National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
White Sands Test Facility
P.O. Box 20
Las Cruces, NM 88004-0020

December 21, 2023

Reply to Attn of: RE-23-198

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 of the NASA White Sands Test Facility (WSTF) 500 Area Former Oxidizer Burner (FOB) Investigation Work Plan (IWP) and Historical Information Summary (HIS)

NASA submitted the *NASA White Sands Test Facility (WSTF) 500 Area Former Oxidizer Burner (FOB) Investigation Work Plan (IWP) and Historical Information Summary (HIS)* on August 25, 2022. On November 1, 2023, NMED approved the IWP and HIS with modifications and directed NASA to address five comments by December 29, 2023.

Enclosure 1 includes a printed response table addressing NMED's comments. Enclosure 2 includes printed copies of the revised IWP and HIS, and Enclosure 3 includes a CD-ROM of the IWP, HIS, 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 known violations.

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

Amanda Skarsgard
Digitally signed by Amanda Skarsgard
Date: 2023.12.21 10:42:35 -07'00'
For: Timothy J. Davis
Chief, Environmental Office

3 Enclosures

cc:
Mr. Gabriel Acevedo
Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

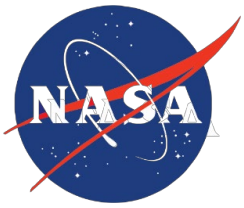
Ms. Melanie Sandoval
New Mexico Environment Department
Ground Water Quality Bureau
NASA Box folder

Responses to NMED Comments for Approval with Modifications of the SWMU 54 IWP and HIS

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
1. Historical Information Summary (HIS): Section 6.3, Indication of Releases to the Environment, Page 9	**NMED Comment:** HIS Appendix A, 500 Area Summary of Findings from Employee Interviews or Questionnaires, includes interview information from a NASA employee who worked at White Sands Test Facility (WSTF) from 1977 to 1980 that provides historical information on two tests conducted at the original oxidizer storage area (OOSA) involving the release of 250-gallons and 70-gallons of nitrogen-tetroxide (N_2O_4) on to paved areas at the OOSA. Photographs from 1979 of one of these tests have also been included in HIS Appendix B, 500 Fuel Oxidizer Burner Historical Photographs. For completeness, revise Section 6.3 to also include a discussion of the oxidizer release tests and provide respective replacement pages.	Section 6.3 has been revised to include a discussion of the oxidizer release tests conducted at the OOSA in 1979 and is now new Section 6.3.2, Oxidizer Release Testing.
2. Work Plan: Section 2.1.1, 500 Area Operational History, Page 2	**NMED Comment:** HIS Section 6.3.2, Spills, includes information regarding a release of N_2O_4 to pavement during oxidizer transfer from a truck to the oxidizer aboveground storage tank during Apollo space program testing in the 1960s. For completeness, revise the Section 2.1.1 discussion to include this information originally provided in the HIS and provide a replacement page.	NASA has revised the Work Plan Section 2.1.1, to include information from HIS Section 6.3.3 (Re-numbered due to inclusion of the new 6.3.2 requested by Comment 1, above), Spills, which includes information regarding a release of N_2O_4 to the pavement during oxidizer transfer from a truck to the oxidizer aboveground storage tank during Apollo space program testing in the 1960s.
3. Work Plan: Section 4.1.2, Decision Statement and Alternative Actions, Page 8	**Permittee Statement:** "Complete Health Risk Assessment and request for corrective action complete for the 500 Area FOB [Former Oxidizer Burner]." **NMED Comment:** As clarification, evaluation of residential receptor exposure in addition to industrial and construction work exposure is required for a complete risk screen evaluation for the site. If residential exposure is not addressed, the site will not qualify for corrective action complete status. Revise the Work Plan to propose a complete risk screen evaluation to include residential receptor exposure and provide necessary revised replacement pages.	NASA has revised the Work Plan Section 2.4.4, Potential Receptors, to include ecological receptors and that the residential exposure scenario will also be evaluated even though the exposure pathway is currently incomplete. In addition, the section has been revised to state that when a health risk screen evaluation is conducted, it will include residential receptor exposure in accordance with the procedures detailed in the current version of the NMED RA Guidance.

NMED Comment Number	NMED Comments	NASA Revisions/Responses/Discussion
4. Work Plan: Section 4.1.2, Soil Sampling, Page 10	**NMED Comment:** The proposed sampling depths (surface and 4 to 5 feet below ground surface (ft bgs)) are potentially valid based on available site information; however, if a continuous sampling methodology is not used for boring advancement, an additional sample for at least field screening and soils classification must be collected at 2.5 ft bgs to comply with soil sampling requirements outlined in March 2023 *NASA WSTF Post Closure Permit*, Section 4.2.3.3, Soils Sampling. Revise the Work Plan to specify this requirement and provide any necessary replacement pages.	NASA has revised the Work Plan Section 4.2.3, Soil Sampling Plan, to state that if a continuous sampling methodology is not used for boring advancement, an additional sample for potential field screening and soils classification will be collected at 2.5 ft bgs to comply with soil sampling requirements in the WSTF Resource Conservation and Recovery Act Permit.
5. Work Plan: Figure 2.2, Site Conceptual Exposure Model [SCEM] Former Oxidizer Burner, Page 28	**NMED Comment:** The following Figure 2.2 issues must be addressed: a. The conceptual site exposure model for the 500 Area FOB shows potential exposure to surface soil as incomplete for non-burrowing and burrowing ecological receptors. Both of these ecological receptors have direct contact with surface soil and have potential exposure through ingestion and dermal contact. Revise Figure 2.2 to document that these surface soil exposure pathways are potentially complete for non-burrowing and burrowing ecological receptors and provide a replacement figure. b. Figure 2.2 reflects that all exposure pathways associated with subsurface soil are incomplete. However, the soil exposure interval for the construction worker and resident is 0 to 10 ft bgs and exposure to surface and subsurface soil would apply for ingestion and dermal contact for these human health receptors. Revise the SCEM to appropriately identify all potential exposure pathways for site receptors and provide a replacement figure.	a. NASA has revised the Work Plan Figure 2.2 to show that non-burrowing and burrowing ecological receptors have potential exposure through ingestion and dermal contact. A replacement figure is provided. b. NASA has revised the Work Plan Figure 2.2 to appropriately identify all potential exposure pathways for site receptors. A replacement figure is provided.
6. N/A		Revised RCRA Permit and Groundwater Monitoring Plan references reflect current documents throughout.

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 DAVIS Digitally signed by TIMOTHY DAVIS
Date: 2023.05.22 07:56:27 -06'00'

Timothy J. Davis
Chief, NASA Environmental Office

See Electronic Signature
Date

National Aeronautics and Space Administration

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
www.nasa.gov/centers/wstf

www.nasa.gov

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.

[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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Well Driller Licensing; Construction, Repair, and Plugging of Wells, Office of the State Engineer, 19.27.4.30.C NMAC (6-30-17).

Figures

Figure 1.1 WSTF Location

(SEE NEXT PAGE)

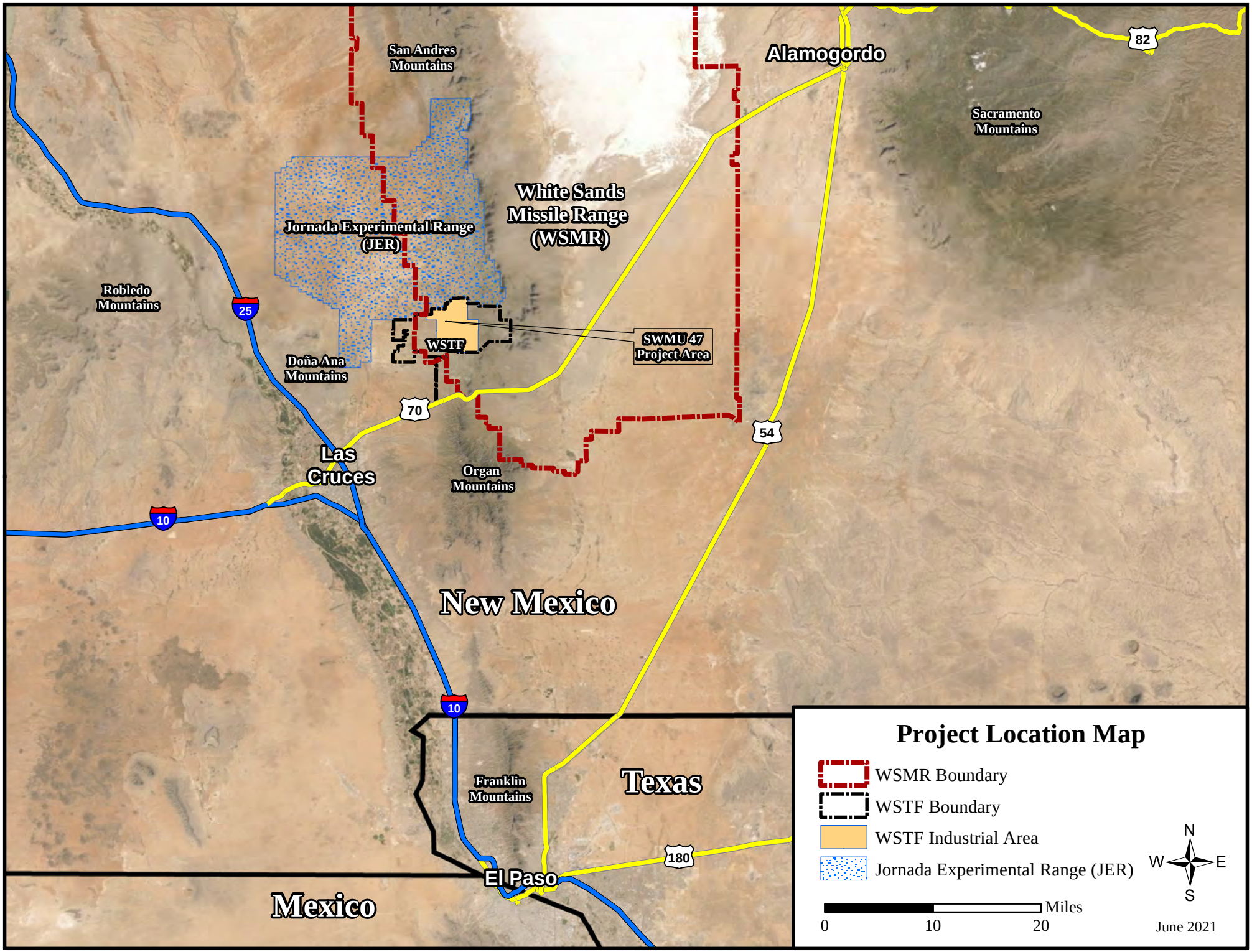

San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
SWMU 47 Project Area
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
Project Location Map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

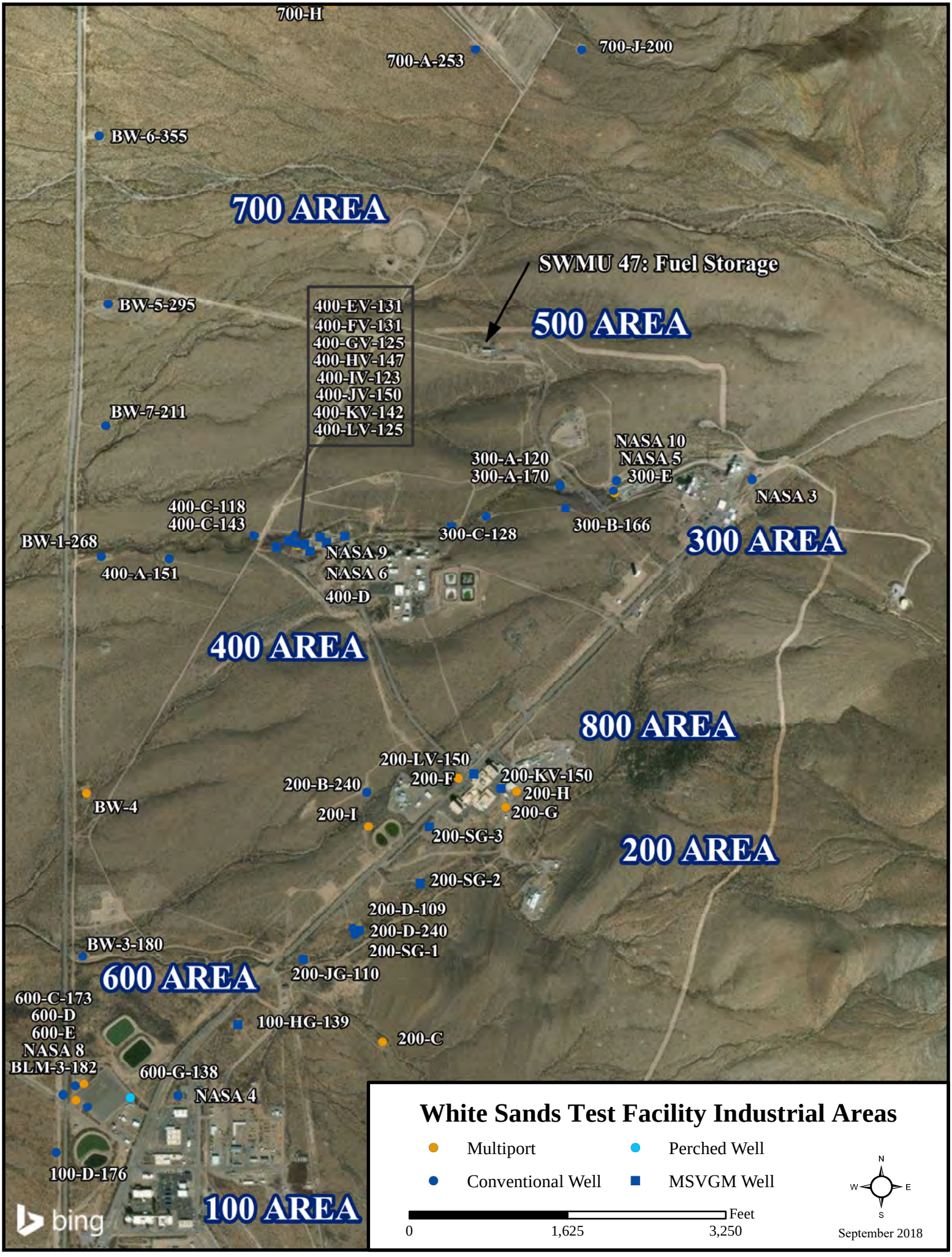

700-H
700-A-253
700-J-200
BW-6-355
700 AREA
SWMU 47: Fuel Storage
BW-5-295
400-EV-131
400-FV-131
400-GV-125
400-HV-147
400-IV-123
400-JV-150
400-KV-142
400-LV-125
500 AREA
BW-7-211
NASA 10
NASA 5
300-E
300-A-120
300-A-170
NASA 3
400-C-118
400-C-143
300-B-166
300-C-128
BW-1-268
300 AREA
NASA 9
NASA 6
400-D
400-A-151
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
200-JG-110
600 AREA
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
Feet
0
1,625
3,250
N
W
E
S
September 2018

Figure 1.3 **WSTF 500 Area SWMU 47**

(SEE NEXT PAGE)

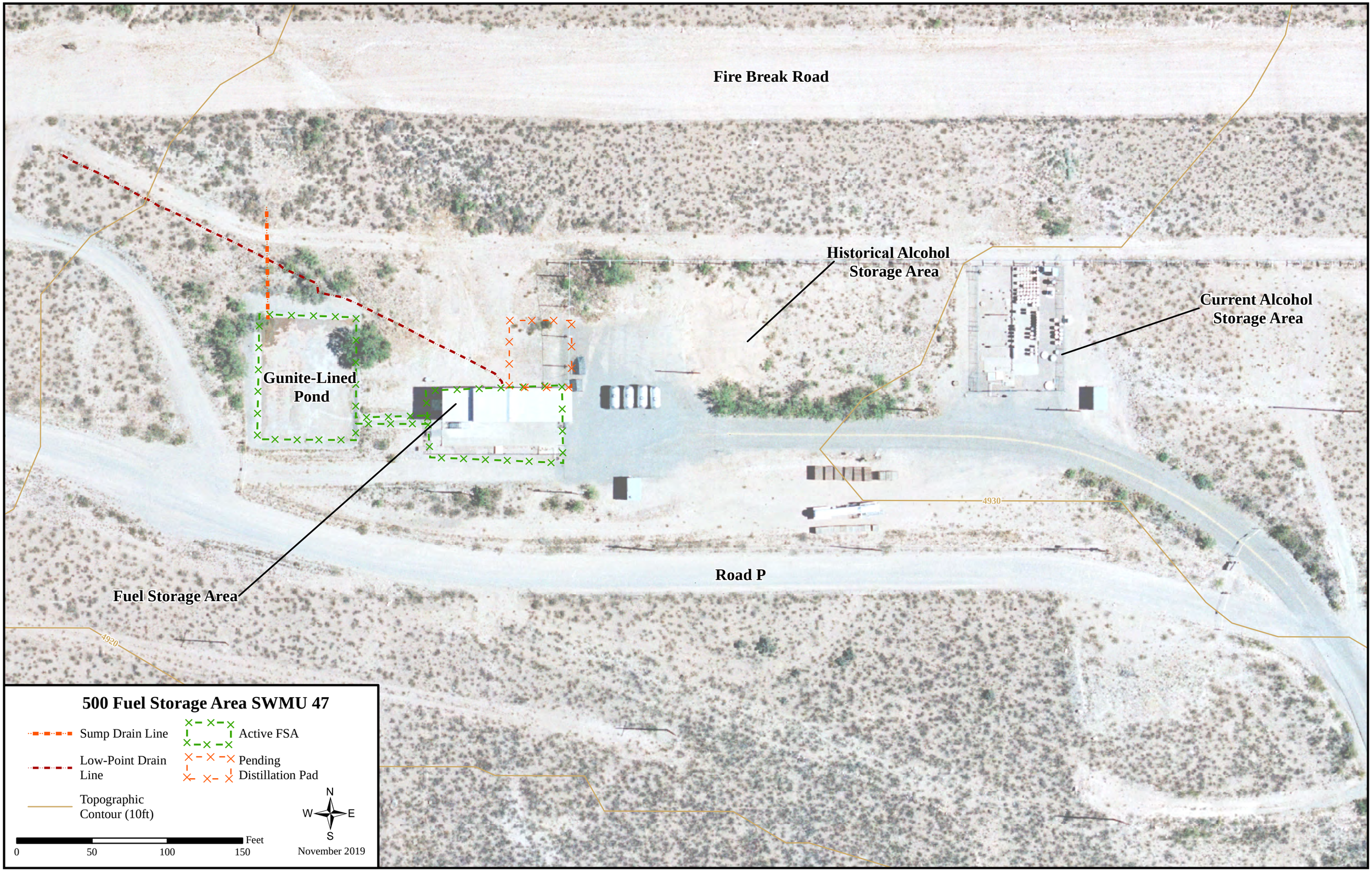

Fire Break Road
Historical Alcohol Storage Area
Current Alcohol Storage Area
Gunite-Lined Pond
Fuel Storage Area
Road P
4930
4920
500 Fuel Storage Area SWMU 47
Sump Drain Line
Low-Point Drain Line
Topographic Contour (10ft)
Active FSA
Pending Distillation Pad
N
W
E
S
Feet
0
50
100
150
November 2019

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

(SEE NEXT PAGE)

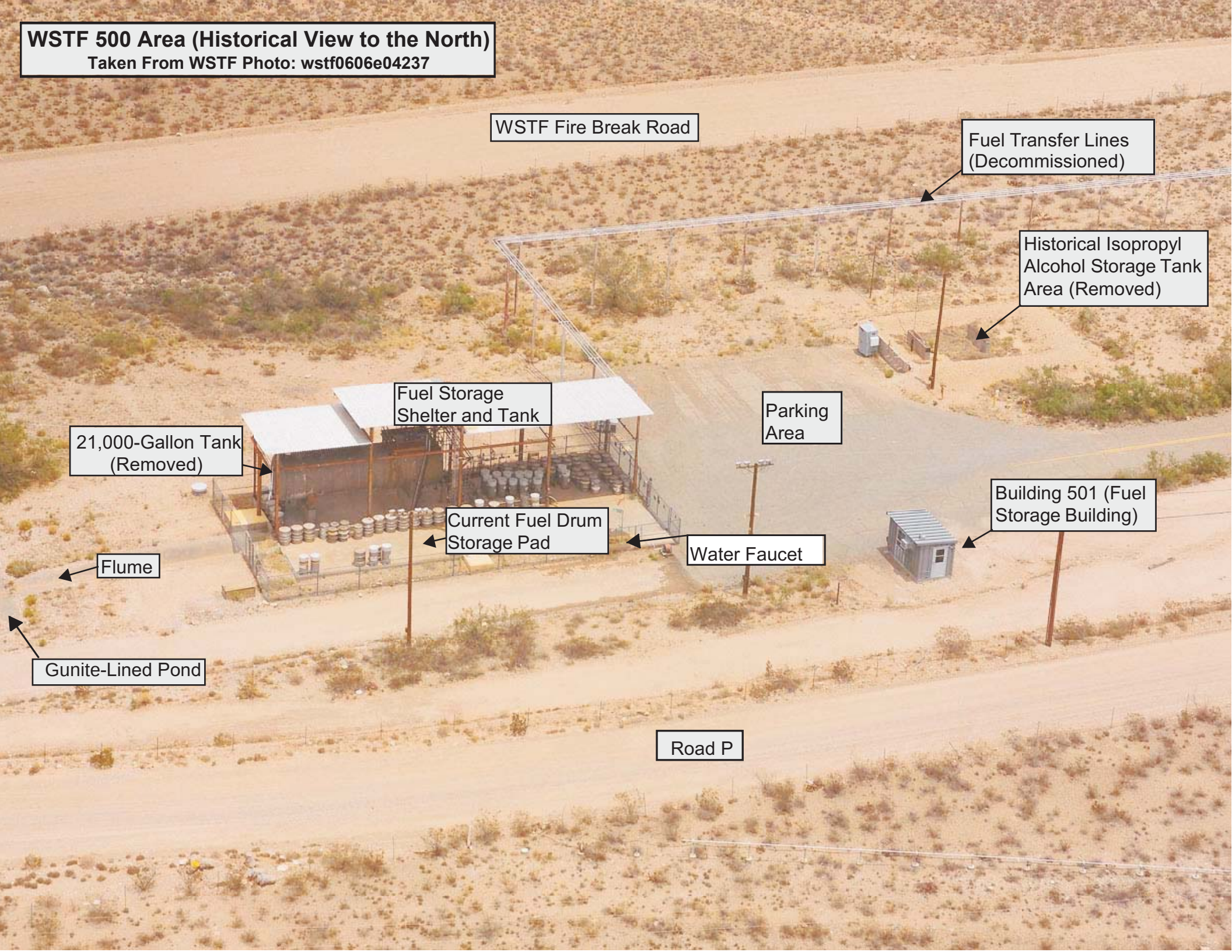

WSTF 500 Area (Historical View to the North)
Taken From WSTF Photo: wstf0606e04237
WSTF Fire Break Road
Fuel Transfer Lines (Decommissioned)
Historical Isopropyl Alcohol Storage Tank Area (Removed)
Fuel Storage Shelter and Tank
Parking Area
21,000-Gallon Tank (Removed)
Building 501 (Fuel Storage Building)
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)

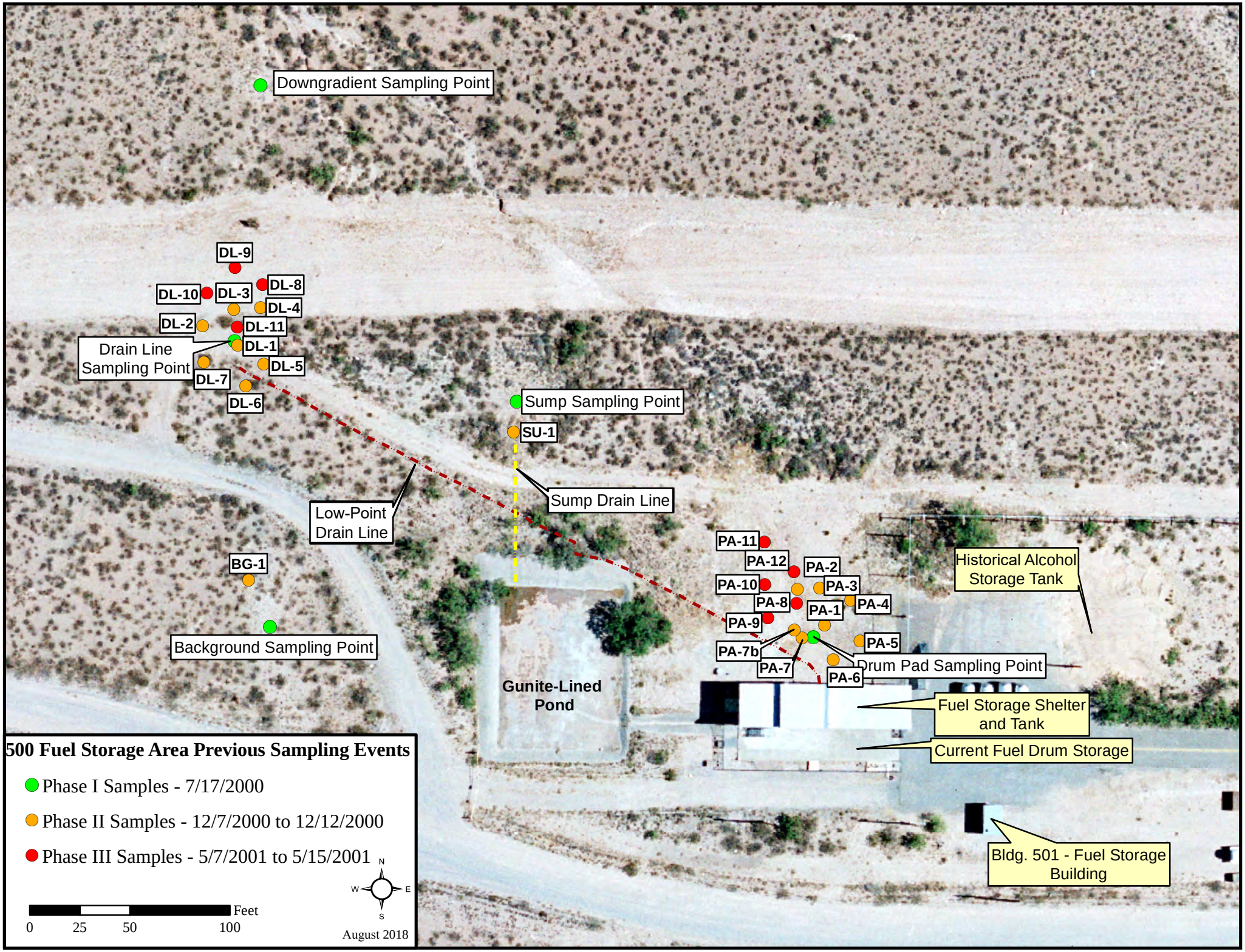

Downgradient Sampling Point
DL-9
DL-10
DL-3
DL-8
DL-4
DL-2
DL-11
DL-1
DL-5
DL-7
DL-6
Drain Line Sampling Point
Sump Sampling Point
SU-1
Sump Drain Line
Low-Point Drain Line
BG-1
Background Sampling Point
PA-11
PA-12
PA-2
PA-10
PA-3
PA-8
PA-4
PA-1
PA-9
PA-5
PA-7b
PA-7
PA-6
Drum Pad Sampling Point
Historical Alcohol Storage Tank
Gunite-Lined Pond
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

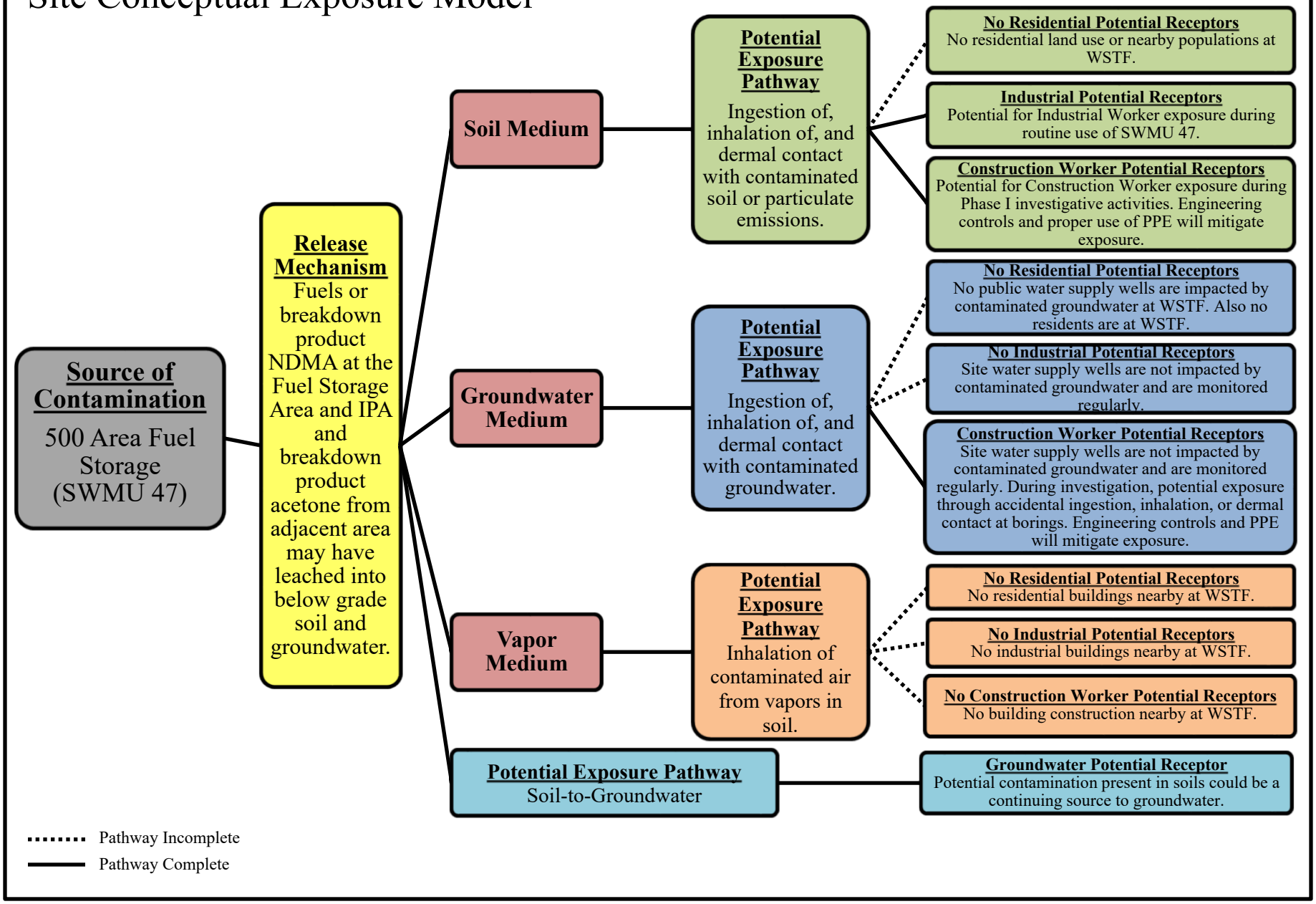


Figure 4.1 **SWMU 47 Proposed Borings**

(SEE NEXT PAGE)

