lines and the tank were triple-rinsed, sampled, and verified that decontamination was successful. The lines and tank were removed and relocated to the WSTF 150 Storage Area.

In 2015, four 3,300-gallon aboveground fuel tanks were installed in the location of the original 21,000-gallon tank (see Figure 2.1). Fuel is stored in these four aboveground tanks and in a mobile tanker truck with a 2,500-gallon capacity on an as-needed basis.

Only one spill was recorded during post-HIS operations at SWMU 47. On April 5, 2016, approximately 0.90 pounds of MMH (monomethyl hydrazine) was noticed on the concrete containment underneath a tank flange. The spill was cleaned up with water and wipes, and drip pans were placed underneath the leaking fittings. The flange was decontaminated with water and wipes which were collected and placed in the area 90-Day Accumulation Area. The flange bolts torque was verified and re-torqued to repair the leak. No MMH was released to soil.

2.3 Previous Investigations

A three-phased soil investigation was conducted at SWMU 47 between July 2000 and May 2001 to evaluate concentrations of NDMA (N-nitrosodimethylamine), the common byproduct of hydrazine fuel oxidation and a current WSTF groundwater contaminant. The results of these investigations are shown in Table 2.1 and were previously provided to NMED in Section 20.35 of the August 8, 2002 RCRA Permit Renewal Application (NASA, 2002) and the May 6, 2004 Notice of Deficiency Response and Submittal of the Revised RCRA Permit Renewal Application Package (NASA, 2004). A brief summary of the soil investigation and historical data is provided in this section. The SWMU 47 HIS (NASA, 2011b) provides additional details. In Phase I, a backhoe was used to collect soil samples at depths of 5 ft and 10 ft bgs (below ground surface) at five locations: one to the west of the gunite-lined pond termed "background;" the low-point drain line terminus; the gunite-lined pond sump drain line terminus; to the north of the hydrazines tank location; and, to the north of the low-point drain line terminus termed "downgradient" (Figure 2.2). NDMA was detected at the 5 ft sampling interval at both the low-point drain line terminus (25.3 ppb [parts per billion]) and north of the tank location (maximum detected was 4.9 ppb).

For Phase II, a HSA (hollow stem auger) drilling rig was used to install 17 soil borings to approximately 30 ft bgs. Locations of the soil borings were: one boring located to the west of the gunite-lined pond termed "background;" one boring at the gunite-lined pond sump drain line terminus; seven borings near the low-point drain line terminus; and, eight borings north of the hydrazines tank location (Figure 2.2). NDMA was detected at two low-point terminus borings (all detected up to 30 ft bgs with a maximum detected concentration of 1.17 ppb) and three borings north of the hydrazines tank (all detected up to 30 ft bgs with a maximum concentration of 14.8 ppb).

Phase III soil borings were located downgradient of Phase II borings to further delineate NDMA in soils at SWMU 47. An HSA drilling rig was used to install nine soil borings to approximately 50 ft bgs. Four borings were located near the low-point drain line terminus, and five borings were located north of the hydrazines tank location (Figure 2.2). NDMA was detected at four low-point drain line terminus borings (all up to 50 ft with a maximum detected concentration of 1.26 ppb) and four borings north of the hydrazines tank (two detected to 50 ft bgs with a maximum detected concentration of 1.59 ppb).

2.4 Current Area Usage

SWMU 47 is currently used for the storage of hydrazine fuels (MMH, hydrazine, and hydrazine blends), with a maximum storage capacity of 19,200 gallons (up to 3,500 gallons within 55-gallon drums, up to 3,300 gallons each in 4 tanks, and up to 2,500 gallons in a mobile tanker). The fuel is stored to support propulsion testing operations, primarily for use in the WSTF 300, 400, and 800 Areas (Figure 1.2).

2.5 Contaminants of Potential Concern

Fuels historically stored at SWMU 47 include hydrazine, 1,1-dimethylhydrazine (UDMH [unsymmetrical dimethylhydrazine]), Aerozine 50 (a 50/50 blend of hydrazine and UDMH), and MMH. The on-site oxidation of fuels may have also resulted in the formation of NDMA, which was detected in soils near SWMU 47 during previous investigations (NASA, 2011b). As previously indicated, there was also an IPA storage tank originally located adjacent to SWMU 47. COPC (contaminants of potential concern) for this investigation therefore comprise hydrazine, UDMH, and MMH, collectively referred to as hydrazines, as well as NDMA, IPA, and acetone (a potential component of IPA degradation in soil). Table 2.2 provides a complete list of COPCs based on the historic operations and documented chemical releases.

2.6 Preliminary Site Conceptual Exposure Model

A preliminary SCEM (site conceptual exposure model) was developed to provide an understanding of the potential for exposure to hazardous constituents at SWMU 47 based on the source of contamination, the release mechanism, the receiving or contact medium, the exposure pathway(s), and the potential receptors(residential, industrial/occupational, construction worker, and soil-to-groundwater) exposure scenarios. Figure 2.3 summarizes and presents the SCEM in diagram form. Incomplete exposure pathways are denoted by dashed lines to potential receptors, and complete exposure pathways are denoted by solid lines.

2.6.1 Contamination Sources

Potential contamination sources are fuels (hydrazines) that may have been spilled or discharged to the environment from historical operations at SWMU 47, NDMA that may have formed or been discharged to the environment from oxidation of fuels, IPA that may have spilled or discharged from the adjacent historical WSTF alcohol storage area, and acetone that may have formed from IPA. During this investigation, the areas adjacent to and downgradient of SWMU 47 will be investigated to determine if any fuels, NDMA, IPA, or acetone are present in soils and groundwater.

2.6.2 Release Mechanisms

Fuels may have been released to the environment through spills from the low-point stainless steel drain line, leaks or spills from the 55-gallon open top barrel at the low-point drain line terminus, leaks from the hydrazines tank, or discharges to grade of treated fuel and water from the gunite-lined pond. NDMA could have formed from oxidation of the fuels through natural exposure or HTH usage. IPA could have been spilled during loading/unloading the alcohol tank and become the breakdown product acetone in the environment.

2.6.3 Exposure Pathways

NASA evaluated seven potential exposure pathways with current conditions at SWMU 47: 1) ingestion (direct and incidental) of soil; 2) dermal contact with soil; 3) inhalation of volatiles and particulate emissions (dust); 4) ingestion of groundwater; 5) dermal contact with groundwater; 6) inhalation of indoor air vapors; and 7) migration of COPCs through soil to underlying potable groundwater. There are no current or future residential land use scenarios anticipated in the vicinity of SWMU 47. WSTF is a controlled test site located on the U.S. Army White Sands Missile Range, and there are no encroaching residential areas. Therefore, there are no complete exposure pathways identified for the residential exposure scenario in the SCEM (Pathways 1 through 6).

SWMU 47 is currently used at WSTF to store fuels and there are no industrial buildings in the area (Pathway 6). Industrial/occupational workers deliver and remove fuel containers for use in propulsion testing performed at other areas at WSTF. If there is any residual surface soil contamination at SWMU 47, workers could come into contact with potentially contaminated wind-blown surface soils during routine working activities. Therefore, inadvertent ingestion or inhalation of, or dermal contact with, contaminated soil may be considered complete exposure pathways (Pathways 1, 2, and 3).

The groundwater underlying much of WSTF is known to be contaminated, and its future use and potential risk to receptors are part of ongoing site-wide evaluation and corrective actions. The only water supply wells for the site are located several miles to the west and down hydraulic gradient from SWMU 47. The supply wells are monitored regularly for the presence of any site-source contaminants. Ingestion of groundwater (Pathway 4) is not considered a completed exposure pathway for the residential, industrial/occupational, or construction worker exposure scenarios.

Environmental Department and subcontractor drilling crews (construction workers) will be performing this investigation, which includes installation of borings that intercept soil and potentially groundwater. A potential exposure pathway exists for that population to ingest, inhale, or come into dermal contact with potentially contaminated soil (Pathways 1, 2 and 3) or come into dermal contact with potentially contaminated groundwater (Pathway 5). This potential exposure will be mitigated by the use of engineering controls and proper use of PPE (personal protective equipment) during the investigation activities.

Pathway 7 represents the soil-to-groundwater pathway, which is a first step to determine if the release is a continuing source for contamination to groundwater. Data collected from this investigation will be evaluated as part of the SWMU 47 Investigation Report. A point-to-point comparison of maximum investigation soil concentrations will be compared to SSLs (soil screening levels). Complete current WSTF exposure pathways (Figure 2.3) will be evaluated per the NMED Risk Assessment Guidance for Site Investigations and Remediation, Volume I, Soil Screening Guidance for Human Health Risk Assessments (RA Guidance; NMED, 2022~~19~~), as updated.

2.6.4 Potential Receptors

Investigation activities at SWMU 47 will include subsurface investigation that will provide complete release and exposure mechanisms to field personnel and subcontractor crews (site receptors - industrial/occupational and construction workers and potentially groundwater through the soil-to-groundwater pathway). NASA will conduct a risk and hazard evaluation for the potential receptors for complete pathways for receptors as outlined in the SCEM (Figure 2.3) in accordance with the NMED RA Guidance (NMED, 202219), as updated. A summary of the site receptor evaluation will be provided in the SWMU 47 Phase 1 Investigation Report. NASA will utilize procedures detailed in Section 5.5 to mitigate personnel exposure.

3.0 Site Conditions

3.1 SWMU 47 Description

SWMU 47 was built on a concrete pad with a secondary containment concrete pad to the south that sloped into a gunite-lined pond with dimensions of 60 ft x 80 ft. See Section 2.1 and the SWMU 47 HIS (NASA, 2011b) for a more detailed description.

3.2 Surface Conditions

Soil surface conditions at and near SWMU 47 consist of Quaternary piedmont slope facies of the Camp Rice Formation. The Camp Rice Formation represents part of the widespread upper Santa Fe Group alluvium (Seager, 1981) derived from the adjacent SAM (San Andres Mountains) to the east. The piedmont slope deposits comprise coalescent alluvial fans that originated from Bear Canyon, a major east-west-trending transverse canyon in the southern SAM located 1 mile east of SWMU 47. The alluvial fan that houses SWMU 47 has a gentle gradient towards the north indicating any surface flow or drainage would propagate northward and intersect the main arroyo running along the north side of SWMU 47.

Santa Fe Group alluvial deposits comprise variably sized gravel clasts within a sand silt, and clay sized matrix. The alluvium is consolidated to unconsolidated, poorly sorted and locally contains discontinuous cemented caliche horizons a few inches in thickness. The most proximal outcropping lithologic units are located approximately 1 mile to the east in the Bear Canyon area and comprise Pennsylvanian to Permian age limestone, sandstone, siltstone, and shale.

The soil type present at SWMU 47 is the Tencee-Nickel Association, Steep unit ([USDA] United States Department of Agriculture [SCS] Soil Conservation Service, 1976). This soil consists of approximately 45% Tencee Very Gravelly Loam and 40% Nickel Fine Sandy Loam with slopes up to 35% grade. General characteristics of this soil type include moderate permeability, very low water capacity, rapid runoff, severe water erosion capacity, and low probability of generating wind-blown soils. Gravelly soils containing less than 35% coarse fragments, badland, stony rock land, and arroyos are included in this soil type.

3.3 Subsurface Conditions

Unconformably overlying older Santa Fe Group alluvium in the vadose zone is Quaternary alluvium of the Camp Rice Formation and younger piedmont slope alluvium. These younger alluvial units are syntectonic with a period of younger Basin and Range faulting. Several subsurface faults in the vicinity of SWMU 47 have been inferred from seismic and in the adjacent 300, 400, and 700 Areas, well log data (Reynolds, 1988; Maciejewski, 1996).

No monitoring wells have been installed in the 500 Area. However, the adjacent 300, 400, and 700 Areas provide likely analogs to subsurface conditions at SWMU 47. Based on adjacent areas, bedrock lithology in the vicinity of SWMU 47 is expected to consist of Tertiary (Eocene or Oligocene) Orejon Andesite (Seager, 1981) at approximate depths between 110 and 225 ft bgs.

3.3.1 Structure

Two styles of geologic deformation are present in the vicinity of SWMU 47. The oldest and less prevalent deformation consists of west to northwest-trending folding and faulting associated with the Late Cretaceous to Early Tertiary Laramide Orogeny. This compressional deformation style is present east of SWMU 47, exposed along Bear Canyon, and defined by Seager (1981) as the Bear Peak Fold and Thrust Zone. Thrust faults of the Bear Peak Fold and Thrust zone are interpreted to extend northwestward along strike in the subsurface and pass north of SWMU 47. The second more recent and more prevalent deformational style consists of extensional northwest-trending Late Tertiary Basin and Range normal faulting. The local expression of this structural style is the Rio Grande Rift. Basin and Range normal faulting began in the Rio Grande Rift between 26 and 32 million years ago (Seager, 1981).

3.3.2 Hydrogeology

Based on adjacent areas to SWMU 47, the aquifer in the vicinity of SWMU 47 is likely hosted within the Tertiary andesite bedrock, typically at depths of between 121 ft bgs (monitoring well 700-J-200) and 233 ft bgs (monitoring well BW-5-295). The andesite bedrock has little to no primary porosity; therefore, any porosity and groundwater flow is within secondary fractures induced through structural episodes. Groundwater flow in the SWMU 47 vicinity is from east to west based on the latest groundwater depth measurements of monitoring wells in surrounding areas. Groundwater volume is generally restricted based on low hydraulic conductivities within the andesite aquifer determined from slug testing at monitoring wells in surrounding areas.

4.0 Scope of Activities

Investigation activities will be conducted under the supervision of the site supervisor (a qualified engineer, environmental scientist, or geologist) or designated field lead. The following activities will be performed during the investigation of the currently unused portion of SWMU 47 and the area adjacent to and downgradient of the SWMU.

- Field investigation of soil boring and groundwater monitoring locations. These locations will be based on:
  - Information within the SWMU 47 HIS
  - Information collected from previous investigations in the area.
  - Information identified in the field relative to any visible staining of soil or odors detected using portable field monitoring equipment.
- Daily safety and health briefings.
- Field data and GPS (global positioning system) survey data collection.
- Field operations for collection, management, and shipment of soil and groundwater samples (including field quality control samples).
- Laboratory analyses (including laboratory quality control samples), analytical reporting, and data processing using the established WSTF data management system.

- Interpretation of field and analytical data for use in development of an investigation report for the unused portion of SWMU 47.

4.1 Data Quality Objective Process

The investigation methodology was developed based on “Guidance on Systematic Planning Using the DQO [Data Quality Objectives] Process” (USEPA, 2006) and the Corrective Action Site Investigations requirements of the Hazardous Waste Permit (NMED, 201609; Section VII.H). The data acquisition plan (i.e., sampling design) is based on the DQO process and formulated to meet Hazardous Waste pPermit requirements.

4.1.1 Problem Statement

The problem statement is summarized in the Hazardous Waste Permit (NMED, 200916; Section VII.H.1.b), which states that the IWP “…shall include schedules for implementation and completion of specific actions necessary to determine the nature and extent of contamination and the potential migration pathways of contaminant releases to the air, soil, surface water, and ground water.” The problem statement is further clarified in NMED’s December 16, 2015 comment on NASA’s November 17, 2015 Permit Modification, which indicated that further delineation of subsurface contamination is required and that NASA “…must either demonstrate that migration of COC (contaminants of concern) to groundwater has not occurred or provide justification showing that COCs in the vadose zone are not a threat to groundwater.”

4.1.2 Decision Statement and Alternative Actions

The primary decision is to determine the nature and extent of vadose zone contamination and whether contaminant migration to the groundwater has occurred. Alternative actions for the decisions include:

- If needed, perform further investigation for the site (or portions thereof) to further delineate potential source(s) of continuing contamination.

4.1.3 Decision Inputs

COPC concentrations measured in the vadose zone soil and local groundwater are the primary inputs to the decision. COPCs for this investigation were identified in Section 2.4. This section provides four decision inputs for evaluation of COPCs in soil and groundwater:

- Detailed information pertinent to the establishment and operational history of the 500 Area Fuel Storage as documented in the historical information summaries for SWMU 47 through a variety of historical documents and reports, personnel interviews, and personnel questionnaires.
- Validated analytical results from soil samples collected during the investigation will be compared to all applicable SSL including human health risk and hazard screenings using NMED SSL (NMED, 202219) and EPA's RSL (regional screening levels; November 2019) for analytes not listed in the NMED guidance. Results will also be compared with risk-based and MCL (maximum contaminant level)-based SSLs protective of groundwater for identified complete exposure pathways, in accordance with the NMED Risk Assessment Guidance for Site Investigations and Remediation (RA [Risk Assessment] Guidance; NMED, 202219).
- Validated analytical results from groundwater samples collected during the investigation will be compared to the RCRA Permit Attachment 15.1Section 3.5.1, Groundwater Cleanup Levels (NMED, 20162023b, pp28-29).

- Soil analytical methods selected for this investigation will be used to quantify COPC concentrations at or below NMED SSLs whenever possible (NMED, 202219). Groundwater analytical methods selected for this investigation will be used to quantify COPC concentrations at or below RCRA Permit 15.13.5.1 cleanup levels whenever possible (NMED, 20162023b, pp28-29).