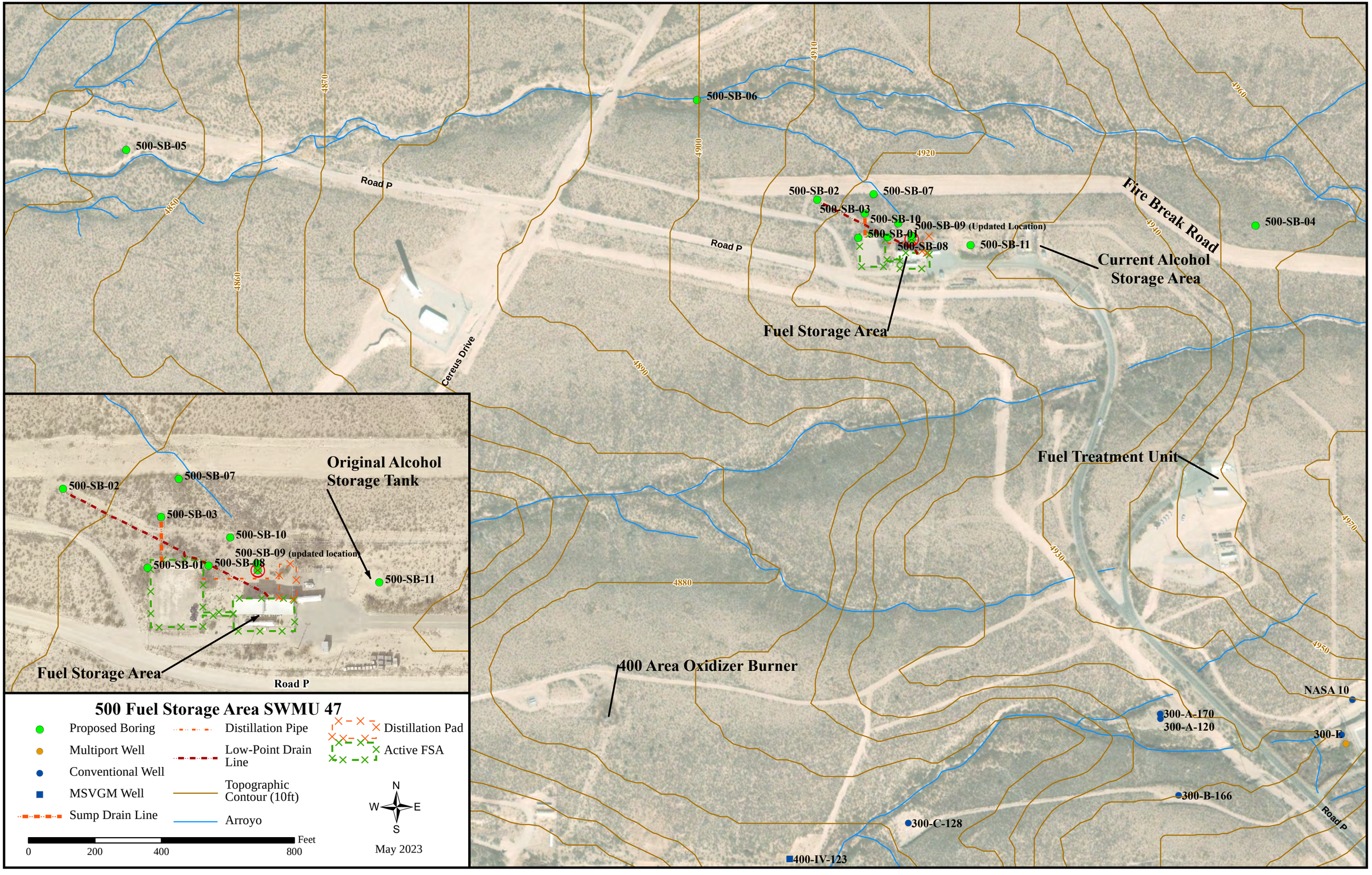

500-SB-05
500-SB-06
500-SB-02
500-SB-07
500-SB-03
500-SB-10
500-SB-09 (Updated Location)
500-SB-01
500-SB-08
500-SB-11
500-SB-04
Road P
Cereus Drive
Fire Break Road
Current Alcohol Storage Area
Fuel Storage Area
Fuel Treatment Unit
400 Area Oxidizer Burner
4850
4860
4870
4880
4890
4900
4910
4920
4930
4940
4950
4960
4970
NASA 10
300-A-170
300-A-120
300-E
300-B-166
300-C-128
400-IV-123
Road P
Original Alcohol Storage Tank
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
Fuel Storage Area
Road P
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
0
200
400
800
Feet
May 2023

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

(SEE NEXT PAGE)

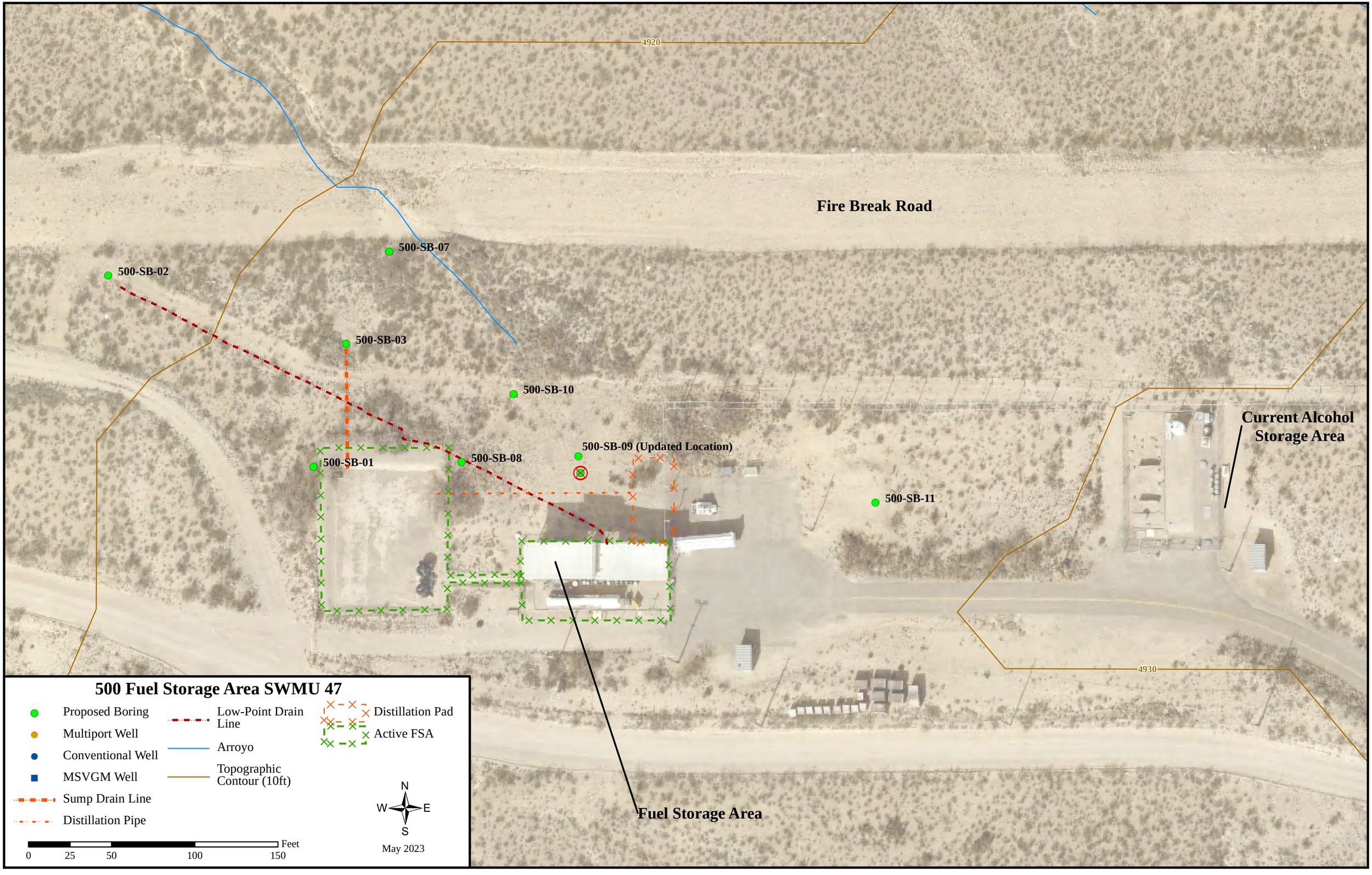
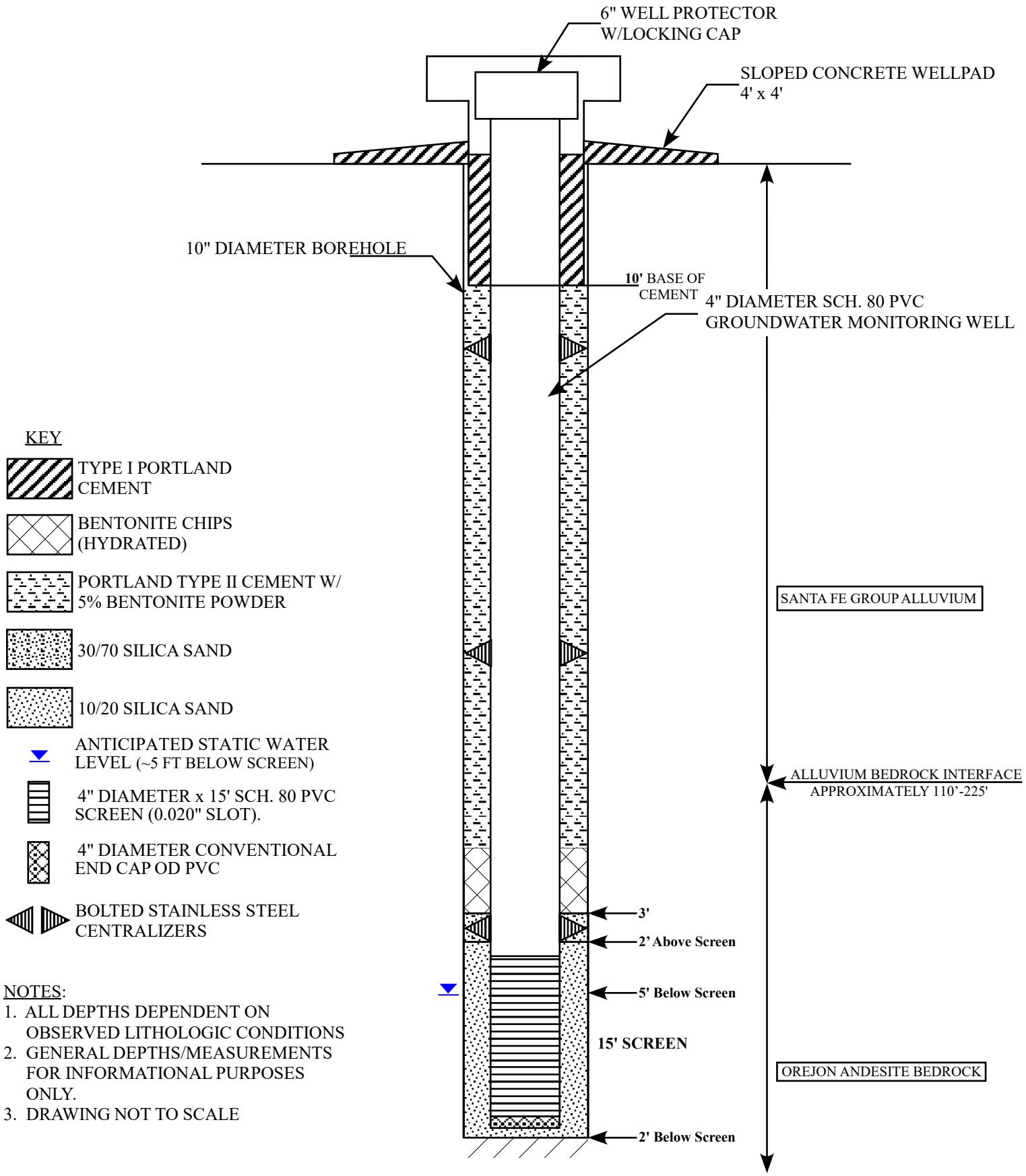

Fire Break Road
4920
4930
500-SB-01
500-SB-02
500-SB-03
500-SB-07
500-SB-08
500-SB-09 (Updated Location)
500-SB-10
500-SB-11
Current Alcohol Storage Area
Fuel Storage Area
500 Fuel Storage Area SWMU 47
Proposed Boring
Multiport Well
Conventional Well
MSVGM Well
Sump Drain Line
Distillation Pipe
Low-Point 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)



NOTES:
1. ALL DEPTHS DEPENDENT ON OBSERVED LITHOLOGIC CONDITIONS
2. GENERAL DEPTHS/MEASUREMENTS FOR INFORMATIONAL PURPOSES ONLY.
3. DRAWING NOT TO SCALE

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**				

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]
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)			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)					

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

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
www.nasa.gov/centers/wstf

www.nasa.gov

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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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National Aeronautics and Space Administration

500 Area Former Oxidizer Burner Investigation Work Plan

August 2022

Revised December 2023

NM8800019434

NASA Johnson Space Center White Sands Test Facility

500 Area Former Oxidizer Burner Investigation Work Plan

August 2022

Revised December 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

Johnson Space Center
White Sands Test Facility
12600 NASA Road
Las Cruces, NM 88012
www.nasa.gov/centers/wstf

www.nasa.gov

Executive Summary

The National Aeronautics and Space Administration (NASA) White Sands Test Facility (WSTF) is required by the WSTF Hazardous Waste and Resource and Recovery Act (RCRA) Permits issued by the New Mexico Environment Department NMED) to develop Investigation Work Plans (IWP) for solid waste management units (SWMU) at WSTF. The 500 Area Former Oxidizer Burner (FOB) was discovered during closure activities at the Fuel Treatment Unit (FTU). NASA notified the NMED in a letter dated October 16, 2019 that the former location of the FOB was a SWMU (NASA, 2019b). The notification was submitted within 15 days of discovery, in accordance with section VII.D of the then Permit (NMED, 2009, pp74-75). On November 13, 2019, NMED requested that additional information be provided in a release assessment report in accordance with Section V.II.F.1 of the then Permit (NMED, 2009, p75-76). NASA submitted the 500 Area Newly Identified SWMU Release Assessment Report (RAR) on June 22, 2020. On December 20, 2021, NMED approved the RAR and directed NASA to proceed with investigation of the reported release and submit an IWP to further evaluate the site in accordance with then Permit Section VII.F.2 (NMED, 2021), no later than August 31, 2022. This IWP is provided in accordance with NMED's directive and in conjunction with the Historical Information Summary as required by Section VII.H.1.c of the 2009 Permit (NMED, 2009, pp 78-79) and Section 3.10.2 of the 2023 Permit (NMED, 2023, p32).

This IWP describes field investigation activities that will be conducted at the 500 Area FOB for this investigation. Eleven proposed shallow soil borings will be advanced from ground surface to 5 feet (ft) in accordance with Permit requirements in Attachment 17 for shallow structures such as piping (NMED, 2009, p536). Two soil samples will be collected (from 0-1 ft and 4-5 ft intervals) for each boring. Samples will be analyzed for nitrate/nitrite by SW-846 Method 353.2 and soil pH by SW-846 Method 9045D as possible indicators of dinitrogen tetroxide release to soils.

NASA expects to initiate investigation fieldwork approximately three months after NMED approval of this IWP, complete fieldwork approximately one to three weeks following initiation, and complete and submit an investigation report to NMED approximately eight months following NMED approval of this IWP.

The use of trademarks or names of manufacturers is for accurate reporting and does not constitute an official endorsement either expressed or implied of such products or manufacturers by the National Aeronautics and Space Administration.

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List of Acronyms

ASTM	American Society for Testing and Materials
bgs	below ground surface
COPC	Contaminant of Potential Concern
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
FOB	Former Oxidizer Burner
ft	Feet
ft^2	Square feet
FTU	Fuel Treatment Unit
gal	Gallon
GPS	Global Positioning System
HAZWOPER	Hazardous Waste Operations and Emergency Response
HF	Hydrogen fluoride
HIS	Historical Information Summary
HSA	Hollow stem auger
Hz	Hydrazine
IWP	Investigation Work Plan
JDMB	Jornada del Muerto Basin
JSC	Johnson Space Center
MDL	Method Detection Limit
mg/Kg	Milligrams per kilogram
mm Hg	Millimeter of mercury
MMH	Monomethylhydrazine
N_2O_4	Dinitrogen tetroxide
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
NMED	New Mexico Environment Department
NO_2	Nitrogen dioxide
OOSA	Original Oxidizer Storage Area
OSHA	Occupational Safety and Health Administration
PDF	Portable document files
PID	Photoionization Detector
PPE	Personal Protective Equipment
PWCAA	Propellant Waste Central Accumulation Area
QA/QC	Quality Assurance and Quality Control
RA	Risk Assessment
RA Guidance	Risk Assessment Guidance
RAR	Release assessment report
RSL	Regional Screening Level
SAM	San Andres Mountains
SCEM	Site Conceptual Exposure Model
SCS	Soil Conservation Service
SDS	Safety Data Sheet
SHP	Safety and Health Plan
SOP	Standard Operating Procedure
SSL	Soil Screening Level

SWMU	Solid Waste Management Unit
TIVC	Total Ionizable Volatile Compounds
UDMH	Unsymmetrical dimethylhydrazine
USDA	United States Department of Agriculture
VOC	Volatile Organic Compounds
WMP	Waste Management Plan
WSTF	White Sands Test Facility

1.0 Introduction

The National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) White Sands Test Facility (WSTF) 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. Environmental Protection Agency (EPA) Facility Identification Number is NM8800019434.

NASA notified the New Mexico Environment Department (NMED) in a letter dated October 16, 2019 that the former location of the 500 Area Former Oxidizer Burner (FOB) was a newly identified solid waste management unit (SWMU; NASA, 2019b). The notification was submitted within 15 days of discovery, in accordance with section VII.D of the 2009 WSTF Resource Conservation and Recovery Act Hazardous Waste Permit (Permit; NMED, 2009, pp74-75). On November 13, 2019, NMED requested that additional information be provided in a release assessment report (RAR) in accordance with Section V.II.F.1 of the 2009 Permit (NMED, 2009, pp75-76). NASA submitted the 500 Area Newly Identified SWMU Release Assessment Report on June 22, 2020. On December 20, 2021, NMED approved the RAR and directed NASA to proceed with investigation of the reported release and submit an investigation work plan (IWP) to further evaluate the site in accordance with 2009 Permit Section VII.F.2 (NMED, 2021). The 2009 Permit required the preparation of IWPs to assess the potential impact of historical releases of hazardous waste or hazardous constituents. This IWP is provided in accordance with Section VII.F.2. and 3.8.3 of the 2009 and 2023 RCRA Permits, respectively (NMED, 2009, p76; NMED, 2023, p31). The following sections describe the approach for a planned investigation of the 500 Area FOB. Figure 1.2 shows the location of the FOB 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 contaminants of potential concern (COPC) in the vadose zone and potential migration pathways of contaminant releases to the soil in the area immediately adjacent to the 500 Area FOB. The investigation is described in this work plan accordingly and includes shallow soil sampling in 11 locations at the FOB and adjacent area. The scope of this investigation is limited to the vadose zone in the immediate area surrounding the FOB and specific to the known COPCs, determined by historical use of the FOB as identified in the Historical Information Summary (HIS) submitted concurrently with this IWP.

1.2 Regulatory Requirements

Permit sections VII and 1.3 (p1) requires NASA to conduct corrective action to address releases of hazardous waste or hazardous constituents from SWMUs and Areas of Concern at WSTF in accordance with the requirements of 40 CFR 264.101 (NMED, 2009, 2023). Further direction from NMED states "the required investigation work plan must propose soil sampling for identified contaminants of concern associated with the use of the FOB" (NMED, 2021, p2). In conjunction with submittal of IWPs, the Permits (Sections VII.H.1.c and 3.10.2) requires the submittal of a HIS to the NMED Hazardous Waste Bureau. This document is prepared in accordance with the current Permit and NMED direction and describes the work proposed for the investigation. Deviations from several specific Permit requirements for the purpose of this investigation are summarized in Appendix A.

1.3 Other Considerations

The 500 Area FOB is located within 1,500 feet (ft) of active fuel storage, oxidizer storage, and testing areas. Because of the nature of the COPCs potentially released at the FOB, NASA will only investigate

areas at and directly adjacent to the former burner and stack. Figure 1.3 shows adjacent 500 Area structures in relation to the FOB location. Due to its proximity to other active areas at WSTF, there may be periods during the investigation when field personnel will not be allowed access to the work area due to active testing or operations within the vicinity of the project site. NASA will make every attempt to anticipate and mitigate delays to the project schedule and will notify NMED if operations or test activities impact 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 to the extent possible.

2.0 Background

A brief description of the 500 Area FOB, a summary of historical information, a description of the preliminary site conceptual model, and a summary of previous investigations conducted within the 500 Area, near the FOB, are provided in this section. Additional details of historical operations at the unit are described in the 500 Area FOB HIS (NASA, 2022). The HIS provides a complete description of the FOB site use, waste management, and an assessment of known or potential releases of hazardous substances.

2.1 Operational History

2.1.1 500 Area Operational History

The 500 Area Original Oxidizer Storage Area (OOSA) was the initial storage area used during Apollo-era testing at WSTF. The OOSA was completed in 1964 with a 19,700-gallon (gal) tank used to store liquid oxidizer, specifically dinitrogen tetroxide (N_2O_4). This area included a cement secondary containment area below the oxidizer tank that drained into a gunite-lined open channel or trench into a containment basin adjacent to the storage area. This basin was a rectangular (50 ft by 75 ft exterior and 40 ft by 65 ft interior) gunite-lined ponding area designed for emergency secondary containment for the large tank. The open trench was 2 ft wide by 76 ft long. Between the oxidizer tank with secondary containment and the oxidizer containment basin was a concrete truck parking and oxidizer off-load area. The 500 Area OOSA was used during the Apollo testing at WSTF and ceased use between July 1 and September 30, 1973 (Dynalectron, 1973).

No spills were documented at the OOSA in WSTF spill logs (generated from 1985 to present). However, the HIS identified one spill during an oxidizer transfer from a transport truck to the large oxidizer tank during the Apollo testing in the 1960s. A spill to the truck loading pad concrete containment occurred because a valve was not closed completely. When the truck driver disconnected the transfer line, oxidizer sprayed on the driver (and in the transfer area). This spill area was on concrete, and there was no reported oxidizer spilled to soil. The oxidizer volatilized and evaporated. The amount spilled is unknown.

In 1979, NASA conducted two oxidizer tests, releasing approximately 250 gal and 70 gal of N_2O_4 to concrete in the 500 Area OOSA. The oxidizer immediately vaporized to nitrogen dioxide (NO_2) and dissipated. No other spills nor leaks were ever documented. In 1995, the 500 Area OOSA became part of the Fuel Treatment Unit (FTU). The oxidizer containment basin or ponding area remained abandoned outside the FTU fencing. There were never any reported or documented fuel leaks or spills at the OOSA. For a brief time between 1990 and 1993, hydrogen fluoride canisters were stored in the OOSA on the concrete off-load area. No hydrogen fluoride (HF) leaks or spills were documented or known by employees. No other substance was ever stored or used in the area. As part of FTU closure, the FTU structures (including concrete associated with the OOSA) and the gunite-lined trench and containment basin were removed in early 2019 and the area was graded level.

2.1.2 500 Area Former Oxidizer Burner and Vent Stack

An oxidizer burner and vent stack, along with the associated 500-gal propane tank, and control unit with cabling, were added to the 500 Area OOSA in 1965 (NASA, 1967a, pp2-3; 1994, p34-42). "The burner consists of an injector system for the propane and the nitrogen tetroxide, a mixing chamber, a burner head…, a spark-plug igniter system, and windshield" (NASA, 1967a, p2). The location of the 500 Area FOB was determined based on WSTF drawings, aerial photography, and locating the remaining concrete footings and steel stands in the field.

A vent stack at WSTF is a tall (approximately 20 ft) pipe-like structure that is part of the oxidizer burner system. The vent stack was designed to release to the atmosphere very small amounts of residual oxidizer vapors in the lines following oxidizer disposal/flaring by the burner. Like other oxidizer burners at WSTF, the 500 Area FOB burner was designed with a vent stack as well, located adjacent to the oxidizer burner (Figure 1.3). A historical photograph of the 500 FOB (in use) and the adjacent vent stack from 1967 is provided as Figure 1.4. The burner/vent stack system was used in the 500 OOSA to dispose of excess oxidizer until the large oxidizer tank was abandoned following the Apollo program work at WSTF in 1973.

As documented in the HIS (NASA, 2022, Appendix A), the 500 Area oxidizer burner system was moved to the 800 Area as part of establishing the 800 Area facility at WSTF in 1974. This coincides with the timing of 500 Area OOSA large oxidizer tank closure (between July and September 30, 1973; Dynalectron, 1973), providing further evidence that the 500 Area oxidizer burner was removed and reinstalled for use in the 800 Area. The 800 Area Oxidizer Burner is identified as SWMU 20 in Attachment 4, Table 4-122 of the WSTF Permit (NMED, 202309, 610).

When the 500 Area oxidizer burner and vent stack were removed and relocated to the 800 Area in 1974, the stands for the piping and the underground instrumentation/control cable were abandoned in place. The conduit for the cable is still visible at the former burner location and near Building 521.

2.2 Contaminant of Concern - Dinitrogen Tetroxide (N_2O_4)

The primary oxidizer used at WSTF from the inception of the site to present is dinitrogen tetroxide (N_2O_4). It is a strong oxidizing agent, has a high vapor pressure (1,551 millimeters of mercury [mm Hg]), a low boiling point (70.1° Fahrenheit [F] at 760 mm Hg), and a density greater than air (1.45 g/cm^3 at 68° F; U.S. National Library of Medicine, n.d.). Due to the low boiling point and high vapor pressure of N_2O_4, any potential oxidizer released would have become vapor and dissipated into the atmosphere.

N_2O_4 and NO_2 form a gas phase equilibrium, with N_2O_4 prevalent in the liquid phase and NO_2 prevalent in the gas phase. Vapors of NO_2 are reddish-brown in color and have been described as a "cloud" (NASA, 2010, pp2-3). With the highly corrosive nature of N_2O_4 (Terra Industries, 2011), any N_2O_4 or NO_2 present in soils would result in low (acidic) soil pH due to the formation of nitrous and nitric acids with rainwater. Soil pH would be expected to be much lower than 7.0. Nitrite (NO_2-) does not persist in soils; however, the ultimate fate of N_2O_4 is the formation of nitrates (NO_3-) with minerals in the soil (Gray and Yoffe, 1955, 1069-1154; Greene and McClure, 2014; Terra Industries, 2011). The Safety Data Sheet (SDS) for N_2O_4 is provided in Appendix C of the HIS (NASA, 2022).

Due to its rapid dissipation and breakdown, N_2O_4 analysis in soils is not practical. Nitrate is considered a byproduct COPC for this investigation as a possible indicator of N_2O_4 release to soils. Soil samples will be analyzed for COPCs using the analytical methods indicated:

- Nitrate/Nitrite – SW-846 Method 353.2

- Soil pH – SW-846 Method 9045D

2.3 500 Area Previous Investigations

2.3.1 500 Area FTU Closure

A soil investigation was conducted as part of closure activities for the FTU in 2019. Soil sampling was performed to confirm that no releases to the environment occurred at the FTU. Based on historical records, there were no releases from the FTU tanks or ancillary equipment to the environment. Two grids were placed over the concrete/secondary containment structure for the FTU to determine sampling frequency:

- A 16 ft x 16 ft (256 square feet [ft^2]) grid was placed over the loading/unloading zones, where FTU waste transfer activities occurred.
- A 22 ft x 22 ft (~500 ft^2) grid was placed over the surrounding concrete structure where no FTU waste transfer activities occurred.

As specified in 2009 Permit Section 11.3 (2009, pp8-9), a sample was collected every 250 ft^2 in the loading and unloading zones of the FTU pad, and a sample was collected every 500 ft^2 beneath the rest of the permitted unit. Shallow soil samples were taken at a depth of 0 to 1 ft below ground surface (bgs) within the grid. One sample location (500-SB-01) was sampled at intervals 5 ft, 15 ft, and 25 ft bgs beneath the location of the lowest point of the loading/unloading pad. Samples from 0 and 1 ft bgs were collected with a decontaminated shovel. The hollow stem auger drilling method was used to collect samples at 5 ft, 15 ft, and 25 ft bgs at the 500-SB-01 location. Figure 2.1 identifies the previous investigation sampling locations.

Analytical results from FTU closure soil sampling activities are provided in Appendix B and were previously provided to NMED in the 500 Area FTU Closure Certification Report (NASA, 2019). These results confirmed that there were no releases to the environment from the FTU Tank System and that FTU operations did not cause harm to the environment. Constituents of concern, hydrazine (Hz), monomethylhydrazine (MMH), and unsymmetrical dimethylhydrazine (UDMH), were not detected in any soil samples collected during FTU closure. The samples were analyzed using EPA Method 8315. The method detection limits for the analysis were 7.7 milligrams per kilogram (mg/kg) for Hz, 20 mg/kg for MMH, and 20 mg/kg for UDMH. Practical quantitation limits for the analysis were 10 mg/kg for Hz, 20 mg/kg for MMH, and 20 mg/kg for UDMH.

2.3.2 500 Area Fuel Storage

A three-phased soil investigation was conducted at the 500 Area Fuel Storage (SWMU 47) between July 2000 and May 2001 to evaluate concentrations of N-nitrosodimethylamine (NDMA), the common byproduct of hydrazine fuel oxidation and a current WSTF groundwater contaminant. The results of these investigations are shown in Appendix B and were previously provided to NMED in the 500 Area Fuel Storage Phase I IWP.

In Phase I, a backhoe was used to collect soil samples at depths of 5 ft and 10 ft bgs 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 hydrazine tank location; and to the north of the low-point drain line terminus termed “downgradient” (Figure 2.1). NDMA was detected at the 5 ft sampling interval at both the low-point drain line terminus (0.0253 mg/kg) and north of the tank location (maximum detected was 0.0049 mg/kg).

For Phase II, a hollow stem auger (HSA) 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 hydrazine tank location (Figure 2.1). NDMA was detected at two low-point terminus borings (all detected up to 30 ft bgs with a maximum detected concentration of 0.00117 mg/kg) and three borings north of the hydrazine tank (all detected up to 30 ft bgs with a maximum concentration of 0.0148 mg/kg).

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 hydrazine tank location (Figure 2.1). NDMA was detected at four low-point drain line terminus borings (all up to 50 ft with a maximum detected concentration of 0.00126 mg/kg) and four borings north of the hydrazine tank (two detected to 50 ft bgs with a maximum detected concentration of 0.00159 mg/kg).

2.4 Preliminary Site Conceptual Exposure Model

A preliminary site conceptual exposure model (SCEM) was developed to provide an understanding of the potential for exposure to hazardous constituents at the 500 Area FOB based on the source of contamination, the release mechanism, and the exposure pathways as these relate to residential, industrial/occupational, and construction worker exposure scenarios. Figure 2.2 summarizes and presents the SCEM in diagram form. Incomplete exposure pathways are denoted by lines with a diamond termination, and complete exposure pathways are denoted by solid lines with an arrow termination.

2.4.1 Contamination Sources

The 500 Area FOB was designed to release to the atmosphere very small amounts of residual oxidizer vapors following oxidizer disposal/flaring by the burner. Potential contamination sources could be a result of this venting process associated with the FOB. During this investigation, the areas directly associated with and adjacent to the FOB will be investigated to determine if any COPCs are present in the soil.

2.4.2 Release Mechanisms

Releases of liquid oxidizer/gaseous nitrogen dioxide from the burner were possible if the mixture was less than 1:1 ratio of propane to oxidizer (oxidizer-rich), if the operating procedure was not followed, or if equipment malfunctions. This would result in incomplete combustion of oxidizer, releasing to the atmosphere "such products as nitrogen dioxide, nitrogen tetroxide, nitric oxide, and nitrous oxide, in addition to the normal combustion products, could be found in the exhaust" (NASA, 1967a, p3).

Venting processes could have potentially released contamination to atmosphere and subsequently to surrounding surface soils due to its heavier than air density (Terra Industries, 2011). However, the volatility of N_2O_4 and the small amounts that were vented during each event, make it unlikely that N_2O_4 came in contact with soil. Potentially contaminated soil would be within close vicinity of the stack, if it is even present.

2.4.3 Exposure Pathways

The burner, stack, and associated piping have all been removed from the 500 Area and no longer have a direct vapor pathway component. Ingestion, inhalation of, and dermal contact with contaminated soil denote one possible exposure pathway. Due to the volatilization and breakdown to secondary nitrates, any extended presence of N_2O_4 in soil is highly unlikely and is not considered a completed pathway for soil

leachate of runoff to groundwater. The ultimate fate of N_2O_4 is the formation of nitrates with minerals in the soil (Gray and Yoffe, 1955, 1069-1154; Greene and McClure, 2014; Terra Industries, 2011).

2.4.4 Potential Receptors

Since any surficial soil contamination from the 500 Area FOB is open to environmental forces, wind could release soil to the air, and industrial workers driving or walking past the area could possibly breathe in potentially contaminated airborne soil. Construction work also provides a potential exposure scenario because the site is within the 500 Area industrial area and there is a potential for future growth or construction activities. Therefore, potential receptors for the 500 Area FOB include~~are~~ workers driving, walking, or working outside near the areas or conducting excavation or construction activities in the areas. In addition, non-burrowing and burrowing ecological receptors will also have potential exposure to soil through ingestion and dermal contact. The residential exposure scenario is incomplete at WSTF due to no receptors exposed to contaminated groundwater now and in the foreseeable future. However, when a health risk screening is completed for SWMU 54, residential receptors will also be assessed in accordance with the current version of the NMED RA Guidance (NMED, 2022).

3.0 Site Conditions

The 500 Area FOB is located northwest of the 500 Area cryogenic and inert gas storage and the 300 Area, northeast of the 400 Area, and southeast of the 500 Area Fuel Storage. It is located in Section 35 of Township 20 South, Range 3 East. Access to this area is provided by a paved road (Road P) that intersects Apollo Boulevard and ends at the 500 Area Fuel Storage. A topographic map of the 500 Area is provided in Figure 3.1.

3.1 Surface Conditions

Soil surface conditions at and near the FOB 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, p32-37) derived from the adjacent San Andres Mountains (SAM) 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 approximately 1 mile east of the FOB. The alluvial fan that houses the FOB 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 the FOB.

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 500 Area FOB is the Tencee-Nickel Association, Steep unit (United States Department of Agriculture [USDA] Soil Conservation Service [SCS], 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.

3.2 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 FOB have been inferred from seismic and in the adjacent 300, 400, and 700 Areas, well log data (Reynolds, 1988, pp1-11; Maciejewski, 1996, pp46-52).

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 the FOB. Based on adjacent areas, bedrock lithology in the vicinity of the FOB is expected to consist of Tertiary (Eocene or Oligocene) Orejon Andesite (Seager, 1981, p43) at approximate depths between 110 and 225 ft bgs.

3.2.1 Structure

Two styles of geologic deformation are present in the vicinity of the FOB. 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 the FOB, exposed along Bear Canyon, and defined by Seager (1981, p18) 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 the FOB. 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, p70).

3.2.2 Hydrogeology

Based on areas adjacent to the 500 Area, the aquifer in the vicinity of the FOB is likely hosted within the Tertiary andesite bedrock, typically at depths of between 116 ft bgs (monitoring well NASA 10) and 130 ft bgs (monitoring well 300-A-120 and 300-A-170). The nearest wells are shown on Figure 1.2. 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 FOB 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 FOB.

- Field investigation of shallow soil boring locations. These locations will be based on:
    - Information within the 500 Area FOB HIS
    - Information collected from previous investigations in the area.
    - Information identified in the field relative to any visible staining of soil or total ionizable volatile compounds (TIVC) detected using a portable photoionization detector (PID).
- Daily safety and health briefings.
- Field data and global positioning system (GPS) survey data collection.

- Field operations for collection, management, and shipment of soil 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 500 Area FOB.

4.1 Data Quality Objective Process

The investigation methodology was developed based on "Guidance on Systematic Planning Using the DQO [Data Quality Objectives] Process" (EPA, 2006) and the Corrective Action Site Investigations requirements of the then and current Permits (NMED, 2009, p78-79; ~~Section VII.H~~2023, pp34-35). The data acquisition plan (i.e., sampling design) is based on the DQO process and formulated to meet Permit requirements.

4.1.1 Problem Statement

The problem statement is summarized in the 2009 Permit (NMED, 2009, p78; 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 20, 2021 comment on NASA's June 22, 2020 500 Area Newly Identified SWMU Release Assessment Report, which stated that "at a minimum, the required investigation work plan must propose soil sampling for identified contaminants of concern associated with the use of the FOB."

4.1.2 Decision Statement and Alternative Actions

The primary decision is to determine the nature and extent of potential vadose zone contamination. Alternative actions for the decisions include:

- Complete a Health Risk Screening~~Assessment~~ and request ~~for~~ corrective action complete status for the 500 Area FOB.
- Consider a request for no further investigation for the 500 Area FOB.
- 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 are the primary inputs to the decision. COPCs for this investigation were identified in Section 2.2. This section provides four decision inputs for evaluation of COPCs in soil:

- Detailed information pertinent to the establishment and operational history of the 500 FOB as documented in the HIS for the FOB 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 soil screening levels (SSL) including human health risk and hazard screenings

using NMED SSL (NMED, 2022) and EPA's regional screening levels (RSL; May 2022) for analytes not listed in the NMED guidance. Results will also be compared with risk-based and maximum contaminant level-based SSLs protective of groundwater for identified complete exposure pathways, in accordance with the NMED Risk Assessment (RA) Guidance for Site Investigations and Remediation (RA Guidance; NMED, 2022, pp51-55).

- pH analysis, in conjunction with the presence of nitrates in soils, will be used as a degradation indicator to qualify the original presence of N_2O_4 in soils. Extreme acidic pH conditions (low pH) would potentially indicate past N_2O_4 presence in soils. Results will be compared to soil property estimates from the Soil Survey of White Sands Missile Range, New Mexico (USDA SCS, et al., 1976) and the for the type of soil in the 500 Area since no NMED SSL nor EPA RSL exist for pH values in soils.

4.1.4 Study Boundaries

The horizontal boundaries of the study represent a 50-ft radius extending from the FOB (Figure 4.1) based on operational standards for burners and vent stacks on site and the rapid dissipation or consumption by burning of N_2O_4. This investigation addresses the shallow vadose zone in accordance with Permit Attachment 17.2.2.b (NMED, 2009, p32) and 2023 Permit Section 4.2.3.1 (p46-47). The vertical boundary is limited to the upper 5 ft of the vadose zone in accordance with the Permit requirements for shallow structures and based on the historical use noted in the HIS.

4.1.5 Study Constraints

One primary constraint is related to operations and testing in nearby areas. The proximity of the project area to the active testing and test support facilities imposes logistical constraints. 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 investigation site. The Propellant Waste Central Accumulation Area (PWCAA) is currently located in the 500 Area adjacent to the FOB and is used to manage aqueous propellant waste generated throughout the facility. The PWCAA is operated in accordance with the conditions for exemption for a large quantity generator that accumulates hazardous waste (40 CFR 262.17). 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 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 this investigation, 11 shallow soil borings (500-FOB-01 through 500-FOB-11; Figure 4.1) are anticipated to be installed to a depth of 5 ft bgs in accordance with Attachment 17.2.2.b of the 2009 Permit (NMED, 2009, p32) and 2023 Permit Section 4.2.3.1 (NMED, 2023, pp46-47). The following sections discuss sampling tasks. Boring and sampling procedures are discussed in Section 5.0.

4.2.1 Soil Borings

The 11 soil borings are positioned to allow collection of samples that will characterize the vadose zone below and immediately adjacent to the FOB (Figure 4.1). Table 4.1 provides the rationale for soil boring placement. Three borings are specifically biased to locations related to the FOB (Figure 4.1): one boring is planned for the original location of the burner (500-FOB-01), one boring is planned for the original location of the stack (500-FOB-02), and one boring is planned near the elbow in the piping that was

interpolated from WSTF drawings and photographs (500-FOB-11). Due to the nature of the COPCs and the historical use of the FOB, no further location biases were determined and the ESRI Random Point Generator tool was used to determine the eight remaining boring locations. The circular, 50-ft radius study area is further broken down into four quadrants (NW, SW, NE, and SE). The random point generation was directed by considering the prevailing wind direction from west to east (Figure 4.1).

Soil borings proposed for the investigation are specifically designed to provide the information necessary to characterize the extent of potential vadose zone contamination. The soil borings will be installed to 5 ft bgs to characterize the potential soil contamination. The borings will be drilled in numerical order (Figure 4.1), or as close to numerical order as possible pending any possible project constraints. Adjustments to the numerical sequence may be made to install borings in a manner that minimizes any disruption of nearby operations or test support activities.

4.2.2 Sampling Design

The sampling design must fulfill the project DQOs, which requires contaminant concentration data from soil samples. Table 4.2 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 5 ft bgs as previously described. Based on boring experience in similar geological conditions during the 300, 400, and 600 Area Closure Investigations, NASA does not expect difficulty with the recovery of shallow soil samples during boring installation. NASA plans to collect samples over discrete intervals using a technically acceptable drilling method without the use of drilling fluids. Potential drilling methods are provided in Section 5.1 and will allow the collection 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, etc.).

To address project DQOs and exposure pathways, soil samples will be collected at the surface (0 to 1 ft), and the base (4 to 5 ft) of each boring. If continuous sampling methodology is not used for boring advancement, an additional sample for potential field screening and soils classification will be collected at 2.5 ft bgs to comply with soil sampling requirements outlined in the 2023 Permit (NMED, 2023). Sampling procedures are discussed in Section 5.0. Soil samples collected from the borings will be analyzed for the FOB COPCs, listed in Section 2. Table 4.2 summarizes planned soil samples, analytical methods, and field quality control samples.

5.0 Investigation Methods

This section addresses activities related to the acquisition and evaluation of field data. The drilling, sampling, and quality assurance/quality control (QA/QC) 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 without the use of drilling additives. Drilling methods will be considered based on capability of reaching the target depths, cost, and time. Proposed methods include auger, direct push, air-rotary, and

sonic. NASA also expects to consider the use of any technically acceptable drilling method proposed by potential drilling subcontractors.

5.2 Rig Access Procedures

Overhead lines, underground utilities, and equipment access to the FOB boring locations will be surveyed and evaluated following NMED approval of the proposed soil boring locations. A 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 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

A decontaminated split-barrel sampler, a coring device, or other method approved by NMED shall be used to obtain samples during the drilling of each boring in accordance with Section 17.2.2.b.ii, Soil and Rock Sampling, of the 2009 Permit (NMED, 2009, p33) and Section 4.2.3.3 of the 2023 Permit (NMED, 2023, p48). 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 500 Area FOB Waste Management Plan (WMP) in Appendix C.

The physical characteristics of the sediment (such as mineralogy, ASTM soil classification, moisture content, texture, color, presence of stains or odors, and/or field screening results), depth of samples, and other observations shall be recorded in the field log in accordance with Section 17.2.2.b.iii, Sediment Sampling, of the 2009 Permit (NMED, 2009, p34) and Section 4.2.4 of the 2023 Permit (NMED, 2023, pp49-50). Detailed logs will be completed by a qualified field scientist and reviewed by a qualified geologist for inclusion in the investigation report.

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 with a PID. The PID will be calibrated according to manufacturer's instructions.

Using the headspace method in accordance with 2009 Permit 17.2.2.d (NMED, 2009, p35) and 2023 Permit Section 4.2.5 (NMED, 2023, p50), 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. Each reading 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 Sample Containers, Volume, and Preservation

Appropriately prepared and preserved (if required) sample containers for soil samples will be provided by the contracted analytical laboratory. Chemical samples will be containerized and preserved according to the instructions provided by the analytical laboratory selected during the competitive procurement process to be completed following approval of this work plan.

5.3.4 Field Quality Control Samples

Field quality control samples will be collected as required in Attachment 17.2 of the 2009 Permit (NMED, 2009, p30) and Section 4.2 of the 2023 Permit (NMED, 2023, p45) to ensure high quality data are generated during the investigation ~~(NMED, 2009, p30)~~. Field quality control samples will be collected as indicated below.

- Field blanks will be collected for soil medium 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.

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 2009 Permit (NMED, 2009, p44) and 2023 Permit (NMED, 2023, p61). Laboratories considered to support this project must conduct all sample analysis quality assurance and quality control in accordance with 2009 Permit Section 17.3.1 (NMED, 2009, p45) and 2023 Permit Section 4.5.1 (NMED, 2023, 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 standard operating procedures (SOPs), 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 method detection limits (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. 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 Occupational Safety and Health Administration (OSHA) Standards for Hazardous Waste Operations and Emergency Response (HAZWOPER, 29 CFR 1910.120 [b] – [o]). The WSTF environmental contractor's Safety and Health Plan (SHP) will be augmented with site-specific Job Hazard Analyses to address potential hazards 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, 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.
- Personal protective equipment (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 COPCs).
- 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.
- 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 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 (e.g., PWCAA) 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]).

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.

6.0 Decontamination Procedures

All non-disposable equipment, including drilling equipment, must be decontaminated prior to commencement of investigation activities at WSTF. Sampler tooling will be decontaminated after completion of each sampling event, downhole tooling will be decontaminated between borings, and drilling equipment will be decontaminated prior to leaving the investigation site. General decontamination guidance available in ASTM International®[1] D5088-20 (ASTM, 2020) 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 boring 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 500 Area FOB Waste Management Plan provided in Appendix C. 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

[1] ASTM International is a registered trademark of American Society for Testing and Materials.

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

The following sections discuss the decontamination methods in accordance with general decontamination guidance available in ASTM International D5088-20 (ASTM, 2020).

6.2.1 Contamination Reduction

Drilling activities will be performed 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-gal 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 locations 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 handwashing the item with non-phosphate detergent such as Alconox®[2] 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.

6.2.3 Decontamination of Field Screening Instruments

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. Solid waste materials removed from the equipment and the wipes used will be disposed of as investigation-derived waste and managed as indicated in Appendix C.

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

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 2009 Permit Attachment 20 (p74; Section 20.2.13) and 2023 Permit Section 4.3.10 (NMED, 2023, p59), the Waste Management Plan is provided as Appendix C. The Waste Management Plan provides a description of the potential wastes that will be generated from the 500 Area FOB 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 portable document files (PDF) 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 (EPA, 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 (EPA, 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 (EPA, 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 (EPA, 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 500 Area FOB, 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~~NMED, 2023~~1~~). Groundwater samples are collected for the analysis of the following primary constituents: VOCs, 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 three months after NMED approval of this plan.

11.2 Field Investigation

Field activities for the initial investigation at the 500 Area FOB will be executed in the vicinity of active operation and 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 operations or testing that may be carried out in the 300, 400, and 500 Areas at this time, but 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 the 500 Area FOB is expected to be completed approximately one to three weeks after initiation. Unforeseen field conditions, such as access issues mentioned above impacting this schedule will be discussed with NMED.

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. The data will be evaluated as previously described; a process that typically requires up to two months. The results of the evaluations will be incorporated into a final report for submittal to NMED approximately eight months following NMED approval of this work plan. Unforeseen delays in the completion of field investigation activities or data evaluation that may adversely impact the completion of the report on this schedule 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 Map**

(SEE NEXT PAGE)

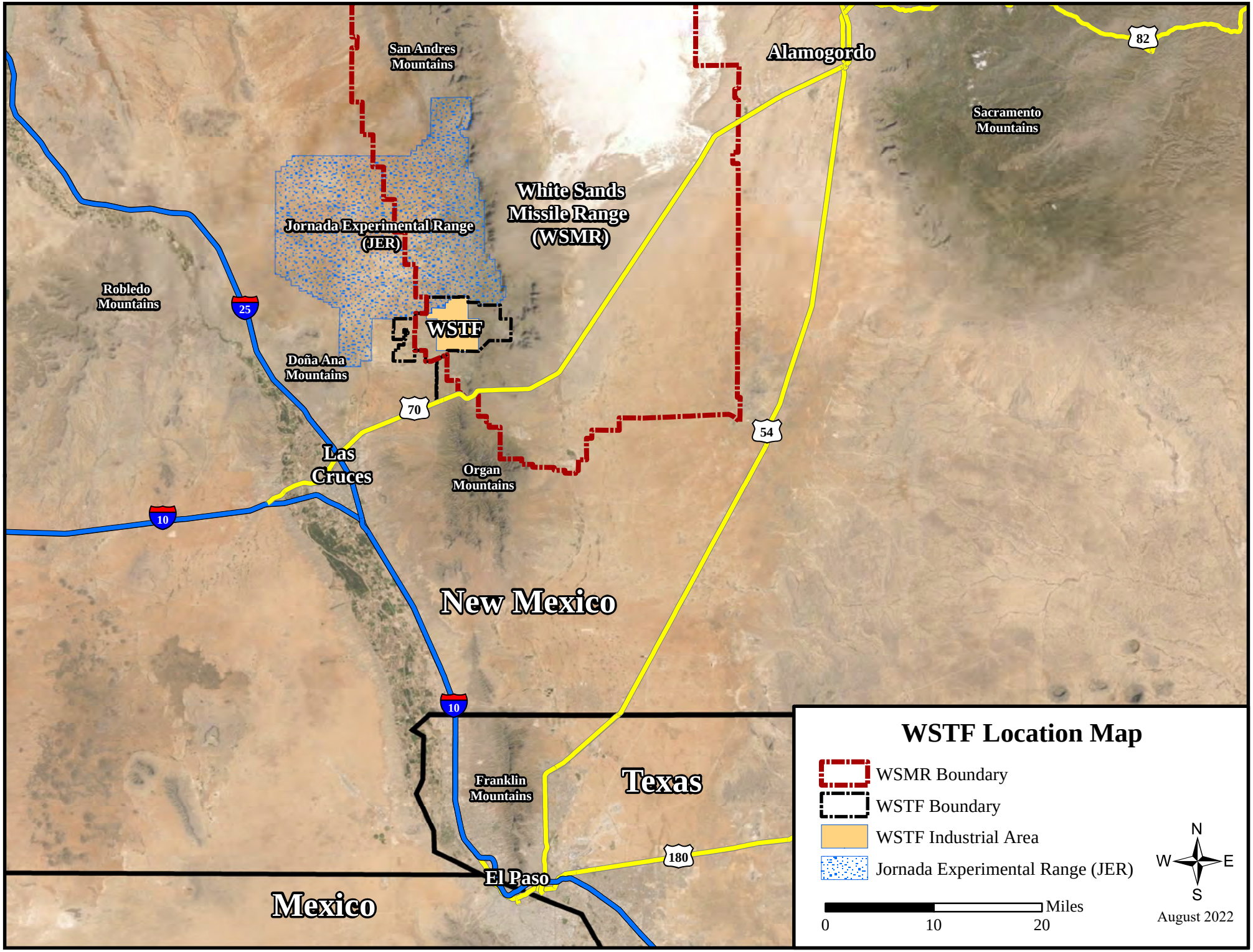

San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
WSTF Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
Miles
0
10
20
N
W
E
S
August 2022

Figure 1.2 500 Area FOB with Industrial Areas and Groundwater Wells

(SEE NEXT PAGE)

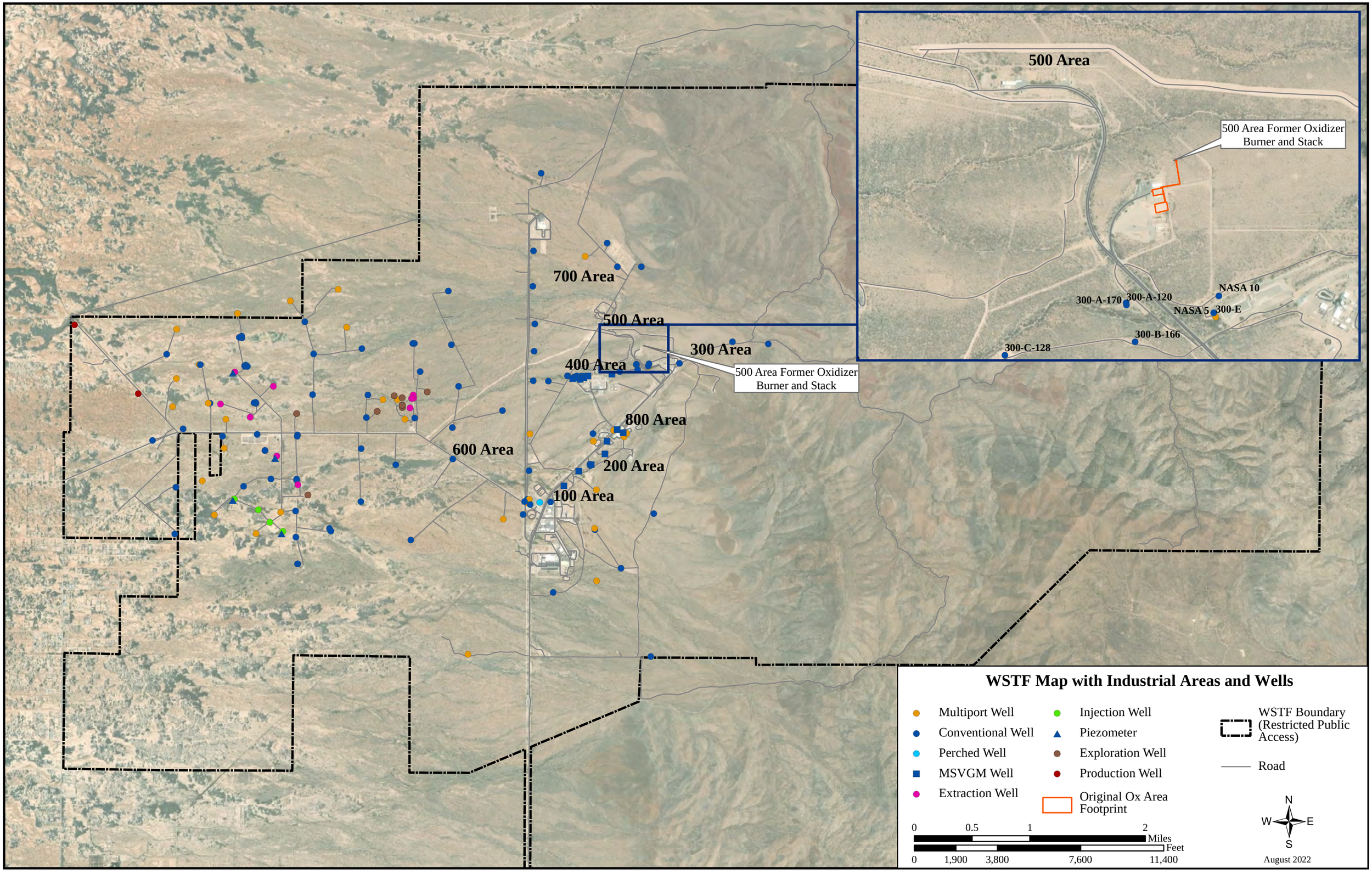

500 Area
500 Area Former Oxidizer Burner and Stack
300-A-170
300-A-120
NASA 10
NASA 5
300-E
300-B-166
300-C-128
700 Area
500 Area
300 Area
400 Area
500 Area Former Oxidizer Burner and Stack
800 Area
600 Area
200 Area
100 Area
WSTF Map with Industrial Areas and Wells
Multiport Well
Conventional Well
Perched Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
Original Ox Area Footprint
WSTF Boundary (Restricted Public Access)
Road
0 0.5 1 2
Miles
Feet
0 1,900 3,800 7,600 11,400
N
W
E
S
August 2022

Figure 1.3 **500 Area Structures Map**

(SEE NEXT PAGE)

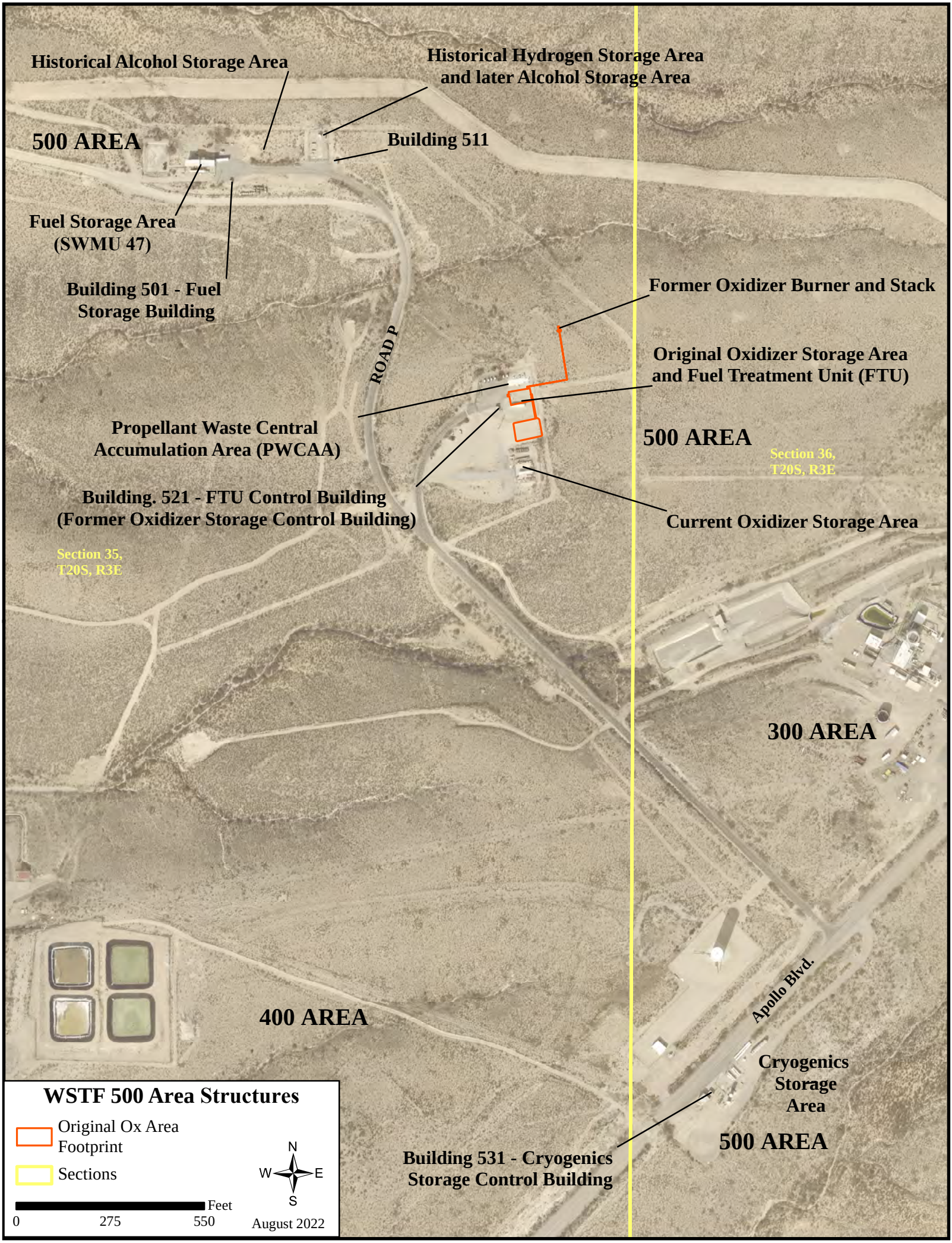
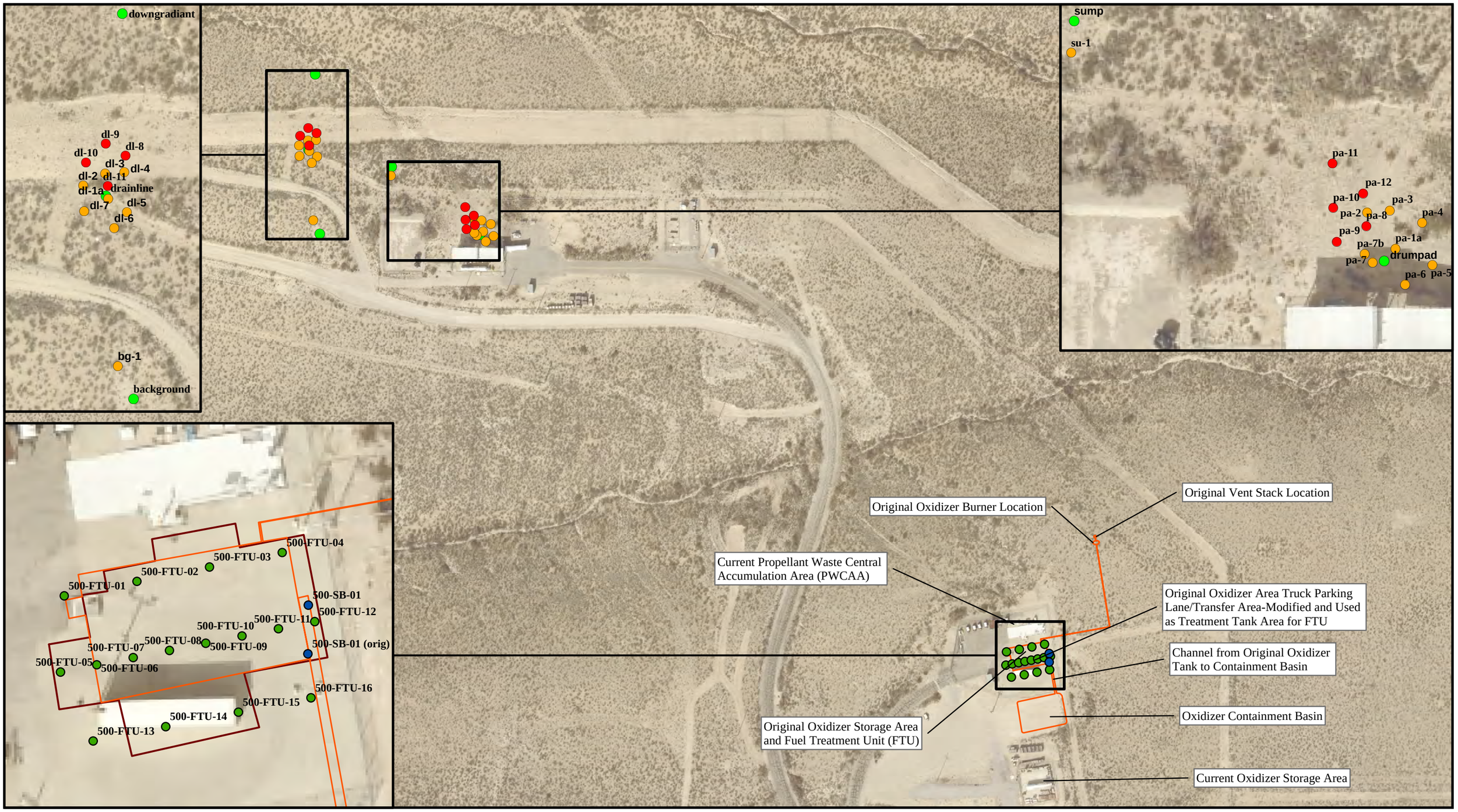

Historical Alcohol Storage Area
Historical Hydrogen Storage Area and later Alcohol Storage Area
500 AREA
Building 511
Fuel Storage Area (SWMU 47)
Building 501 - Fuel Storage Building
ROAD P
Former Oxidizer Burner and Stack
Original Oxidizer Storage Area and Fuel Treatment Unit (FTU)
Propellant Waste Central Accumulation Area (PWCAA)
500 AREA
Section 36, T20S, R3E
Building. 521 - FTU Control Building (Former Oxidizer Storage Control Building)
Current Oxidizer Storage Area
Section 35, T20S, R3E
300 AREA
400 AREA
Apollo Blvd.
Cryogenics Storage Area
500 AREA
Building 531 - Cryogenics Storage Control Building
WSTF 500 Area Structures
Original Ox Area Footprint
Sections
N
W
E
S
Feet
0
275
550
August 2022

Figure 1.4 500 Area Former Oxidizer Burner (1967) – view to the east

This photograph shows the 500 Area FOB in use and the adjacent vent stack in January 1967.