4.1.4 Study Boundaries

The horizontal boundaries of the study represent the known extent of the SWMU as determined by historical research and confirmed by field surveys of the sites. The currently inactive and unused portion of SWMU 47 will be investigated. This investigation addresses and is limited to the upper portion of the vadose zone and groundwater beneath and downgradient of the unused portion of the SWMU. Adjacent areas to be included in the investigation include the upgradient portion of the Fire Break Road and the downgradient portion of the arroyo located to the north of SWMU 47 (Figure 4.1). The vertical boundary is the approximate depth to bedrock (110 ft to 225 ft). However, because groundwater is also of concern, three to five borings are expected to be advanced to groundwater (120 ft to 230 ft bgs), with depths not to exceed 250 ft bgs if groundwater is not encountered.

4.1.5 Study Constraints

One of the primary constraints to drilling and sampling in the 500 Area is related to subsurface geology. Based on previous soil boring and well installations across the site, cobbles and boulders are common within the coarse-grained coalescent alluvial fan deposits. These make collection of representative soil samples difficult, with previously reported soil sample recoveries as low as 20% using hollow stem augers equipped with split spoon samplers (NASA, 1996). Standard coring techniques also typically experience very low recoveries and problems with sidewall sloughing and collapse due to the extremely dry and relatively coarse-grained nature of the alluvium. Rotary techniques have the potential to contaminate samples through the use of drilling fluids or air. Small drill rigs (i.e., direct-push or mini-sonic rigs) are incapable of penetrating the difficult lithologies known to exist near the SAM front beyond a depth of a few feet. During the 600 Area and 300 Area Closure field investigations (performed November 2010 through January 2011), a modified heavy-duty sampling core barrel was used with an air-rotary casing hammer drilling strategy. This boring installation technique allowed for improved soil sample recovery (typically 20 to 50%) with minimal boring collapse. For the 400 Area Closure investigation, a combination of sonic and air rotatory drilling was utilized: sonic – to advance soil borings and collect soil cores within the uncemented alluvium; and rotary – to advancing borings to bedrock or groundwater. It has been concluded that only a limited number of drilling and sample collection approaches can be employed within the WSTF industrialized areas.

Another constraint is related to operations and testing in nearby areas. The proximity of the project area to the active testing and test support facilities also imposes logistical constraints. The active portion of SWMU 47 is currently used for fuel storage. Test support operations, fuel transfers, and other materials transfers (e.g., cryogenics and inert gases) may occur within the 500 area temporarily restricting access to SWMU 47. Current operations at the 300 and 400 Areas include support facilities for propulsion system and components testing. These areas were constructed to perform hazardous testing of hardware safely with access to essential utilities and control facilities. For safety purposes, access to select areas of the investigation site could be periodically restricted during testing and other hazardous operations. Field activities will be closely coordinated with the 300, 400 and 500 Areas in accordance with an internal communications matrix to minimize schedule impacts to testing and investigation activities.

4.2 Sampling Tasks

For the Phase I investigation, 11 soil boring locations (500-SB-01 through 500-SB-11; Figure 4.1) are anticipated to be installed using air rotary or sonic drilling methods. The following sections discuss sampling tasks. Drilling and sampling procedures are discussed in Section 5.0.

4.2.1 Soil Borings

The 11 soil borings are positioned to allow the collection of samples that will characterize the vadose zone below and adjacent to SWMU 47 (Figure 4.1). Table 1.1 provides the rationale for soil boring placement. One boring is planned upgradient of SWMU 47 to the north of the Fire Break Road (500-SB-04). Six borings are located within or immediately adjacent to the current SWMU 47 (Figure 4.2): one at the terminus of the removed low-point drain line (500-SB-02); one at the terminus of the sump drain line (500-SB-03); one at the historical alcohol storage tank (removed prior to 1998) location (500-SB-11); one at the termination of an “unknown” line (500-SB-10); one directly north of the active fuel storage pad (500-SB-09); and, one adjacent to the northeast of the gunite-lined pond (500-SB-08). Two borings will be positioned immediately adjacent to the secondary SWMU 47 fence: one near the northwestern corner of the gunite lined pond (500-SB-01); and, one near the arroyo to the north that originates within the SWMU 47 boundary (500-SB-07). Two borings are positioned downgradient: two borings adjacent to the main arroyo to the north of SWMU 47 (500-SB-05 and 500-SB-06).

Soil borings proposed for the initial investigation are specifically designed to provide the information necessary to characterize the extent of vadose zone contamination beyond the low-point drain line and the sump drain line. Most soil borings will be installed to bedrock in order to fully characterize the vertical extent of potential soil contamination. Three to five of the borings will be advanced into bedrock in an attempt to locate and sample groundwater. These borings will extend to 20 ft below the first encounter of groundwater. Potential boring locations for advancement to groundwater may include borings 500-SB-02, 500-SB-04, 500-SB-05, 500-SB-07, and 500-SB-09. If groundwater is not encountered in at least three of the five borings advanced to the anticipated depth of groundwater, NASA will propose additional locations in the next phased IWP for SWMU 47. Additional information related to groundwater sampling is provided in subsequent sections.

Four soil borings, located by the northwest corner of the gunite-lined pond (500-SB-01), the low-point drain line terminus (500-SB-02), the sump drain line terminus (500-SB-03), and the drum pad area (500-SB-09) will be drilled first in order to obtain representative analytical data for waste characterization according to the investigation-derived waste procedures (Appendix B). The remaining borings will be drilled in numerical order, or as close to numerical order as possible given recognized project constraints. Adjustments to the numerical sequence may be made in order to install borings in a manner that minimizes any disruption of the 500 Area operations and test support activities.

4.2.2 Sampling Design

The sampling design must fulfill the project DQOs, which requires contaminant concentration data from subsurface soil samples and groundwater samples. Sections 4.2.2 through 4.2.4 provide a detailed discussion of the project sampling design for soils and groundwater. Table 4.1 summarizes the sampling and analyses that will be performed during the initial investigation. A detailed discussion of drilling methods proposed for the investigation is provided in Section 5.1.

4.2.3 Soil Sampling Plan

To facilitate the collection of representative soil samples, investigation borings will be installed from ground surface to bedrock (approximately 110 ft to 225 ft bgs) or groundwater (approximately 130 ft to 200 ft bgs) as previously described. Based on drilling experience in similar geological conditions during the 300, 400 and 600 Area Closure Investigations, NASA expects moderate difficulty with the recovery of soil samples during boring installation. NASA plans to collect samples over discrete intervals without the use of drilling fluids. The air rotary drilling and sonic drilling methods, described in Section 5.1, will allow sampling of undisturbed cores over short depth intervals without using drilling fluids that could interfere with the chemical analysis. Additional soil samples may be attempted based on pertinent geological conditions or field observations (discolored soil, revised depth to bedrock, etc.).

To address project DQOs and exposure pathways, soil samples will be collected on 5-ft intervals to 30 ft bgs beginning with a surface sample (0 to 1 ft), on ten-foot intervals from 30 ft to 50 ft bgs, and on 25-ft intervals from 50 ft bgs to the bedrock. The depth to bedrock beneath the 500 Area is expected to vary between approximately 110 ft and 225 ft bgs. The deepest sample will be collected as close to the alluvial bedrock interface as feasible, taking into account issues of sample quality, sample recovery, and the position of the water table if encountered unexpectedly. Sampling procedures are discussed in Section 5.0.

Soil samples collected from the borings will be analyzed for the SWMU 47 COPCs (Table 2.2) using standardized analytical methods approved for use at WSTF. Table 4.1 summarizes planned soil samples and anticipated analytical methods.

NASA suggests conducting an if/then analysis for NDMA due to the unknown nature of the soils at depth, the groundwater in the 500 Area, and in consideration of the health risk requirements. This approach will prevent laboratory calibration blow-out issues as consulted and recommended by analytical laboratory personnel. The historical shallow soil investigations already suggest the presence of NDMA by Method 607, indicating that perspective samples within SWMU 47 could produce qualitative results by NDMA low-level instead of the quantitative results needed to perform health risk calculations. The if/then analysis will be analyzed by Method 607 first. For soil samples analyzed by method 607 in which NDMA is detected, low-level analysis will not be performed. For soil samples analyzed by method 607 in which NDMA is not detected, the low-level method will then be performed at the discretion of the laboratory.

NDMA low-level analyses will be completed using a gas chromatograph and mass spectrometer analytical method developed by Southwest Research Institute (SRI) that can achieve a low-level NDMA RL (reporting limit) and MDL (method detection limit). SRI developed the Test/Analytical Procedure 01-0408-031 (TAP-01-0408-031) to achieve low level (matrix spike) instrumental analytical technique for NDMA analysis. The SRI method is based on EPA Method 607 that SRI has modified to provide for lowest available detection limits. The NDMA low-level MDL of 1.7E-04 mg/kg exceeds the SL-SSL of 2.04E-05 mg/kg.

4.2.4 Groundwater Sampling Plan

NASA does not expect to encounter groundwater above bedrock at SWMU 47. However, per the NMED approved Class 1 Permit Modification Request with Modifications (NMED, 2015), "The Permittee must either demonstrate that migration of COC to groundwater has not occurred or provide justification showing that COC in the vadose zone are not a threat to groundwater." To fulfill this requirement, three to five of the soil borings will be drilled to the anticipated depth of groundwater (approximately 120 to 230 ft bgs) as indicated in Section 4.2.1. If groundwater is not encountered, the boring will be plugged and abandoned according to RCRA Permit Attachment 19Section 5.3 (pp78-79) and New Mexico Office of the State Engineer Regulations 19.27.4.30.C NMAC.

The closest cross-gradient wells are 300-A-120, 300-A-170, and 700-J-200. These cross-gradient wells encounter groundwater between 120 ft and 130 ft bgs. Downgradient wells BW-5-295 and BW-7-211 encounter groundwater between 190 ft and 235 ft bgs. Groundwater is anticipated under poorly confined to non-confined conditions within the fractured Tertiary Orejon andesite at irregular depths of between 120-240 ft bgs, several tens of feet below the bedrock surface. If groundwater is encountered during drilling, it will be allowed to stabilize overnight. A piezometric level will be recorded the following morning, and a disposable or decontaminated Teflon®[2] bailer will be lowered into the boring and used to collect a grab sample of groundwater. Water quality parameters will be measured and grab samples will be analyzed for the COPC specified in Section 2.4.

If perched groundwater is encountered in the vadose zone above the alluvium/bedrock interface at a sufficient volume to allow for sample collection, drilling will be suspended and groundwater will be allowed to accumulate for sample collection as described in the preceding paragraph.

4.2.5 Monitoring Well Installation

Each of the borings planned for advancement to groundwater (borings 500-SB-02, 500-SB-04, 500-SB-05, 500-SB-07, and 500-SB-09) is a candidate for the installation of a groundwater monitoring well. Following contact with groundwater in these borings, if it occurs, each boring will be reviewed for monitoring well installation. Recharge, groundwater quality parameters, location, and long-term support for the WSTF groundwater assessment program as described in the GMP (Groundwater Monitoring Plan; NASA, 20182022) will be considered as factors for well installation. Based on experience gained from monitoring wells installed in the 400 Area, there is a minimum amount of recharge required to obtain representative samples of approximately 0.5 gpm. In addition, there must be sufficient water in the well to purge the proposed sampling system (pump and tubing) and the well. This can be as much as 8 to 10 gallons. Additionally, the potential low-flow bladder pumps must be submerged in the water to function properly, Therefore, the completed well must have at least 15 10 ft of groundwater. If the borings do not meet these minimum criteria, they will not be considered for well installation.

Investigation groundwater monitoring wells will be constructed in accordance with the requirements stated in Section 19.3.25.2.2 of the WSTF Hazardous WasteRCRA Permit (NMED, 20162023b) with nominal 4 in. Schedule 80 PVC (polyvinyl chloride) casing and screen. Each groundwater monitoring well will include a 15 ft (0.010-in. slot) screen straddling the water table, with 5 ft of screen above the water table and 10 ft below the water table. The annular seal for the screened sampling zones will be comprised of bentonite chips or pellets. A generalized construction design for groundwater monitoring wells is presented in Figure 4.3. NASA will provide final monitoring well location, rationale, and proposed well construction details (i.e., well design, sampling system, etc.) to NMED for each well prior to construction for review and approval. In the event that a proposed location is determined to be insufficient for monitoring well installation, NASA will provide an email notification to NMED.

Annular materials will be emplaced using a minimum 1.5-in. ID tremie pipe. A 10/20 or similar silica sand filter pack will be placed to a height of 2 ft above and below the monitoring screen. Three feet of fine silica sand, such as 30/70 or similar, will be used to grade from the sand pack to a 5-ft bentonite seal composed of hydrated bentonite chips or pellets. Materials above the bentonite seal will be comprised of bentonite grout with at least 20% solids. The upper 10 ft of the borehole and well pad will be completed

[2] Teflon is a registered trademark of The Chemours Company FC, LLC.

with Type I Portland concrete. Figure 4.3 provides a diagram of the general well design with annular materials.

A 4-ft square (1.5 square miles) concrete pad that slopes away from the well will be constructed at ground level and surrounded by bollards. In locations where well stick-up and bollards may cause concern for traffic or safety, a flush well head design may be considered as an alternative. Final well design will be provided to NMED for approval prior to installation. A brass cap will be installed in the concrete well pad at each well. A survey will be conducted in accordance with the requirements for surveying monitoring wells listed in RCRA Permit ~~Attachment 17.2.2.f~~Section 4.2.7 (NMED, ~~2016~~2023b, pp51-52). Coordinates and elevation will be recorded in the applicable well files. A permit application will be submitted to the New Mexico Office of the State Engineer to provide a record for each monitoring well.

Several types of dedicated and non-dedicated well sampling systems are used at WSTF due to the variability of sampling conditions encountered. A low-flow bladder pump sampling system or an appropriate alternative NMED-approved purging and sampling method capable of providing representative groundwater samples, for long-term support of the WSTF Groundwater Monitoring Program, will be considered for each of the proposed monitoring wells. In accordance with Section 5.1 (Conventional Monitoring Wells) of the approved GMP (NASA, 2022), the sampling system will be selected based on factors such as the depth to water, volume of water to be purged, water recovery rate, frequency of sampling, overall integrity of the well casing, and the cost of system installation.

Groundwater monitoring wells will be developed following the completion of the last well or boring installation for the project and then allowed to equilibrate for four weeks before commencing groundwater sampling activities. Samples will be collected as described in Section 5.3. As part of this initial investigation, a single set of groundwater samples will be collected, analyzed for investigation COPCs, and evaluated. Subsequent groundwater monitoring will be performed in accordance with the GMP (NASA, ~~2018~~2022).

For NDMA analysis, groundwater samples will be analyzed by an if/than approach similar to the NDMA soil samples. Groundwater samples analyzed by method 607 in which NDMA is detected, low-level analysis will not be performed. For groundwater samples analyzed by method 607 in which NDMA is not detected, the specific monitoring well will be resampled and analyzed for low-level NDMA.

5.0 Investigation Methods

This section addresses activities related to the acquisition and evaluation of field data. The drilling, sampling, and QA/QC (quality assurance/quality control) procedures required to achieve the project DQOs are presented in this section.

5.1 Drilling Procedures

Drilling will be conducted with methods selected to enhance the ability to collect representative soil samples, optimize the potential for completion of the wells without the use of drilling additives, and complete the wells to the targeted depth. The methods that will be considered, in order of preference based on cost, time, and capability of reaching the target depths, are air rotary and rotosonic (sonic). NASA also expects to consider the use of other technically acceptable methods proposed by potential drilling subcontractors.

5.1.1 Air Rotary Drilling

The air rotary drilling (e.g., ARCH [air rotary casing advance] drilling, Stratex™ drilling, etc) method uses compressed air as the fluid to clean the borehole of cuttings during advancement of the bit followed by 9 5/8-in. diameter casing used to prevent borehole collapse. Because cuttings will be a combination of chips from the bottom of the borehole and slough from above the bit, they will not be entirely representative of the specific bit depth at sample collection. Lithologic logs recorded for the borehole will include as much detail as is feasible.

In order to collect samples at specific depths, the borehole will be cleaned of cuttings and a sampling core barrel (e.g., modified sonic core barrel) will be driven 2 to 5 ft into the undisturbed formation at the bottom of the open borehole using a pneumatic driver head or drop hammer. The percentage of sample recovery will depend on the coarseness of the formation, which can impede or altogether prevent advancement of the core barrel.

Given that drilling conditions in the 500 Area are expected to be similar to those in the 300 and 400 Areas, split-spoon sampling tubes will not be used because of the high probability of sample refusal and equipment damage.

5.1.2 Sonic Drilling

The sonic drilling method involves driving a core barrel using vibration, rotation, and a downward force to collect soil core samples. The drilling rig has a hydraulically powered oscillator, which generates adjustable high-frequency vibrational forces. The sonic head is attached directly to the drill pipe or outer casing, sending vibrations down through the drill pipe to the bit. The core barrel will be advanced using vibration, rotation, and downward force to collect soil cores from the undisturbed formation. Once the core barrel has been advanced, a secondary casing will be advanced down to the same depth as the inner core barrel. The over-ride casing keeps the borehole from collapsing. Once the core barrel is removed, the core barrel will be retrieved to the surface and the soil core will be extruded from the core barrel through the use of gravity-aided vibration, into chemically-resistant containers (e.g. sampling sleeves, stainless steel troughs), minimizing the disturbance of the soil core and ensuring the collection of a representative soil sample.