Figure 2.1 **500 Area Previous Investigations**

(SEE NEXT PAGE)



500 Area Previous Investigation Samples

- FTU Deep Soil Boring (25 ft)
- FTU Shallow Soil Boring (1 ft)
- FSA Phase I Samples
- FSA Phase II Samples
- FSA Phase III Samples
- Original Ox Area Footprint
- FTU Footprint

0 75 150 300 Feet

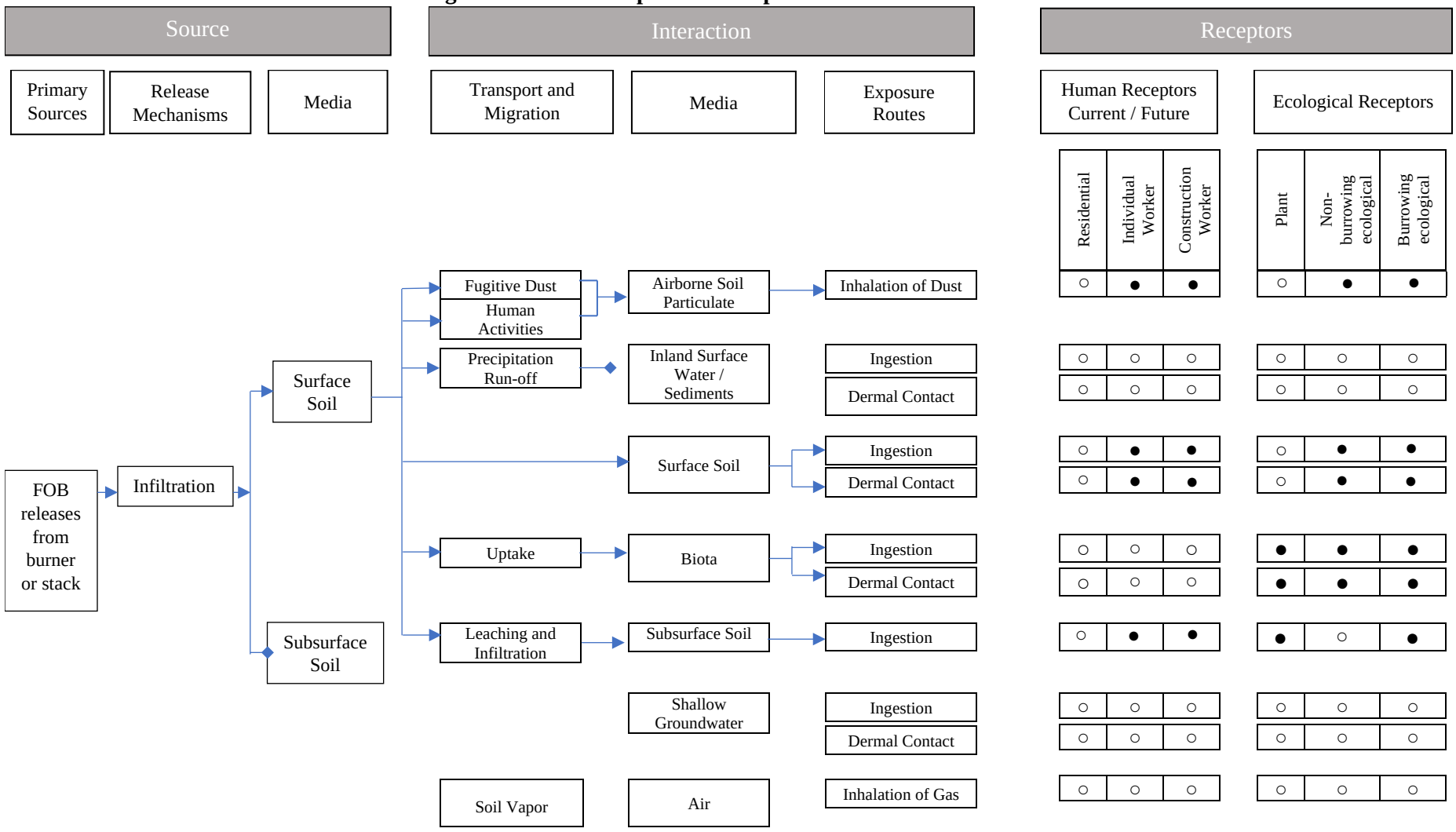
N W E S

August 2022

Figure 2.2 **Site Conceptual Exposure Model**

(SEE NEXT PAGE)

Figure 2.2 Conceptual Site Exposure Model Former Oxidizer Burner



LEGEND	
◆———	Flow-chart stops here; incomplete pathway
———►	Flowchart continues; potentially complete pathway
●	Potential pathway
○	Incomplete pathway

Figure 3.1 **Topographic Map**

(SEE NEXT PAGE)

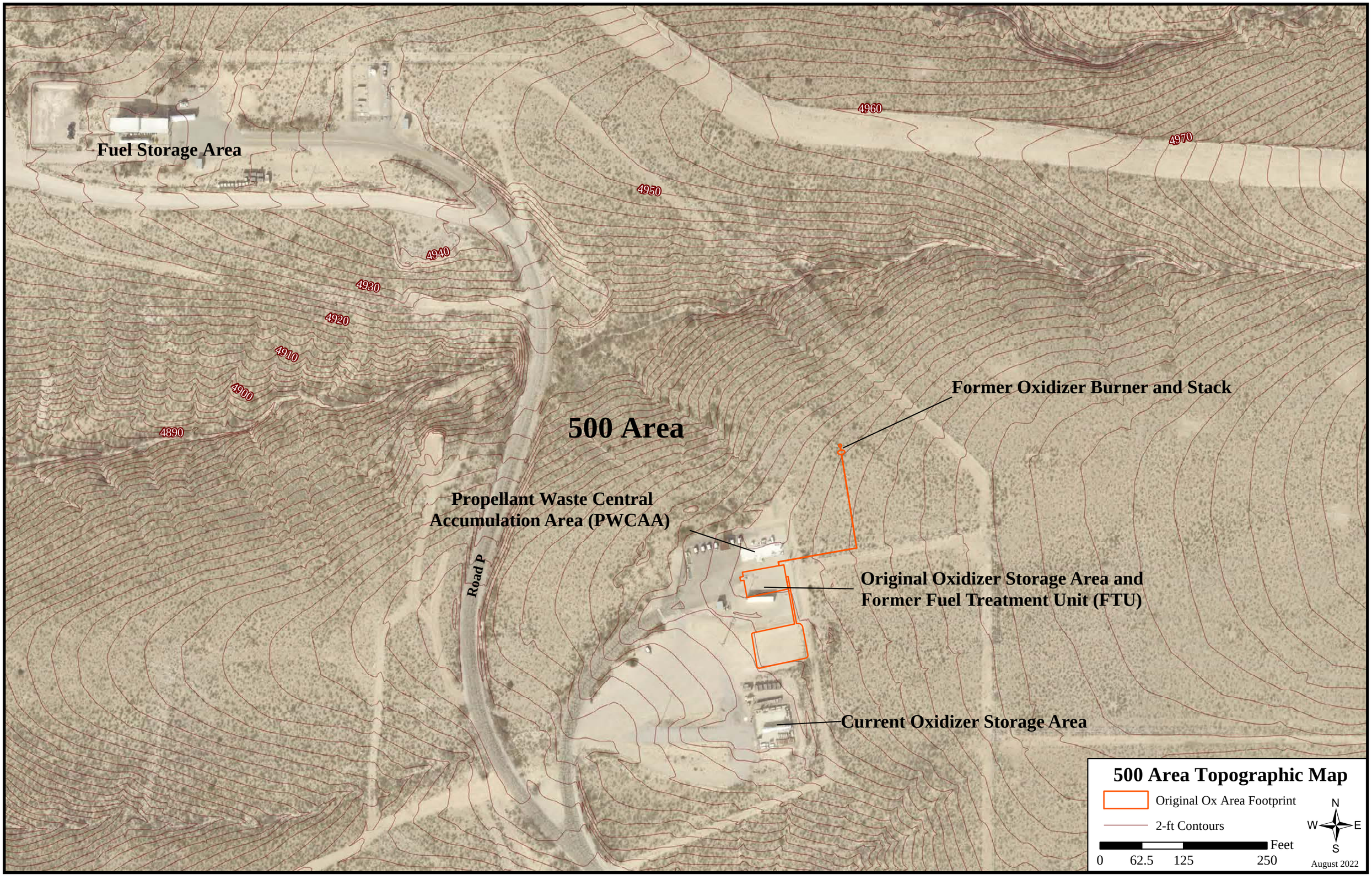

Fuel Storage Area
4960
4970
4950
4940
4930
4920
4910
4900
4890
500 Area
Former Oxidizer Burner and Stack
Propellant Waste Central
Accumulation Area (PWCAA)
Road P
Original Oxidizer Storage Area and
Former Fuel Treatment Unit (FTU)
Current Oxidizer Storage Area
500 Area Topographic Map
Original Ox Area Footprint
2-ft Contours
Feet
0
62.5
125
250
N
W
E
S
August 2022

Figure 4.1 500 Area Former Oxidizer Burner Proposed Sampling Locations

(SEE NEXT PAGE)

500-FOB-03
500-FOB-04
500-FOB-05
Original Vent Stack Location
500-FOB-02
Original Oxidizer Burner Location
500-FOB-10
500-FOB-01
500-FOB-07
500-FOB-08
500-FOB-06
500-FOB-09
500-FOB-11
Original Oxidizer Tank Location
Original Oxidizer Area Truck Parking Lane/Transfer Area-Modified and Used as Treatment Tank Area for FTU
Channel from Original Oxidizer Tank to Containment Basin
Oxidizer Containment Basin

500 Area Former Oxidizer Burner Proposed Sampling Locations

Proposed Shallow Borings
FOB Quadrants (50-ft Radius)
Original Ox Area Footprint
FTU Footprint

0 7.5 15 30 Feet

N W E S

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Tables

Table 4.1 Boring Rational

Proposed Boring ID	Proposed Well Location	Rational for Location
500-FOB-01	500 Area FOB burner location	Location is biased to the original location of the burner
500-FOB-02	500 Area FOB stack location	Location is biased to the original location of the stack
500-FOB-03	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, NE quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-04	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, NE quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-05	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, NE quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-06	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, SE quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-07	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, SE quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-08	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, SE quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-09	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, SW quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-10	500 Area FOB vicinity within a 50-ft Radius from the location of the Burner and Stack, NW quadrant	Location was randomly selected through ArcGIS random point generation
500-FOB-11	500 Area FOB vicinity of elbow location in removed above ground line oxidizer line.	Location is biased to the 90° elbow of the original pipeline (removed between 1973 and 1974) south of the burner and stack.

Table 4.2 Sampling and Analysis for the 500 Area FOB Investigation

Soil Boring ID [1]	Borehole Depth	Analytical Parameters	Sample Collection Summary			
			Soil Chemical[2]	Duplicates	Spikes	Blanks
500-FOB-01	5 ft	Nitrate/Nitrite and pH	**2**	Field Duplicate		Field, Rinsate, Trip
500-FOB-02	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-03	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-04	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-05	5 ft	Nitrate/Nitrite and pH	**2**		Matrix Spike	
500-FOB-06	5 ft	Nitrate/Nitrite and pH	**2**	Field Duplicate		
500-FOB-07	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-08	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-09	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-10	5 ft	Nitrate/Nitrite and pH	**2**			
500-FOB-11	5 ft	Nitrate/Nitrite and pH	**2**			
Maximum Sample Totals: Soil Chemical Parameters: Nitrate/Nitrite (22 samples) and pH (22 samples).			Sample Blank/Duplicate Totals: 1 x field blank per day (estimated 1-3 samples) 1 x Equipment blank per day (estimated 1-3 samples) Field Duplicates + Matrix Spikes Samples: Soil Chemical Parameters: Nitrate/Nitrite (2 + 1 samples) and pH (2 + 1 samples).			

Notes:

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

[2] Samples to be collected from 0-1 ft and 4-5 ft bgs. Anticipated order, preparation, and analytical methods: Nitrate/Nitrite – SW-846 Method 353.2 and soil pH – SW-846 Method 9045D.

Appendix A
Summary of Deviations

Investigation Work Plan Deviations

The 2009 and 2023 Permits indicate NASA shall explain omissions or deviations from the minimum reporting requirements included in the corresponding Permits ~~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, 2009, p78~~);~~ NMED, 2023, p34). According to the requirements established in 2009 Permit Attachment 20.2 and 2023 Permit Section 3.10.2 ~~Investigation Work Plan~~, this investigation work plan (IWP) fulfills the general requirements.

The 2009 and 2023 Permits provide~~s~~ a number of detailed requirements related to the IWP process aside from the reporting requirements in Attachment 20.2 and Section 3.10.2, respectively. Some of these requirements include, but are not limited to: drilling methods, sampling methods, chemical analysis, background data requirements, etc. (Attachment 17 [NMED, 2009] and Section 4 [NMED, 2023]~~;~~ ~~NMED, 2009)~~. 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.

Table A-1 Permit Requirements and Implementation in the IWP

Permit Specification		Implementation in IWP
2009 Permit 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.	IWP Section 5.1 Drilling will be conducted with methods selected to enhance the ability to collect representative soil samples, optimize the potential for completion of the borings without the use of drilling additives. Drilling methods will be considered based on capability of reaching the target depths, cost, and time. Proposed methods include auger, direct push, air-rotary, and sonic. NASA also expects to consider the use of any technically acceptable drilling method proposed by potential drilling subcontractors.
2023 Permit Section 4.2.3.3 and 4.2.3.1	(4.2.3.3) The use of an Encore® Sampler or other similar device is required during collection of soil samples for VOC analysis. (4.2.3.1) The Permit does not specify a specific drilling method for borings intersecting groundwater.	IWP Section 2.2 Soil samples will be analyzed for COPCs using the analytical methods indicated: • Nitrate/Nitrite – SW-846 Method 353.2 • Soil pH – SW-846 Method 9045D
2009 Permit Attachment 17.2.2.b.i and 2023 Permit	(Both Permits) 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.	IWP Section 4.0 Investigation activities will be conducted under the supervision of the site supervisor (a qualified engineer, environmental

Permit Specification		Implementation in IWP
Section 4.2.3.1		scientist, or geologist) or designated field lead.
2009 Permit Attachment 17.2.2.c and 2023 Permit Section 4.2.3.1	(Both Permits) Detailed logs of each boring shall be completed in the field by a qualified engineer or geologist.	IWP Section 5.3.1 Detailed logs will be completed by a qualified field scientist and reviewed by a qualified geologist for inclusion in the investigation report.
2009 Permit Attachment 17.2.2.d ~~and~~ ~~Attachment 17.2.2.d (cont.)~~ 2023 Permit Section 4.2.5	(2009 Permit) 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. (2023 Permit) The primary screening methods to be used shall include one or more of the following: (1) visual examination; (2) headspace vapor screening for volatile organic compounds; and (3) metals screening using X-ray fluorescence. Additional screening for site- or release-specific characteristics such as pH or specific compounds using field test kits shall be conducted where appropriate.	IWP Section 5.3.2 During borehole installation activities, soil vapors derived from soil samples will be analyzed via the headspace method for TIVC with a PID.
2009 Permit Attachment 17.2.2.g and 2023 Permit Section 4.2.8	(Both Permits) 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 FOB, monitoring of subsurface vapors is not planned for this investigation.
2009 Permit Attachment 17.2.2.i and 2023 Permit	(2009 Permit) Groundwater samples shall initially be obtained from newly installed monitoring wells between ten and 30 days after completion of well development.	Due to the nature of the site-specific COCs and available historical information on the FOB, Groundwater sampling is not planned for this investigation.

	Permit Specification	Implementation in IWP
Section 4.3.2	(2023 Permit) Groundwater samples shall initially be obtained from newly constructed monitoring wells no later than five days after the completion of well development.	
2009 Permit Attachment 20.2.11; Tables and 2023 Permit Section 6.2.11	(2009 Permit) …summary tables, if applicable, shall be included in the investigation work plans, if previous investigations have been conducted at the site (2023 Permit) The following tables shall be included in investigation work plans, as applicable: The Permit provides a list of ten types of historical information to be tabulated.	IWP Appendix C Previous investigation summary tables are provided in Appendix C instead of within the IWP Tables section.

References

NMED Hazardous Waste Bureau. (2009, November 3). *Hazardous Waste Permit No. NM8800019434* (modified December 2019). Santa Fe, NM.

NMED Hazardous Waste Bureau. (2023, March 28). *RCRA Permit EPA ID # NM8800019434*. Santa Fe, NM.

Appendix B
500 Area Summary Tables for Previous Investigations

Table B-1 FTU Closure Soil Analytical Data Summary

Sample Location	Sample ID	HZ Concentration (mg/kg)	MMH Concentration (mg/kg)	UDMH Concentration (mg/kg)
FTU-01	1904220835	<7.7	<20	<20
FTU-02	1904220853	<7.7	<20	<20
FTU-03	1904220900	<7.7	<20	<20
FTU-03 (Duplicate)	1904220901	<7.7	<20	<20
FTU-04	1904220907	<7.7	<20	<20
FTU-05	1904220914	<7.7	<20	<20
FTU-06	1904220922	<7.7	<20	<20
FTU-07	1904220929	<7.7	<20	<20
FTU-08	1904220936	<7.7	<20	<20
FTU-08 (Duplicate)	1904220936	<7.7	<20	<20
FTU-09	1904220945	<7.7	<20	<20
FTU-10	1904220957	<7.7	<20	<20
FTU-11	1904221009	<7.7	<20	<20
FTU-12	1904221024	<7.7	<20	<20
FTU-13	1904221315	<7.7	<20	<20
FTU-14	1904221323	<7.7	<20	<20
FTU-15	1904221336	<7.7	<20	<20
FTU-16	1904221346	<7.7	<20	<20
500-SB-1 (5'-7')	1904231205	<7.7	<20	<20
500-SB-1 (5'-7') (Duplicate)	1904231206	<7.7	<20	<20
500-SB-1 (15'-17')	1904231220	<7.7	<20	<20
500-SB-1 (25'-27')	1904231235	<7.7	<20	<20

Non-detect results are displayed as less than the analyte's detection limit
Hz Detection Limit: 7.7 mg/kg
MMH Detection Limit: 20 mg/kg
UDMH Detection Limit: 20 mg/kg

Table B-2 500 Fuel Storage Area Phase I Sampling Results

Sample ID	Sample Number	Depth (ft)	NDMA (mg/kg)	DMN (mg/kg)
Background	0007170840	5	< 0.0003	< 0.0003
Downgradient	0007170910	5	< 0.0003	< 0.0003
	0007170920	10	< 0.0003	< 0.0003
Drain Line	0007171000	5	**0.0253**	**0.0013**
	0007171020	10	< 0.0003	< 0.0003
Sump	0001711210	5	< 0.0003	< 0.0003
	0001711220	10	< 0.0003	< 0.0003
Drum Pad	0007171240	5	**0.0049**	**0.0012**
	0007171250	10	**0.0015**	**0.0005**

Unless otherwise indicated, the sample is a soil matrix.
Samples analyzed by Modified EPA Method 607.
Laboratory Control Sample Recovery (extraction efficiency) NDMA – 75%, DMN – 76%
Reporting Limit – 0.0003 mg/kg
Detection Limit – 0.0002 mg/kg

Table B-3 500 Fuel Storage Area Phase II Sampling Results

Sample ID	Sample Number	Depth (ft)	NDMA (ng/g)	DMN (ng/g)
BG-1	0012111440	1	< 0.00033	< 0.00033
SU-1	0012071209	2	< 0.00033	< 0.00033
	0012071217	5	< 0.00033	< 0.00033
	0012071333	13	< 0.00033	< 0.00033
	0012071409	20	< 0.00033	< 0.00033
DL-1	0012071533	1	< 0.00033	< 0.00033
	0012071615	6	< 0.00033	< 0.00033
	0012071633	10	**0.00018 J**	< 0.00033
	0012080926	20	**0.00069**	< 0.00033
	0012080928	20 Dup	**0.00060**	< 0.00033
	0012081010	30	**0.00021 J**	< 0.00033
DL-2	0012081116	5	< 0.00033	< 0.00033
	0012081132	10	< 0.00033	< 0.00033
	0012081154	20	< 0.00033	< 0.00033
	0012081226	30	< 0.00033	< 0.00033
DL-3	0012081406	5	< 0.00033	< 0.00033
	0012081418	10	< 0.00033	< 0.00033
	0012081446	20	**0.00088**	< 0.00033
	0012081512	30	**0.00117**	< 0.00033
DL-4	0012081542	5	< 0.00033	< 0.00033
	0012081544	5 Dup	< 0.00033	< 0.00033
	0012081608	10	< 0.00033	< 0.00033
	0012081630	20	< 0.00033	< 0.00033
	0012081656	30	< 0.00033	< 0.00033
DL-5	0012090840	5	< 0.00033	< 0.00033
	0012090850	10	< 0.00033	< 0.00033
	0012090910	20	< 0.00033	< 0.00033
	0012090940	30	< 0.00033	< 0.00033
DL-6	0012091040	5	< 0.00033	< 0.00033
	0012091042	5 Dup	< 0.00033	< 0.00033
	0012091050	10	< 0.00033	< 0.00033
	0012091210	20	< 0.00033	< 0.00033
	0012091234	30	< 0.00033	< 0.00033
DL-7	0012091420	5	< 0.00033	< 0.00033
	0012091428	10	< 0.00033	< 0.00033
	0012091450	20	< 0.00033	< 0.00033
	0012091508	30	< 0.00033	< 0.00033
PA-1	0012091610	1	< 0.00033	< 0.00033
	0012091620	5	< 0.00033	< 0.00033
	0012091654	10	**0.0148**	**0.00151**
	0012100900	20	**0.0137**	**0.00076**

Sample ID	Sample Number	Depth (ft)	NDMA (ng/g)	DMN (ng/g)
	0012100950	30	**0.00792**	**0.00033 J**
	0012100952	30 Dup	**0.00741**	**0.00029 J**
PA-2	0012101032	5	**0.00175**	< 0.00033
PA-2	0012101040	10	**0.00213**	< 0.00033
	0012101250	20	**0.00108**	< 0.00033
	0012101316	30	**0.00019 J**	< 0.00033
PA-3	0012101430	5	< 0.00033	< 0.00033
	0012101440	10	< 0.00033	< 0.00033
	0012101500	20	< 0.00033	< 0.00033
	0012101536	30	< 0.00033	< 0.00033
PA-4	0012110828	5	< 0.00033	< 0.00033
	0012110840	10	< 0.00033	< 0.00033
	0012110910	20	< 0.00033	< 0.00033
	0012110944	30	< 0.00033	< 0.00033
PA-5	0012111030	5	< 0.00033	< 0.00033
	0012111040	10	< 0.00033	< 0.00033
	0012111042	10 Dup	< 0.00033	< 0.00033
	0012111101	20	< 0.00033	< 0.00033
	0012111200	30	< 0.00033	< 0.00033
PA-6	0012111402	5	< 0.00033	< 0.00033
	0012111408	10	< 0.00033	< 0.00033
	0012111450	20	< 0.00033	< 0.00033
	0012111530	30	< 0.00033	< 0.00033
PA-7	0012120816	5	**0.00116**	**0.00030 J**
	0012120830	10	**0.00032 J**	< 0.00033
PA-7B	0012121110	20	**0.00066**	< 0.00033
	0012121112	20	**0.00066**	< 0.00033

Unless otherwise indicated, the sample is a soil matrix.
Samples analyzed by Modified EPA Method 607.
Laboratory Control Sample Recovery (extraction efficiency) ranged from NDMA = 79-113%, DMN = 54-81%
Reporting Limit – 0.00033 mg/kg
Detection Limit – 0.17 mg/kg
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.

Table B-4 500 Fuel Storage Area Phase III Sampling Results

Sample ID	Sample Number	Depth (ft)	NDMA (ng/g)	DMN (ng/g)
BG-1	0105071340	1	< 0.00033	< 0.00033
DL-8	0105071130	5	< 0.00033	< 0.00033
	0105071140	10	< 0.00033	< 0.00033
	0105071215	20	< 0.00033	< 0.00033
	0105071250	30	**0.00027 J**	< 0.00033
	0105080820	40	**0.00046**	< 0.00033
DL-9	0105081020	5	< 0.00033	**0.00466**
	0105081040	10	**0.00037**	< 0.00033
	0105081150	30	**0.00126**	< 0.00033
	0105081315	40	**0.0058**	< 0.00033
	0105081545	50	**0.0034**	< 0.00033
DL-10	0105091010	5	< 0.00033	< 0.00033
	0105091015	5 Dup	< 0.00033	< 0.00033
	0105091025	10	< 0.00033	< 0.00033
	0105091050	20	< 0.00033	< 0.00033
	0105091115	30	< 0.00033	< 0.00033
	0105091145	40	< 0.00033	< 0.00033
	0105091245	50	**0.0017 J**	< 0.00033
DL-11	0105091500	5	< 0.00033	< 0.00033
	0105091515	10	< 0.00033	< 0.00033
	0105091550	20	**0.00043**	< 0.00033
	0105091630	30	**0.00052**	< 0.00033
	0105091730	40	**0.00093**	< 0.00033
	0105091735	40	**0.00085**	< 0.00033
	0105091820	45	**0.00048**	< 0.00033
PA-8	0105100920	5	< 0.00033	< 0.00033
	0105100940	10	**0.00057**	< 0.00033
	0105101010	20	**0.00080**	< 0.00033
	0105101050	30	**0.00110**	< 0.00033
	0105101140	40	< 0.00033	< 0.00033
	0105101240	50	**0.00048 T**	< 0.00033 T
PA-9	0105101505	5	< 0.00033 T	< 0.00033 T
	0105101520	10	< 0.00033 T	< 0.00033 T
	0105101550	20	< 0.00033 T	< 0.00033 T
PA-10	0105110845	5	< 0.00033 T	< 0.00033 T
	0105110905	10	< 0.00033 T	< 0.00033 T
	0105110907	10 Dup	< 0.00033 T	< 0.00033 T
	0105110935	20	< 0.00033 T	< 0.00033 T
	0105111035	32	< 0.00033 T	< 0.00033 T
	0105111120	40	< 0.00033 T	< 0.00033 T
	0105111235	50	**0.00018 J**	< 0.00033

Sample ID	Sample Number	Depth (ft)	NDMA (ng/g)	DMN (ng/g)
PA-11	0105111430	5	**0.00081**	< 0.00033
	0105111500	10	**0.00057**	< 0.00033
	0105111545	20	**0.00159**	< 0.00033
PA-11	0105151400	30	**0.00021 J**	< 0.00033
	0105151530	40	< 0.00033	< 0.00033
	0105151610	50	< 0.00033	< 0.00033
	0105151612	50 Dup	< 0.00033	< 0.00033
PA-12	0105151800	5	< 0.00033	< 0.00033
	0105151815	10	**0.00091**	< 0.00033
	0105151835	20	**0.00092**	< 0.00033
	0105151905	30	< 0.00033	< 0.00033
	0105161105	40	< 0.00033	< 0.00033
	0105161205	50	< 0.00033	< 0.00033

Unless otherwise indicated, the sample is a soil matrix.
Samples analyzed by Modified EPA Method 607.
Laboratory Control Sample Recovery (extraction efficiency) ranged from NDMA = 90-167%, DMN = 86-153%
Reporting Limit – 0.00033 mg/kg
Detection Limit – 0.00017 mg/kg
BG – Background; 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.

Appendix C
500 Area Former Oxidizer Burner Waste Management Plan

500 Area Former Oxidizer Burner Waste Management Plan

1.0 Introduction

The National Aeronautics and Space Administration (NASA) will perform an investigation of the 500 Area Former Oxidizer Burner (FOB) at the Johnson Space Center (JSC) White Sands Test Facility (WSTF), in accordance with the 500 Area FOB Investigation Work Plan (IWP; NASA, 2022). The purpose of this waste management plan is to determine if any possible residual contamination exists above regulatory limits in the soils surrounding the FOB due to activities conducted at the FOB. Based on waste characterization, NASA will select an appropriate disposal pathway for the investigation-derived waste (IDW) generated during this investigation.

The IWP was developed in accordance with the requirements of ~~Section VII.H of the WSTF Hazardous Waste Permit (Permit; NMED, 2009)~~Section 3.10 of the Resource Conservation and Recovery Act (RCRA) Permit (NMED, 2023, p34), which requires the methods and procedures for characterization and remediation sample collection and analysis to be discussed. Permit Section ~~VII.H.1.b~~3.10.1 also requires the IWP to be prepared in general accordance with the requirements of Permit ~~Attachment 20~~Section 6.2, ~~Reporting Requirements~~ (NMED, 2023, p86~~09~~). Permit ~~Attachment 20~~Section 6.2 requires IDW management to be discussed in an appendix of IWPs. This Waste Management Plan satisfies these requirements for IWPs developed in accordance with the Permit by providing waste characterization, waste management, and anticipated waste disposal activities associated with the planned IWP activities at the 500 Area FOB.

2.0 Waste Identification and Generation Activity Description

In accordance with the IWP NASA plans to install soil borings at depths of 0 to 1 foot (ft) and 4 to 5 ft below the ground surface at 11 locations, or at a depth approved by the New Mexico Environment Department (NMED) and collect soil chemical samples for analysis. The borings will be installed with a power auger. All implements contacting the soil (environmental media) will be decontaminated prior to use, and between boreholes, and after completion of the investigation. The specific IDW expected to be generated during IWP activities include:

- Contaminated environmental media. consisting of soil cuttings from the vadose zone generated during borehole installation and sampling process.
- Decontamination fluids. Decontamination fluids such as water and soap solutions used to wash and decontaminate equipment that has contacted potentially contaminated soil and drill cuttings.
- Contact waste. Contact waste, or debris, such as used disposable sampling equipment, personal protective equipment (PPE), plastic sheeting, and other debris generated during investigation activities which have been contacted by contaminated soil or fluids.
- Petroleum Contaminated Debris and Environmental Media. Debris such as rags and wipes may be contaminated with petroleum products during routine drilling equipment maintenance. While every precaution will be taken, petroleum contaminated environmental media may also be generated during an unexpected drilling equipment failure. The petroleum contaminated debris and environmental media will be characterized as hazardous waste with the D018 hazardous waste code.

As a best management practice, NASA will conduct a preliminary waste characterization determination for the IDW anticipated to be generated based on acceptable knowledge and information obtained from the 500 Area FOB Historical Information Summary (HIS; NASA, 2022).

3.0 Waste Characterization

Based on review of the 500 Area FOB IWP and HIS (NASA, 2022) the contaminants of potential concern (COPC) are dinitrogen tetroxide (CAS No. 105-44-6) and nitrogen dioxide (CAS No. 10102-44-0). The chemical derivatives resulting from environmental decomposition of COPC are nitrogenous compounds. The environmental media waste does not exhibit the characteristics of a hazardous waste described in 40 CFR §261.21 and §261.24. The COPC as described in the release mechanisms section of the 500 Area IWP are newly generated waste byproducts from incomplete combustion, and therefore are not considered a pure, unused commercial chemical products. As such, the COPC and their nitrogenous derivatives are not contaminants listed under 40 CFR 261, Subpart D.

The environmental fate of the COPC can also result in adjustments to the physical parameter of pH, potentially creating acidic soil conditions. NASA also acknowledges that nitrogenous compounds may be present in the in-situ soils surrounding the 500 Area FOB. NASA investigated another FOB location in the 800 Area and reported the investigation findings to NMED in the *Response to Disapproval of Revised SWMU 19 (800 Area Below Grade Storage Tank) Investigation Report* (NASA, 2019). The pH values of the soil from this investigation were comparable to the soil property estimates for the given soil type in the Area of Interest where the 800 Area oxidizer burner was formerly located and exhibited no indication of an acidic soil condition. The nitrate analytical results were measured between 0.44 to 5.8 mg/kg, and nitrite were not detected in the samples collected.

The contaminated environmental media and decontamination fluids will be managed as a non-hazardous solid waste. Characterization samples for the contaminants of concern will be collected from the as-generated waste prior to proper disposal. The as-generated saturated drill cuttings will be sampled, and analytical data used to further characterize the waste. Waste characterization samples will be analyzed by the most current methods for soil nitrate and nitrite of SW-846 Method 300.0/ 353.2, soil pH by SW-846 Method 9040/ 9045, and Total Kjeldahl Nitrogen by EPA Method 351.2.

4.0 Waste Management

Drill cuttings, decontamination fluids, and contact waste generated during this project will be managed as non-hazardous solid waste in accordance with Title 20 Chapter 9 of the New Mexico Administrative Code. The as-generated drill cuttings will be containerized in intermediate bulk containers or other Department of Transportation (DOT)-compliant containers. Decontamination fluids generated during decontamination of equipment will be accumulated in appropriately sized containers that may include drums, intermediate bulk, or tanker trailer containers. Contact waste generated during drilling activities will be collected at the end of each working shift and transferred to an appropriate container.

Debris that may have come into contact with petroleum-based oils or fuels and any petroleum contaminated media will be managed as hazardous waste in accordance with 20.4.1.300 NMAC, 40 CFR 262.15, and 40 CFR 262.17.

The anticipated IDW will be managed and accumulated as follows:

- Used personal protective equipment, plastic sheeting, and other debris will be containerized in

DOT-compliant drums or bulk containers (roll-offs, Super Sacks[1], or similar).

- Soils, cuttings, generated during drilling and sampling will be containerized in DOT compliant drums or bulk containers (roll-offs, Super Sacks, or similar).
- Decontamination fluids, muddy water, etc. will be containerized in DOT compliant drums.
- Wastes typically associated with equipment maintenance (e.g., grease, contaminated rags, oil, WD-40®[2], diesel, soil contaminated with hydraulic fluids, etc.) may also be generated and will be managed as a hazardous waste.

5.0 Waste Disposal

Final characterization will be conducted prior to proper disposal. All non-hazardous solid waste will be managed and disposed of in accordance with the New Mexico Solid Waste Rules (~~Resource and Recovery Act [~~RCRA~~]~~ Subtitle D). Drill cuttings will be land applied within the vicinity of the 500 Area FOB footprint and will be recorded with a memo to file documenting the disposal location. Contact waste will be disposed at a properly permitted solid waste disposal facility. Aqueous decontamination fluid will be discharged to the WSTF sanitary sewer, in accordance with significant user wastewater discharge permit, or shipped off-site for proper disposal.

Petroleum contaminated debris and contaminated media will be characterized, managed, and disposed as a hazardous waste. NASA does not anticipate the as-generated drill cuttings contain listed hazardous waste or exhibit characteristics of a hazardous waste. If final waste characterization analytical results indicate the presence of hazardous constituents, the waste will be managed as a hazardous solid waste in accordance with 20.4.1.300 NMAC incorporating 40 CFR 262.15 and 40 CFR 262.17. For waste that is characterized as hazardous waste, land disposal restriction notifications, disposal facility profiles, and hazardous waste manifests will be completed as required. Hazardous waste manifested off-site will be transported for treatment and disposal at a permitted RCRA TSDF within the applicable regulatory time limits. Waste characterization and disposal records will be retained in accordance with WSTF procedures that follow state and federal regulations.

6.0 References

NASA Johnson Space Center White Sands Test Facility. (2019, June 27). *Response to Disapproval of Revised SWMU 19 (800 Area Below Grade Storage Tank) Investigation Report*. Las Cruces, NM.

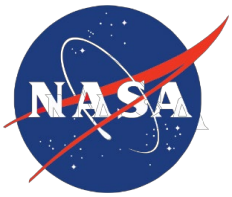
NASA Johnson Space Center White Sands Test Facility. (2022, August). *500 Area Former Oxidizer Burner (SWMU 54) Investigation Work Plan (IWP) and Historical Information Summary (HIS)*. Las Cruces, NM.

~~NMED Hazardous Waste Bureau. (2009, November 3). *Hazardous Waste Permit No. NM8800019434 (modified December 2019). Santa Fe, NM.*~~NMED Hazardous Waste Bureau. (2023, March 28). *RCRA Permit EPA ID # NM8800019434*. Santa Fe, NM.

Solid Waste Management General Requirements, New Mexico Environmental Improvement Board, 20.9.2 NMAC (8-2-07).

[1] Super Sack is a registered trademark of Better Agricultural Goals Corporation DBA/ B.A.G. Corp.
[2] WD-40 is a registered trademark of WD-40 Manufacturing Company.

National Aeronautics and Space Administration



500 Area Former Oxidizer Burner

Historical Information Summary

August 2022

Revised December 2023

NM8800019434

Executive Summary

This Historical Information Summary (HIS) provides information regarding historical site operations, facilities, hazardous chemical use, and waste management practices related to the 500 Area Former Oxidizer Burner (FOB) at the National Aeronautics and Space Administration (NASA) White Sands Test Facility (WSTF). The FOB was discovered during closure activities at the Fuel Treatment Unit (FTU). NASA notified the New Mexico Environment Department (NMED) in a letter dated October 16, 2019 that the former location of the FOB was a SWMU (NASA, 2019). The notification was submitted within 15 days of discovery, in accordance with section VII.D of the then Permit (NMED, 2009, pp74-75). On November 13, 2019, NMED requested additional information be provided in a release assessment report in accordance with the Section V.II.F.1 of the then Permit (NMED, 2009, pp75-76). NASA submitted the 500 Area Newly Identified SWMU Release Assessment Report on June 22, 2020. On December 20, 2021, NMED approved the RAR and directed NASA to proceed with investigation of the reported release. No later than August 31, 2022, NASA was required to submit an investigation work plan to further evaluate the site in accordance with then Permit Section VII.F.2., Requirement to Proceed (NMED, 2009, p76). This HIS is provided in conjunction with the Investigation Work Plan in accordance with Section VII.H.1.c of the 2009 Permit (NMED, 2009, pp 78-79) and Section 3.10.2 of the 2023 Permit (NMED, 2023, p32).