Sonic drilling was successfully used during the 400 Area Closure Investigation and the continuous coring allowed for the entire volume of lithologic material in the boring to be captured for more complete downhole interpretation (NASA, 2017b). The continuous coring was also useful in determining specific depths for the well designs during the 400 Area Investigation. Sonic coring methods, however, have historically had difficulty advancing through bedrock at WSTF. Due to the improved representativeness of samples collected during the recent 400 Area Closure Investigation, sonic drilling will be considered in addition to the air rotary method.

5.2 Rig Access Procedures

Overhead lines, underground utilities, and equipment access to the SWMU 47 boring locations will be surveyed and evaluated following NMED approval of the proposed soil boring locations. The site inspection will include a review of the most current updated utility maps of the area to ensure that proposed sampling locations are not coincident with the location of known underground utilities and an evaluation to establish appropriate setback distance between equipment and any overhead lines.

The drilling subcontractor will provide specific drilling rig information prior to mobilization to WSTF in order to ensure that potential access issues can be resolved in advance. Upon arrival at WSTF, the drilling subcontractor is required to submit all drilling and related equipment to a detailed safety inspection prior to admission to the specific soil boring locations. Any concerns regarding the condition or performance of drilling equipment are resolved prior to proceeding to the first soil boring location. Equipment unloading and rigging up will take place at or near the exact soil boring location that it will occupy during operations.

5.3 Sampling Procedures (Collection, Management, Shipment) and Requirements

5.3.1 Soil Samples

Soil collected for analysis will be transferred from the sampler or sample collection tool using decontaminated stainless steel or polyethylene spatulas or spoons and placed directly into clean sample containers provided by the laboratory contracted to analyze the investigation samples. Excess soil around the top of the sample container will be removed to ensure proper lid fit and container closure. Disposable gloves will be worn to collect soil samples and changed between sampling intervals within each boring. Gloves and other disposable materials contacting the samples will be collected and managed in accordance with the SWMU 47 IDW (Investigation-Derived Waste) Management Plan in Appendix B.

5.3.2 Field Screening Procedures

During borehole installation activities, soil vapors derived from soil samples will be analyzed via the headspace method for TIVC (total ionizable volatile compounds) with a PID (portable photoionization detector) and total hydrazines with a Dräger®[3] vapor monitor. The PID and Dräger will be calibrated according to manufacturer's instructions.

Using the headspace method, a representative soil sample will be immediately placed in an airtight plastic zip bag. The soil will be agitated and left in the bag for a minimum of five minutes, after which the headspace soil vapors in the bag will be measured for TIVC and total hydrazines. Each meter's readings will be recorded in the field logbook. Headspace readings from soil samples may be used to assist with the selection of soil chemical samples as applicable.

5.3.3 Groundwater Sampling Procedures

Groundwater grab samples will be collected during drilling activities, for informational purposes, from boreholes that intercept groundwater. Groundwater will be collected using a decontaminated or disposable Teflon bailer. Grab samples will be dispensed from the bailer into appropriate laboratory-provided containers in accordance with site-specific procedural documentation and the GMP (NASA, ~~2018~~2022). Groundwater samples will also be collected following development, purging, and equilibration activities for up to five monitoring wells installed as described in Sections 4.2.4 and 4.2.5. The installed groundwater monitoring wells will be allowed to equilibrate for four weeks after the last well is fully developed for groundwater monitoring zones. Groundwater sample collection and management activities performed after well equilibration will be conducted in accordance with the GMP (NASA, ~~2018~~2022).

5.3.4 Sample Containers, Volume, and Preservation

Appropriately prepared and preserved (if required) sample containers for all sample media will be procured. Chemical samples will be containerized and preserved according to the instructions provided by

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[3] Dräger is a registered trademark of Draegerwerk AG & Co. KGaA.

the analytical laboratory selected during the competitive procurement process planned following approval of this work plan. Geotechnical samples will be collected in clean plastic sealable bags or buckets.

5.3.5 Field Quality Control Samples

Field quality control samples will be collected as required in ~~Attachment 17~~Part 4 of the RCRA Permit to ensure high quality data are generated during the investigation (NMED, ~~2016~~2023b). Field quality control samples will be collected as indicated below.

- Field blanks will be collected for each investigation medium (soil or groundwater) at a rate of one per sampling day.
- Field rinsate (equipment) blanks are typically collected from the sampling tooling at the onset of the project prior to sampling activities and if the sampling tooling is required to leave the project site prior to completion of the project. In addition, field rinsate blanks will be collected at a rate of 10% of investigation samples or one per sampling day if disposable sampling equipment is used.
- Field duplicate samples will be collected at a rate of 10% of investigation samples at select sampling locations. Duplicate samples will be analyzed for the same parameters as the primary samples.
- Five percent matrix spike/matrix spike duplicate MS/MSD (matrix spike/matrix spike duplicate) samples will be collected for specified analyses.
- Trip blanks will accompany ~~VOC~~ VOA (volatile organic analysis) samples at a rate of one for each shipping container.

NASA has developed comprehensive internal procedures for sample collection, shipping, and management. These procedures provide specific information on sample management and related documentation, including instructions for sample custody (internal to NASA and external during shipment), storage, packaging, shipment, delivery tracking, and related recordkeeping. These procedures will be utilized during this project to ensure appropriate sample management.

5.4 Analytical Tasks

NASA contracts services from off-site, accredited analytical laboratories to support program and project needs, as required by the Section 4.5 of the RCRA Permit (NMED, ~~2016~~2023b, p61). Laboratories considered to support this project must conduct all sample analysis quality assurance and quality control in accordance Permit Section~~s 17.3~~ 4.5.1, ~~(~~Laboratory QA/QC Requirements, (NMED, 2023b, p61)~~)~~. The analytical tasks required to achieve the project objectives will be awarded to the off-site laboratory that is successful in the competitive procurement process. Potential laboratories must respond to a comprehensive statement of work developed to meet the project objectives defined in this IWP. Analytical SOP (standard operating procedures), laboratory quality manuals, and other laboratory-specific documentation are provided by the analytical laboratory following award of the contract and are not available in advance. These documents are retained in the project record and will be available for NMED review as required.

The overall objective for laboratory analysis is to produce data of known and sufficient quality to support project decision-making. Appropriate procedures and quality checks will be used so that known and acceptable levels of accuracy and precision are maintained for each data set. All samples will be analyzed by a fully qualified laboratory in accordance with the laboratory's quality plan, which ensures that the contract laboratory adheres to standardized analytical protocols and reporting requirements and is capable of producing accurate analytical data.

As part of the competitive procurement process for analytical services, NASA requests that contracted laboratories achieve low MDLs. However, laboratories report that MDL can vary by several orders of magnitude for various analyses dependent on properties such as low-level calibration issues and matrix interference. The lowest possible MDL may not be achievable for every analysis. This is the case with hydrazines; WSTF soils have a history of matrix interference and do not always achieve the lowest MDL. In order to limit this occurrence, NASA will request laboratory analysis of hydrazines by EPA Method 8315 using liquid chromatography with tandem mass spectrometry (LC/MS/MS). Analyses that consistently produce an MDL above NMED and EPA screening levels will be discussed in the investigation report.

Method blanks and laboratory QC samples are prepared and analyzed in accordance with the laboratory's method-specific SOPs. The analytical results of method blanks shall be reviewed to evaluate the possibility of contamination caused by analytical procedures. At a minimum, the laboratory will analyze method blanks and laboratory control samples at a frequency of 1 in 20 for all batch runs.

5.5 Safety and Health

Field activities will be conducted in accordance with requirements of OSHA (Occupational Safety and Health Administration) Standards for HAZWOPER (Hazardous Waste Operations and Emergency Response, 29 CFR 1910.120 [b] – [o], 2013). The WSTF environmental contractor's SHP (Safety and Health Plan) will be augmented with site-specific Job Hazard Analyses to address potential hazard foreseeable for the project; and, will be followed in accordance with applicable requirements of the standards. The augmented SHP will address safety and health issues pertaining to work activities, including known and reasonably anticipated hazards associated with project scope of work as well as contingencies for unexpected conditions. The requirements of the SHP will apply to prime and sub-tier contractors as well as personnel requesting access to controlled areas of the investigation site. Project field personnel are required to be current in HAZWOPER training. In the event that new hazards are encountered that are not addressed by the SHP, the field team will stop work and coordinate with contractor health and safety experts to develop additional guidance on means to eliminate or mitigate any new hazards. As required by the Hazardous Waste Operations and Emergency Response (2013), the SHP and related project-specific safety documents will address:

- A safety and health risk or hazard analysis for each site task and operation found in this work plan.
- Employee training assignments.
- PPE to be used by employees for each of the site tasks and operations being conducted.
- Medical surveillance and fitness for duty requirements (based on nature of the project scope and COC).
- Frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used, including methods of maintenance and calibration of monitoring and sampling equipment to be used.
- Site control measures in accordance with the site control program.
- Decontamination procedures.
- An emergency response plan for safe and effective responses to emergencies, including the necessary PPE and other equipment.
- Confined space entry procedures.

- A spill containment program.
- Pre-entry briefing. The SHP shall provide for pre-entry briefings to be held prior to initiating any site activity, and at such other times as necessary to ensure that employees are apprised of the SHP and that this plan is being followed.
- Inspections shall be conducted by a recognized competent person is knowledgeable in occupational safety and health at WSTF.

During the project, subcontractors must comply with OSHA and EPA standards applicable to this IWP, the SHP, and any related area-specific (SWMU 47) safety documentation. Project subcontractor field personnel are required to be current in HAZWOPER training required under Hazardous Waste Operations and Emergency Response (29 CFR 1910.120 [b] – [o], 2013).

Safety professionals, or their designees, will inspect subcontractor equipment prior to the commencement of work. Any significant safety and health concerns will be identified, and the subcontractor will be allowed to address the concerns. If significant concerns cannot be rectified, this may be cause for termination of the subcontract.

5.6 Final Site Restoration and Grading

Final restoration and grading activities at the investigation site will commence after the completion of investigation field activities, receipt of the final analytical results, submittal of the investigation report to NMED, and receipt of concurrence from NMED. Soils characterized as non-hazardous will be spread to grade in the vicinity of the soil boring locations following NMED approval of a "no longer contained in" determination. All site grading will be completed to prevent ponding of water at the site location. Site restoration and grading activities may also include the installation of best management controls (e.g., diversion culverts, temporary berms, silt fences, etc.) to direct storm water away from the site locations to prevent storm water runoff impacts. Site restoration activities will not include any efforts to reseed the areas. Vegetation will be allowed to return naturally in the 500 Area.

6.0 Decontamination

All equipment, including drilling equipment, must be decontaminated prior to commencement of investigation activities at WSTF. All sampling and soil boring equipment will be decontaminated after completion of each sampling event and drilling equipment will be decontaminated prior to leaving the investigation site. General decontamination guidance available in ASTM International D5088-15a (ASTM, 2015) will be followed for this project.

Decontamination procedures will be performed by 40-hour HAZWOPER trained personnel wearing appropriate PPE. The decontamination of the drilling rig will be performed by the drilling subcontractor under the supervision of the site supervisor or their designee.

6.1 Decontamination Area

Initial decontamination of large equipment is expected to be performed at the existing concrete decontamination pad in the 600 Area. In addition, at least one decontamination area is expected to be established at a central location in the 500 Area. Individual smaller-scale decontamination pads may be constructed adjacent to individual boing locations to collect and contain soil brushed from the sampling equipment. All contamination reduction or decontamination activities will be performed over a properly designed pad or containment device that will retain any waste generated during the decontamination process. Waste generated during the decontamination process will be managed in accordance with the SWMU 47 IDW Management Plan provided in Appendix B. In the event that the decontamination pad requires any repairs to effectively contain decontamination fluids, activities that require decontamination will be halted until the decontamination pad is repaired.

Safeguards will be implemented to ensure no cross-contamination occurs between other projects that may be simultaneously conducted with this investigation. The decontamination area will be established within the contamination reduction zone in order to prevent any transport of contamination outside the investigation area. The decontamination area will be located away from the potential influence of the active 500 Area operations. Best practices will be employed to maintain the integrity of the decontamination process and protect the area from dust-producing site operations that could contaminate the equipment. Sampling and decontamination operations may be modified or delayed during dusty conditions, if necessary.

6.2 Decontamination Methods

6.2.1 Contamination Reduction

Drilling activities (if required subsequent to initial soil sampling) will be performed using an air-rotary or sonic drill rig without the application of drilling fluids (dry drilling). Adherence of the soil to the downhole equipment as well as production of liquid waste will be kept to a minimum with these methods. Soil will be removed from drilling equipment and sampling equipment using wire brushes and scraping tools such as spatulas or paint stirring sticks. Removal of solids will be performed over or inside an open-top 55-gallon drum or other suitable container using underlying plastic sheeting, or over plastic sheeting, to collect any soils.

6.2.2 Decontamination

Following the contamination reduction described above, decontamination will be performed to minimize the potential for cross-contamination between location and samples. Any tools or drilling equipment will be required to undergo contamination reduction and decontamination prior to exiting the area in order to ensure potentially contaminated soil or liquid is contained within the work area. Decontamination utilizes steam cleaning or pressurized heated water and/or detergent in conjunction with brushes, sprayers (as required), and a final rinse with purified water.

Equipment will be decontaminated between boreholes if it is to be reused at different sampling locations. All non-disposable equipment will be decontaminated at the end of the project or before leaving WSTF for any reason. The drilling rig, downhole equipment, and other reusable equipment that will not directly contact soil samples will be decontaminated using a steam cleaner or high-pressure heated water wash followed by thorough rinsing with WSTF potable water. Hand augers, core barrels, and other reusable equipment that will contact soil samples will be decontaminated by first, hand washing the item with non-phosphate detergent such as Alconox®[4] or by using a steam cleaner or high pressure heated water wash, then by rinsing with WSTF potable water, and finally by rinsing with purified water.

6.3 Decontamination of Field Screening Instruments

In the event field screening instruments are used to monitor the condition of the soil, dry decontamination followed by an alcohol-free moist wipe will be used for moisture sensitive equipment such as a PID.

[4] Alconox is a registered trademark of Alconox, Inc.

Solid waste materials removed from the equipment and the wipes used will be disposed of as IDW and managed as indicated in Appendix B.

7.0 Field Documentation Procedures

The site supervisor will ensure that details of all activities related to this investigation are documented using a field logbook, field data records, and/or any required site-specific procedural documentation. Logbook entries will include, as applicable, information such as:

- Standard Daily Header – project name, logbook number, date, weather conditions, team members present and their affiliations (including subcontractors), sample location identification, day's task(s), daily safety meeting topics, PPE to be used, equipment in use, and any calibration information, if applicable.
- Daily activities (time and observations recorded) – site arrival and departure, visitors and the purpose of their visit, sampling information, soil type, soil conditions, decontamination (i.e., method, equipment cleaned), reference data sheets or maps, if applicable.
- Daily summary – action items, materials used, changes or deviations made from planned protocol, plan for next day.
- Signatures (field personnel and logbook reviewer).

At a minimum, field records will include observations of soil conditions, location surveys using GPS, and sample documentation. For analytical samples, the date, location, depth, sample type, collection method, identification number, sampler, and any circumstances, events, or decisions that could impact sample quality will be documented by the site supervisor in the project field logbook. Even though each case may be unique, the site supervisor's decision must be documented as to conditions that precipitated any decisions for the unsuitability of samples for analyses. In addition to the field logbook notes for sampling events, chain-of-custody forms will be completed for analytical samples and maintained with project documentation.

Evidential records for the entire project will be maintained in hard copy or electronic form and will consist of:

- Project IWP with any deviations redlined.
- Site-specific internal procedural documentation or plans.
- Project logbooks.
- Field data records (i.e., surveyed site location).
- Sample chain-of-custody forms.
- Correspondence with NMED.
- Final analytical data packages.
- Reports.
- Miscellaneous related records such as photos, maps, drawings, etc.

8.0 Investigation-Derived Waste Management Plan

As required in Hazardous Waste Permit Attachment 20 (Section 20.2.13), the IDW Management Plan is provided as Appendix B. The IDW Management Plan provides a description of the potential wastes that will be generated from the SWMU 47 investigation as well as procedures for waste management, waste characterization, and waste disposition. Wastes that may be generated as part of the investigation include: soil in the form of soil cuttings or remnants from sample collection; used sampling equipment; PPE; plastic sheeting; rags; miscellaneous debris contaminated by boring soil or fluids; and, water and soap solutions used for equipment decontamination.

9.0 Data Management Tasks

Data management tasks include project documentation and data review and assessment. The details related to these tasks are outlined below.

9.1 Project Documentation and Records

All facets of this investigation will be documented in detail by the responsible project personnel. Records are retained in the WSTF Operating Record and can be accessed at any time by authorized WSTF personnel.

9.1.1 Sample Collection and Field Measurements Data

Sample information and field measurements are recorded in the field logbook by the responsible project field personnel. These are reviewed by knowledgeable project personnel on a regular basis during the investigation and are retained in the project file. They are ultimately archived in the WSTF Records Management System as part of the Operating Record. As required for reporting, these data are also transferred to and archived in operational and historical databases.

9.1.2 Off-site Laboratory Data

Data packages from off-site analytical laboratories will consist of two primary components: comprehensive reports, to be submitted as Adobe PDF (portable document files) for review and archiving; and electronic data deliverable files to facilitate transfer of chemical analytical data into WSTF's analytical database(s). The PDF report will include a variety of information, including laboratory name, report date, sample-specific information, analyte names and Chemical Abstract Service numbers, analytical results, QC sample results, data qualifiers and narratives, pertinent analytical notes, laboratory reviewer signatures, and a variety of other information specific to the laboratory and analytical method. The electronic data deliverable will include the associated electronic data and follow the same review and approval cycle as the paper report.

9.2 Data Assessment and Review Procedures

A QA/QC specialist will evaluate the sample data, field, and laboratory QC results for acceptability with respect to the project quality objectives. Chemical analytical data will be compared with the project quality objectives and evaluated using the data validation guidelines contained in EPA guidance documents, the latest version of SW-846 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods and industry-accepted QA/QC methods and procedures (USEPA, n.d.).

9.3 Assessment and Response Actions

The conformance of investigation activities to the IWP will be evaluated on an ongoing basis while field activities are in progress. Additional verification will be provided through oversight of the field activities by the site supervisor or other responsible personnel. If a sample cannot be collected as planned, the site supervisor will be notified and, if possible, an alternate location or sampling method may be selected.

Significant deviation from the number and locations of samples indicated in the IWP will be discussed with NMED for concurrence. The assessment process will include immediate evaluation of any change to the sampling plan so that, if necessary, an alternate field procedure may be quickly established. Daily quality field assessments may be conducted during drilling and sampling activities. Field assessments will be performed by environmental professionals who are not immediate members of the field team. Following completion of field activities, a final review of field activities will be performed. Any deviations from the IWP or procedures will be documented and noted in the investigation report.

The contract laboratory will be required to notify NASA of significant data quality exceptions within one business day of discovery. Sample re-analysis will be performed, if possible. NASA will contact NMED as soon as practical to discuss any data quality exceptions that may affect the ability to meet the objectives of the investigation.

9.4 Data Review Process

A comprehensive review of sample analytical data will be conducted. Prior to conducting the review, the following information (where required and applicable) will be compiled and provided for the review.

- The NMED-approved IWP.
- Field sampling records and other pertinent field records.
- Laboratory reports.
- Statements of work and the laboratory Quality Management Plan.
- Electronic Data Deliverable Files.
- Standard Operating Procedures.
- Database tools.

9.5 Data Review Elements

Step I: Verification – Verification (review for completeness) is the confirmation by examination and provision of objective evidence that the specified requirements (sampling and analytical) have been completed (USEPA, 2005).

Data verification is the process of determining whether data have been collected or generated as required by the project documents. The process consists of the following categories: 1) verifying that field sampling operations were performed as outlined in the IWP; 2) verifying that the data collection procedures and protocols were followed; 3) verifying completeness to establish that sufficient data necessary to meet project objectives have been collected; and 4) checking that QC sample results meet control limits defined in the analytical methods.

Step II: Validation – Validation is the confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. Validation is a sampling and analytical process that includes evaluating compliance with method, procedure, or contract requirements and extends to evaluating against criteria based on the quality objectives developed (USEPA, 2005).

The purpose of validation is to assess the performance of the sampling and analysis processes to determine the quality of specified data. Data validation consists of the following objectives: 1) verifying that measurements (field and laboratory) meet the user's needs; 2) providing information to the data user regarding data quality by assignment of individual data qualifiers based on the associated degree of variability; and 3) determining whether project quality objectives were met. Data management personnel will perform data validation in accordance with the requirements in this IWP and existing WSTF procedures.

Step III: Usability Assessment – Usability assessment is the determination of the adequacy of data, based on the results of validation and verification, for the decisions being made. The usability process involves assessing whether the process execution and resulting data meet project quality objectives (USEPA, 2005).

The goal of the usability assessment is to determine the quality of each data point and to identify data that are not acceptable to support project quality objectives. Data may be qualified as being unusable or R (rejected), as based on established quality review protocols. Data qualified as J (estimated) are less precise, or less accurate, than unqualified data but are still acceptable for use. The data users, with support from the contractor environmental data management staff, are responsible for assessing the effect of the inaccuracy or imprecision of the qualified data on statistical procedures and other data uses. The data reporting will include a discussion of data limitations and their effect on data interpretation activities.

10.0 Current Monitoring and Sampling Programs

The most significant current monitoring program that contributes to this investigation is WSTF's ongoing groundwater assessment program. Though there are few groundwater monitoring wells in proximity to SMWU 47, there are several downgradient wells and cross-gradient wells (Figure 1.2). NASA relies on the data generated from groundwater monitoring to provide input for the development of IWPs. NASA routinely collects groundwater samples from a comprehensive network of monitoring wells at WSTF in accordance with the NMED-approved GMP (NASA, ~~2018~~2022). Groundwater samples are collected for the analysis of the following primary constituents: ~~VOCs~~VOAs, NDMA, bromacil, and metals. In addition to routine groundwater samples required by the GMP, samples for other chemical analyses are frequently collected at many of the groundwater monitoring wells. Because these samples are not a direct requirement of the GMP, the results of these analyses are provided in the appropriate project-specific report.

11.0 Schedule

This investigation consists of three primary phases: 1) pre-investigation planning and preparation; 2) execution of the field investigation activities; and 3) data assessment and preparation of the investigation report detailing the findings of the investigation. The schedule for these activities is presented below.

11.1 Planning and Preparation

In addition to NMED review of this IWP, NASA must complete several important activities prior to the initiation of field activities. Resource requirements must be clearly identified and scheduled using the established NASA process for planning, funding, and executing work at WSTF. In addition, off-site resources must be coordinated. NASA expects these activities to require four to six months after NMED approval of this plan.

11.2 Field Investigation

Field activities for the initial investigation at SWMU 47 will be executed in the vicinity of a fuel storage area and active testing facilities. As a result, there may be periods during which field personnel will not be allowed access to the work area. NASA cannot accurately forecast distillation operations, fuel transfers, or testing that may be carried out in the 300, 400, ~~and~~ 500, and 700 Areas at this time, ~~but~~ and may propose an alternate schedule in the future if testing impacts the field schedule. Any concerns relative to the scheduled start up of fieldwork will be discussed and resolved with NMED in advance.

Investigation of SWMU 47 is expected to be completed approximately eight to ten months after initiation. Unforeseen field conditions, such as access issues mentioned above, off-site resource availability, delays in approval of this IWP, or other complications possibly impacting this schedule will be discussed with NMED as they arise to determine the best resolution.

Field lithologic information, ~~and~~ a revised well construction diagram, and any pertinent borehole details will be provided to NMED via email to expedite the review process after completion of any soil boring that is ~~planned to deviate from the general well design~~ advanced to groundwater (Figure 4.3). NMED review and approval of the ~~revised~~ proposed well construction diagram is required prior the specific well installation. Expedited turnaround from NMED will be required in order to avoid short-term (or potentially longer term) standby delays.

11.3 Data Assessment and Reporting

Chemical analytical data from samples collected during the investigation should be fully available for verification and validation by NASA scientists within one month of the completion of field activities. These data will be evaluated as previously described, a process that typically requires up to two months. NASA will report non-detect values as less than the laboratory detection limit (e.g., groundwater NDMA-LL non-detect will be "<0.0022 µg/L"). Data that does not meet RCRA Permit requirements of 20 percent of the cleanup, screening, or background levels will be identified (NMED, 2023b, p61). Additional resources, guidance, or supporting data will also be assessed and utilized to support the investigation. NASA will include a risk and hazard evaluation based on complete exposure pathways in the SCEM (Figure 2.3) to support the conclusions and recommendations in the Phase I SWMU 47 Investigation Report in accordance with the NMED RA Guidance (NMED, 2022~~19~~), current version. The results of these evaluations will be incorporated into a final report for submittal to NMED approximately 18 months following NMED approval of this work plan. Unforeseen delays in the completion of field investigation activities or data evaluation may adversely impact the completion of the report on this schedule and will be discussed with NMED as soon as possible upon NASA becoming aware of a problem.

12.0 References

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Figures

Figure 1.1 **WSTF Location**

(SEE NEXT PAGE)

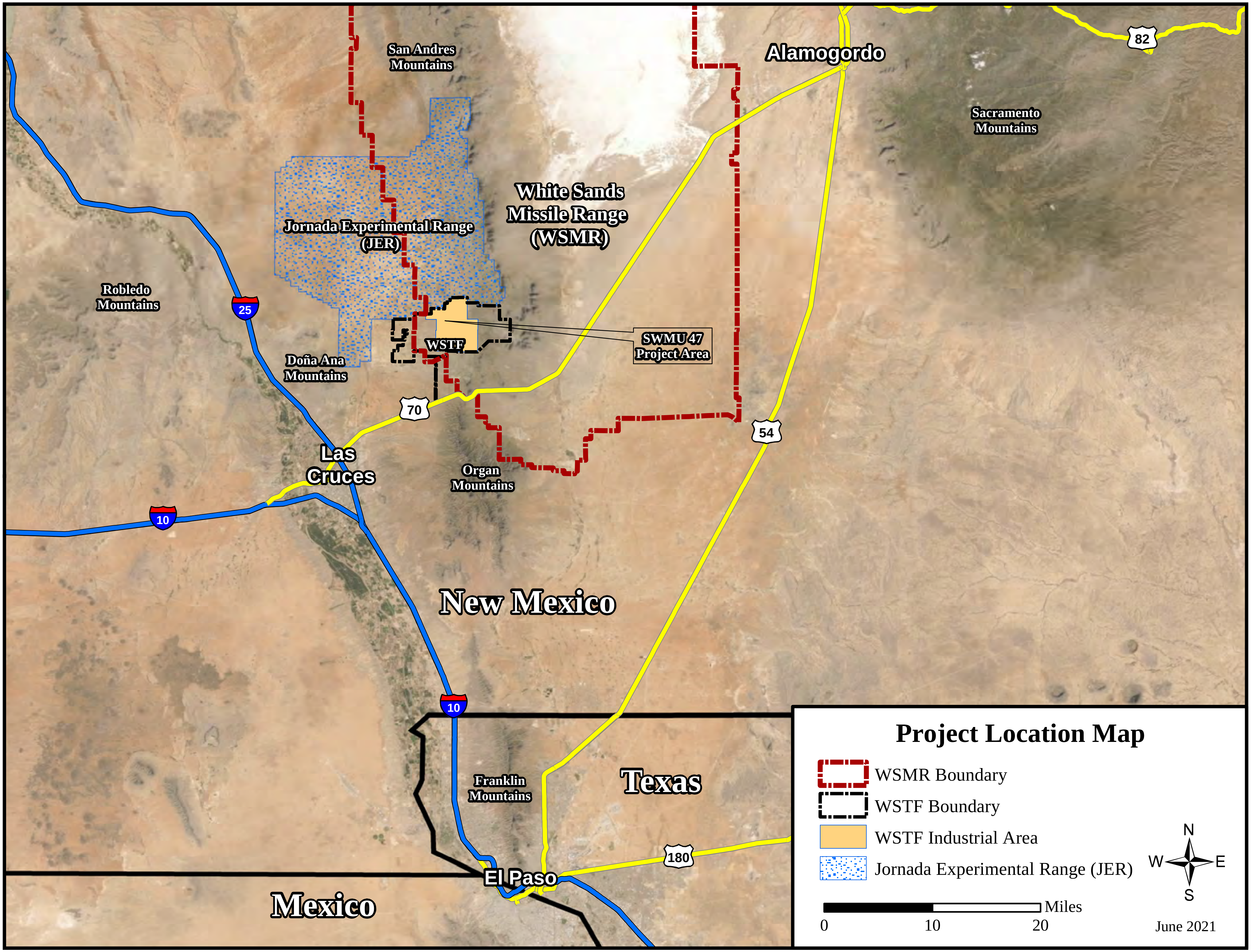

San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
SWMU 47 Project Area
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
Project Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
N
W
E
S
Miles
0
10
20
June 2021

Figure 1.2 **WSTF Industrial Areas**

(SEE NEXT PAGE)

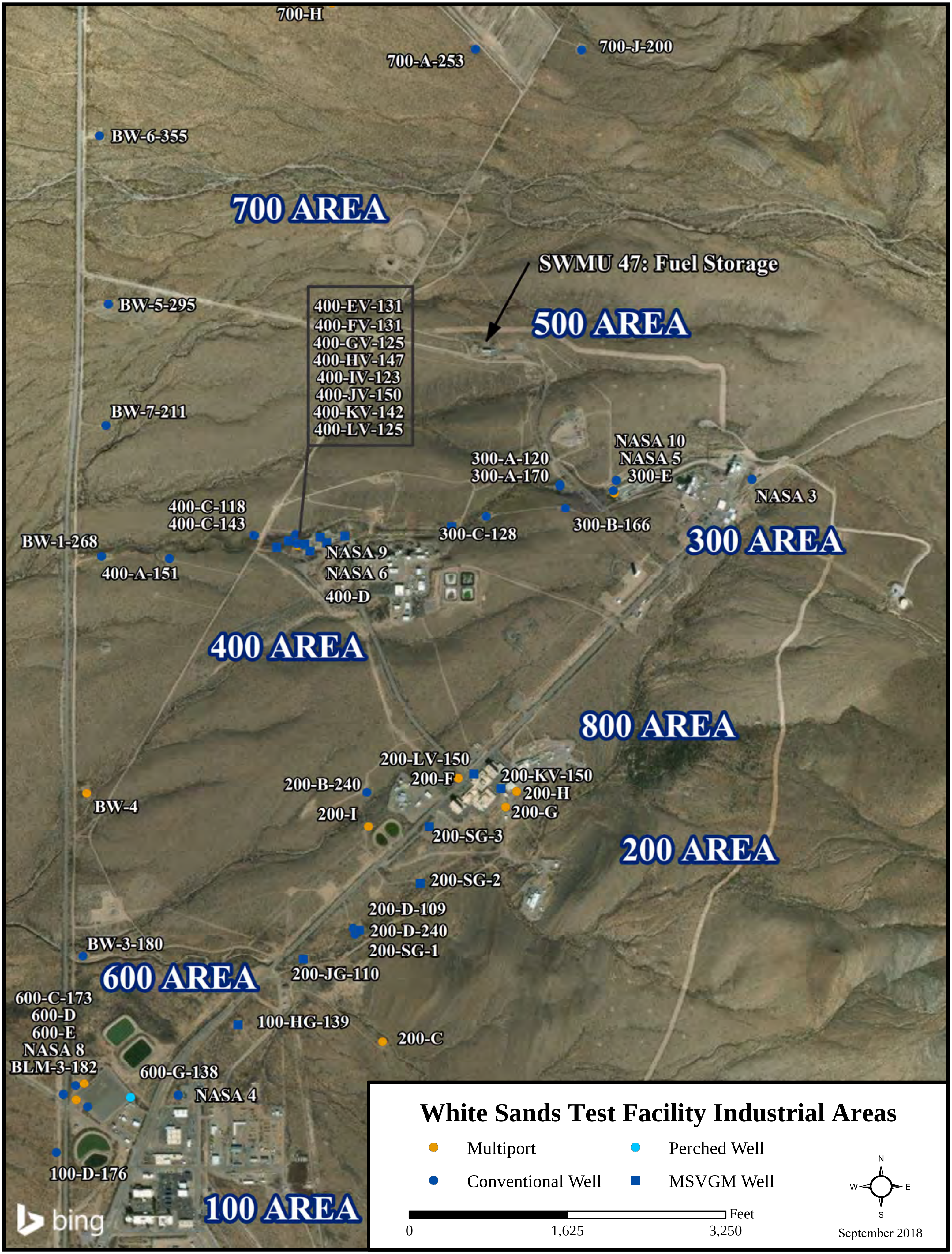

700-H
700-A-253
700-J-200
BW-6-355
700 AREA
SWMU 47: Fuel Storage
500 AREA
BW-5-295
400-EV-131
400-FV-131
400-GV-125
400-HV-147
400-IV-123
400-JV-150
400-KV-142
400-LV-125
BW-7-211
NASA 10
NASA 5
300-E
300-A-120
300-A-170
NASA 3
400-C-118
400-C-143
300-C-128
300-B-166
BW-1-268
400-A-151
NASA 9
NASA 6
400-D
300 AREA
400 AREA
800 AREA
200-LV-150
200-F
200-KV-150
200-H
200-B-240
200-G
BW-4
200-I
200-SG-3
200 AREA
200-SG-2
200-D-109
200-D-240
200-SG-1
BW-3-180
600 AREA
200-JG-110
600-C-173
600-D
600-E
NASA 8
BLM-3-182
100-HG-139
200-C
600-G-138
NASA 4
100-D-176
bing
100 AREA
White Sands Test Facility Industrial Areas
Multiport
Perched Well
Conventional Well
MSVGM Well
N
W
E
S
0
1,625
3,250
Feet
September 2018

Figure 1.3 **WSTF 500 Area SWMU 47**

(SEE NEXT PAGE)