The objective of this HIS is to identify any known or potential releases of hazardous waste or hazardous substances to the environment related to the 500 Area FOB in preparation for the investigation work plan. NASA reviewed historical documentation, reports, photographs, and interviewed both retired and long-term site employees to understand the historical management and waste management practices related to the 500 Area FOB and determine the nature and timeframes of any releases.

The use of trademarks or names of manufacturers is for accurate reporting and does not constitute an official endorsement either expressed or implied of such products or manufacturers by the National Aeronautics and Space Administration.

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List of Acronyms

amsl	Above mean sea level
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
DOD	Department of Defense
ETU	Evaporative Tank Unit
FOB	Former Oxidizer Burner
FSA	Fuel Storage Area
ft	Feet
FTU	Fuel Treatment Unit
gal	Gallon
HIS	Historical Information Summary
IPA	Isopropyl alcohol
IWP	Investigation Work Plan
JDMB	Jornada del Muerto Basin
JER	Jornada Experimental Range
mi	Mile
mm Hg	Millimeter of mercury
MMH	Monomethylhydrazine
MSDS	Material Safety Data Sheet
N_2O_4	Dinitrogen tetroxide
NASA	National Aeronautics and Space Administration
NMED	New Mexico Environment Department
NMSLO	New Mexico State Land Office
NO_2	Nitrogen dioxide
OOSA	Original Oxidizer Storage Area
PWCAA	Propellant Waste Central Accumulation Area
SAM	San Andres Mountains
SWMU	Solid Waste Management Unit
UDMH	Unsymmetrical dimethylhydrazine
WSTF	White Sands Test Facility

1.0 Introduction

1.1 Purpose and Regulatory Criteria

The 500 Area Former Oxidizer Burner (FOB) was discovered during the 500 Area Fuel Treatment Unit (FTU) closure fieldwork activities when field personnel noted an unidentified stub out line. NASA reviewed 500 Area records and interviewed former employees who worked in the area. The stub out line was identified as the location of an oxidizer burner that operated from 1965 through 1973. NASA notified the New Mexico Environment Department (NMED) in a letter dated October 16, 2019, that the former location of the FOB was a newly identified solid waste management unit (SWMU; NASA, 2019). The notification was submitted within 15 days of discovery, in accordance with section VII.D of the 2009 National Aeronautics and Space Administration (NASA) Hazardous Waste Permit (Permit; NMED, 2009, p73). On November 13, 2019, NMED requested additional information be provided in a Release Assessment Report (RAR) in accordance with the Section V.II.F.1 of the 2009 Permit (NMED, 2009, p74). NASA provided the RAR on June 22, 2020. On December 20, 2021, NMED approved the RAR and directed NASA to list the 500 Area FOB as a "SWMU requiring corrective action during a Permit renewal, or during a 40 CFR 270.42 Permit modification" (NMED, 2021). NASA updated the SWMU list for the Permit renewal to include the 500 Area FOB as SWMU 54. NASA will proceed with investigation in accordance with NMED's direction and 2009 and 2023 Permit Sections VII.F.2 and 3.8.3, respectively (NMED, 2009, p76; NMED, 2023, p31).

This Historical Information Summary (HIS) summarizes information regarding site use, waste management, and assessment of known or potential releases of hazardous substances at the 500 Area FOB. This is a requirement of Section VII.H.1.c of the 2009 Permit (NMED, 2009, p77) and Section 3.10.2 of the 2023 Permit (NMED, 2023, p35). The preparation and submittal of this HIS coincides with the Investigation Work Plan (IWP) for the 500 Area FOB.

1.1.1 Scope

The objective and scope of this HIS is to provide a summary of all available information for the 500 Area FOB operational history. This summary compiles data obtained from the review of relevant and pertinent historical documentation (e.g., reports, maps, and engineering drawings) and interviews with current and former employees (Appendix A).

1.1.2 Limitations and Assumptions

NASA performed due diligence in reviewing historical files, correspondence, and reports, and obtaining information from current and former employees with knowledge of 500 Area FOB operations. All known historical reference resources were examined to evaluate operational and environmental management practices during operation of the unit. This report is limited to records currently available in WSTF files and recollections of current and former WSTF personnel that were directly or indirectly involved in the 500 Area FOB operations.

2.0 Site Description

2.1 Location

WSTF is located in Doña Ana County, 18 miles (mi) northeast of Las Cruces, New Mexico and 65 mi north of El Paso, Texas. Figure 2.1 provides a WSTF location map. Access to the site is provided via a paved road with a guarded security gate. NASA Road intersects U.S. Highway 70, 6 mi west of Organ, New Mexico (Figure 2.1).

2.2 Land Ownership

WSTF administrative and testing facilities are located on White Sands Missile Range (WSMR), owned by the U.S. Department of Defense, Department of the Army (DoD). NASA operates the facility under an inter-agency agreement with the U.S. Army (DoD, 2019). NASA also maintains land-use agreements with the Bureau of Land Management (BLM; a right-of-way agreement, 2012), the New Mexico State Land Office (NMSLO; a right-of-way easement; NMSLO, 1963; a water exploration/development easement; NMSLO, 1989; a water monitoring easement, NASA, 2021b), and the U.S. Department of Agriculture, Agricultural Research Service Jornada Experimental Range (JER; an easement deed; USDA, 2003) for the use of lands located to the west of the industrial facility. In 2014, the National Defense Authorization Act set aside lands previously owned by the BLM for a buffer to WSMR to prevent development close to the missile range. Figure 2.2 provides an ownership overview of lands used by NASA.

2.3 Land Use

The 500 Area FOB is located within the 500 Area of the WSTF industrial area. There are no residents at WSTF, and all WSTF areas are strictly for industrial use. Security and firefighting personnel staff the facility 24-hours per day, seven days per week. WSTF is a restricted access area closed to the public, and access by visitors is provided only in accordance with NASA Johnson Space Center policies.

2.4 General Physical Setting

WSTF is located on soil composed of coalescent alluvial fans that are locally dissected by arroyos. The north-south trending San Andres Mountains (SAM) that ascend over 6,000 feet (ft) above mean sea level (amsl) border the facility on the east. The WSTF site is bordered on the west by a broad uniformly sloping alluvial pediment plain extending into the southern Jornada del Muerto Basin (JDMB) and the Doña Ana Mountains. The major alluvial fan systems originate from Bear Canyon to the northeast and Loman Canyon to the southeast of WSTF. Foothills on the western pediment of the SAM at WSTF are typically 4,800 to 5,000 ft amsl, are moderately sloping (15 to 25%), and consist of thin layers of alluvium covering fractured limestone and volcanic bedrock. The numerous dissecting arroyos only flow during periods of heavy rainfall. Figure 2.3 provides a topographic map of WSTF and surrounding areas.

3.0 500 Area Former Oxidizer Burner Area

3.1 Location

Figure 3.1 provides the location of the 500 Area FOB and surrounding WSTF structures. The 500 Area FOB is located northwest of the 500 Area cryogenic and inert gas storage Area and the 300 Area, northeast of the 400 Area, and southeast of the 500 Fuel Storage Area (FSA). It is located in Section 35 of Township 20 South, Range 3 East. Access to this area is provided by a paved road (Road P) that intersects Apollo Boulevard and ends at the 500 Area FSA (Figure 3.1).

3.2 500 Former Oxidizer Burner Area Physical Setting

The most prominent topographic features in the vicinity of the 500 Area are the adjacent SAM that includes Quartzite Mountain (6,768 ft amsl) to the southeast and Bear Canyon to the east (Figure 2.3). The 500 Area is situated atop the Bear Canyon alluvial fan. The elevation at the 500 Area FOB is approximately 4,960 ft amsl (Figure 2.3). Figure 3.2 provides the arroyos and topographic features within the 500 Area. Several ephemeral arroyos originating from the Bear Canyon area transect the 500 Area and drain west and southwest toward the southern JDMB (Figure 3.2).

3.2.1 Soils and Geologic Setting

WSTF soils are described in detail in the Draft Resource Conservation and Recovery Act Facility Investigation (NASA, 1996, p25). Soils in the 500 Area are associated with alluvial fans, gentle slopes, and arroyos and identified as the Tencee-Nickel Association. The Tencee Series is comprised of shallow, well-drained soils which formed in calcareous gravelly loamy alluvial sediments on ancient alluvial fans. The upper 5 ft are characterized by brown to light-brown gravelly loam with interbeds of pink indurated caliche. The Nickel Series comprises deep, well-drained soils on ancient alluvial fans. The soils are formed in gravelly, medium-textured alluvial sediments. The upper 5 ft are characterized by light brown to pink gravelly to fine sandy loam. Gravel contents are typically 50%.

Tencee Very Gravelly Loam is typically light to dark brown, coarse, and has a subangular blocky structure. The soil is slightly hard, dry, and very friable. Interstitial pores are common. The soil is approximately 30 to 45% caliche and gravel, strongly calcareous, and has nearly continuous lime coatings on all clasts. The Tencee-Nickel, Gently Sloping unit of the 500 Area is approximately 65% Tencee Very Gravelly Loam and 20% Nickel Fine Sandy Loam. The soil is gently sloping and occurs on ancient alluvial fans. Included within these soils are arroyo bottoms and areas of soils similar to Tencee and Nickel soils except containing less than 35% coarse fragments.

Runoff ranges from slow to rapid and permeability is slow to moderately rapid. There are no wells in the immediate 500 Area; as a result, subsurface parameters are estimated from wells in the surrounding areas. Alluvial cover is estimated to be approximately 90 to 115 ft thick. The bedrock immediately below the alluvium is inferred to be Tertiary Orejon Andesite that dips two to four degrees to the west.

3.2.2 Groundwater and Surface Water

Based on nearby wells in the 300 and 400 Areas, groundwater resides within a fractured bedrock aquifer, at approximate elevations of 4,700 to 4,820 ft amsl. Irregular groundwater flow through the fractured bedrock of the WSTF industrial area is primarily to the west with estimated flow rates indicative of relatively steep mountain-front topography ranging from 0.3 to 1.6 ft per day.

There is no surface water in the vicinity of the 500 Area FOB. The nearest man-made water bodies are the WSTF Test Stand 302 cooling water pond to the southeast and the 400 Area Salt Ponds to the south. The only natural water body located within WSTF's industrial area is Gardner Spring, located approximately 1.5 mi southeast, which forms a small sporadic pool. Bear Creek is approximately 0.75 mi north of the 500 Area FOB, but only contains water periodically during rainfall events. The nearest natural water body of significant scale is the ephemeral Isaacs Lake located approximately 10 mi to the southwest of WSTF within the lowest point of the southern JDMB at an elevation of 4,285 ft amsl.

3.3 Description of Structures

The 500 Area FOB was originally constructed as part of the Original Oxidizer Storage Area (OOSA) at WSTF. Structures near the 500 Area FOB currently include a control building (Building 521) that was historically used for the OOSA and later the FTU, electrical poles, an asphalt parking lot, an emergency shower, and utility lines that were associated with the FTU. The area used for the FTU is still within a chain-link fence. All other structures were removed, and the area was graded level during FTU closure activities.

3.4 Current Uses of Adjoining Properties

3.4.1 Propellant Waste Central Accumulation Area (PWCAA)

The Propellant Waste Central Accumulation Area (PWCAA) is currently located in the WSTF 500 Area and is used to manage aqueous propellant waste generated throughout the facility (NASA, 2021a, pp18-19). It is located adjacent to the former FTU location and is operated in accordance with the conditions for exemption for a large quantity generator that accumulates hazardous waste (40 CFR 262.17). Aqueous hydrazine-type and oxidizer propellant hazardous waste is transferred, from points of generation in the 200, 300, 400, 500, and 800 Areas in containers, to the PWCAA prior to shipment for off-site disposal. All propellant hazardous waste is shipped off-site prior to 90-days from when waste was first placed in a container. This waste may be combined to facilitate shipment in fewer containers, or the waste may be transferred to a tanker for transportation to the disposal facility.

3.4.2 Current Oxidizer Storage Area

NASA designed a new oxidizer storage area to the south of the original area (Figure 3.3) prior to constructing the FTU at the 500 OOSA location. This was required to separate hydrazine fuels and oxidizer propellant products. The new area was completed September 6, 1995. From 1993 to September 1995, oxidizer cylinders were stored temporarily at the original hydrogen storage area (Appendix A).

3.5 Former Uses of Adjoining Properties

3.5.1 Original Oxidizer Storage Area

The 500 OOSA was originally set up in 1964 to store oxidizer (N_2O_4) for use in propulsion testing in the WSTF 300 and 400 Areas (NASA, 1994). Long-term WSTF personnel stated that the 500 Area FSA and the OOSA were built similarly, with large storage tanks and piping with shelters to protect the tanks and piping from weather damage, concrete pads (with curbs to provide secondary containment) and a gunite-lined channel leading to a gunite-lined rectangular containment basin or ponding area that was designed to be used only for secondary emergency containment if the large storage tank failed or there was a large spill (Appendix A).

Structures within the 500 OOSA consisted of utilities, an oxidizer storage tank (Tank 522), a sprinkler system in case of fire, steel piping and valves for oxidizer transfer and transport to the WSTF propulsion testing areas, a steel shade to cover the tank, a sprinkler system, a portion of the piping (Appendix A), a secondary containment area for the oxidizer tank, a control building (Building 521), an oxidizer containment basin or ponding area, and an open trench that led to the ponding area. The oxidizer storage tank had a capacity of 19,700 gallons (gal), was horizontal, and sat on two concrete pedestals (NASA, 1994) inside a concrete secondary containment and oxidizer transfer area in the northern part of the OOSA. South of the tank and secondary containment area was an adjacent concrete pad for truck parking (Figure 3.3). In the southeast corner of the oxidizer tank secondary containment area, there was an opening in the containment wall which connected to a gunite-lined open trench or channel (Appendix B). The open trench was 2 ft wide by 76 ft long and ended in an area described on historical WSTF drawings as an oxidizer containment basin (Figure 3.3) and referred to by WSTF personnel as a ponding area. The oxidizer containment basin or ponding area was rectangular (50 ft by 75 ft exterior and 40 ft by 65 ft interior) and gunite-lined (Appendix B). The basin contained a drain 10 ft from the west edge and centered. The drain emptied into a 4-in. (inch) steel pipe (Appendix B) that extended 50 ft to the west of the basin and terminated with a 4-in. shear gate shut off valve.

In preparation for the construction of the FTU, the OOSA was dismantled, leaving only the concrete pad and secondary containment area where the oxidizer tank was, the oxidizer containment basin or ponding area, and the utilities. The large 19,700-gal oxidizer tank was removed from the OOSA on July 18, 1995, prior to the first hypergolic fuel waste received (Appendix A). The OOSA became part of the FTU, with the oxidizer containment basin, or ponding area remaining abandoned outside the FTU fencing. Refer to Section 3.5.2 for a description and brief history of the FTU.

During research for the RAR (NASA, 2020), the oxidizer containment basin drain and drainpipe were located. Photographs are provided in Appendix B. The end of the drainpipe was located 32.5 ft west of the drain, instead of 50 ft as originally installed. The pipe appeared to have been cut off with a saw. No soil staining was visible.

3.5.2 Fuel Treatment Unit

Initially, in the 1960s until closure of the units in the mid-1980s, the 300 and 400 Area impoundments were used to treat hydrazine fuel wastes by oxidation. After closure of the impoundments, hydrazine fuels were still treated at WSTF in a mobile tanker, but NASA wished to have a permitted, more permanent treatment facility for use at WSTF. The FTU was designed and permitted to be that more permanent treatment facility. The location for the FTU was chosen to be the 500 OOSA. The OOSA already had concrete areas with secondary containment. The FTU incorporated the truck parking concrete area into the FTU design. The FTU was designed to treat hydrazine fuel wastes by oxidation using chlorine gas. Construction of the FTU began in 1991 and was completed by September 1994 (NASA, 1995). Photographs during construction are provided in Appendix B. The concrete pad originally used for the truck parking and transfer area was used for the FTU treatment tank, and a new concrete pad with secondary containment was built for the FTU storage tank and the sodium hydroxide tank. The FTU began receiving waste on August 23, 1995. The oxidation treatment using chlorine was tested between November 6, 1995 and February 20, 1996. During the initial testing, the chlorine gas damaged some system parts, and due to newly enacted regulations (evaporative tank unit [ETU] waste had to be <500 ppm) volatile organic compounds at the point of generation, the treated waste from the FTU could not be disposed at the ETU. Therefore, no further oxidation of aqueous hydrazine fuel waste was attempted at the FTU after the initial testing phase. Aqueous fuel waste was instead stored and diluted prior to being shipped off-site for disposal at a RCRA permitted facility. Only hydrazine fuels (aqueous hydrazine, Monomethylhydrazine [MMH], and Unsymmetrical dimethylhydrazine [UDMH]) were stored and treated at the FTU. FTU closure activities began on December 11, 2018.

3.6 Other 500 Areas

The 500 Area was designed to store non-hazardous and hazardous substances needed for WSTF operations. There are three separate geographic areas with a total of six separate areas that have been used to store various products throughout WSTF history, and a brief summary of the six areas is provided below. Historical 500 Areas are shown on Figure 3.1.

3.6.1 Cryogenic and Inert Gas Storage

The cryogenic and inert gas storage area (Figure 3.1) was completed in 1964 and has been used at WSTF to store liquid and gaseous nitrogen and generate breathing air used for human support. Building 536 contains two breathing air compressors/systems that have supplied and continue to supply breathing air to all air stations at WSTF (for mobile trailers, and in the 200, 300, 400, 500, and 800 Areas; Appendix A) (NASA, 1994).

3.6.2 Hydrogen Storage

The initial hydrogen storage area (Figure 3.1) was completed in 1964 (NASA, 1994). Hydrogen was stored in a large above-ground tank that was removed in approximately 1990. Oxidizer cylinders were briefly stored in the initial hydrogen area from approximately 1993 to September 1995 when the 500 OOSA was being converted to the FTU and the new oxidizer storage area was not completed yet (Appendix A). Currently, the original hydrogen storage area is being used as an alcohol storage area with a maximum of 65, 55-gal drums (3,250 gal or 21,287.5 pounds of isopropyl alcohol (IPA) and ethyl alcohol are stored for use at WSTF (Appendix A).

3.6.3 Alcohol Storage

The initial alcohol storage area was also completed in 1964 (NASA, 1994) and was located between the original hydrogen storage area and the 500 FSA (Figure 3.1). Alcohol (IPA) was stored in a large above ground tank that has subsequently been removed. Other alcohols stored in this area were methanol and ethyl alcohol. Methanol was used for a rocket engine propellant for testing in the propulsion department. The initial alcohol storage area is currently not being used for storage.

3.6.4 Fuel Storage

The 500 FSA was constructed in 1964 and 1965. The large fuel tank (21,000 ga]) was installed in 1964 and historically stored Aerozine 50 (a 50/50 mixture of hydrazine and UDMH). The shelter above the tank was installed in 1965. The large tank was "closed down" between July 1 and September 30, 1973, and abandoned in place (Dynalectron, 1973). After the large tank was abandoned, NASA continued using the area for fuel storage, but with smaller 55-gal drums of hydrazine fuels (mostly MMH). The large tank was decontaminated and removed in 2011 (Appendix A). Currently, the smaller 55-gal drums of hydrazine fuels are stored in the FSA on a cement pad under the shelter/cover where the large tank was originally located and within the tanker transfer area as needed (Appendix A).

4.0 Historical Records Review

4.1 Record Sources

As part of the HIS process, records relevant to the area history, operations, and environmental conditions are reviewed. The type and location of these records are as follows:

- NASA Environmental Records – Located on-site in the WSTF Environmental Department, available in electronic form and some in paper copy form. Records reviewed included correspondence, maps, memoranda, regulatory submittals, and reports.
- NASA Drafting Records – Located on-site in the WSTF Drafting Department, available in paper copy files and some in electronic form.
- NASA Photographic Archives – Located on-site in the WSTF Photographic Laboratory. Negative logs were reviewed, and pertinent photographs were obtained for review.

4.2 Interviews and Questionnaires

In addition to the historical records review, interviews with current and former long-term employees were conducted. Refer to Appendix A for a summary of information from interviews conducted for this HIS.

5.0 Operational History

5.1 Pre-WSTF History

From the early 1800s to approximately 1935, the Organ Mountains and the SAM were mined for gold, silver, zinc, copper, and lead. There were several established mines and numerous prospect mines located in the SAM. The nearest established mine to WSTF was the Smith Mine located approximately 1 mi southeast of WSTF within the Loman Canyon area. The Smith mine produced approximately $30,000 of silver ore during its operation. Deposits of galena (lead sulfide) and barite (barium sulfate) were also mined just north of the eastern mouth of Bear Canyon (Seager, 1981, p87).

Lands now occupied by WSTF were historically open-range grazing lands. The ruins of a historic ranch house (Gardner Ranch, operated prior to 1960) are located just east of the current 200 Area laboratory facilities (southeast of the 500 Area), and Love Ranch (believed to be in operation from the early 1900s until 1960) is located approximately 2 mi northeast of the 500 Area. These properties were acquired by the federal government to become a part of WSMR.

5.2 Inception of WSTF

NASA Headquarters announced selection of a testing site in south-central New Mexico on July 6, 1962. The site was chosen for the isolated location and topography, which minimize the inherent hazards of aerospace propulsion testing to the general population. From the date of the official announcement until January 1965, the site was known as the Propulsion Systems Development Facility. From January to June 1965, the official designation was White Sands Operations. On June 16, 1965, the official name of the installation was changed to White Sands Test Facility (NASA, 1994).

Site planning activities began in August 1962. Exploratory drilling to locate a water supply source began in December 1962, with drilling of water supply wells completed in May 1963. Development of the site location began in May 1963 with construction of the access road (NASA Road) from U.S. Highway 70. The access road was completed in October 1963 (NASA, 1980, p.22, 1986 p.2). The first increment of the 300 Propulsion Test Area was completed in January 1964, followed by completion of the second increment of the 300 Propulsion Test Area by June 1964.

5.3 500 Area Oxidizer Burner and Vent Stack

An oxidizer burner (with the associated 500-gal propane tank, vent stack, and control unit with cabling) was added to the 500 OOSA in 1965 (NASA, 1967a, pp2-3; NASA, 1994). “The burner consists of an injector system for the propane and the nitrogen tetroxide, a mixing chamber, a burner head…, a spark-plug igniter system, and windshield” (NASA, 1967a, p2).

Drawing number 019-14800 (Appendix B, pB-2) shows that the instrumentation or control cabling for the oxidizer burner was buried underground on a direct path northeast to the burner from the eastern portion of the OOSA (Appendix B). The location of the 500 Area FOB was documented on WSTF drawing number 500-CP-04. From that drawing, aerial photography, and locating the remaining concrete and steel footings or stands in the field, the location where the 500 Area oxidizer burner was installed was determined and added to a map (Figure 3.3).

A vent stack at WSTF is a tall (approximately 20 ft) pipe-like structure that is part of the oxidizer burner system. The vent stack was designed to release to the atmosphere very small amounts of residual oxidizer vapors in the lines following oxidizer disposal/flaring by the burner (Appendix A). Like other oxidizer burners on site at WSTF, the 500 Area FOB was designed with a vent stack as well, located adjacent to

the oxidizer burner (Figure 3.3). A historical photograph of the 500 Area FOB oxidizer burner (in use) and the adjacent vent stack from 1967 is provided in Appendix B. The burner/vent stack system was used in the 500 OOSA to dispose of excess oxidizer until the large oxidizer tank was abandoned following the Apollo program work at WSTF in 1973.

The fate of the 500 Area oxidizer burner was also explained on historical WSTF 500 Area drawings. On the drawing 500-CP-18, written directly adjacent to the enlarged oxidizer burner detail, it states, "equip. to be relocated – see DWG (drawing) 284-10964…Equipment will be disconnected…and delivered to construction site for reinstallation…" The corresponding WSTF drawing 284-10964 shows the 800 Area with an oxidizer burner area that references back to drawing "CP-18." The 800 Area drawing (284-10964) was made in June 1973. Long-term WSTF personnel also stated that the 800 Area facility was established at WSTF in 1974, and an employee confirmed that the 500 Area oxidizer burner system was moved to the 800 Area from the 500 Area (Appendix A). This coincides with the timing of 500 OOSA large oxidizer tank closure (between July and September 30, 1973; Dynalectron, 1973), providing further evidence that the 500 Area oxidizer burner was removed and reinstalled for use in the 800 Area. The 800 Area Oxidizer Burner is identified as SWMU 20 in Attachment 22 of the 2009 Permit (NMED, 2009, p106) and Attachment 4 of the 2023 Permit (NMED, 2023) . Appendix B shows a photograph taken in May 2000 of the oxidizer burner located in the 800 Area.

6.0 Findings

6.1 Evidence of Hazardous Substances - Dinitrogen Tetroxide (N_2O_4)

The primary oxidizer used at WSTF from the inception of the site is N_2O_4 (NASA, 2020, p5). It is a strong oxidizing agent, has a high vapor pressure (1,551 millimeters of mercury [mm Hg]), a low boiling point (70.1° Fahrenheit [F] at 760 mm Hg), and a density greater than air (1.45 g/cm^3 at 68° F; U.S. National Library of Medicine, n.d.). Due to the low boiling point and high vapor pressure of N_2O_4, any potential oxidizer released would have become vapor and dissipated into the air.

N_2O_4 and nitrogen dioxide (NO_2) form a gas phase equilibrium, with N_2O_4 prevalent in the liquid phase and NO_2 prevalent in the gas phase. Vapors of NO_2 are reddish-brown in color and have been described as a "cloud" (NASA, 2010, pp2-3). With the highly corrosive nature of N_2O_4 (Terra Industries, 2011), any N_2O_4 or NO_2 present in soils would result in low (acidic) soil pH (due to the formation of nitrous and nitric acids with rainwater), likely much lower than 7.0. Nitrite does not persist in soils; however, the ultimate fate of N_2O_4 is the formation of nitrates with minerals in the soil (Gray and Yoffe, 1955 pp1069-1154, Greene and McClure, 2014; Terra Industries, 2011). The Material Safety Data Sheet (MSDS) for N_2O_4 is provided in Appendix C.

6.2 FOB Oxidizer Flaring and Oxidizer Disposal

Oxidizer disposal at the 500 Area FOB was documented by an employee in a memorandum dated May 23, 1967 (with attached report) titled Appraisal of Environmental Hazards in Treatment, Storage, and Disposal of Liquid Propellants and Other Chemicals at White Sands Test Facility (NASA, 1967b, p9). This document states:

> A complete estimate of the quantities of fuel and oxidizer disposed of in the storage area is not known. Currently, waste N_2O_4 which results from transporter off-loads and transfer operations is burned with propane. N_2O_4 from sample remainders (estimated to be 12 gallons per month) is vented to the atmosphere in the storage area…

The practice of burning oxidizer with propane identified in the document is referring to the process where propane is ignited, and oxidizer is added for destruction by flaring or burning at the burner. The oxidizer

burners at WSTF were similarly constructed and were "designed to dispose of at least 10 pounds of nitrogen tetroxide per minute" (NASA, 1967a, p.2). The employee estimated 12 gal of oxidizer per month was processed through the burner and vent stack. Oxidizer vent stacks at WSTF are also similarly constructed, and only release small quantities of oxidizer vapor at a time (Appendix A). The venting occurs from the top of the vent stack, approximately 20 ft above the soil. Due to the volatility of oxidizer and the small amounts of oxidizer vented during each event, it is unlikely oxidizer came into contact with soil. But, as discussed in Section 6.3.1, oxidizer added to the burner at non-optimum flaring configurations may have caused some oxidizer liquid or vapor to contact the ground.

6.3 Indication of Releases to the Environment

The following sections discuss releases to the environment of N_2O_4 in the 500 Area.

6.3.1 500 Area FOB Oxidizer Output Test

An Oxidizer Output Test was conducted in 1966 using the 500 Area FOB to identify the combustion products emitted by the burner (NASA, 2020, p6). When the burner was operated in accordance with NASA's normal operating procedures (slightly propane-rich), samples were collected "by holding an inverted funnel witch [sic] was connected to a flex hose leading to an evacuated 3-liter pressure bottle over the densest portion of the flame; the sample valve on the bottle was then opened to pull in the sample" (NASA, 1967a, p3). All sample system parts were constructed of stainless-steel or Teflon®[1]-lined components. The testing concluded that when the burner was operated with a slightly greater than 1:1 ratio of propane to oxidizer (propane-rich), the process of flaring/burning oxidizer with propane completely destroyed the oxidizer, releasing to the atmosphere only carbon dioxide, water vapor, nitrogen, and small amounts of unburned propane (NASA, 1967a, p4). If the burner was operated too propane-rich, "then such products as unburned propane, methane, ethane, and carbon monoxide, in addition to the normal combustion products, could be found in the exhaust. These predictions do not consider the fact that the hot gases are expelled into the atmosphere. Subsequently, a portion of the unburned propane and its degradation products would be burned with the oxygen in the air rather than with the nitrogen tetroxide" (NASA, 1967a, p3).

However, releases of liquid oxidizer/gaseous nitrogen dioxide from the burner were possible if the mixture was less than 1:1 ratio of propane to oxidizer (oxidizer-rich), if the operating procedure was not followed, or if equipment malfunctioned. This would result in incomplete combustion of oxidizer, releasing to the atmosphere "such products as nitrogen dioxide, nitrogen tetroxide, nitric oxide, and nitrous oxide, in addition to the normal combustion products, could be found in the exhaust" (NASA, 1967a, p3).

6.3.2 Oxidizer Release Testing

Prior to computer modelling capabilities, NASA conducted testing using video to determine characteristics of a potential large or catastrophic oxidizer release at WSTF. This testing was conducted in June 1979 at the 500 Area OOSA. Oxidizer was released to concrete in two sessions in amounts estimated by WSTF personnel to be approximately 250 gal for the first test and approximately 70 gal for the second test. The oxidizer immediately vaporized to nitrogen dioxide (NO_2), as shown by the red color, and began dissipating. As part of the testing, employees in protective suits released white balloons into the vapor cloud to assist visualization for tracking wind direction, cloud intensity, and distance. The maximum

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

distance estimated by a WSTF employee that the oxidizer cloud could have reached was the base of the canyon near Quartzite Mountain.

6.3.3 Spills

NASA maintains logs of spills that occur at WSTF. No spills or leaks at the 500 Area FOB or OOSA were documented in spill logs. However, these spill logs have only been generated and maintained at WSTF since 1985. A long-term employee remembered hearing of one incident from an employee present during an oxidizer transfer from a truck to the large oxidizer tank during the Apollo testing in the 1960s. A spill to the truck loading pad concrete containment occurred because a valve was not closed completely. When the truck driver disconnected the transfer line, oxidizer sprayed on the driver (and in the transfer area). This spill area was on concrete, and there was no reported oxidizer spilled to soil. The oxidizer volatilized and evaporated. The amount spilled is unknown. There were no known spills large enough to have oxidizer flow to the ponding area or containment basin (Appendix A).

7.0 Uncertainty

WSTF historical operations and waste management practices were not well documented from the inception of the site in 1963 through the mid-1980s, and the formation of a full-time Environmental Department. And over such a long operational history with few to no regulations requiring records retention, historical records were sometimes discarded or were retained by contractors upon departure, and some historical records were stored on media that is currently inaccessible. Also, information from employee interviews is subject to the limitations of the recollection of the individuals interviewed, which could result in uncertainty and contradictory information. NASA used the available records and documentation for this HIS whenever possible to minimize uncertainty.