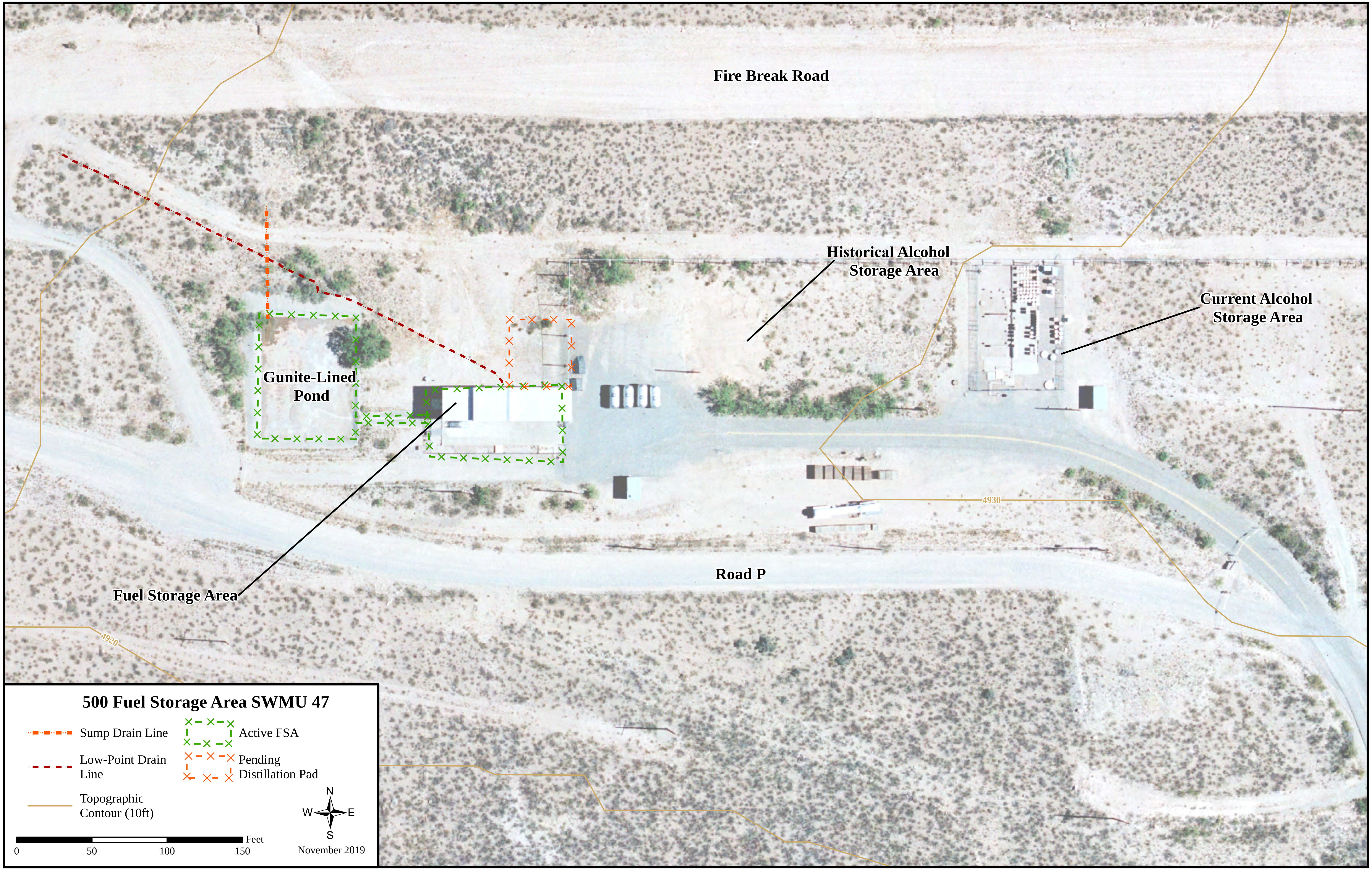

Fire Break Road
Historical Alcohol Storage Area
Current Alcohol Storage Area
Gunite-Lined Pond
Fuel Storage Area
Road P
4930
4920
500 Fuel Storage Area SWMU 47
Sump Drain Line
Low-Point Drain Line
Topographic Contour (10ft)
Active FSA
Pending Distillation Pad
N
W
E
S
0
50
100
150
Feet
November 2019

Figure 2.1 **WSTF 500 Area – View to the North**

(SEE NEXT PAGE)

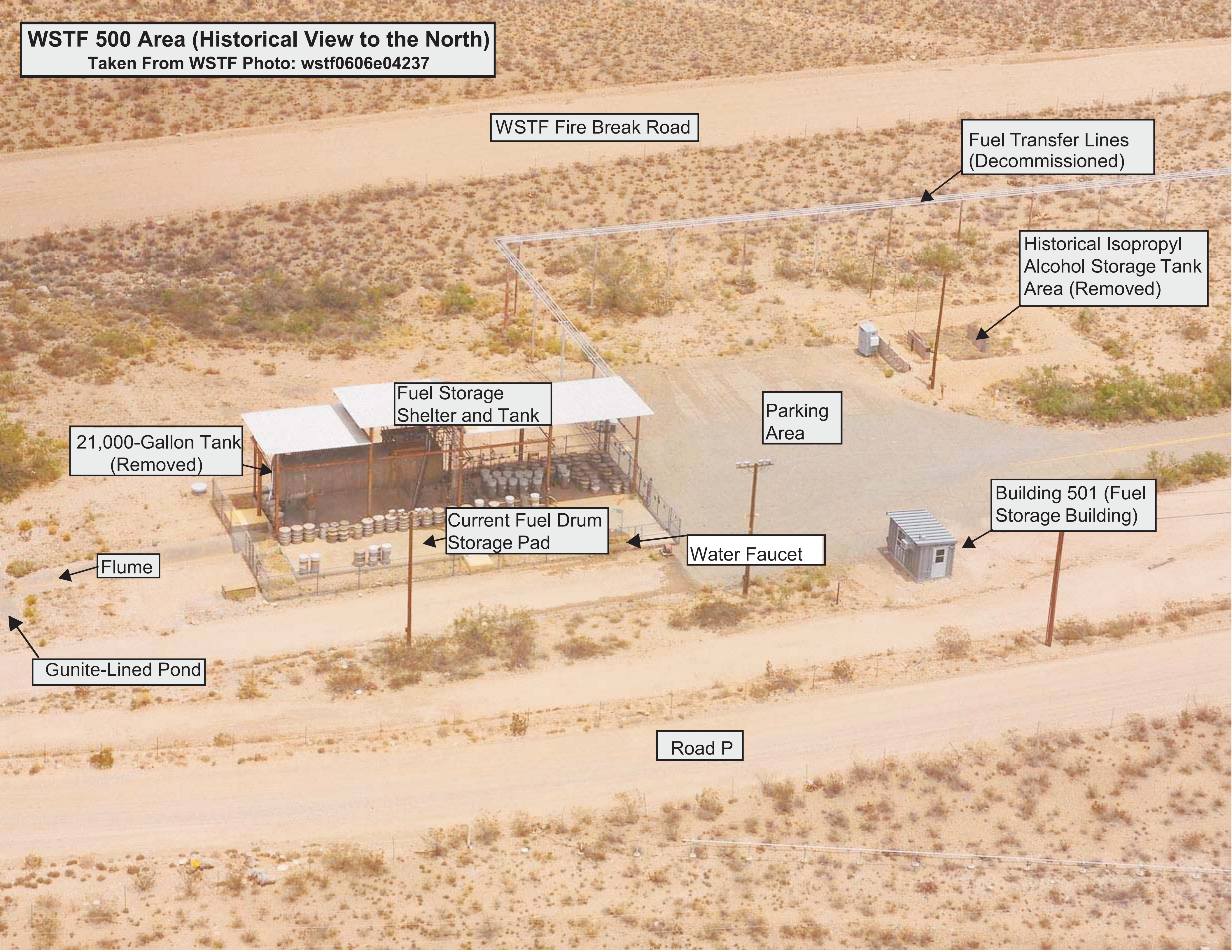
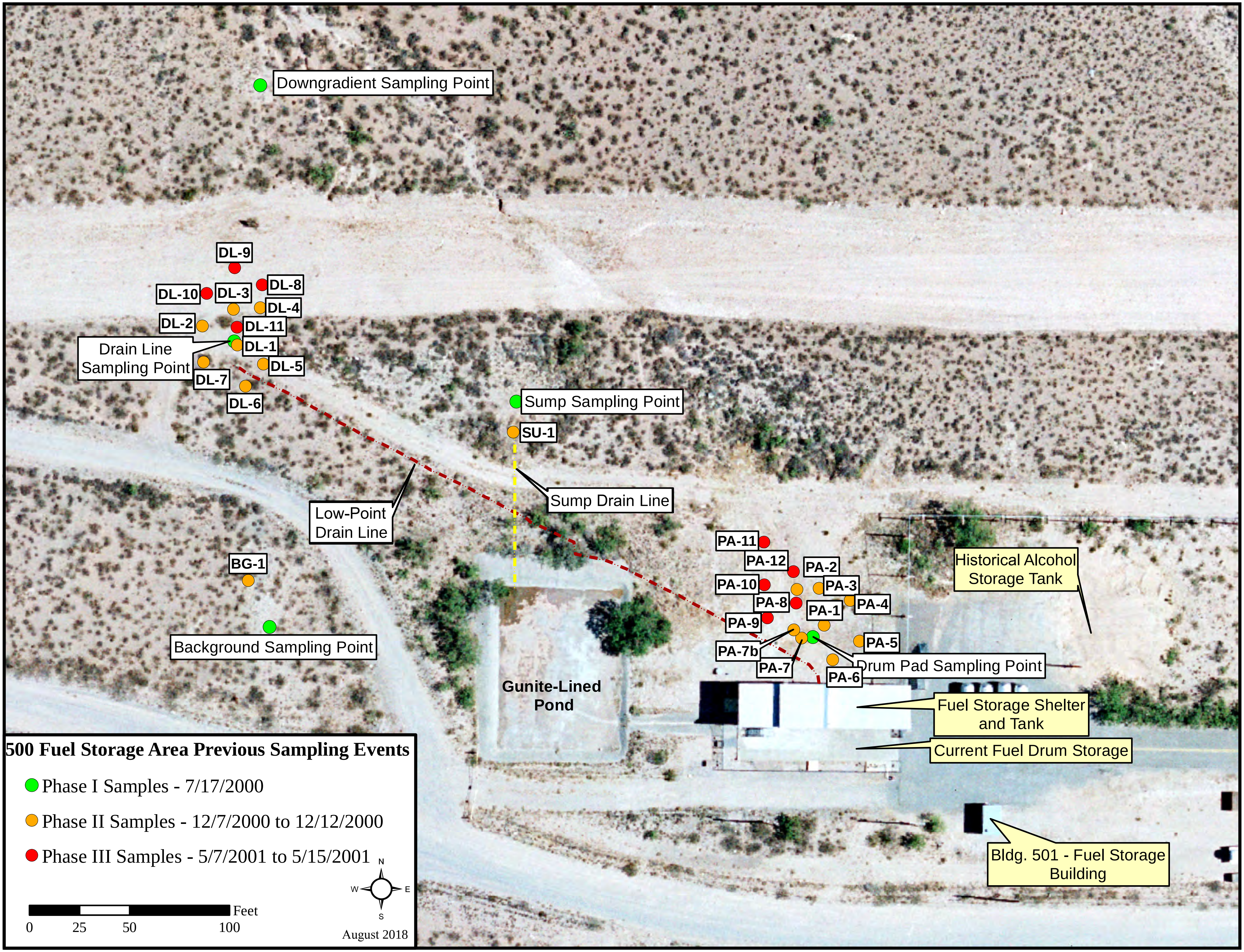

WSTF 500 Area (Historical View to the North)
Taken From WSTF Photo: wstf0606e04237
WSTF Fire Break Road
Fuel Transfer Lines (Decommissioned)
Historical Isopropyl Alcohol Storage Tank Area (Removed)
Fuel Storage Shelter and Tank
Parking Area
21,000-Gallon Tank (Removed)
Building 501 (Fuel Storage Building)
Current Fuel Drum Storage Pad
Water Faucet
Flume
Gunite-Lined Pond
Road P

Figure 2.2 500 Area Fuel Storage Previous Sampling Events

(SEE NEXT PAGE)



Downgradient Sampling Point
DL-9
DL-8
DL-10
DL-3
DL-4
DL-2
DL-11
Drain Line Sampling Point
DL-1
DL-5
DL-7
DL-6
Sump Sampling Point
SU-1
Sump Drain Line
Low-Point Drain Line
BG-1
Background Sampling Point
Gunite-Lined Pond
PA-11
PA-12
PA-2
PA-10
PA-3
PA-8
PA-4
PA-1
PA-9
PA-5
PA-7b
PA-7
PA-6
Drum Pad Sampling Point
Historical Alcohol Storage Tank
Fuel Storage Shelter and Tank
Current Fuel Drum Storage
Bldg. 501 - Fuel Storage Building
500 Fuel Storage Area Previous Sampling Events
Phase I Samples - 7/17/2000
Phase II Samples - 12/7/2000 to 12/12/2000
Phase III Samples - 5/7/2001 to 5/15/2001
N
W
E
S
Feet
0
25
50
100
August 2018

Figure 2.3 Preliminary Site Conceptual Exposure Model

(SEE NEXT PAGE)

Site Conceptual Exposure Model

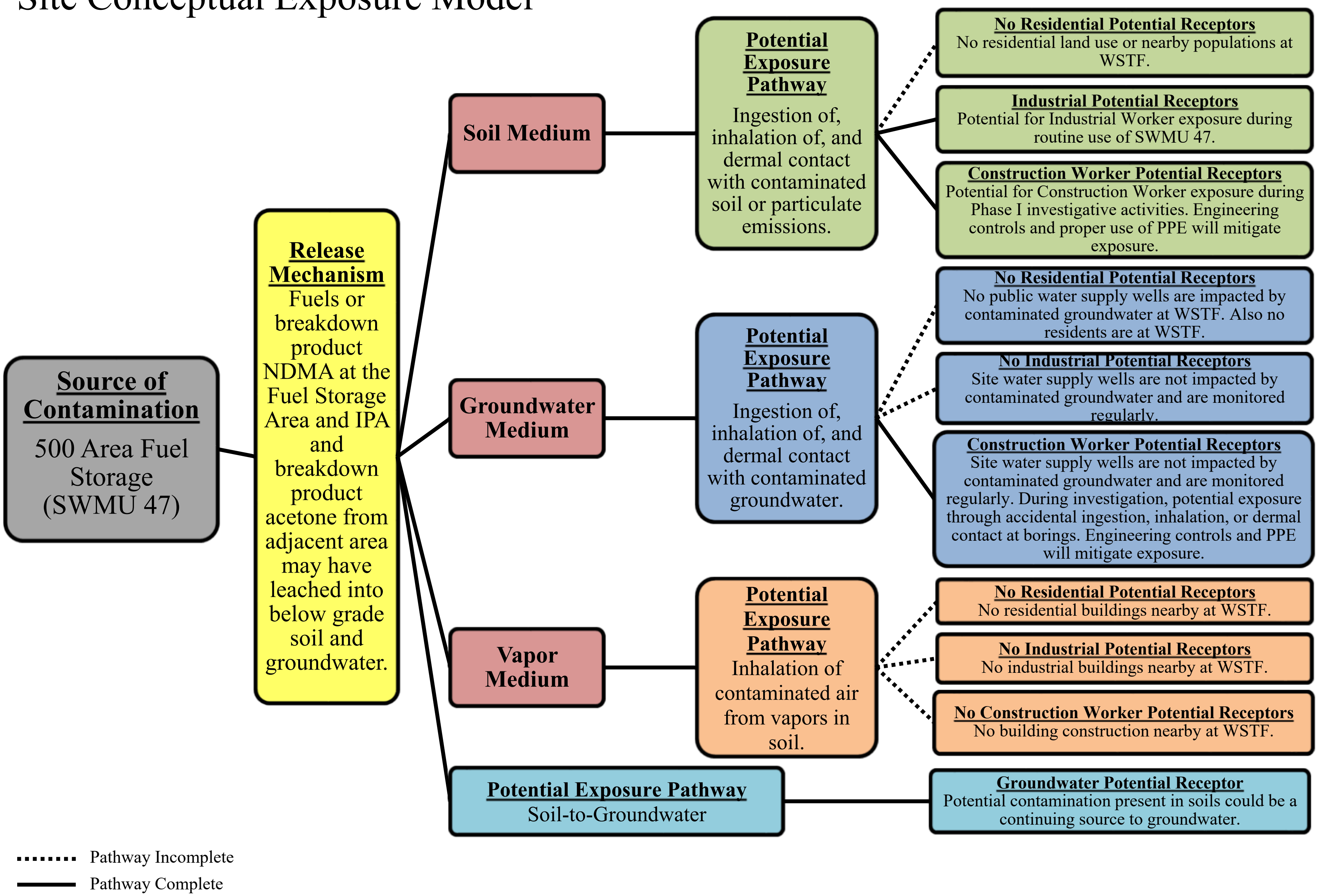
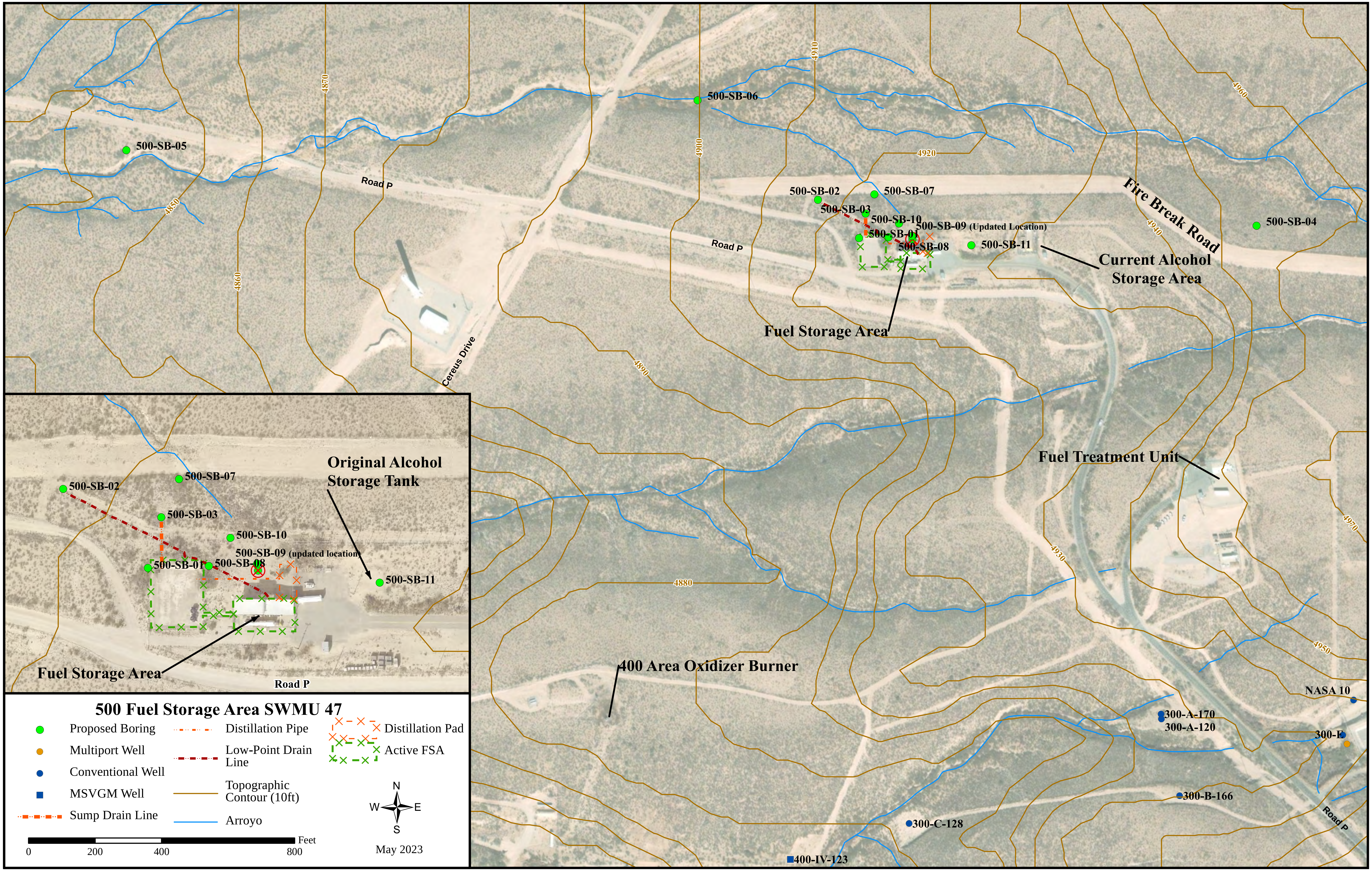


Figure 4.1 **SWMU 47 Proposed Borings**

(SEE NEXT PAGE)



500 Fuel Storage Area SWMU 47
Proposed Boring
Multiport Well
Conventional Well
MSVGM Well
Sump Drain Line
Distillation Pipe
Low-Point Drain Line
Topographic Contour (10ft)
Arroyo
Distillation Pad
Active FSA
N
W
E
S
May 2023
0
200
400
800
Feet
Original Alcohol Storage Tank
Fuel Storage Area
Road P
500-SB-02
500-SB-07
500-SB-03
500-SB-10
500-SB-09 (updated location)
500-SB-01
500-SB-08
500-SB-11
500-SB-05
500-SB-06
500-SB-04
500-SB-09 (Updated Location)
Fire Break Road
Current Alcohol Storage Area
Cereus Drive
Fuel Treatment Unit
400 Area Oxidizer Burner
NASA 10
300-A-170
300-A-120
300-B-166
300-C-128
400-IV-123
4850
4860
4870
4880
4890
4900
4910
4920
4930
4940
4950
4960
4970

Figure 4.2 Proposed Borings Within and Adjacent to the SWMU 47 Boundary

(SEE NEXT PAGE)

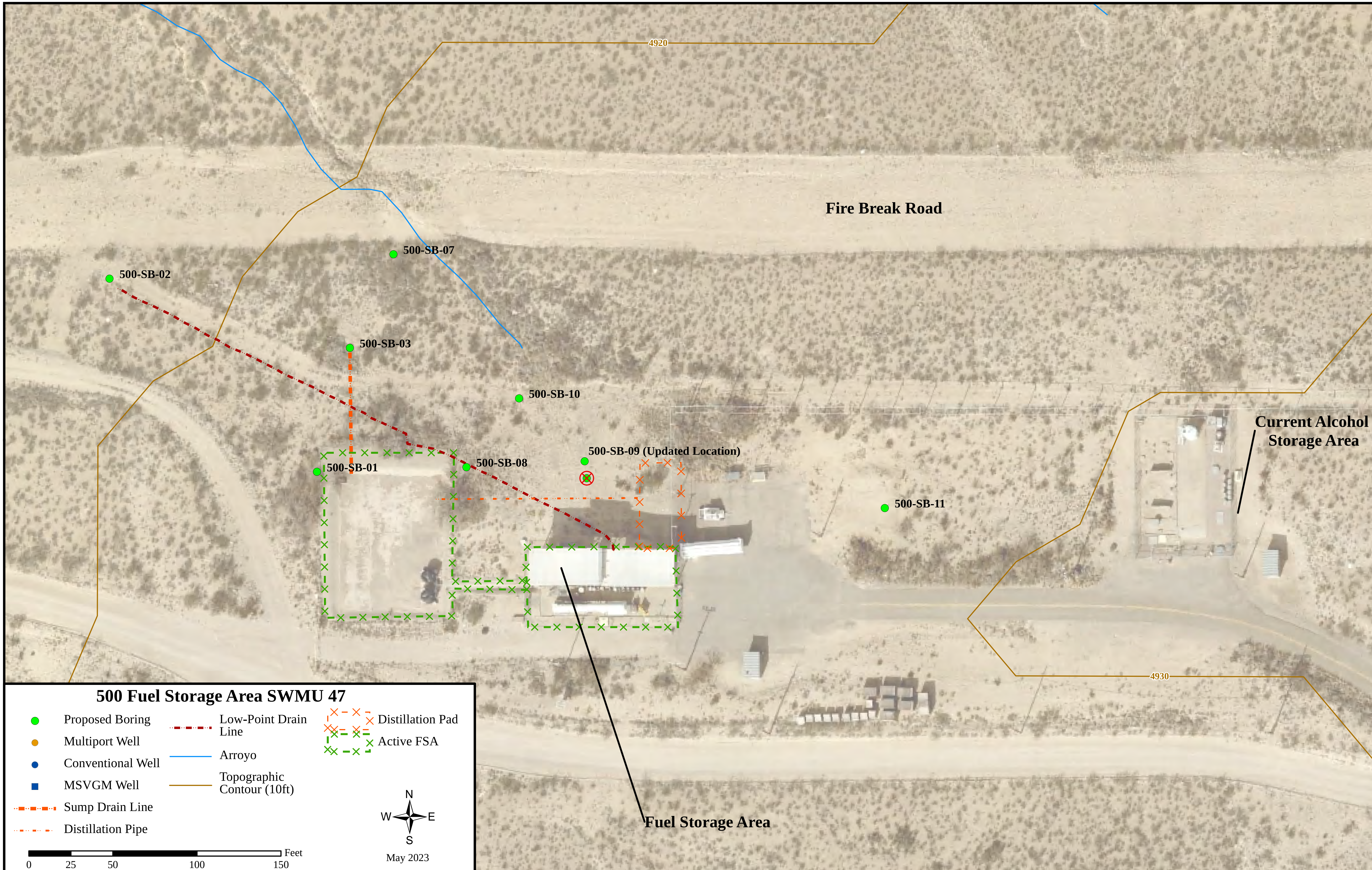
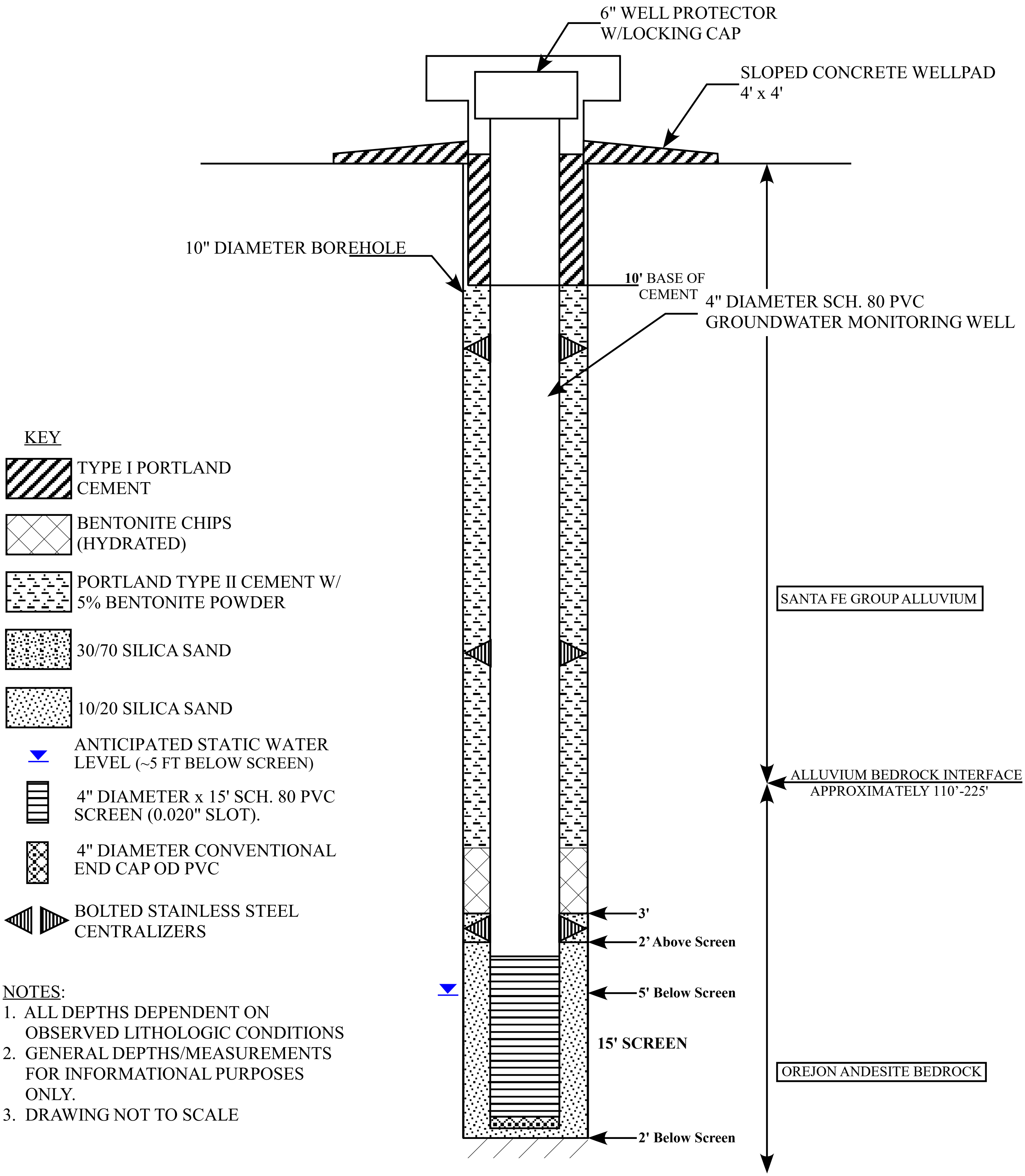

Fire Break Road
4920
4930
500-SB-02
500-SB-07
500-SB-03
500-SB-10
500-SB-09 (Updated Location)
500-SB-01
500-SB-08
500-SB-11
Current Alcohol Storage Area
Fuel Storage Area
500 Fuel Storage Area SWMU 47
Proposed Boring
Multiport Well
Conventional Well
MSVGM Well
Sump Drain Line
Distillation Pipe
Low-Point Drain Line
Arroyo
Topographic Contour (10ft)
Distillation Pad
Active FSA
N
W
E
S
Feet
0
25
50
100
150
May 2023

Figure 4.3 General Monitoring Well Construction Diagram

(SEE NEXT PAGE)



GENERAL CONSTRUCTION DIAGRAM FOR 500 AREA GROUNDWATER MONITORING WELLS

Tables

Table 1.1 Soil Boring Rationale

Original Name	2nd NOD Proposed Name	Proposed Status	Location	Rational to Keep or Remove Proposed Soil Boring for Phase I
500-SB-01	500-SB-01	Keep	Immediately adjacent to SWMU 47, adjacent to northwest corner of gunite-lined pond, and the ponds low-point	Propose to keep due to the downgradient side of the gunite-lined pond. If hypothetical contaminants/wastewater were released to the pond, this location is the closest spot to drill where they would have pooled without compromising the existing structure.
500-SB-02	500-SB-02	Keep	SWMU 47, terminus of the removed low-point drain line	Propose to keep due to the terminus of the removed low-point drain line and historical detections of NDMA at this location. This is also a proposed well location due to its historical detections and its potential for soil-to-groundwater health risk evaluations.
500-SB-03	500-SB-03	Keep	SWMU 47, terminus of the gunite-lined pond sump drain line	Propose to keep due to the terminus of the gunite-lined pond sump drain line. If hypothetical contaminants/wastewater in the pond were released to grade, this location is a site of potential infiltration.
500-SB-04	500-SB-04	Keep	Upgradient, North of Fire Break Rd	Propose to keep due to the upgradient location. This location is assumed to be clean and would provide baseline data for comparisons. This is also a proposed well location for the same reasons.
500-SB-05	500-SB-05	Keep	Downgradient, 500 Area main arroyo, mid-way from SWMU 47 to BW-5-295	Propose to keep due to the downgradient location. This is also a proposed well location that is mid-way between SWMU 47 and BW-5- 295 and would potentially fill a data gap that exists between the two locations.
500-SB-06	500-SB-06	Keep	Downgradient, 500 Area main arroyo, NW of SWMU 47	Propose to keep due to the downgradient location. This location is where runoff waters from SWMU 47 join the main arroyo.

Original Name	2nd NOD Proposed Name	Proposed Status	Location	Rational to Keep or Remove Proposed Soil Boring for Phase I
500-SB-07	500-SB-07	Keep	Immediately adjacent to SWMU 47, 500 feed arroyo drains to the N of SWMU 47	Propose to keep due to the surface gradient within SWMU 47. This is a proposed well location and marks the beginning of the feed arroyo for SWMU 47 runoff waters.
500-SB-08		Remove	Adjacent to SWMU 47, 500 feed arroyo drains N of SWMU 47 and N of Fire Break Rd	Propose to remove due to the proximity to 500-SB-07. This location is where runoff waters from the Fire Break Road join SWMU 47 feed arroyo and drains to the north.
500-SB-09		Remove	Adjacent to SWMU 47, 500 Area feed arroyo drains NW of SWMU 47 & N of Fire Break Rd	Propose to remove due to the proximity to 500-SB-02. This location is where runoff waters from the Fire Break Road drains north toward the feed arroyo.
500-SB-10		Remove	Immediately adjacent to SWMU 47, Adjacent to southwest corner of gunite-lined pond	Propose to remove due to the gradient of the gunite-lined pond. If hypothetical contaminants/wastewater were released to the pond, would have pooled on the north side of the structure.
500-SB-11	500-SB-08	Keep	SWMU 47, adjacent to the NE of the gunite-lined pond	Propose to keep due to the gradient of the gunite-lined pond. If hypothetical contaminants/wastewater were released to the pond, would have pooled on the north side of the structure. This location is staged adjacent to the northeast of the pond and beneath the removed drain line.
500-SB-12	500-SB-09	Keep	SWMU 47, directly north of the active fuel storage pad	Proposed to keep due to the historical NDMA detections. This is also a proposed well location due to its historical detections and its potential for soil-to-groundwater health risk evaluations.
500-SB-13	500-SB-10	Keep	SWMU 47, termination of an "unknown" line	Propose to keep due to the "unknown" nature of the line.

Original Name	2nd NOD Proposed Name	Proposed Status	Location	Rational to Keep or Remove Proposed Soil Boring for Phase I
500-SB-14	500-SB-11	Keep	SWMU 47, historical location of alcohol storage tank, E of parking lot	Propose to keep due to the historical location of alcohol storage tank and the spills noted in the HIS.
500-SB-15		Remove	Upgradient, South of Fire Break Rd	Propose to remove due to its proximity to 500-SB-04, the location is on a steeper slope than 500-SB-04 increasing safety risks, and only one upgradient location is needed for comparison.
500-SB-16		Remove	Downgradient, 500 Area feed arroyo drains to the south of SWMU 47	Propose to remove due to the natural surface gradient of SWMU 47 to the north. This feed arroyo drains from Road P and not directly from SWMU 47.

Red text = Soil borings NASA proposes for removal.