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Figures

Figure 2.1 **WSTF Location Map**

(SEE NEXT PAGE)

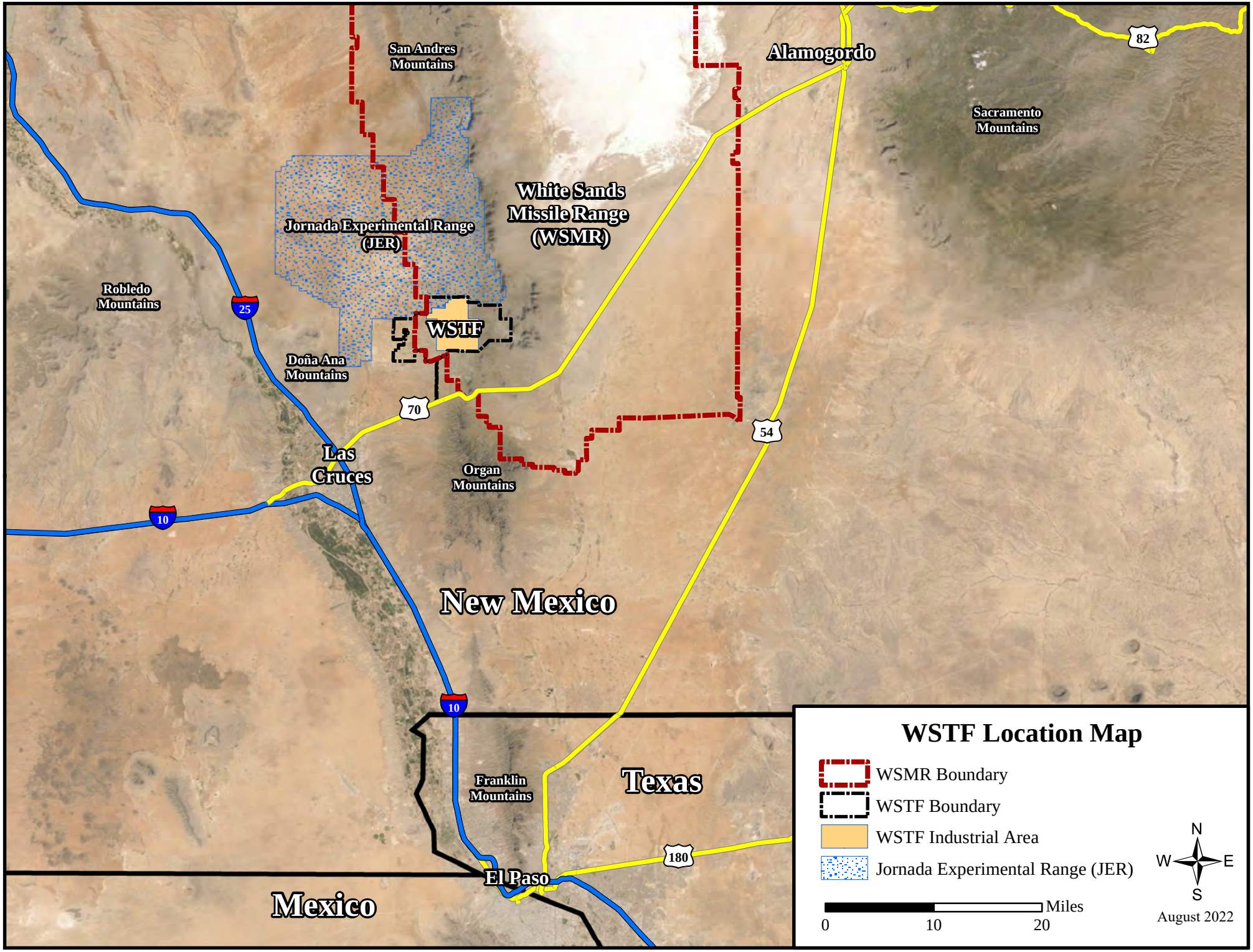

San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
WSTF Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
Miles
0
10
20
N
W
E
S
August 2022

Figure 2.2 **Land Ownership Map**

(SEE NEXT PAGE)

1,505,558 1,515,558 1,525,558 1,535,558 1,545,558 1,555,558

563,526

553,526

543,526

533,526

United States Department of Agriculture
Jornada Experimental Range

White Sands Missile Range
Department of Defense
NASA Tenant

United States Fish and Wildlife Service

White Sands Missile Range
Department of Defense
NASA Tenant

New Mexico State
Land Office

Bureau of Land
Management
Withdrawn

NASA Owned

White Sands Missile Range
Department of Defense
NASA Tenant

WSTF Industrial Area
(White Sands Missile Range)

Private Land

Forward Guard Gate

Bureau of Land Management

New Mexico State
Land Office

White Sands Missile Range
Department of Defense

Private Land

Bureau of Land Management

WSTF Land Use Map

- WSTF Boundary
- Building
- WSTF Industrial Area
- NASA Tenant - WSMR Owned
- BLM Withdrawn Land
- United States Fish and Wildlife Service
- Bureau of Land Management
- NASA Property
- NM State Land Office
- Jornada Experimental Range
- White Sands Missile Range
- White Sands Missile Range Boundary
- Private Land

N
W E
S

July 2022

0 0.5 1 2 Miles

Coordinate System: NMSP, Central Zone, Ft. NAD83

Figure 2.3 **WSTF Topographic Map**

(SEE NEXT PAGE)

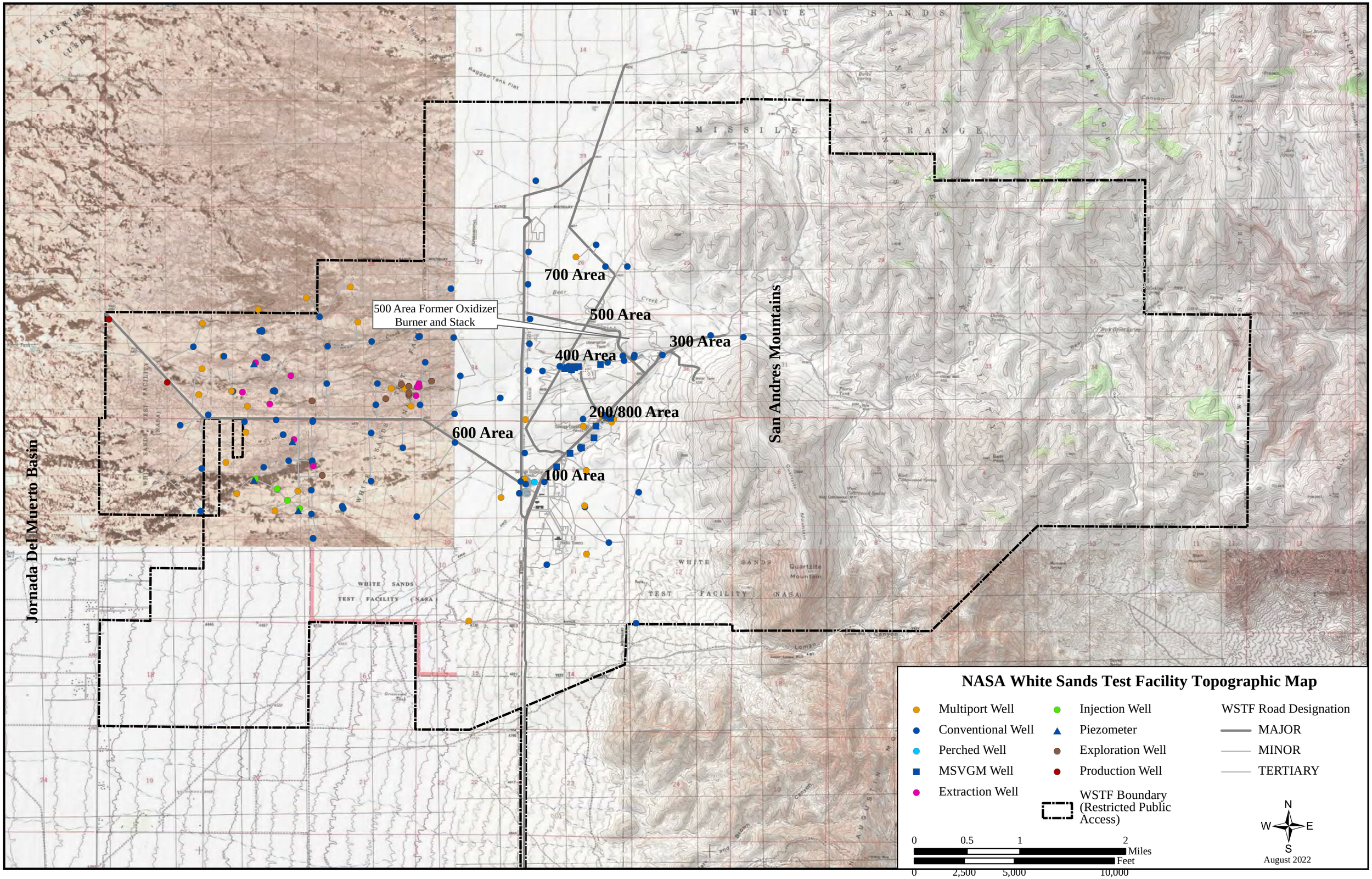

700 Area
500 Area Former Oxidizer Burner and Stack
500 Area
300 Area
400 Area
200/800 Area
600 Area
100 Area
San Andres Mountains
Jornada Del Muerto Basin
WHITE SANDS TEST FACILITY (NASA)
MISSILE RANGE
Ragged Tank Flat
Bear Creek
Quartzite Mountain
NASA White Sands Test Facility Topographic Map
Multiport Well
Conventional Well
Perched Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
WSTF Boundary (Restricted Public Access)
WSTF Road Designation
MAJOR
MINOR
TERTIARY
0 0.5 1 2 Miles
0 2,500 5,000 10,000 Feet
N
W E
S
August 2022

Figure 3.1 **500 Area Structures**

(SEE NEXT PAGE)

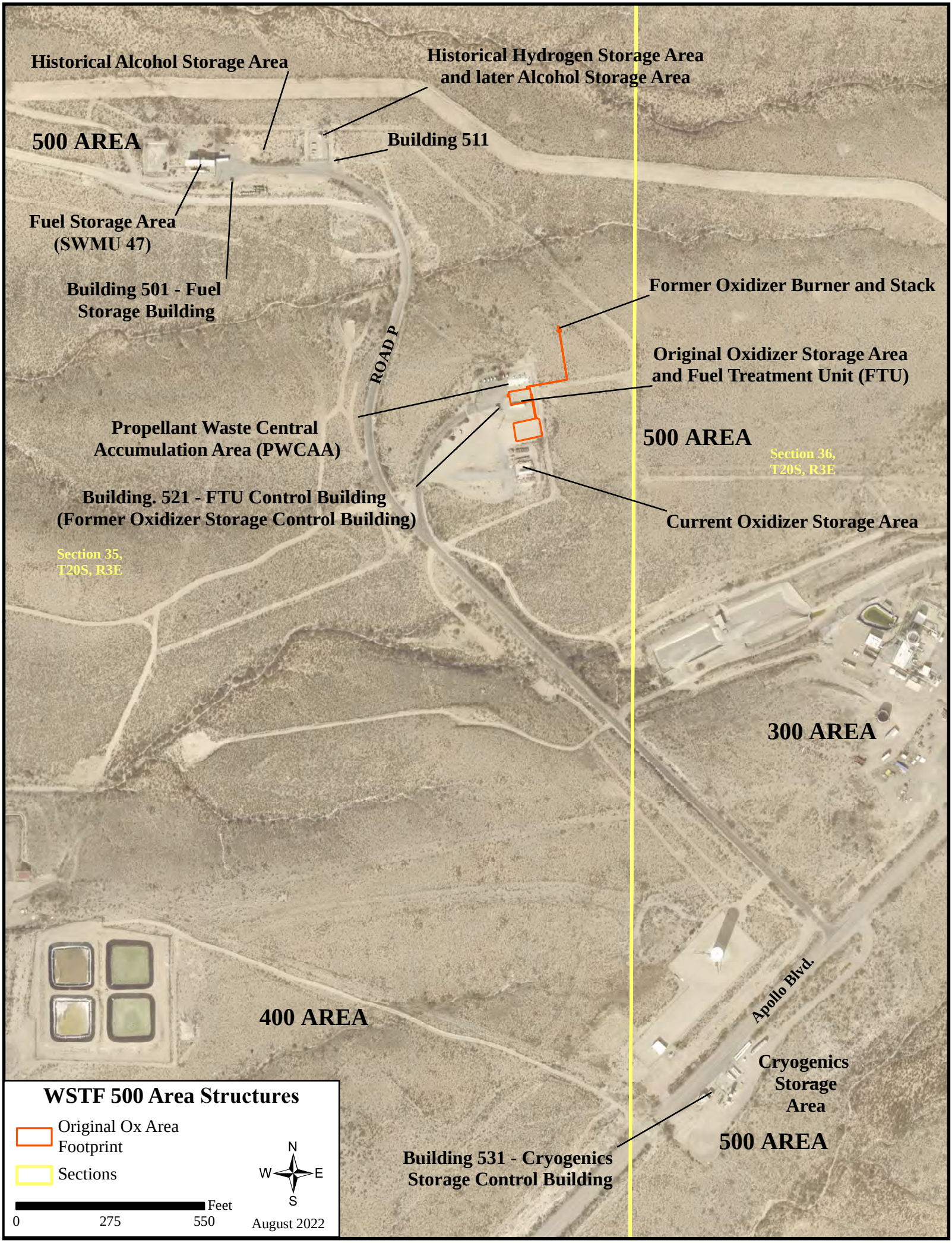

Historical Alcohol Storage Area
Historical Hydrogen Storage Area and later Alcohol Storage Area
500 AREA
Building 511
Fuel Storage Area (SWMU 47)
Building 501 - Fuel Storage Building
ROAD P
Former Oxidizer Burner and Stack
Original Oxidizer Storage Area and Fuel Treatment Unit (FTU)
Propellant Waste Central Accumulation Area (PWCAA)
500 AREA
Section 36, T20S, R3E
Building. 521 - FTU Control Building (Former Oxidizer Storage Control Building)
Current Oxidizer Storage Area
Section 35, T20S, R3E
300 AREA
400 AREA
Apollo Blvd.
Cryogenics Storage Area
500 AREA
Building 531 - Cryogenics Storage Control Building
WSTF 500 Area Structures
Original Ox Area Footprint
Sections
N
W
E
S
Feet
0
275
550
August 2022

Figure 3.2 500 Area Arroyos and Topographic Structures

(SEE NEXT PAGE)

Fuel Storage Area

500 Area

Former Oxidizer Burner and Stack

Road P

Original Oxidizer Storage Area and
Former Fuel Treatment Unit (FTU)

Propellant Waste Central
Accumulation Area (PWCAA)

Current Oxidizer Storage Area

400 Area

300 Area

4880 4890 4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 4850 4860 4870

500 Area Topographic Map

10-ft Contours

Arroyo

Original Ox Area Footprint

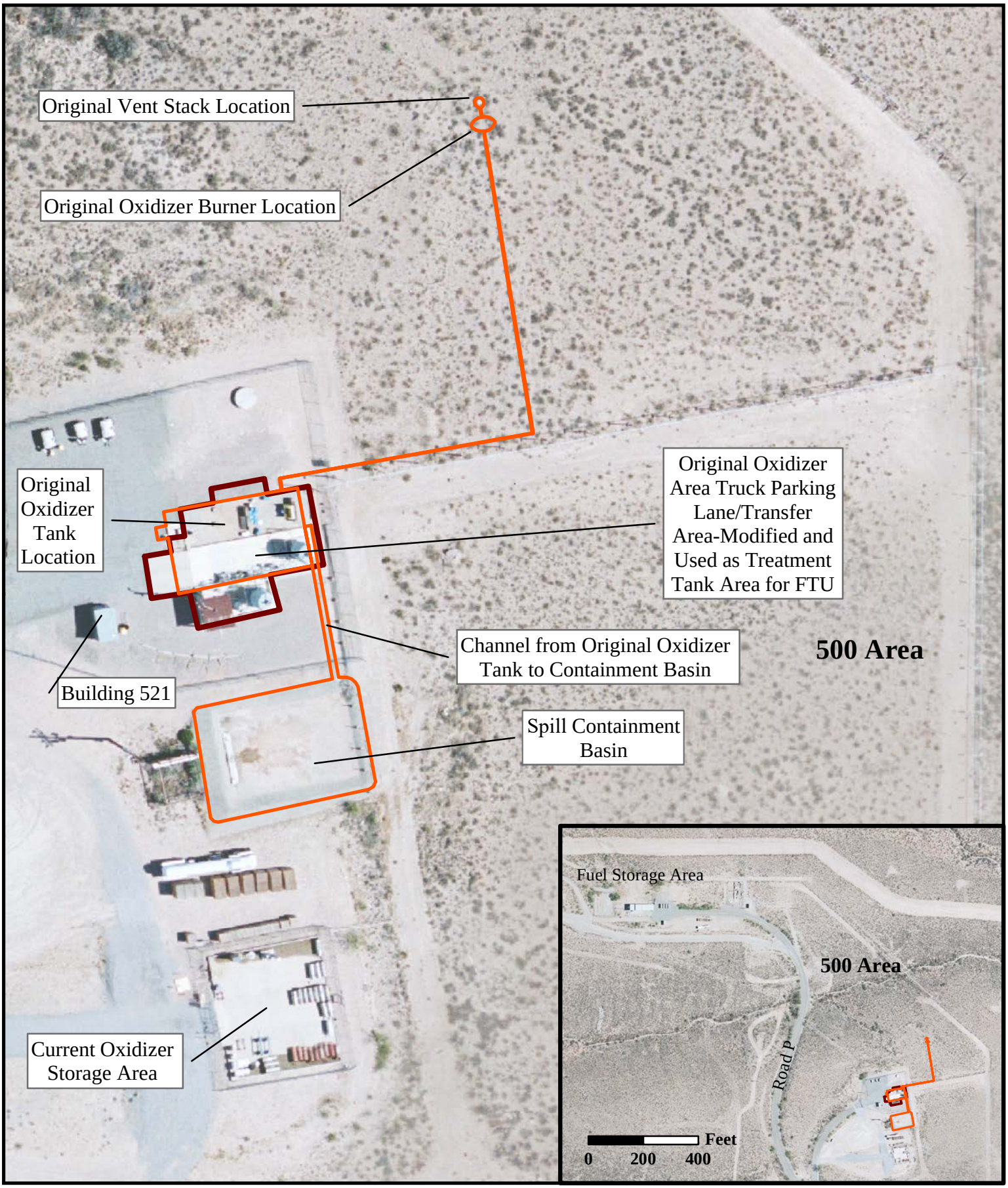
N W E S

0 125 250 500 Feet

August 2022

Figure 3.3 500 Area Former Oxidizer Burner and Original Oxidizer Storage Area

(SEE NEXT PAGE)



500 Area Original Oxidizer Storage Area (1963-1973) and Fuel Treatment Unit (FTU; 1995-2018)

FTU Footprint

Original Oxidizer Area Footprint

Feet
0 40 80

N
W E
S

August 2022

Appendix A
500 Area Summary of Findings from Employee Interviews or Questionnaires

Appendix A 500 Area Summary of Findings from Employee Interviews or Questionnaires

Position	Significant 500 Area Information	Other Information or Comments
Environmental Department 1989-2010	The 500 Area stored 55-gallon drums of chemicals. The employee had no knowledge of any leaks or spills. The Fuel Treatment Unit (FTU) contained an unregistered above ground tank that stored oxidizer. The Fuel Storage Area contained an unregistered above ground tank that stored Aerozine-50. There may have been burning or treating of fuel in 500 Area in the past.	The employee provided information in May 2011 in a questionnaire.
Propulsion Department, Environmental Department 1990-2012	The employee provided the following information regarding the 500 Fuel Storage Area (FSA) but also applies to the **500 Original Oxidizer Storage Area (OOSA)**: "The sump is a low point in the spalled (blown) concrete pond below ground surface, so liquids will drain there." The pipe leading from the sump area within the pond is buried underground until the discharge point and currently (2011) closed. Water does not drain out. Other OOSA information provided: Building 521 was the OOSA control building, but became the FTU (fuel treatment unit) control building when the FTU was built. The original large oxidizer tank was approximately 19,700 gallons. It was used from the mid-1960s to the mid-1970s. It was removed (information from a logbook) on 7/18/1995. If there was a shelter above the large tank, it had been removed prior to 1990 when the employee was hired. The oxidizer and fuel lines that connected the 500 fuel and oxidizer storage areas to the WSTF testing areas (300 and 400 Areas) were decontaminated and dismantled beginning January 2011. The employee stated that hydrogen Fluoride for use at HELSTF (high energy laser systems test facility) was briefly stored at the OOSA (in the tank transfer/parking area) from at ~1990 when the employee was hired) to 1993. No spills/leaks occurred. A new oxidizer storage area was built south of the original. Construction began 9/6/1995 (information from a logbook).	The employee was interviewed in May 2011. The employee also provided in depth information regarding the 500 fuel storage area and permitted fuel treatment unit that is not provided here.

Position	Significant 500 Area Information	Other Information or Comments
	FTU: Part of the FTU tanks were built on the previous OOSA concrete, and part were built on a new concrete pad built for the FTU. The NAOH tank is on the new concrete pad with one of the 4,000 gallon tanks. Physical construction of the FTU was complete in 1993, engineer certified the build in 1994; NMED approved the use in 1995. June 1, 1995 (from the employee's logbook) was the first day the facility was open. The first fuel waste was received on 8/23/1995. System testing was conducted 11/6/1995 through 2/20/1996. The chlorine damaged the system during testing. The system was fixed, but it was decided not to treat fuel waste using chlorine, but to store fuel waste at the FTU and ship off-site for disposal. Chlorine left WSTF 7/9/1997. The first fuel waste was shipped off-site 7/8/1997. FTU was classified in its history as a storage unit and a treatment unit. (Later, still a treatment unit due to dilution of fuel waste.) The employee provided information regarding the **original hydrogen storage area**: The original hydrogen storage tank was removed in approximately 1990. The only remaining (in 2011) structures are the original concrete pad and concrete pedestal where the tank was located. Prior to building/finishing the new oxidizer storage area, the oxidizer cylinders were stored in the original hydrogen area until the oxidizer area was built in 9/1995. When the oxidizer was moved to the new oxidizer storage area, alcohol began being stored at the original hydrogen storage area. The area has become the alcohol storage area, storing individual drums of alcohol. Currently (in 2011) the alcohol stored is a maximum of 65 55-gallon drums (3,250 gallons; 21, 287.5 lbs) of IPA and ethyl alcohol can be stored. The employee provided information regarding the **original alcohol storage area**: Built in the mid-1960s. The tank has been removed "many years ago". The site now has the original concrete pad and concrete pedestal where the tank was located. Methanol was also stored in the original alcohol area. It was used for a rocket engine fuel propellant in the propulsion department.	

Position	Significant 500 Area Information	Other Information or Comments
	This area is not currently being used. Nothing is stored there now. The employee provided information regarding the **500 FSA**: The fuel storage area control building (501) contains no controls, since the tank is out of service. The building contains lights and a telephone. From January to May 2011, the storage tank (21,000-gallon capacity) was decontaminated to non-detect (which took 7 rinses), and is currently "abandoned in place." (The tank was removed in 2012). The FSA "currently stores 55-gallon drums of fuel on the cement pad that holds the tank." Fuel is provided to any area at WSTF that requires fuel from the FSA. The tank is currently (2011) covered with a sun shelter. The shelter is scheduled to be moved to shade more of the 55-gallon drums (lowered after large tank removal). The employee provided information for the **cryogenic and inert gas storage area**: Building 536 contains a breathing air system that supplies breathing air to all air stations at WSTF. Air stations are located in the 200, 300, 400, 500, and 800 Areas. There are also mobile air station trailers for supplying breathing air for WSTF operations. Liquid and gaseous nitrogen is stored in the cryogenic area and sent to any WSTF area that requires gaseous operations.	
Anonymous	The large tank in the FSA was used for Aerozine-50. The employee provided information for the 500 FSA but also applies to the 500 OOSA: "The concrete pad to the south of the large tank was for transporters (tankers) to back into for transferring [fuel] into the tank." "…the tanker pad and the storage pad are sloped to drain to the ditch and then to the pond…" (The ditch is the flume or channel that leads to the containment pond, both are gunnite-lined.)	The employee provided information in May 2011. The employee provided additional information regarding SWMU 47, (the FSA) that is not provided here.
800 Area 1976~2015	The 800 Area test cells were constructed in approximately 1974. The employee stated that personnel were not concerned with small amounts of oxidizer released when fittings were disconnected	Employee was interviewed in April 2015

Position	Significant 500 Area Information	Other Information or Comments
	because "oxidizer boils at 70 degrees; it flashes to vapor and is gone."	Employee provided additional information regarding SWMU 19, the below grade storage tank, and 800 Area that are not provided here.
800 Area 1974-2010; consulted until 2013	The 800 Area test cells were constructed in 1974. It took approximately 18 months to build the 800 Area. The employee stated that SWMU 19, the below grade storage tank, was originally designed to have small amounts of fuel and oxidizer enter the tank underwater. However, "an old oxidizer burner…" that wasn't being used was added to the 800 Area, and all oxidizer from 800 Area testing was always disposed of by the oxidizer burner and vent stack. Employee stated that "oxidizer boils off at normal temperatures and pressures." Oxidizer was sent to the burner for disposal.	Employee was interviewed in April 2015 Employee provided additional information regarding SWMU 19, the below grade storage tank, SWMU 10, the hazardous waste transmission line, and 800 Area that are not provided here.
800 Area 1978-present (2019)	The oxidizer burner systems at WSTF also contain a separate vent stack. The vent stack is much taller than the burner and was used for releasing small amounts of oxidizer vapor in the lines after testing was completed and the oxidizer had been disposed of with the burner. The vent stack currently has a screen to prevent debris from entering. However, the vent stack was historically open at the top (in the 800 Area). The employee stated that releases of red colored vapor oxidizer was common from the 800 Area oxidizer burner. Oxidizer evaporates and dissipates.	Employee was interviewed in June 2015 Employee provided additional information regarding SWMU 19, the below grade storage tank, SWMU 10 and 800 Area that are

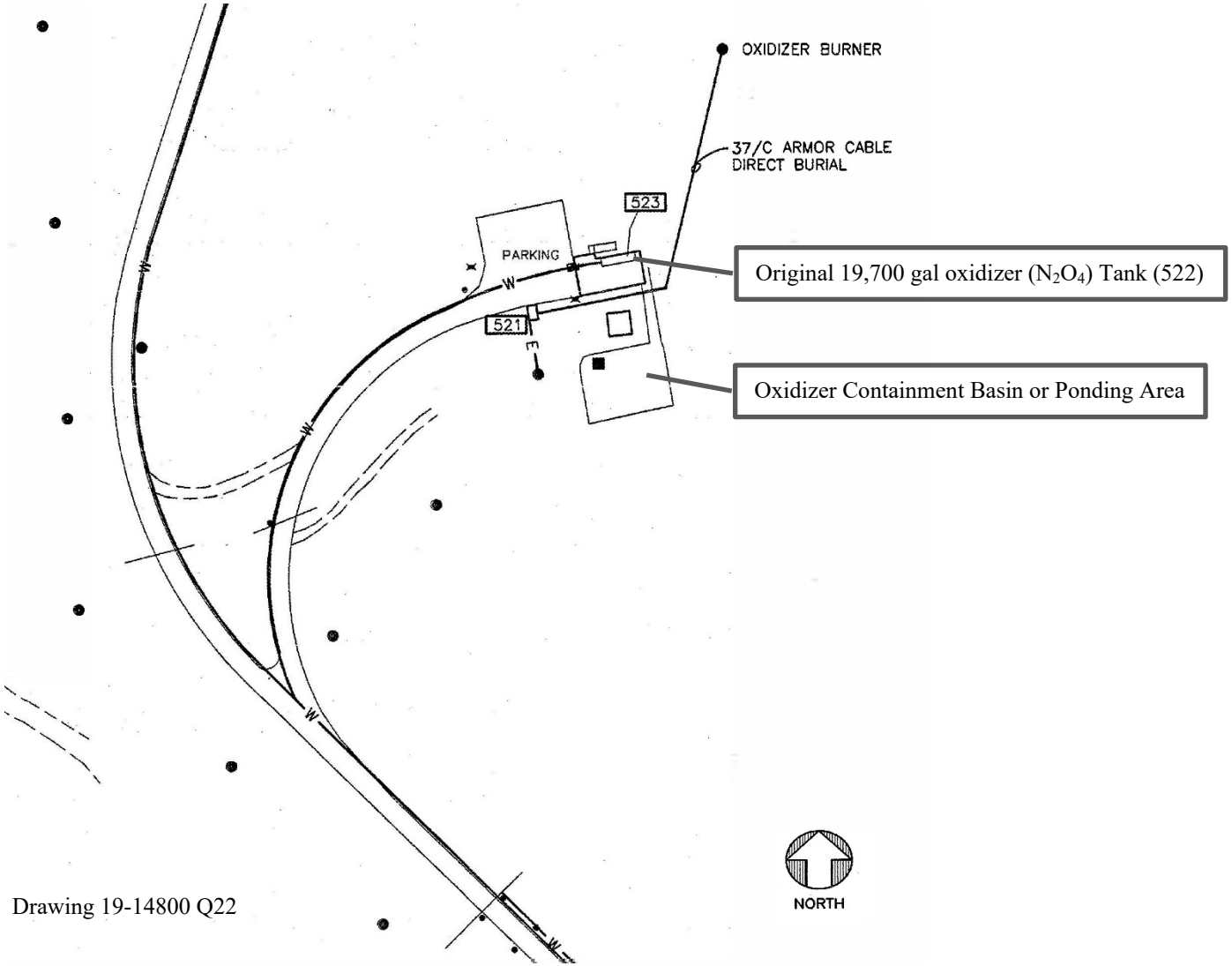
Position	Significant 500 Area Information	Other Information or Comments
	When liquid and gaseous spills occurred in the past onto soil, no clean-up was ever conducted. In the early WSTF history (1960s-early 1980s), employees did not always wear protective suits and employees were exposed to oxidizer vapors.	not provided here.
Propulsion Department (~1976-current [2019])	The employee stated that when the employee began working at WSTF, the original oxidizer storage area was no longer in use. The oxidizer containment basin was used as a spill containment area for the large oxidizer storage tank when it was in use.	Interviewed September 2018
800 Area and Propulsion 1977~1980; Safety Department 2002-2012	The employee stated that NASA performed testing at the 500 OOSA on "the concrete catch pad" using oxidizer (N_2O_4) in 1977, 1978, or 1979, but he believed 1978. The employee believed that the WSTF photo lab had taken pictures, so the year might be found from photographs. This was before computer modelling, so NASA needed to perform testing with video to determine characteristics of a potential large or "catastrophic" oxidizer release at WSTF. "The two tests were done because NASA wanted data to understand oxidizer. However, this only provided video of what a release would look like and a visual look at how far the cloud could spread. This didn't have quantitative data." Employees in protective suits released balloons into the oxidizer vapor cloud to assist visualization. "The balloons helped track wind direction and cloud intensity." The employees in the protective suites were to release the balloons when told to at a certain time to be used in the video to help see wind direction and to track the oxidizer cloud. "It was important to know how far the cloud went and what direction". The employee stated that two tests were performed at the original oxidizer storage area many months apart. The amount of oxidizer released was estimated by the employee as ~250 gallons for the first test and ~70 gallons for the second test. The employees in protective suits walked through the liquid oxidizer on the concrete pad sometimes "ankle deep". The employee estimated that the NO_2 vapor cloud could have reached as far as the base of the canyon near Quartzite Mountain from the first test. "No environmental cleaning was done."	Interviewed October 2019 The employee also discussed WSTF and WSMR history and groundwater contamination that is not provided here.

Position	Significant 500 Area Information	Other Information or Comments
	The only thing ever stored at the 500 OOSA was oxidizer, the employee said. The purpose of the ponding area/oxidizer basin was "to catch any liquid oxidizer from the big tank" if workers had to do an emergency "dump". The employee heard from a longer term employee that when the 500 OOSA was in use during the Apollo testing in the 1960s that there was one incident of an oxidizer spill at the storage area. "A truck came in unloading into the big tank. The driver was not taking safety seriously and only wearing gloves, no other PPE. A valve wasn't closed all the way. When the driver disconnected the 3" or 4" transfer line, oxidizer sprayed all over him...Technicians present at the time soaked him in the emergency shower there…He was ok in the end…The oxidizer volatized and evaporated." The employee did not know the amount of oxidizer spilled, but the transfer area was concrete, not released to soil. The ponding area or containment basin never held oxidizer to the employee's knowledge. "The 500 OOSA was abandoned by the time of the oxidizer testing in the late 1970s. The area was only used for the Apollo program. After the Apollo program, fuel use went from UDMH and Aerozine 50 to MMH. These fuels weren't compatible for use in the same tank. The oxidizer tank (and fuel tank) was a huge tank. Originally, lines were built from the 500 Area to the test areas (300/400 Areas)…Any fuel or oxidizer not used during a test was pushed back into the 500 Area again…NASA thought they were losing fuel or oxidizer [by having product remain in the lines] by pushing them all the way back to the storage areas." Fuel and oxidizer was stored in the manufacturer's storage tanks. The manufacturer's tanks were called "pigs" and were much smaller than the original large tanks. These "pigs" were stored in the concrete areas next to the big tanks until they were needed for a test. Then the "pig" would be transported to the 300 or 400 Area. Then the leftover (unused) "pig" of fuel or oxidizer was kept at the 300 or 400 Area. "So with this system, the big tanks and transfer lines in the 500 Area were not needed. NASA isolated the 500 Area and abandoned the big tanks." The employee stated that the 500 Area oxidizer burner became the 800 Area oxidizer burner. Any oxidizer that couldn't be sent back to the tank was burned in the oxidizer burner.	