Table 2.1 Historical 500 Area Fuel Storage Soil Sampling Results

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
Background	07/17/00	007170840	5	< 0.3	< 0.3	0.3	0.2
Downgradient	07/17/00	007170910	5	< 0.3	< 0.3	0.3	0.2
	07/17/00	007170920	10	< 0.3	< 0.3	0.3	0.2
Drain Line	07/17/00	007171000	5	**25.3**	**1.3**	0.3	0.2
	07/17/00	007171020	10	< 0.3	< 0.3	0.3	0.2
Sump	07/17/00	001711210	5	< 0.3	< 0.3	0.3	0.2
	07/17/00	001711220	10	< 0.3	< 0.3	0.3	0.2
Drum Pad	07/17/00	007171240	5	**4.9**	**1.2**	0.3	0.2
	07/17/00	007171250	10	**1.5**	**0.5**	0.3	0.2
BG-1	12/11/00	0012111440	1	< 0.33	< 0.33	0.33	0.17
SU-1	12/07/00	0012071209	2	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071217	5	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071333	13	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071409	20	< 0.33	< 0.33	0.33	0.17
DL-1	12/07/00	0012071533	1	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071615	6	< 0.33	< 0.33	0.33	0.17
	12/07/00	0012071633	10	**0.18 J**	< 0.33	0.33	0.17
	12/08/00	0012080926	20	**0.69**	< 0.33	0.33	0.17
	12/08/00	0012080928	20 Dup	**0.6**	< 0.33	0.33	0.17
	12/08/00	0012081010	30	**0.21 J**	< 0.33	0.33	0.17
DL-2	12/08/00	0012081116	5	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081132	10	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081154	20	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081226	30	< 0.33	< 0.33	0.33	0.17
DL-3	12/08/00	0012081406	5	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081418	10	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081446	20	**0.88**	< 0.33	0.33	0.17
	12/08/00	0012081512	30	**1.17**	< 0.33	0.33	0.17
DL-4	12/08/00	0012081542	5	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081544	5 Dup	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081608	10	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081630	20	< 0.33	< 0.33	0.33	0.17
	12/08/00	0012081656	30	< 0.33	< 0.33	0.33	0.17
DL-5	12/09/00	0012090840	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012090850	10	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012090910	20	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012090940	30	< 0.33	< 0.33	0.33	0.17

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
DL-6	12/09/00	0012091040	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091042	5 Dup	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091050	10	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091210	20	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091234	30	< 0.33	< 0.33	0.33	0.17
DL-7	12/09/00	0012091420	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091428	10	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091450	20	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091508	30	< 0.33	< 0.33	0.33	0.17
PA-1	12/09/00	0012091610	1	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091620	5	< 0.33	< 0.33	0.33	0.17
	12/09/00	0012091654	10	**14.8**	**1.51**	0.33	0.17
	12/10/00	0012100900	20	**13.7**	**0.76**	0.33	0.17
	12/10/00	0012100950	30	**7.92**	**0.33 J**	0.33	0.17
	12/10/00	0012100952	30 Dup	**7.41**	**0.29 J**	0.33	0.17
PA-2	12/10/00	0012101032	5	**1.75**	< 0.33	0.33	0.17
PA-2	12/10/00	0012101040	10	**2.13**	< 0.33	0.33	0.17
	12/10/00	0012101250	20	**1.08**	< 0.33	0.33	0.17
	12/10/00	0012101316	30	**0.19 J**	< 0.33	0.33	0.17
PA-3	12/10/00	0012101430	5	< 0.33	< 0.33	0.33	0.17
	12/10/00	0012101440	10	< 0.33	< 0.33	0.33	0.17
	12/10/00	0012101500	20	< 0.33	< 0.33	0.33	0.17
	12/10/00	0012101536	30	< 0.33	< 0.33	0.33	0.17
PA-4	12/11/00	0012110828	5	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012110840	10	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012110910	20	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012110944	30	< 0.33	< 0.33	0.33	0.17
PA-5	12/11/00	0012111030	5	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111040	10	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111042	10 Dup	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111101	20	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111200	30	< 0.33	< 0.33	0.33	0.17
PA-6	12/11/00	0012111402	5	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111408	10	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111450	20	< 0.33	< 0.33	0.33	0.17
	12/11/00	0012111530	30	< 0.33	< 0.33	0.33	0.17

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
PA-7	12/12/00	0012120816	5	**1.16**	**0.30 J**	0.33	0.17
	12/12/00	0012120830	10	**0.32 J**	< 0.33	0.33	0.17
PA-7B	12/12/00	0012121110	20	**0.66**	< 0.33	0.33	0.17
	12/12/00	0012121112	20	**0.66**	< 0.33	0.33	0.17
BG-1	05/07/01	0105071340	1	< 0.33	< 0.33	0.33	0.17
DL-8	05/07/01	0105071130	5	< 0.33	< 0.33	0.33	0.17
	05/07/01	0105071140	10	< 0.33	< 0.33	0.33	0.17
	05/07/01	0105071215	20	< 0.33	< 0.33	0.33	0.17
	05/07/01	0105071250	30	**0.27 J**	< 0.33	0.33	0.17
	05/08/01	0105080820	40	**0.46**	< 0.33	0.33	0.17
DL-9	05/08/01	0105081020	5	< 0.33	**4.66**	0.33	0.17
	05/08/01	0105081040	10	**0.37**	< 0.33	0.33	0.17
	05/08/01	0105081150	30	**1.26**	< 0.33	0.33	0.17
	05/08/01	0105081315	40	**0.58**	< 0.33	0.33	0.17
	05/08/01	0105081545	50	**0.34**	< 0.33	0.33	0.17
DL-10	05/09/01	0105091010	5	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091015	5 Dup	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091025	10	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091050	20	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091115	30	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091145	40	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091245	50	**0.17 J**	< 0.33	0.33	0.17
DL-11	05/09/01	0105091500	5	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091515	10	< 0.33	< 0.33	0.33	0.17
	05/09/01	0105091550	20	**0.43**	< 0.33	0.33	0.17
	05/09/01	0105091630	30	**0.52**	< 0.33	0.33	0.17
	05/09/01	0105091730	40	**0.93**	< 0.33	0.33	0.17
	05/09/01	0105091735	40	**0.85**	< 0.33	0.33	0.17
	05/09/01	0105091820	45	**0.48**	< 0.33	0.33	0.17
PA-8	05/10/01	0105100920	5	< 0.33	< 0.33	0.33	0.17
	05/10/01	0105100940	10	**0.57**	< 0.33	0.33	0.17
	05/10/01	0105101010	20	**0.8**	< 0.33	0.33	0.17
	05/10/01	0105101050	30	**1.1**	< 0.33	0.33	0.17
	05/10/01	0105101140	40	< 0.33	< 0.33	0.33	0.17
	05/10/01	0105101240	50	**0.48 T**	< 0.33 T	0.33	0.17
PA-9	05/10/01	0105101505	5	< 0.33 T	< 0.33 T	0.33	0.17
	05/10/01	0105101520	10	< 0.33 T	< 0.33 T	0.33	0.17

Sample ID	Sample Date	Sample Number	Depth (ft)	NDMA (ug/kg)	DMN (ug/kg)	Reporting Limit (ug/kg)	Detection Limit (ug/kg)
PA-9	05/10/01	0105101550	20	< 0.33 T	< 0.33 T	0.33	0.17
PA-10	05/11/01	0105110845	5	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105110905	10	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105110907	10 Dup	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105110935	20	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105111035	32	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105111120	40	< 0.33 T	< 0.33 T	0.33	0.17
	05/11/01	0105111235	50	**0.18 J**	< 0.33	0.33	0.17
PA-11	05/11/01	0105111430	5	**0.81**	< 0.33	0.33	0.17
	05/11/01	0105111500	10	**0.57**	< 0.33	0.33	0.17
	05/11/01	0105111545	20	**1.59**	< 0.33	0.33	0.17
PA-11	05/15/01	0105151400	30	**0.21 J**	< 0.33	0.33	0.17
	05/15/01	0105151530	40	< 0.33	< 0.33	0.33	0.17
	05/15/01	0105151610	50	< 0.33	< 0.33	0.33	0.17
	05/15/01	0105151612	50 Dup	< 0.33	< 0.33	0.33	0.17
PA-12	05/15/01	0105151800	5	< 0.33	< 0.33	0.33	0.17
	05/15/01	0105151815	10	**0.91**	< 0.33	0.33	0.17
	05/15/01	0105151835	20	**0.92**	< 0.33	0.33	0.17
	05/15/01	0105151905	30	< 0.33	< 0.33	0.33	0.17
	05/16/01	0105161105	40	< 0.33	< 0.33	0.33	0.17
	05/16/01	0105161205	50	< 0.33	< 0.33	0.33	0.17

Data is taken from the RCRA Permit Renewal Application (NASA, 2002)
Unless otherwise indicated, the sample is a soil matrix.
Samples analyzed by Modified EPA Method 607.
BG – Background; SU – Sump; DL – Drain Line; PA – Drum Pad
Dup – Duplicate Sample
J – The result is an estimated value less than the quantitation limit, but greater than or equal to the detection limit.
T – Samples were received at the laboratory outside of acceptable holding temperature.

Table 2.2 List of Historically Identified COCs for the 500 Area Vadose Zone Investigation

Constituent	CAS Number	Target Detection Limits for Soil Samples (mg/kg)	Target Detection Limits for Aqueous Samples (ug/L)	Sample Suite Type	Anticipated Method
N-Nitrosodimethylamine*	62-75-9	1.60E-01/1.70E-04	4.80E-03/2.20E-04	Nitrosamines	Modified Method 607/NDMA Low-level
Isopropyl Alcohol (2-Propanol)	67-63-0	3.30E-02	1.30E-00	VOA	Method 8260B
Acetone	67-64-1	1.70E-03	1.74E+00	VOA	Method 8260B
Hydrazine	302-01-2	2.0E-01	4.40E-03	Hydrazines	Modified Method 8315
UDMH (Unsymmetrical Dimethylhydrazine)	57-14-7	1.22E+00	4.40E-03	Hydrazines	Modified Method 8315
MMH (Monomethyl Hydrazine)	60-34-4	5.00E-02	4.40E-03	Hydrazines	Modified Method 8315

* N-Nitrosodimethylamine analysis will be conducted using an if/then approach. A sample will first be analyzed by Method 607. If this sample returns a non-detect result, then a second sample will be analyzed by NDMA low-level.

Table 4.1 Sampling and Analysis for the SWMU 47 Investigation

Soil Boring ID and Location[1]	Borehole Depth*	Analytical Parameters	Sample Collection Summary (Estimated Number of Samples)					
			Soil Chemical[2]	Soil Geotech[3]	Ground-water Chemical[4]	Duplicates[5]	Spikes[5]	Potential Blanks[6]
500-SB-01	Bedrock	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon ~~Parameters: VOCs, Hydrazines, NDMA~~	-	**1-3** -	~~**0-2**~~	~~Field Duplicate~~	~~Matrix Spike~~	
500-SB-02	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**	**-**	**-**	Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon	**-**	**1-3**	**-**		-	
		Parameters: IPA, Acetone, Hydrazines, NDMA	**-**	**-**	**0-2**	Field Duplicate	Matrix Spike	
500-SB-03	Bedrock	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
500-SB-04	Bedrock or Ground-water	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA/DMN	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				

Soil Boring ID and Location[1]	Borehole Depth*	Analytical Parameters	Sample Collection Summary (Estimated Number of Samples)					
			Soil Chemical[2]	Soil Geotech[3]	Ground-water Chemical[4]	Duplicates[5]	Spikes[5]	Potential Blanks[6]
		Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-05	Bedrock or Ground-water	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
		Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-06	Bedrock	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon ~~Parameters: VOCs, Hydrazines, NDMA~~	-	**1-3** -	~~**0-2**~~	~~Field Duplicate~~	~~Matrix Spike~~	
500-SB-07	Bedrock or Ground-water	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
		Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA			**0-2**	Field Duplicate	Matrix Spike	
500-SB-08	Bedrock	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	

Soil Boring ID and Location[1]	Borehole Depth*	Analytical Parameters	Sample Collection Summary (Estimated Number of Samples)					
			Soil Chemical[2]	**Soil Geotech[3]**	**Ground-water Chemical[4]**	**Duplicates[5]**	**Spikes[5]**	**Potential Blanks[6]**
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				Field, Rinsate, Trip
500-SB-09	Bedrock or Ground-water	Parameters: IPA, Acetone, Hydrazines, NDMA	**10-15**	**-**	**-**	Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon	**-**	**1-3**	**-**		-	
		Parameters: IPA, Acetone, Hydrazines, NDMA	**-**	**-**	**0-2**	Field Duplicate	Matrix Spike	
500-SB-10	Bedrock	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				
500-SB-11	Bedrock	Parameters: IPA, Acetone~~VOCs~~, Hydrazines, NDMA	**10-15**			Field Duplicate	Matrix Spike	Field, Rinsate, Trip
		Parameters: Soil Classification, Particle Size, Gravimetric Moisture Content, Bulk Density, Porosity, Saturated Hydraulic Conductivity, Unsaturated Hydraulic Conductivity, and Organic Carbon		**1-3**				

<table>
<tr><th rowspan="2">Soil Boring ID and Location[1]</th><th rowspan="2">Borehole Depth*</th><th rowspan="2">Analytical Parameters</th><th colspan="6">Sample Collection Summary (Estimated Number of Samples)</th></tr>
<tr><th>Soil Chemical[2]</th><th>Soil Geotech[3]</th><th>Ground-water Chemical[4]</th><th>Duplicates[5]</th><th>Spikes[5]</th><th>Potential Blanks[6]</th></tr>
<tr><td colspan="3">Maximum Sample Totals:
Soil Chemical Parameters: IPA ~~VOCs~~ (110-165 samples), Acetone (110-165 samples), Hydrazines (110-165 samples), NDMA (110-165 samples)
Soil Geotech Parameters: Soil Classification (11-33 samples), Particle Size (11-33 samples), Gravimetric Moisture Content (11-33 samples), Bulk Density (11-33 samples), Porosity (11-33 samples), Saturated Hydraulic Conductivity (11-33 samples), Unsaturated Hydraulic Conductivity (11-33 samples), and Organic Carbon (11-33 samples)
Groundwater Chemical Parameters: IPA (1-21 samples), Acetone ~~VOCs~~ (1-21 samples), Hydrazines (1-21 samples), and NDMA/DMN (1-21 samples)</td><td colspan="6">Sample Blank/Duplicate Totals:
1 x trip blank (~~VOCs~~VOAs) for each soil boring (estimated 11 samples)
1 x field blank per day (estimated 11 samples)
1 x rinsate blank or field blank per groundwater well (estimated 5 samples)
Field Duplicates + Matrix Spikes Samples:
Soil Chemical Parameters: IPA (11-33 + 6-17 samples), Acetone~~VOCs~~ (11-33 + 6-17 samples), Hydrazines (11-33 + 6-17 samples), NDMA (11-33 + 6-17 samples)
Groundwater Chemical Parameters: IPA (1 + 1 samples), Acetone ~~VOCs~~ (1 + 1 samples), Hydrazines (1 + 1 samples), and NDMA/DMN (1 + 1 samples)</td></tr>
</table>

Notes:

* Soil borings to be drilled to bedrock or groundwater. Bedrock depths vary from 110 ft to 225 ft. Groundwater depths vary from 120 ft to 235 ft.

[1] Refer to Figure 4.1 for soil boring locations.

[2] Samples to be collected: on 5-ft intervals to 30 ft bgs, on 10-ft intervals from 30 ft to 50 ft bgs, and on 25-ft intervals from 50 ft to the bedrock. Anticipated order, preparation, and analytical methods: ~~VOCs~~ IPA – SW-846 Method 8260C; Acetone – SW-846 Method 8260C; hydrazines – SW-846 Method 8315; NDMA – If/Then Modified EPA Method 607/NDMA low-level analysis.

[3] Minimum one geotechnical sample per soil boring. Geotechnical samples will be collected for each primary lithologic change up to a maximum of three. Geotechnical samples will be collected for: soil classification and particle size distribution by laser analysis; volumetric moisture content; bulk density; porosity; saturated hydraulic conductivity; organic carbon content; and unsaturated hydraulic conductivity.

[4] Samples to be collected as groundwater grab samples and monitoring samples. Anticipated order, preparation, and analytical methods: IPA – SW-846 Method 8260B; Acetone – ~~VOCs –~~ SW-846 Method 8260B; hydrazines – SW-846 Method 8315; NDMA – If/Then Modified EPA Method 607 /NDMA low-level analysis. Note: Grab samples will be taken for engineering purposes, and turbidity issues may preclude the collection of a sample meeting laboratory criteria for analysis.

[5] Duplicates and Spikes: 1 x field duplicate per 10 samples, 1 x matrix spike per 20 samples.

[6] Blanks: 1 x soil field blank per day on days when soil is sampled; 1 x trip blank for each shipment of groundwater samples; 1 x aqueous field blank per day on days when groundwater is sampled.

Appendix A
Investigation Work Plan Deviations

Investigation Work Plan Deviations

The Permit states in Section VII.H.1.b Investigation Work Plan Requirements: "The Permittee shall provide sufficient written justification for any omissions or deviations from the minimum requirements specified in Permit Attachment 20 (Reporting Requirements)" (NMED, 2016). According to the requirements established in Attachment 20.2 Investigation Work Plan, this IWP (investigation work plan) fulfills the general requirements.