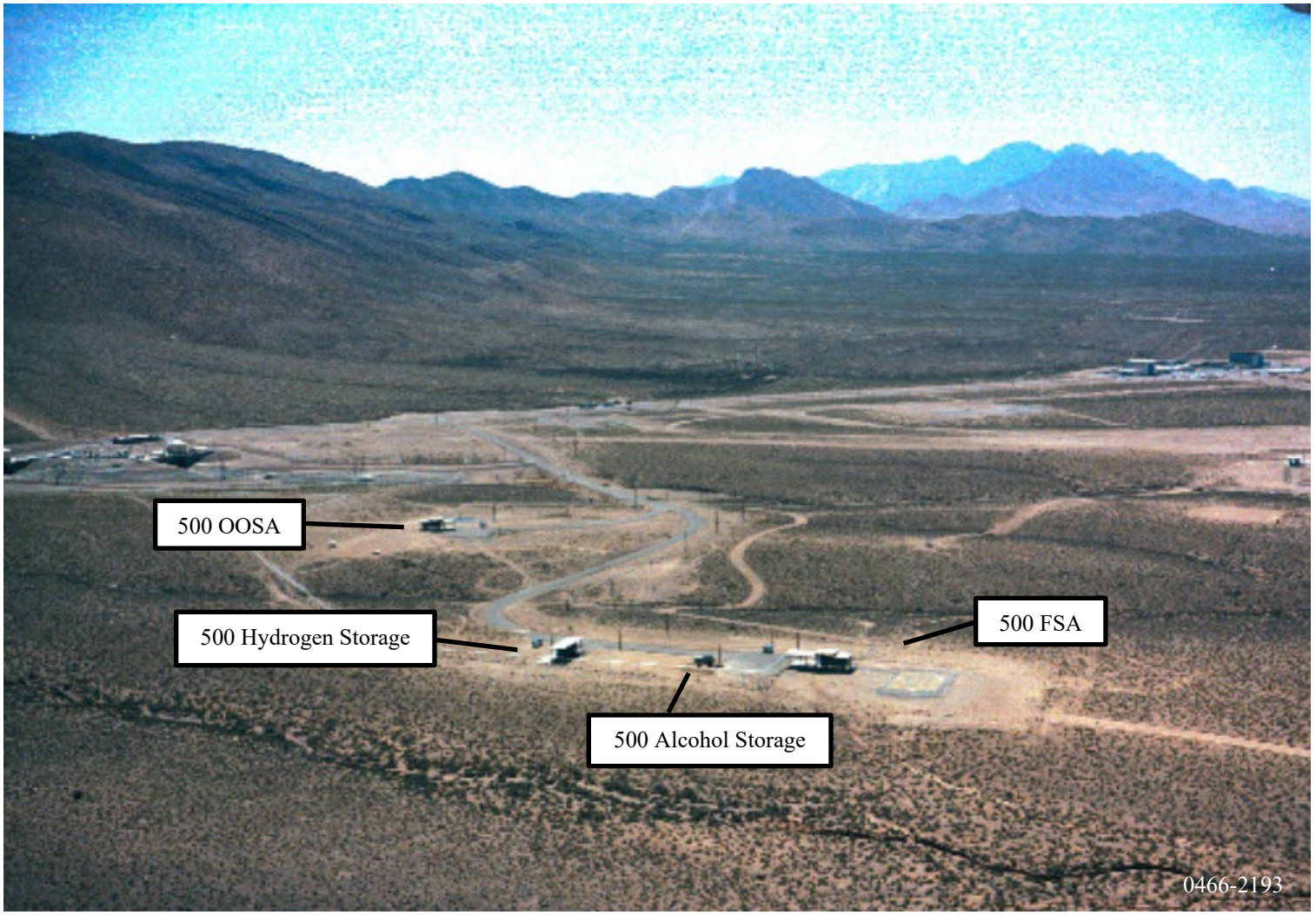
Position	Significant 500 Area Information	Other Information or Comments
	Both in the 500 Area fuel and oxidizer storage areas, there was a shade to cover the big tanks, and sprinkler systems to turn on a water deluge in case of fire.	
	A logbook for 500 Area operations was located, providing dates for 500 OOSA tank removal, FTU operations, and other 500 Area activities.	

Appendix B
500 Fuel Oxidizer Burner Historical Photographs

Figure B.1 **Schematic of the 500 OOSA and FOB**

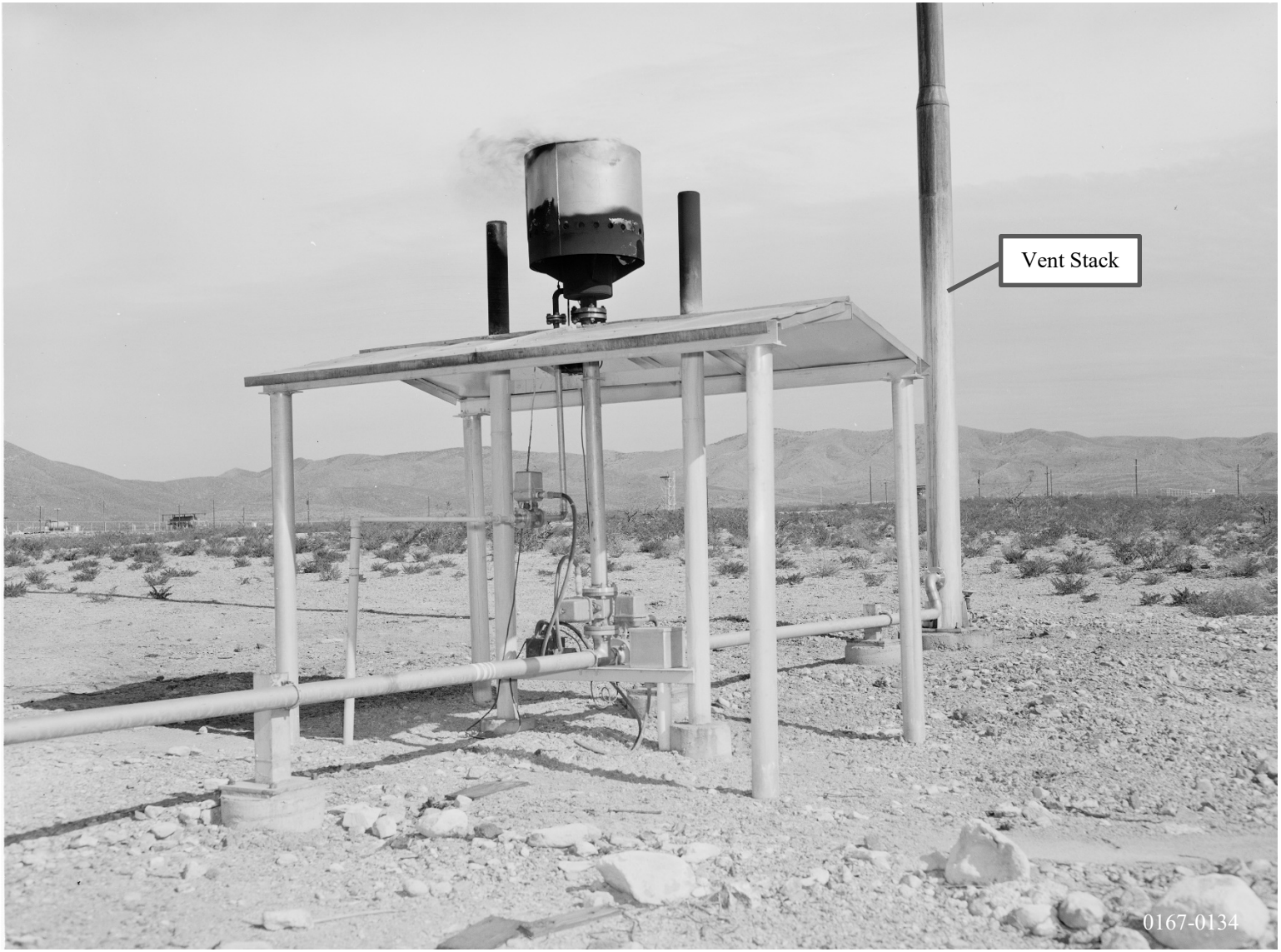


This schematic shows the 500 Original Oxidizer Storage Area (OOSA) and the location of the former oxidizer burner (FOB) and associated underground conduit and cabling. The diagram identifies the control building (B521), the original 19,700-gallon oxidizer tank (B523 is the tank shed cover), and the oxidizer containment basin or ponding area.



This photograph shows the 500 Area OOSA, Hydrogen Storage Area, Alcohol Storage Area, and Fuel Storage Area (FSA) in April 1966.

Figure B.3 **500 Area Former Oxidizer Burner (1967) – view to the east**



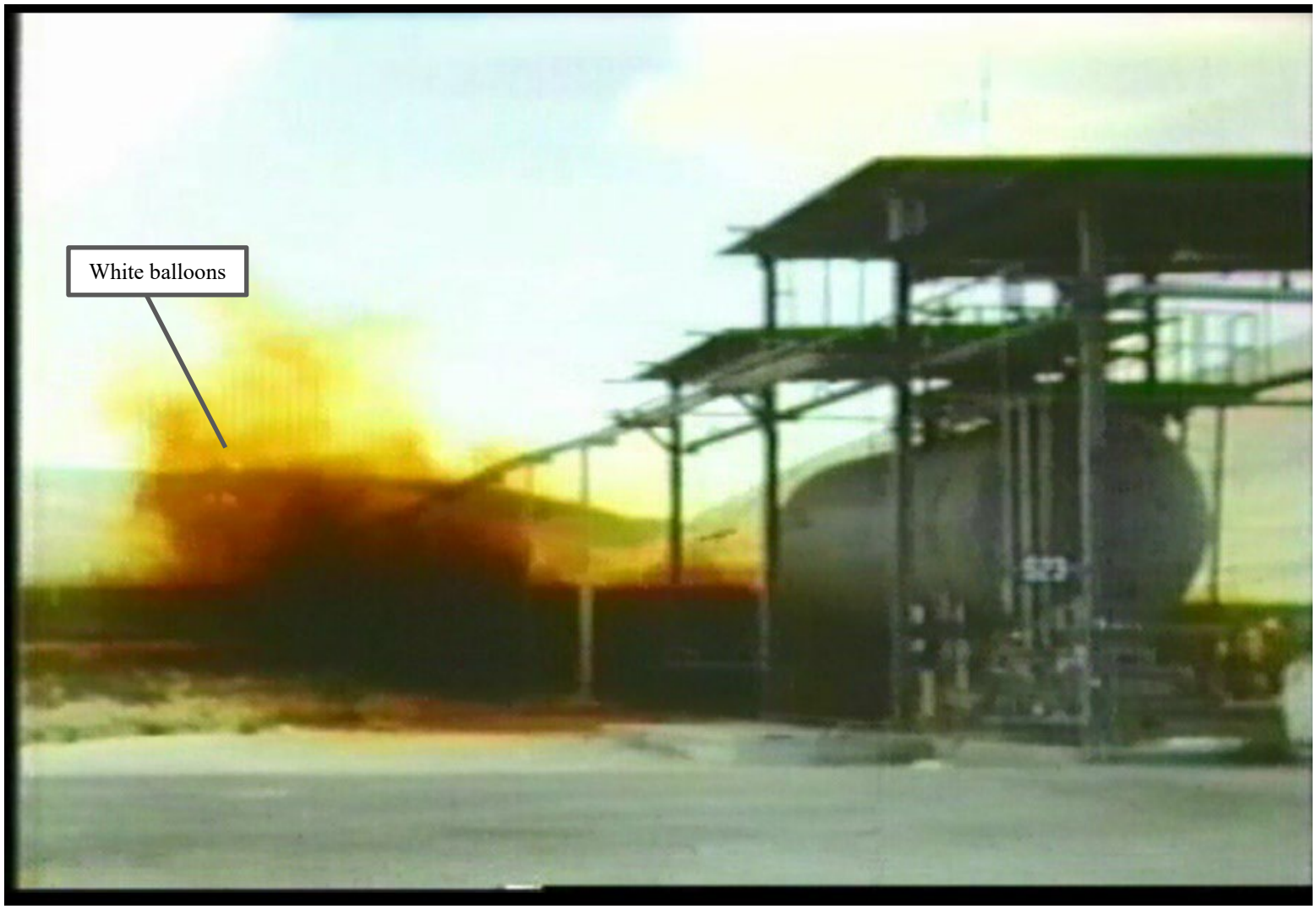
This photograph shows the 500 Area FOB in use and the adjacent vent stack in January 1967.

This photograph shows technicians in protective suits working at the 500 OOSA in May 1967.

Figure B.5 Conducting Oxidizer Testing in 500 OOSA (1979) – view to the east

This photograph shows testing in the 500 OOSA in 1979 to determine characteristics of a potential catastrophic oxidizer release at WSTF. Notice the N_2O_4 is actively being released onto concrete and immediately vaporizing to reddish-brown NO_2.

Figure B.6 **Conducting Oxidizer Testing in 500 OOSA (1979) – view to the east**



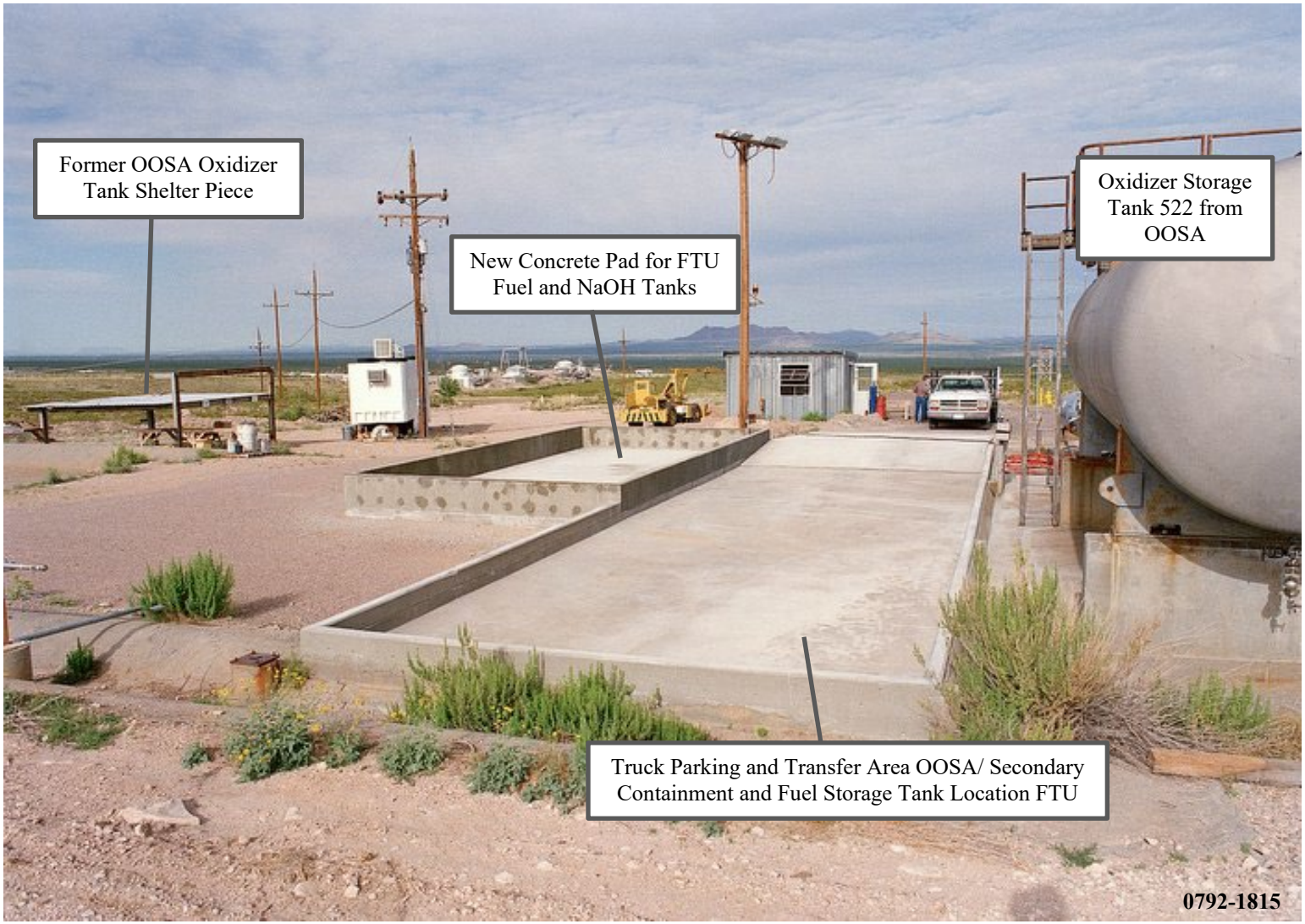
This photograph shows testing in the 500 OOSA in 1979 to determine characteristics of a potential catastrophic oxidizer release at WSTF. Notice the reddish-brown NO_2 vapor has drifted northeast with the wind compared to the previous photo (B.5).

Figure B.7 Conducting Oxidizer Testing in 500 OOSA (1979) – view to the northeast

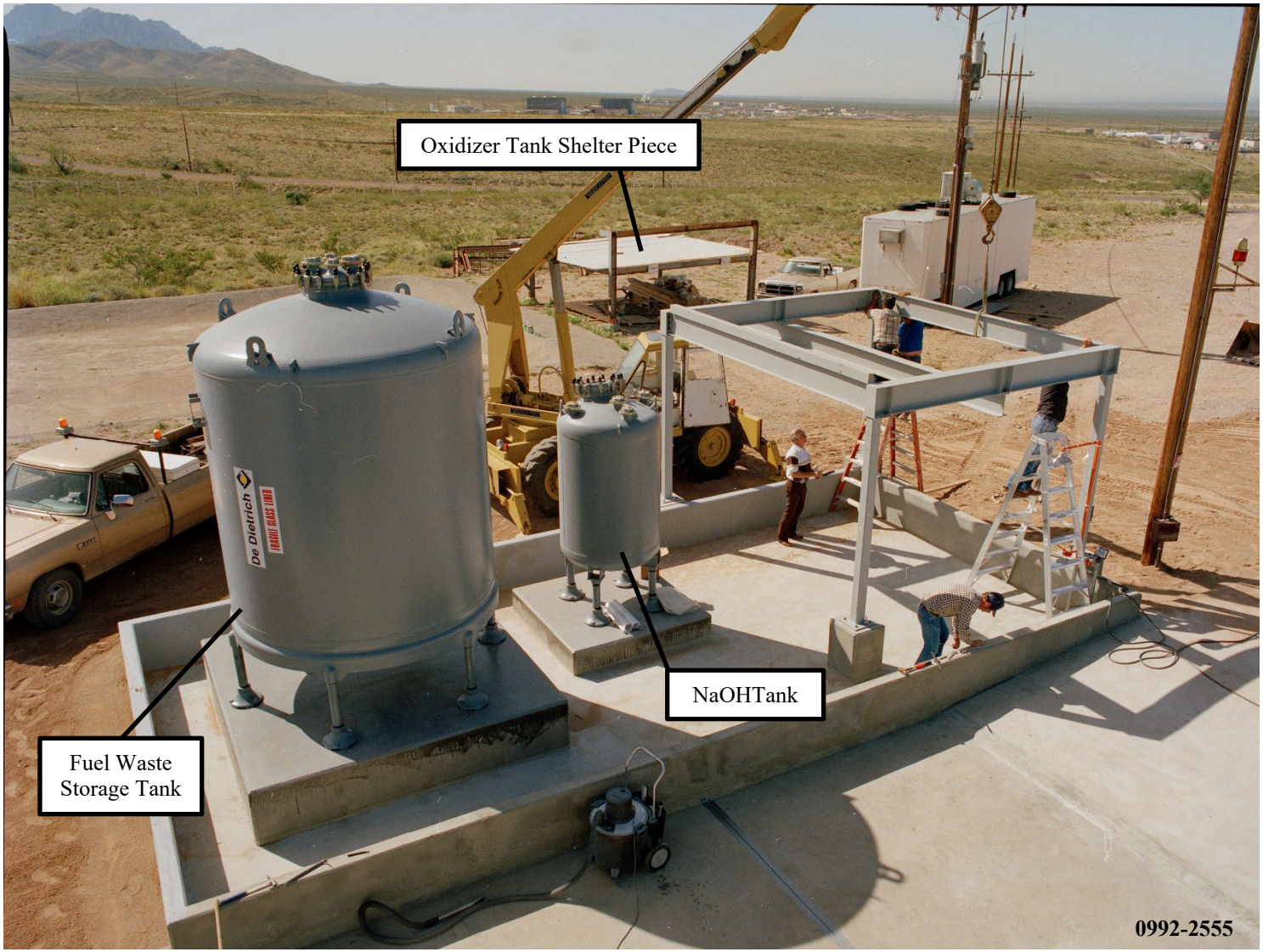
This photograph shows technicians in protective suits working in the released oxidizer during testing in the 500 OOSA in June 1979.

This photograph shows the 500 Area in September 1974. The large oxidizer tank had been "closed" and abandoned and the oxidizer burner moved to the 800 Area.

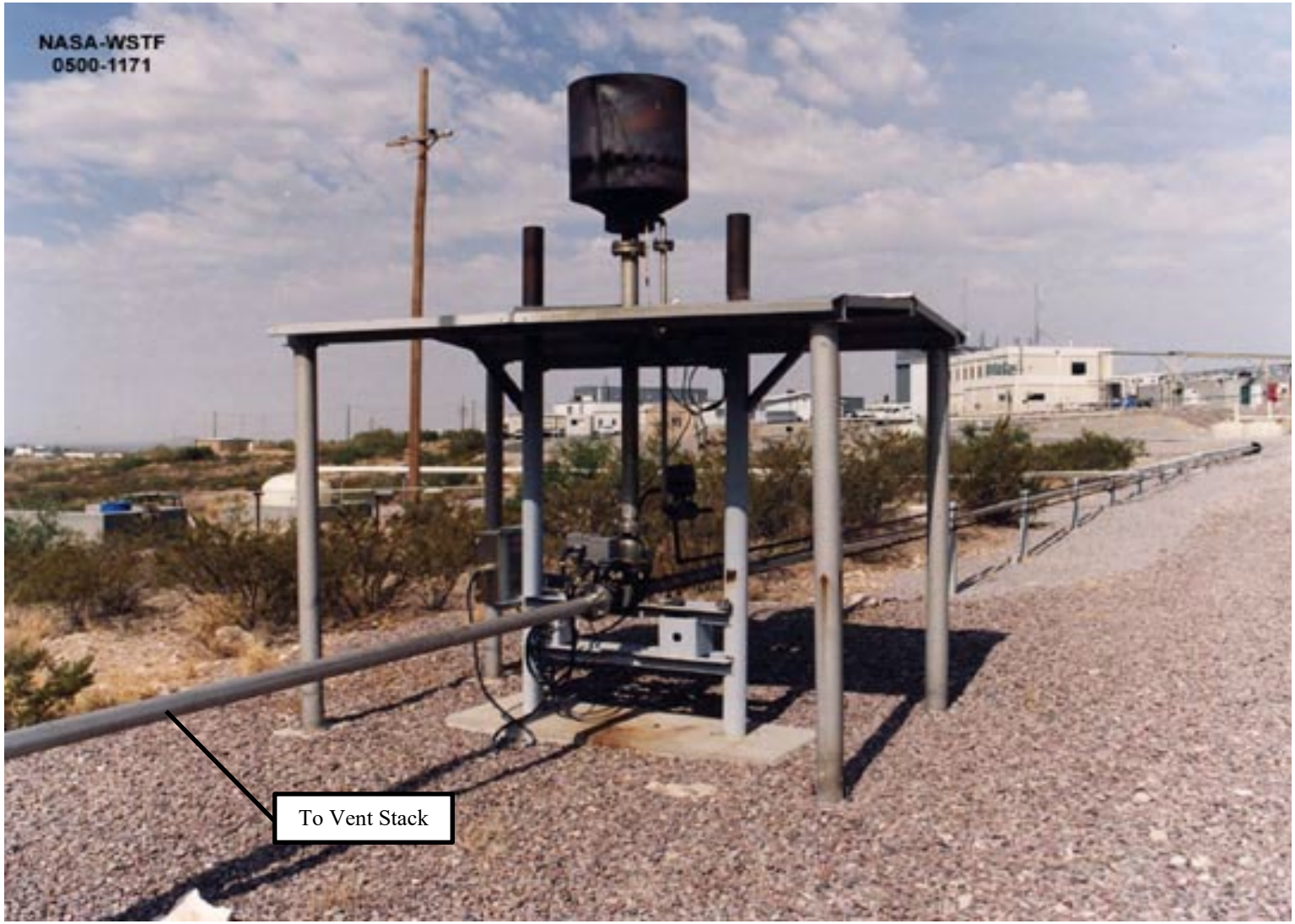
Figure B.9 **Constructing the FTU (1992) – view to the west**



This photograph shows the 500 OOSA undergoing construction to become the Fuel Treatment Unit (FTU) in July 1992. The original 19,700-gallon oxidizer tank is still in place, and to become part of the FTU, the truck parking and transfer area has been modified, and a new concrete pad with containment has been added.

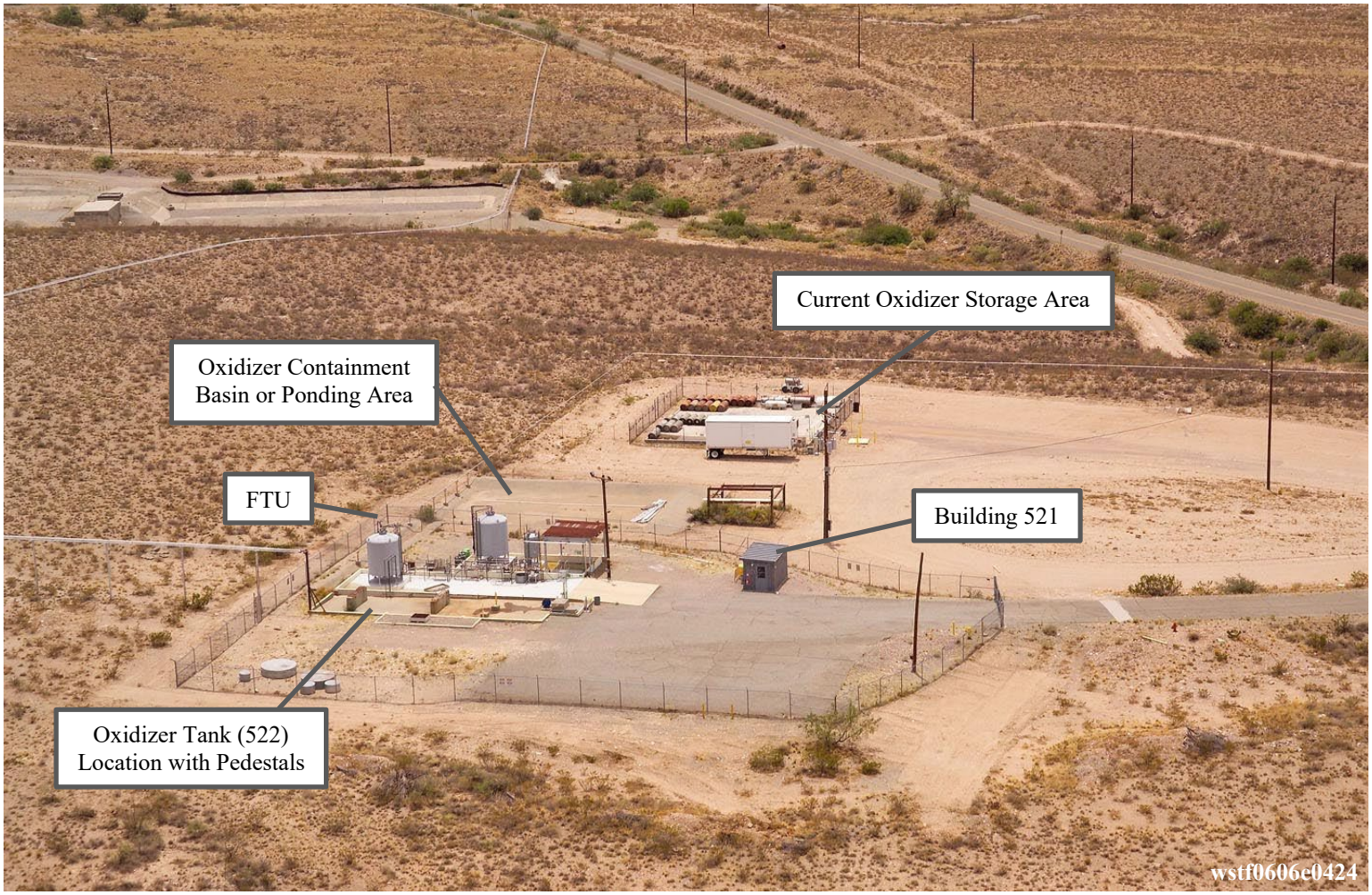


This photograph was taken from the stairs of the large oxidizer tank and shows installation of the fuel and sodium hydroxide (NaOH) tanks on the newly made concrete containment area to become part of the FTU.



This photograph taken May 2000 shows the 800 Area oxidizer burner (1974-present) that currently disposes of leftover oxidizer after testing in the WSTF 800 Area. This burner was previously the 500 OOSA oxidizer burner from 1965-1974. The vent stack is not shown in the photo.

Figure B.12 **500 OOSA and FTU (2006) – view to the south**



This photograph shows the 500 OOSA in June 2006. Notice the secondary containment concrete pad and pedestals for the original 19,700-gallon oxidizer tank (Tank 522) are still present. The current oxidizer storage area is located to the south towards the top of the photo.

Figure B.13 Oxidizer Containment Basin or Ponding Area (2018) – view to the northeast

This photograph shows the gunite-lined oxidizer containment basin or ponding area for the 500 OOSA. The area was originally used only for potential secondary emergency oxidizer containment if the large tank failed or there was a large spill or leak. The drain for the area is marked with a stick and leads to a pipe with a gate valve. This area was not used as part of the FTU.

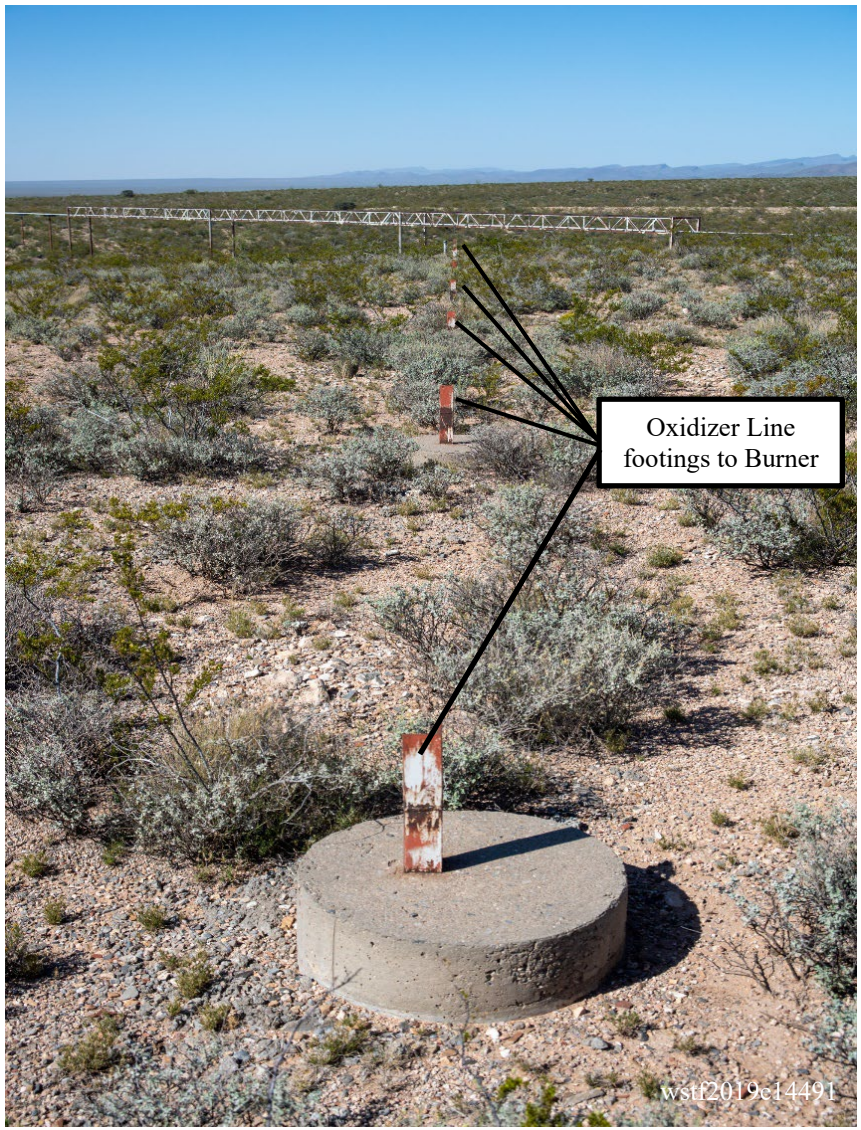
This photograph shows the 500 OOSA oxidizer containment basin or ponding area. There is a channel or open trench from the oxidizer tank concrete pad to the containment basin.

This photograph shows the FTU, the secondary containment and pedestal for the original oxidizer tank, and the opening in the southeast corner of the containment wall that drained to the gunite-lined channel or open trench to the oxidizer containment basin or ponding area. The entire channel was gunite lined during operation of the oxidizer tank, but a portion of the gunite has been removed where the channel meets the tank area opening (likely during FTU construction). Soil has washed into the channel as seen in the photo.