The Permit provides a number of detailed requirements related to the IWP process aside from the reporting requirements in Attachment 20.2. Some of these requirements include, but are not limited to: drilling methods, sampling methods, chemical analysis, background data requirements, etc. (Attachment 17); and monitoring well installation (Attachment 19; NMED, 2016). Omissions or deviations related to these attachments are provided for NMED review and approval. Below is a summary of the specific requirements from the Permit with a discussion of how each requirement is implemented in this IWP.

Reference

NMED Hazardous Waste Bureau. (2016, November 10). Administrative Completeness and Fee Assessment Transmittal of Class 1 Permit Modification Without Prior Approval. Santa Fe, NM.

Table B.1 Permit Requirements and Implementation in the IWP

Permit Specification		Implementation in IWP
Attachment 17.2.2.b.i	Hollow-stem auger or DPT drilling methods are preferred if vapor-phase or VOC contamination is known or suspected to be present. Air rotary drilling is preferred for borings intersecting the regional aquifer.	The methods that will be considered, in order of preference based on cost, time, and capability of reaching the target depths, are air rotary and rotosonic (sonic). NASA concludes that hollow-stem auger or DPT do not have the capabilities to reach the target sample depths based on previous investigations during which these technologies yielded poor sample recovery and boring refusal.
Attachment 17.2.2.b.i	…the borings shall be advanced to the following minimum depths: 1. In all borings, 25 feet (ft) below the deepest detected contamination based on field screening, laboratory analyses, and/or previous investigations at the site; 2. Twenty ft below the base of disposal units if contamination is not detected; 3. Five ft below the base of shallow structures such as piping or building sumps, or other building structures; and 4. Depths specified by NMED based on regional or unit specific data needs.	The vertical boundary of the investigation is the approximate depth to bedrock (110 ft to 225 ft). However, because groundwater is also of concern, one to five borings are expected to be installed to groundwater (120 ft to 230 ft bgs), not to exceed 250 ft bgs if groundwater is not encountered.
Attachment 17.2.2.b.i	The drilling and sampling shall be accomplished under the direction of a qualified engineer or geologist who shall maintain a detailed log of the materials and conditions encountered in each boring.	The drilling and the sampling shall be accomplished under the direction of a qualified and experienced engineer, environmental scientist, or geologist. A detailed field record will be maintained for all investigation fieldwork.
Attachment 17.2.2.b.i.i	Generally, the samples shall be collected at the following intervals and depths:	Soil samples will be collected on five-foot intervals to 30 ft bgs, on ten-foot intervals from 30 ft to 50 ft bgs, and on 25-foot intervals from 50 ft bgs to bedrock.

Permit Specification		Implementation in IWP
Attachment 17.2.2.b.ii (cont.)	1. At five-ft intervals, ten-ft intervals, continuously, or as approved by NMED; 2. At the depth immediately below the base of the disposal unit or facility structure; 3. At the maximum depth of each boring; 4. At the depths of contacts or first encounter, observed during drilling, with geologic units of different lithology, structural or textural characteristics, or of relatively higher or lower permeability; 5. Of soil or rock types relatively more likely to sorb or retain contaminants than surrounding lithology; 6. At the depth of the first encounter, during drilling, with shallow or intermediate saturated zones; 7. At intervals suspected of being source or contaminated zones; 8. At the top of the aquifer; and 9. At other intervals approved or required by NMED.	The deepest sample will be collected as close to the alluvial bedrock interface as feasible, taking into account issues of sample quality, sample recovery, and the position of the water table if encountered unexpectedly.
Attachment 17.2.2.b.ii	A decontaminated split-barrel sampler lined with brass sleeves, a coring device, or other method approved by NMED shall be used to obtain samples during the drilling of each boring.	Given that drilling conditions in the 500 Area are expected to be similar to those in the 300 and 400 Areas, split-spoon sampling tubes will not be used because of the high probability of sample refusal and equipment damage. Instead, a modified heavy-duty sampling core barrel may be used with an air-rotary drilling or a sonic core barrel may be used with a sonic drilling. This equipment has been used successfully at WSTF during previous investigations.
Attachment 17.2.2.b.ii	Upon recovery of the sample, one or more brass sleeves shall be removed from the split barrel sampler and the open ends of the sleeves covered with Teflon tape or foil and sealed with plastic caps fastened to the sleeves with tape for shipment to the analytical laboratory.	For air rotary drilling: A sampling core barrel (e.g., modified sonic core barrel) will be driven 2 to 5 ft into the undisturbed formation at the bottom of the open borehole using a pneumatic driver head or drop hammer For sonic drilling: The soil core will be extruded from the core barrel through the use of gravity-aided vibration, into chemically-resistant containers (e.g. sampling sleeves, stainless steel troughs), minimizing the disturbance of the soil core and ensuring the collection of a representative soil sample. Soil collected for analysis will be transferred from the sampler into clean sample containers provided by the laboratory contracted to analyze the investigation samples.
Attachment 17.2.2.c	Detailed logs of each boring shall be completed in the field by a qualified engineer or geologist.	Detailed logs for each boring will be completed by a qualified engineer, environmental scientist, or geologist and reviewed by a qualified geologist for inclusion in the investigation report.

Permit Specification		Implementation in IWP
Attachment 17.2.2.d	The primary screening methods to be used shall include: 1) visual examination; 2) headspace vapor screening for VOCs; and 3) metals screening using X-ray fluorescence (XRF). Additional screening for site- or release-specific characteristics such as pH, High Explosives (HE), Total Petroleum Hydrocarbons (TPH) or for other specific compounds using field test kits shall be conducted where appropriate.	For site-specific COPCs (hydrazines, NDMA, IPA, and acetone), headspace vapor will be screened using a PID and Dräger vapor monitor.
Attachment 17.2.2.g	Samples of subsurface vapors shall be collected from vapor monitoring points from both discrete zones, selected based on investigation and field screening results, and as total well subsurface vapor samples where required by NMED.	Due to the nature of the site-specific COCs and available historical information on the FSA, monitoring of subsurface vapors is not anticipated for this investigation.
Attachment 17.2.2.i.ii	All purged groundwater and decontamination water transported to ETU shall be temporarily stored at satellite accumulation areas or transfer stations in labeled 55-gallon drums, less-than-90-day storage areas or other containers approved by NMED until proper characterization and disposal can be arranged.	One or more Central Accumulation Areas will be established in the field adjacent to SWMU 47 within the perimeter of the investigation area to manage IDW. Purged groundwater and decontamination water will be managed in DOT-compliant containers, such as 55-gallon drums
Attachment 19.3.5	Newly installed monitoring wells shall not be developed for at least 48 hours after the outer protective casing is installed.	Wells will be developed following the completion of the last well or boring installation for the project.

Appendix B
Investigation-Derived Waste Management Plan

National Aeronautics and Space Administration

500 Area Fuel Storage (SWMU 47) Investigation-Derived Waste Management Plan

September 2018

Revised November 2019

Revised June 2021

NM8800019434

NASA Johnson Space Center White Sands Test Facility

500 Area Fuel Storage (SWMU 47)
Investigation-Derived Waste Management Plan

September 2018

Revised November 2019

Revised June 2021

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

____   ____________________

Timothy J. Davis — Date
Chief, NASA Environmental Office

National Aeronautics and Space Administration

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
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List of Acronyms

CFC	Chlorofluorocarbon
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
IDW	Investigation-Derived Waste
IWP	Investigation Work Plan
MMH	Monomethylhydrazine
MPITS	Mid-plume Interception and Treatment System
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMED	New Mexico Environment Department
RCRA	Resource Conservation and Recovery Act
SSL	Soil Screening Level
SWMU	Solid Waste Management Unit
SWMU 47	500 Area Fuel Storage
TSDF	Treatment, Storage, and Disposal Facility
UDMH	Unsymmetrical Dimethylhydrazine
WSTF	White Sands Test Facility

1.0 Waste Generating Activity and Description

The investigation of SWMU (Solid Waste Management Unit) 47 – 500 Area Fuel Storage will require soil boring installations, well installations, and associated sample collection activities. IDW (investigation-derived waste) generated during the investigation of SWMU 47 will include: saturated and unsaturated soil generated during the drilling and sampling process (soil cuttings or soil cores); used disposable sampling equipment; personal protective equipment (i.e., nitrile gloves); plastic sheeting, rags, and other debris that is contaminated by soil or fluids; groundwater, and decontamination water and soap solutions.

2.0 Waste Characterization Procedures

2.1 Preliminary Waste Characterization

Historical documentation indicates that MMH (monomethylhydrazine), hydrazine, UDMH (unsymmetrical dimethylhydrazine), and Aerozine 50 fuels were stored within SWMU 47. Off-specification hydrazine based fuel may have been treated in the SWMU 47 containment pond and subsequently released to grade (NASA, 2018). Previous investigation results indicates that NDMA (N-Nitrosodimethylamine) is present in soils adjacent to the active portions of SWMU 47 (NASA, 2018). The investigation location is outside of the known boundary of the WSTF groundwater contamination plume, but there are no groundwater monitoring wells in the immediate area of SWMU 47 that can be sampled to confirm groundwater in this area is not contaminated. Because of the lack of groundwater data in the area, it is assumed that the WSTF groundwater COCs (contaminants of concern), NDMA, trichloroethylene, tetrachloroethene, CFC-11 (chlorofluorocarbon), and CFC-113 may be found in groundwater and saturated environmental media during the SWMU 47 investigation. Trichloroethylene, tetrachloroethene, CFC-11, and CFC-113 originate from other WSTF SWMUs and are not a CoC for SWMU 47 investigation.

Discarded commercial chemical products, off-specification species, container residues, and spill residues of materials identified in and meeting the conditions of 40 CFR § 261.33 are listed hazardous wastes. When discarded, hydrazine, MMH, and UDMH are listed hazardous wastes with EPA (Environmental Protection Agency) waste codes U133, P068, U098, respectively. Groundwater extracted from the WSTF groundwater contamination plume has been previously characterized as F001 and F002 listed hazardous waste. This characterization will also be used for this project. Any waste generated with these waste codes are also subject to §268.40 land disposal restriction treatment standards. NDMA was present as an impurity in the hydrazine based fuels and likely also formed as an oxidation byproduct during treatment of the fuels. The P082 EPA waste code is not applicable to waste generated during this project because the NDMA, if present, does not meet the listing description of a hazardous waste per §261.33. No characteristic hazardous waste is expected to be generated during this project.

The EPA has established that groundwater and soil are environmental media that is not solid waste, but is subject to regulation as if it were hazardous waste when it contains listed waste (EPA, 1991). This is commonly referred to as the Contained-In Policy. Through application of this policy, soil and groundwater that may contain listed hazardous waste constituents must be managed as hazardous waste. Groundwater within the WSTF contaminated groundwater plume is characterized as listed hazardous waste with the EPA waste codes F001 and F002, which are associated with trichloroethylene, tetrachloroethene, and CFC-11, and CFC-113 releases from other WSTF SWMUs. Though the location of SWMU 47 is located outside of the current boundaries of the WSTF groundwater plume, there are no available groundwater analytical data within the immediate investigation area. To address this issue, NASA will conservatively manage IDW generated below the water table as carrying the F001 and F002 EPA waste codes in addition to the U133, P068, and U098 codes associated with the investigation CoCs.

Other materials that come into contact with or is mixed with environmental media characterized as hazardous waste is regulated under the EPA's "mixture rule" (§261.3(a)(2)(iv)). This waste could include hazardous debris, such as, spent personal protective equipment, contaminated sampling supplies, and plastic sheeting. Decontamination water and other material that has come into contact with contaminated media must also be regulated as hazardous waste.

The initial waste characterization for specific waste streams that will be generated during this project is provided in Table 2.1.

Table 1 Initial Waste Characterization

Waste	Waste Characterization	EPA Waste Codes
Environmental Media – Unsaturated Soil and Soil Cuttings	Hazardous Waste	U133, U098, P068
Environmental Media – Saturated Soil and Drill Cuttings	Hazardous Waste	U133, U098, P068, F001, F002
Environmental Media - Groundwater	Hazardous Waste	U133, U098, P068, F001, F002
Hazardous Debris Generated Above the Water Table	Hazardous Waste	U133, U098, P068
Hazardous Debris Generated Below the Water Table	Hazardous Waste	U133, U098, P068, F001, F002
Decontamination Water Generated from Equipment Used Above the Water Table	Hazardous Waste	U133, U098, P068
Decontamination Water Generated from Equipment Used Below the Water Table	Hazardous Waste	U133, U098, P068, F001, F002

2.2 Investigation Derived Waste Characterization

Thorough characterization will be performed on the waste generated during this investigation in accordance with the applicable sections of Attachment 12: *Waste Analysis Plan* of the WSTF Hazardous Waste Permit (2016) and 40 CFR Parts 260 and 261. Waste characterization for IDW may be based on the analytical data received for the primary investigation samples (i.e., samples soil collected from the boreholes), or from specific samples collected from the as-generated waste. For environmental media that are identified as containing listed wastes per 40 CFR 261 Subpart D, a request for a no longer contained-in determination may be submitted to the NMED Hazardous Waste Bureau, if waste characterization sample analytical results support such a request.

3.0 Waste Management Procedures

In accordance with the initial waste characterization, all IDW generated during this project will be initially managed as hazardous waste. IDW will be accumulated and placed into appropriate containers and will be managed in accordance with 20.4.1.300 NMAC and 40 CFR 262.17 (2017). This includes, but is not limited to requirements for accumulation start dates, hazardous waste labels, and container specifications.

One or more Central Accumulation Areas will be established in the field adjacent to SWMU 47 within the perimeter of the investigation area to manage IDW. The accumulation area(s) will adhere to the requirements of 20.4.1.300 NMAC and 40 CFR 262.17 (2017). The following waste accumulation and management strategies will be implemented during this project:

- Unsaturated soil and drill cuttings will be containerized in DOT (U.S. Department of Transportation)-compliant containers, such as 55-gallon drums or bulk containers (i.e., 1-CY intermediate bulk container or roll-off). Produced liquids from drilling returns may be decanted off and accumulated in separate DOT compliant containers.
- Saturated soil and drill cuttings will be containerized in DOT-compliant containers, such as 55-gallon drums or bulk containers (i.e., covered roll-off). Produced liquids from drilling returns may be decanted off and accumulated in separate DOT-compliant containers.
- Hazardous debris consisting of used personal protection equipment, plastic sheeting, and other contaminated items will be containerized in DOT-compliant containers, such as 55-gallon drums.
- Decontamination fluids will be managed in DOT-compliant containers, such as 55-gallon drums.
- Wastes typically associated with equipment maintenance (e.g., grease, contaminated rags, oil, penetrating oil, diesel, soil contaminated with hydraulic fluids, etc.) may also be generated and will be managed in a DOT compliant container as hazardous waste pending a full waste characterization.
- Any inadvertent spills of IDW onto the soil will be immediately addressed and containerized as hazardous waste in DOT compliant containers.

4.0 Waste Disposition Procedures

NASA may request a contained-in determination from the NMED if analytical data indicates environmental media IDW does not contain listed hazardous waste or exhibit characteristics of a hazardous waste. A partial contained-in determination may be requested if the analytical data from aqueous IDW, such as contaminated groundwater or decanted water from saturated drill cuttings, does not indicate the presence of U133, P068, or U098 listed waste, but F001 and F002 constituents are present. Should such an instance occur, NASA would request a contained-in determination from NMED to remove the U133, P068, and U098 listing designations from the waste. The waste would continue to carry the F001 and F002 listed hazardous waste codes and would continue to be managed as hazardous waste. This waste would then be transferred to the MPITS (Mid-plume Interception and Treatment System) for storage, treatment, and discharge. The MPITS was designed with provisions for the storage and treatment of IDW (NASA, 2008). If the analytical data indicate the presence of U133, P068, or U098 listed waste or the waste exhibits characteristics of a hazardous waste, the waste will be properly treated and disposed of at a RCRA permitted TSDF (treatment, storage, and disposal facility).

A table listing summarizing chemical analytical data for the waste, applicable treatment standards found in 40 CFR Part 268.40 (2003), NMED SSL (soil screening levels; NMED, 2017), and the concentrations listed in 40 CFR Part 261.24 Subpart C (Table 1; 2012) will be provided to NMED with the contained-in determination request. If NMED finds contaminant concentrations do not pose an unacceptable risk, then NMED may allow the wastes included in the request to be managed as non-hazardous solid waste that no longer contains listed waste and do not exhibit the characteristic of hazardous waste. A letter from NMED will be required to document such a determination.

IDW soil or drill cuttings that do not meet the definition of a hazardous waste, and do not contain hazardous constituents at concentrations above residential SSLs, will be spread on the ground within the project site with NMED approval. IDW soil that does not meet the definition of a hazardous waste but does contain hazardous constituents above residential SSLs, will be properly managed as non-hazardous solid waste and properly disposed of at a RCRA Resource Conservation and Recovery Act) Subtitle D landfill. IDW debris that is determined to be non-hazardous waste will also be disposed of as non-hazardous solid waste. Soil samples sent to the analytical laboratories will be disposed of by the laboratories as environmental samples in accordance with each individual laboratory's procedure.

For materials that are characterized as hazardous waste, land disposal restriction notifications, disposal facility profiles, and hazardous waste manifests will be completed as required. Waste will be transported for treatment and disposal at a permitted RCRA TSDF. Any wastewater generated during the investigation that only carries the F001 and F002 hazardous waste codes will be treated MPITS. If that system is not capable of receiving the waste, it will be disposed of at a permitted RCRA TSDF.

5.0 References

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