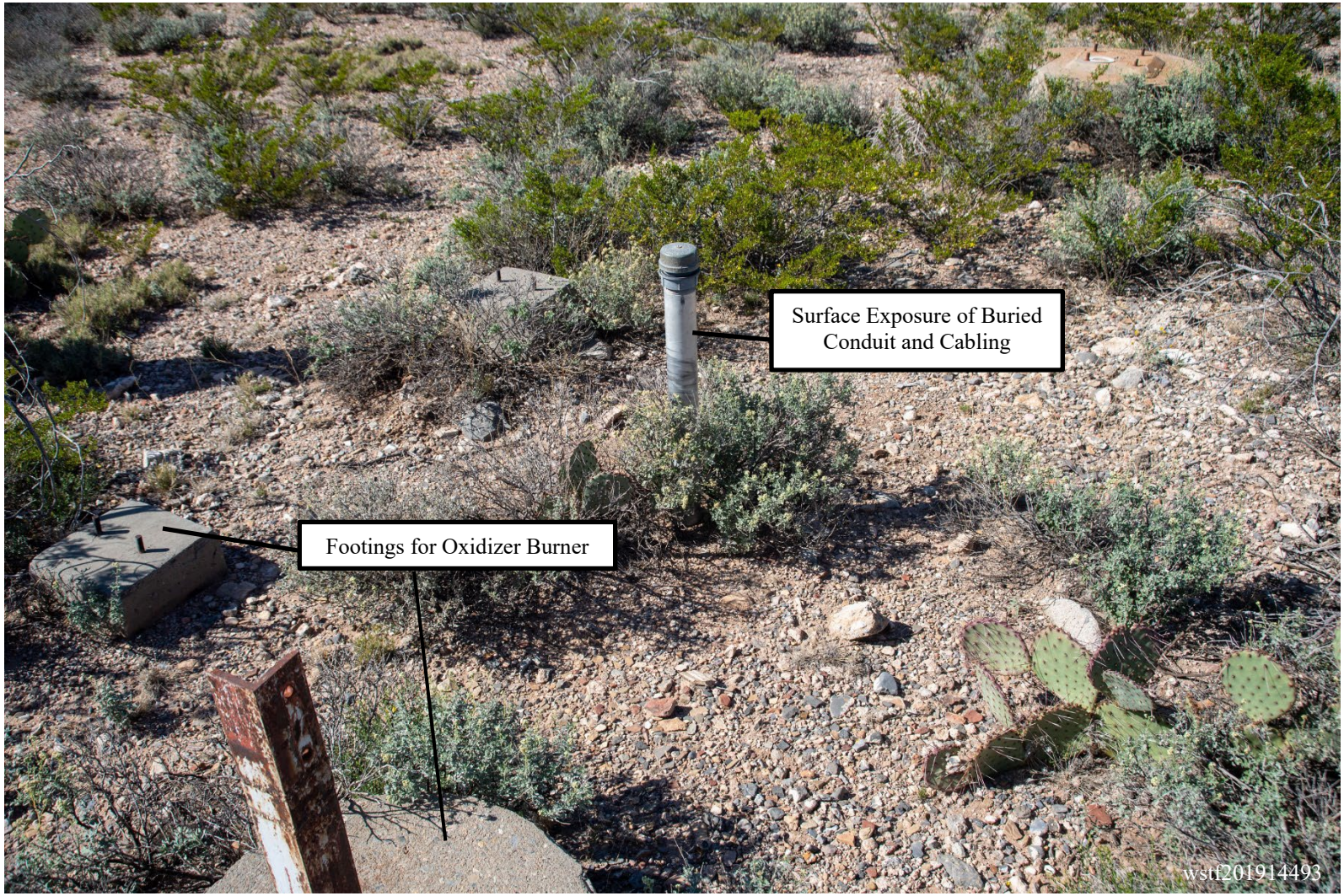
This photograph shows the 4-in. steel pipe that drained the 500 OOSA oxidizer containment basin or ponding area. The pipe end had been cut in the past. The wet area is rain water.

This photograph shows the demolition of the 500 OOSA oxidizer containment basin or ponding area as part of FTU closure procedures.

This is a photograph showing the demolition of the original oxidizer tank (522) area with the concrete pad, pedestals, secondary containment as part of FTU closing procedures.



This photograph shows the remaining abandoned footings to the oxidizer line for the 500 Area FOB as part of the OOSA.



This photograph shows the abandoned footings and conduit with cabling for the 500 Area FOB. The burner and vent stack were removed and installed in the 800 Area in 1974.

Figure B.21 Historical Aerial Imagery of the 500 Area Former Oxidizer Burner (1985, 1996-98, 2014, and Current Esri Imagery)

Appendix C
Material Safety Data Sheets/Safety Data Sheets

MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

HYDROFLUORIC ACID

1. Product Identification

Synonyms: Fluorohydric acid; fluoric acid; Hydrogen fluoride solution
CAS No.: 7664-39-3
Molecular Weight: 20.01
Chemical Formula: HF in Aqueous Solution.
Product Codes:
J.T. Baker: 5368, 5659, 5818, 5823, 5824, 5840, 5865, 5900, 6904, 9559, 9560, 9563, 9564, 9567, 9572, 9573, 9574
Mallinckrodt: 2640, 2648, V141, V580

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Hydrogen Fluoride	7664-39-3	48 - 52%	Yes
Water	7732-18-5	48 - 52%	No

3. Hazards Identification

Emergency Overview

POISON! DANGER! CORROSIVE. EXTREMELY HAZARDOUS LIQUID AND VAPOR. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. MAY BE FATAL IF SWALLOWED OR INHALED. LIQUID AND VAPOR CAN BURN SKIN, EYES AND RESPIRATORY TRACT. CAUSES BONE DAMAGE. REACTION WITH CERTAIN METALS GENERATES FLAMMABLE AND POTENTIALLY EXPLOSIVE HYDROGEN GAS.

SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 4 - Extreme (Poison)
Flammability Rating: 0 - None
Reactivity Rating: 2 - Moderate
Contact Rating: 4 - Extreme (Corrosive)
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Exposure to hydrofluoric acid can produce harmful health effects that may not be immediately apparent.

Inhalation:
Severely corrosive to the respiratory tract. May cause sore throat, coughing, labored breathing and lung congestion/inflammation.
Ingestion:
Corrosive. May cause sore throat, abdominal pain, diarrhea, vomiting, severe burns of the digestive tract, and kidney dysfunction.
Skin Contact:
Corrosive to the skin. Skin contact causes serious skin burns which may not be immediately apparent or painful. Symptoms may be delayed 8 hours or longer. The fluoride ion readily penetrates the skin causing destruction of deep tissue layers and even bone.
Eye Contact:
Corrosive to the eyes. Symptoms of redness, pain, blurred vision, and permanent eye damage may occur.
Chronic Exposure:
Intake of more than 6 mg of fluorine per day may result in fluorosis, bone and joint damage. Hypocalcemia and hypomagnesemia can occur from absorption of fluoride ion into blood stream.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye problems, or impaired kidney or respiratory function may be more susceptible to the effects of this substance.

4. First Aid Measures

For any route of contact: Detailed First Aid procedure should be planned before beginning work with HF.
Inhalation:
Get medical help immediately. If patient is unconscious, give artificial respiration or use inhalator. Keep patient warm and resting, and send to hospital after first aid is complete.
Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
1) Remove the victim from the contaminated area and immediately place him under a safety shower or wash him with a water hose, whichever is available. 2) Remove all contaminated clothing. Handle all HF-contaminated material with gloves made of appropriate material, such as PVC or neoprene. 3) Keep washing with large amounts of water for a minimum of 15 minutes. 4) Have someone make arrangements for medical attention while you continue flushing the affected area with water. 5) If the following materials are available, limit the washing to five minutes and immerse the burned area in a solution of 0.2% iced aqueous Hyamine 1622 or 0.13% iced aqueous Zephiran Chloride. If immersion is not practical, towels should be soaked with one of the above solutions and used as compresses for the burn area. Ideally compresses should be changed every 2 minutes. Alternately, 2.5% calcium gluconate gel should be massaged into the affected area. 6) Seek medical attention as soon as possible for all burns regardless of how minor they may appear initially. Hyamine 1622 is a trade name for tetracaine benzethonium chloride, Merck Index Monograph 1078, a quaternary ammonium compound sold by Rohm & Haas, Philadelphia. Zephiran Chloride is a trade name for benzalkonium chloride, Merck Index Monograph 1059, also a quaternary ammonium compound, sold by Sanofi-Synthelabo Inc., New York, NY.
Eye Contact:
1) Irrigate eyes for at least 30 minutes with copious quantities of water, keeping the eyelids apart and away from eyeballs during irrigation. 2) Get competent medical attention immediately, preferably an eye specialist. 3) If a physician is not immediately available, apply one or two drops of ophthalmic anesthetic, (e.g., 0.5% Pontocaine Hydrochloride solution). 4) Do not use oily drops, ointment or HF skin burn treatments. Place ice pack on eyes until reaching emergency room.

Note to Physician:
General: For burns of moderate areas, (greater than 8 square inches), ingestion and significant inhalation exposure, severe systemic effects may occur, and admission to a critical care unit should be considered. Monitor and correct for hypocalcemia, cardiac arrhythmias, hypomagnesemia and hyperkalemia. In some cases renal dialysis may be indicated.

Inhalation: Treat as chemical pneumonia. Monitor for hypocalcemia, 2.5% calcium gluconate in normal saline by nebulizer or by IPPB with 100% oxygen may decrease pulmonary damage. Bronchodilators may also be administered.

Skin: For deep skin burns or contact with concentrated HF (over 50%) solution, consider infiltration about the affected area with 5% calcium gluconate [equal parts of 10% calcium gluconate and sterile saline for injection]. Burns beneath the nail may require splitting the nail and application of calcium gluconate to the exposed nail bed. For certain burns, especially of the digits, use of intra-arterial calcium gluconate may be indicated.

Eyes: Irrigation may be facilitated by use of Morgan lens or similar ocular irrigator, using 1% aqueous calcium gluconate solution [50ml of calcium gluconate 10% in 500 ml normal saline].

AN ALTERNATIVE FIRST AID PROCEDURE: The effect of HF, i.e. onset of pain, particularly in dilute solutions, may not be felt for up to 24 hours. It is important, therefore, that persons using HF have immediate access to an effective antidote even when they are away from their work place in order that first aid treatment can be commenced immediately.
We recommend that any person in contact with HF should carry, or have access to a tube of HF Antidote Gel at all times; ideally with one tube at the work place, one on the person and one at home.
It is imperative that any person who has been contaminated by HF should seek medical advice when the treatment by HF Antidote Gel has been applied.
REFERENCES: 1. Browno, T.D. Treatment of Hydrofluoric Acid Burns 2. Sprout, W.L. et al Treatment of Severe Hydrofluoric Acid Exposures (Journal of American Occupational Medicine 25:12, 1993) 3. Bracken, W.M. et al Comparative Effectiveness of Topical Treatments for Hydrofluoric Acid Burns, University of Kansas (Journal of Occupational Medicine 27:10:1985) 4. Burke, W.J. , et al Systemic Fluoride Poisoning Resulting from A Fluoride Skin Burn (Journal of Occupational Medicine (5,39:1973)

HF ANTIDOTE GEL:
Distributed by Pharmascience Inc.
8400 Darnley Rd. Montreal, Canada. H4T 1M4
Phone: (514) 340 - 1114
Fax: (514) 342 - 7764
U.S. (Buffalo, NY) distributor: 1-800-207-4477

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5. Fire Fighting Measures

Fire:
Not considered to be a fire hazard. Fire may produce poisonous or irritating gases.
Explosion:
Violent exothermic reaction occurs with water. Sufficient heat may be produced to ignite combustible materials. Reacts with metals forming flammable Hydrogen gas.
Fire Extinguishing Media:
Keep upwind of fire. Use water or carbon dioxide on fires in which Hydrofluoric Acid is involved. Halon or foam may also be used. In case of fire, the sealed containers can be kept cool by spraying with water.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Avoid getting water in tanks or drums; water can cause generation of heat and spattering. In contact with air, the acid gives off corrosive fumes which are heavier than air.

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6. Accidental Release Measures

Notify safety personnel, provide adequate ventilation, and remove ignition sources since hydrogen may be generated by reactions with metals. Wear appropriate personal protective equipment as specified in Section 8. Do not flush to sewers or waterways. Spills: Evacuate the danger area. Apply magnesium sulfate (dry) to the spill area. Follow up with inert absorbent and add soda ash or magnesium oxide and slaked lime. Collect in appropriate plastic containers and save for disposal. Wash spill site with soda ash solution. NOTE: Porous materials (concrete, wood, plastic, etc.) will absorb HF and become a hazard for an indefinite time. Such spills should be cleaned and neutralized immediately. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker Hydrofluoric Acid Emergency Cleanup Kit is recommended for spills of this product.

7. Handling and Storage

Keep in tightly closed polyethylene containers. Store in a cool, dry place with adequate ventilation separated from other chemicals. Protect from physical damage. Storage facilities should be constructed for containment and neutralization of spills. Handling and storage of HF requires special materials and technology for containers, pipes, valves, etc., which is available from suppliers. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
Hydrogen fluoride:
-OSHA Permissible Exposure Limit (PEL):
3 ppm (TWA)
ACGIH Threshold Limit Value (TLV):
3 ppm Ceiling as F
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures as low as possible. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, a full facepiece respirator with an acid gas cartridge may be worn up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres. Since the IDLH is low (30 ppm), the above cartridge system is not specifically approved for HF. (3M Respirator Selection Guide)
Skin Protection:
Wear protective clothing, including boots or safety shoes with polyvinyl chloride (PVC) or neoprene. Use chemical goggles and/or a full face shield. Wear coveralls with long sleeves, gauntlets and gloves of PVC or neoprene. A high degree of protection is obtained with an air-inflated suit with mask and safety belt. Use protection suitable for conditions.
Eye Protection:
Use chemical safety goggles and/or full face shield where splashing is possible. Maintain eye wash fountain and quick drench facilities in work area.

9. Physical and Chemical Properties

Appearance:
Colorless, fuming liquid.
Odor:
Acrid odor. Do not breathe fumes.
Solubility:
Infinitely soluble.
Specific Gravity:
1.15 -1.18
pH:
1.0 (0.1M solution)
% Volatiles by volume @ 21C (70F):
100 (as water and acid)
Boiling Point:
108C (226F)
Melting Point:
< -36C (< -33F)
Vapor Density (Air=1):
1.97
Vapor Pressure (mm Hg):
25 @ 20C (68F)
Evaporation Rate (BuAc=1):
No information found.

10. Stability and Reactivity

Stability:
Stable at room temperature (68F) when stored and used under proper conditions.
Hazardous Decomposition Products:
On contact with metals, liberates hydrogen gas. On heating to decomposition, could yield toxic fumes of fluorides. Attacks glass and other silicon containing compounds. Reacts with silica to produce silicon tetrafluoride, a hazardous colorless gas.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Hydrofluoric acid is incompatible with arsenic trioxide, phosphorus pentoxide, ammonia, calcium oxide, sodium hydroxide, sulfuric acid, vinyl acetate, ethylenediamine, acetic anhydride, alkalis, organic materials, most common metals, rubber, leather, water, strong bases, carbonates, sulfides, cyanides, oxides of silicon, especially glass, concrete, silica, fluorine. Will also react with steam or water to produce toxic fumes.
Conditions to Avoid:
Moisture and incompatibles.

11. Toxicological Information

Hydrofluoric acid: Inhalation rat LC50: 1276 ppm/1H; Investigated as a mutagen, reproductive effector.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Hydrogen Fluoride (7664-39-3)	No	No	None
Water (7732-18-5)	No	No	None

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12. Ecological Information

Environmental Fate:
If the pH is > 6.5, soil can bind fluorides tightly. High calcium content will immobilize fluorides, which can be damaging to plants when present in acid soils.
Environmental Toxicity:
This material is expected to be slightly toxic to aquatic life. 60 ppm/*/Fish/Lethal/Fresh Water *=time period not specified. > 300ppm/48hr./Shrimp/LC50/Aerated Saltwater

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13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

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14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: RQ, HYDROFLUORIC ACID (WITH NOT MORE THAN 60% STRENGTH)
Hazard Class: 8, 6.1
UN/NA: UN1790
Packing Group: II
Information reported for product/size: 500LB

International (Water, I.M.O.)

Proper Shipping Name: HYDROFLUORIC ACID (WITH NOT MORE THAN 60% STRENGTH)
Hazard Class: 8, 6.1
UN/NA: UN1790
Packing Group: II
Information reported for product/size: 500LB

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15. Regulatory Information

--------\Chemical Inventory Status - Part 1\----------

Ingredient	TSCA	EC	Japan	Australia
Hydrogen Fluoride (7664-39-3)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\----------

Ingredient	--Canada-- Korea	DSL	NDSL	Phil.
Hydrogen Fluoride (7664-39-3)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Hydrogen Fluoride (7664-39-3)	100	100	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Hydrogen Fluoride (7664-39-3)	100	U134	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: Yes TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: Yes (Mixture / Liquid)

Australian Hazchem Code: 2R
Poison Schedule: S7
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: **4** Flammability: **0** Reactivity: **1**
Label Hazard Warning:
POISON! DANGER! CORROSIVE. EXTREMELY HAZARDOUS LIQUID AND VAPOR. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. MAY BE FATAL IF SWALLOWED OR INHALED. LIQUID AND VAPOR CAN BURN SKIN, EYES AND RESPIRATORY TRACT. CAUSES BONE DAMAGE. REACTION WITH CERTAIN METALS GENERATES FLAMMABLE AND POTENTIALLY EXPLOSIVE HYDROGEN GAS.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor.
Cool before opening.
Use only with adequate ventilation.
Wash thoroughly after handling.
Store in a tightly closed container.
Label First Aid:
IN ALL CASES, CALL PHYSICIAN IMMEDIATELY. First Aid procedures should be pre-planned for HF emergencies. A supply of 50:50 water/magnesium sulfate paste or 2 1/2% Calcium Gluconate paste should be available where first aid medications are administered. If ingested, DO NOT INDUCE VOMITING. If patient is conscious, give large quantities of milk or water and send to hospital. If inhaled and patient is unconscious, give artificial respiration or use inhalator and send to hospital. In case of eye contact, wash open eyes with large but gentle stream of water for 15 minutes. Place ice pack on eyes until reaching emergency room. In case of skin contact, remove contaminated clothing and wash burn area with plenty of water to remove acid. Cover burn area with a poultice of 50:50 water/magnesium sulfate paste or 2 1/2% calcium gluconate paste. Leave in place until medical help arrives or patient is transferred to hospital.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 6.
Disclaimer:
****
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****
Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

Hydrogen fluoride, anhydrous

Safety Data Sheet M009301

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Revision date: 09/11/2019 Version: 1.1

SECTION 1: Identification

1.1. Identification

Product form	:	Substance
Substance name	:	Hydrogen fluoride, anhydrous
CAS No	:	7664-39-3
Product code	:	M009-3-01
Formula	:	FH

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture	:	Laboratory chemicals Manufacture of substances Scientific research and development

1.3. Details of the supplier of the safety data sheet

SynQuest Laboratories, Inc.
P.O. Box 309
Alachua, FL 32615 - United States of America
T (386) 462-0788 - F (386) 462-7097
info@synquestlabs.com - www.synquestlabs.com

1.4. Emergency telephone number

Emergency number	:	(844) 523-4086 (3E Company - Account 10069)

SECTION 2: Hazard(s) identification

2.1. Classification of the substance or mixture

Classification (GHS-US)

Simple Asphy	H380 -	May displace oxygen and cause rapid suffocation
Liquefied gas	H280 -	Contains gas under pressure; may explode if heated
Acute Tox. 2 (Oral)	H300 -	Fatal if swallowed
Acute Tox. 1 (Dermal)	H310 -	Fatal in contact with skin
Acute Tox. 2 (Inhalation:vapour)	H330 -	Fatal if inhaled
Skin Corr. 1A	H314 -	Causes severe skin burns and eye damage
Eye Dam. 1	H318 -	Causes serious eye damage
STOT SE 3	H335 -	May cause respiratory irritation

Full text of H-phrases: see section 16

2.2. Label elements

GHS-US labeling

Hazard pictograms (GHS-US) :

GHS04 GHS05 GHS06 GHS07

Signal word (GHS-US) : Danger

Hazard statements (GHS-US) :
H280 - Contains gas under pressure; may explode if heated
H300+H310+H330 - Fatal if swallowed, in contact with skin or if inhaled
H314 - Causes severe skin burns and eye damage
H335 - May cause respiratory irritation
H380 - May displace oxygen and cause rapid suffocation

Precautionary statements (GHS-US) :
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P262 - Do not get in eyes, on skin, or on clothing
P264 - Wash skin thoroughly after handling
P270 - Do not eat, drink or smoke when using this product
P271 - Use only outdoors or in a well-ventilated area
P280 - Wear protective gloves/protective clothing/eye protection/face protection
P284 - In case of inadequate ventilation wear respiratory protection
P301+P310 - If swallowed: Immediately call a poison center/doctor/…
P301+P330+P331 - If swallowed: rinse mouth. Do NOT induce vomiting
P303+P361+P353 - If on skin (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower
P304+P340 - If inhaled: Remove person to fresh air and keep comfortable for breathing

P305+P351+P338 - If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a POISON CENTER or doctor/ physician
P320 - Specific treatment is urgent (see supplemental first aid instructions on this label)
P321 - Specific treatment (see supplemental first aid instructions on this label)
P330 - Rinse mouth
P361 - Take off immediately all contaminated clothing
P363 - Wash contaminated clothing before reuse
P403+P233 - Store in a well-ventilated place. Keep container tightly closed
P405 - Store locked up
P410+P403 - Protect from sunlight. Store in a well-ventilated place
P501 - Dispose of contents/container to an approved waste disposal plant

2.3. Other hazards

No additional information available

2.4. Unknown acute toxicity (GHS US)

Not applicable

SECTION 3: Composition/information on ingredients

3.1. Substance

Substance type : Mono-constituent

Name	Product identifier	%	Classification (GHS-US)
Hydrogen fluoride, anhydrous (Main constituent)	(CAS No) 7664-39-3	<= 100	Simple Asphy, H380 Liquefied gas, H280 Acute Tox. 2 (Oral), H300 Acute Tox. 1 (Dermal), H310 Acute Tox. 2 (Inhalation:vapour), H330 Skin Corr. 1A, H314 Eye Dam. 1, H318 STOT SE 3, H335

Full text of H-phrases: see section 16

3.2. Mixture

Not applicable

SECTION 4: First aid measures

4.1. Description of first aid measures

First-aid measures general : In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible). Move the affected personnel away from the contaminated area.

First-aid measures after inhalation : Remove person to fresh air and keep comfortable for breathing. If not breathing, give artificial respiration. Get immediate medical advice/attention.

First-aid measures after skin contact : Wash with plenty of soap and water. Remove contaminated clothing and shoes. In case of skin contact, wearing rubber gloves rub 2.5% calcium gluconate gel continuously into the affected area for 1.5 hours or until further medical care is available. Get immediate medical advice/attention.

First-aid measures after eye contact : Immediately flush eyes thoroughly with water for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Get immediate medical advice/attention.

First-aid measures after ingestion : Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth out with water. Get immediate medical advice/attention.

4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries : The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11.

Symptoms/injuries after inhalation : Material is destructive to tissue of the mucuous membranes and upper respiratory tract. Cough, shortness of breath, headache, nausea.

4.3. Indication of any immediate medical attention and special treatment needed

Treat symptomatically. Absorption of excessive F- can result in acute systemic fluorosis with hypocalcemia, interference with various metabolic functions and organ damage (heart, liver, kidneys).

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media : Use extinguishing media appropriate for surrounding fire.

5.2. Special hazards arising from the substance or mixture

Fire hazard : Thermal decomposition generates: Carbon oxides. Hydrogen fluoride.

Explosion hazard : Risk of explosion if heated under confinement. Use water spray or fog for cooling exposed containers.

Reactivity : Reacts with water, generates gases or heat. Reacts on exposure to water with some metals to release highly explosive/flammable hydrogen gas.

5.3. Advice for firefighters

Firefighting instructions : In case of fire: Evacuate area. Fight fire remotely due to the risk of explosion.

Protection during firefighting : Wear gas tight chemically protective clothing in combination with self contained breathing apparatus. For further information refer to section 8: "Exposure controls/personal protection".

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

General measures : Evacuate unnecessary personnel. Ensure adequate air ventilation. May cause suffocation by reducing oxygen available for breathing. Do not breathe gas, fumes, vapor or spray.

6.1.1. For non-emergency personnel

Emergency procedures : Only qualified personnel equipped with suitable protective equipment may intervene.

6.1.2. For emergency responders

Protective equipment : Do not attempt to take action without suitable protective equipment. For further information refer to section 8: "Exposure controls/personal protection".

Emergency procedures : Gas/vapor heavier than air. May accumulate in confined spaces, particularly at or below ground level.

6.2. Environmental precautions

Avoid release to the environment. Notify authorities if product enters sewers or public waters.

6.3. Methods and material for containment and cleaning up

For containment : Stop leak if safe to do so. Dike for recovery or absorb with appropriate material.

Methods for cleaning up : Take up large spills with pump or vacuum and finish with dry chemical absorbent. Use explosion-proof equipment. Take up small spills with dry chemical absorbent. Sweep or shovel spills into appropriate container for disposal. Ventilate area.

Other information : For disposal of solid materials or residues refer to section 13 : "Disposal considerations".

6.4. Reference to other sections

No additional information available

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Additional hazards when processed : Pressurized container: Do not pierce or burn, even after use. Close valve after each use and when empty.

Precautions for safe handling : Do not handle until all safety precautions have been read and understood. Ensure good ventilation of the work station. Do not breathe fumes, gas, mist, spray, vapors. Wear personal protective equipment. Avoid contact with skin and eyes.

Safe handling of the gas receptacle : Securely chain cylinders when in use and protect against physical damage.

Hygiene measures : Handle in accordance with good industrial hygiene and safety procedures. Do not eat, drink or smoke when using this product. Always wash hands after handling the product.

7.2. Conditions for safe storage, including any incompatibilities

Technical measures : Comply with applicable regulations.

Storage conditions : Protect from sunlight. Do not expose to temperatures exceeding 50 °C. Keep container closed when not in use. Moisture sensitive.

Incompatible materials : Refer to Section 10 on Incompatible Materials.

Storage area : Store in dry, cool, well-ventilated area.

Special rules on packaging : Do not store in glass.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Hydrogen fluoride, anhydrous (7664-39-3)		
ACGIH	ACGIH TWA (ppm)	0.50 ppm
ACGIH	ACGIH Ceiling (ppm)	2 ppm
ACGIH	Remark (ACGIH)	URT, LRT, skin, & eye irr

Hydrogen fluoride, anhydrous (7664-39-3)		
OSHA	OSHA PEL (TWA) (ppm)	3 ppm
OSHA	Remark (OSHA)	(2) See Table Z-2.

8.2. Exposure controls

Appropriate engineering controls : Ensure good ventilation of the work station. Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Systems under pressure should be regularily checked for leakage. Oxygen detectors should be used when asphyxiating gases may be released. Gas detectors should be used when toxic gases may be released.

Hand protection : Protective gloves. 29 CFR 1910.138: Hand Protection.

Eye protection : Chemical goggles or safety glasses. Face shield. 29 CFR 1910.133: Eye and Face Protection.

Skin and body protection : Wear suitable protective clothing.

Respiratory protection : In case of inadequate ventilation wear respiratory protection. 29 CFR 1910.134: Respiratory Protection.

Other information : Safety shoes. 29 CFR 1910.136: Foot Protection.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state : Liquid

Appearance : Colorless gas. Liquid under pressure or at low temperature.

Color : Colorless

Odor : sharp Irritating

Odor threshold : No data available

pH : No data available

Melting point : -83.7 °C

Freezing point : No data available

Boiling point : 19.5 °C

Flash point : No data available

Relative evaporation rate (butyl acetate=1) : No data available

Flammability (solid, gas) : No data available

Explosion limits : No data available

Explosive properties : No data available

Oxidizing properties : No data available

Vapor pressure : 1053 hPa (at 20 °C)

Relative density : No data available

Relative vapor density at 20 °C : No data available

Specific gravity / density : 1.015 g/cm³ (@ 0 °C)

Solubility : Water: 719.8 g/l (at 20 °C)

Log Pow : -1.4

Auto-ignition temperature : No data available

Decomposition temperature : No data available

Viscosity : No data available

Viscosity, kinematic : No data available

Viscosity, dynamic : No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

Reacts with water, generates gases or heat. Reacts on exposure to water with some metals to release highly explosive/flammable hydrogen gas.

10.2. Chemical stability

The product is stable at normal handling and storage conditions.

10.3. Possibility of hazardous reactions

Contact with acids liberates toxic gas. Contact with water liberates toxic gas.

10.4. Conditions to avoid

Protect from sunlight. Do not expose to temperatures exceeding 50 °C. Keep away from heat, sparks and flame.

10.5. Incompatible materials

Acids. Glass. Strong bases. Strong oxidizing agents. Water.

10.6. Hazardous decomposition products

Under normal conditions of storage and use, hazardous decomposition products should not be produced. Hazardous decomposition products in case of fire, see Section 5.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Acute toxicity : Oral: Fatal if swallowed. Dermal: Fatal in contact with skin. Inhalation:vapour: Fatal if inhaled.

Hydrogen fluoride, anhydrous (7664-39-3)	
LC50 inhalation rat (mg/l)	0.79 mg/l (Exposure time: 1 h)
ATE US (oral)	5.000 mg/kg body weight
ATE US (dermal)	5.000 mg/kg body weight
ATE US (vapors)	0.790 mg/l/4h
ATE US (dust, mist)	0.790 mg/l/4h

Skin corrosion/irritation : Causes severe skin burns and eye damage.

Serious eye damage/irritation : Causes serious eye damage.

Respiratory or skin sensitization : Not classified

Germ cell mutagenicity : Not classified

Carcinogenicity : Not classified

Reproductive toxicity : Not classified

Specific target organ toxicity (single exposure) : May cause respiratory irritation.

Specific target organ toxicity (repeated exposure) : Not classified

Aspiration hazard : Not classified

Potential Adverse human health effects and symptoms : Absorption of excessive F- can result in acute systemic fluorosis with hypocalcemia, interference with various metabolic functions and organ damage (heart, liver, kidneys).

Symptoms/injuries after inhalation : Material is destructive to tissue of the mucuous membranes and upper respiratory tract. Cough, shortness of breath, headache, nausea.

SECTION 12: Ecological information

12.1. Toxicity

Hydrogen fluoride, anhydrous (7664-39-3)	
EC50 Daphnia 1	270 mg/l (Exposure time: 48 h - Species: Daphnia species)

12.2. Persistence and degradability

No additional information available

12.3. Bioaccumulative potential

Hydrogen fluoride, anhydrous (7664-39-3)	
BCF fish 1	(no bioaccumulation)
Log Pow	-1.4

12.4. Mobility in soil

No additional information available

12.5. Other adverse effects

No additional information available

SECTION 13: Disposal considerations

13.1. Waste treatment methods

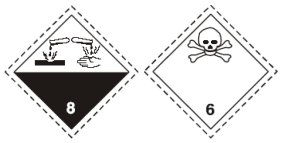
Regional legislation (waste)	:	U.S. - RCRA (Resource Conservation & Recovery Act) - Hazardous Constituents - Appendix VIII to 40 CFR 261. U.S. - RCRA (Resource Conservation & Recovery Act) - U Series Wastes - Acutely Toxic Wastes & Other Hazardous Characteristics.
Waste treatment methods	:	Remove to an authorized incinerator equipped with an afterburner and a flue gas scrubber.
Waste disposal recommendations	:	Dispose of contents/container in accordance with licensed collector's sorting instructions.
Additional information	:	Recycle the material as far as possible.

SECTION 14: Transport information

Department of Transportation (DOT)

In accordance with DOT

Transport document description	:	UN1052 Hydrogen fluoride, anhydrous, 8, I
UN-No.(DOT)	:	UN1052
Proper Shipping Name (DOT)	:	Hydrogen fluoride, anhydrous
Transport hazard class(es) (DOT)	:	8 - Class 8 - Corrosive material 49 CFR 173.136
Hazard labels (DOT)	:	8 - Corrosive 6.1 - Poison



Packing group (DOT)	:	I - Great Danger
DOT Packaging Non Bulk (49 CFR 173.xxx)	:	163
DOT Packaging Bulk (49 CFR 173.xxx)	:	243
DOT Special Provisions (49 CFR 172.102)	:	3 - This material is poisonous by inhalation (see 171.8 of this subchapter) in Hazard Zone C (see 173.116(a) of this subchapter), and must be described as an inhalation hazard under the provisions of this subchapter. B7 - Safety relief devices are not authorized on multi-unit tank car tanks. Openings for safety relief devices on multi-unit tank car tanks shall be plugged or blank flanged. B46 - The detachable protective housing for the loading and unloading valves of multi-unit tank car tanks must withstand tank test pressure and must be approved by the Associate Administrator. B77 - Other packaging are authorized when approved by the Associate Administrator. N86 - UN pressure receptacles made of aluminum alloy are not authorized. T10 - 4 6 mm Prohibited 178.275(g)(3). TP2 - a. The maximum degree of filling must not exceed the degree of filling determined by the following: (image) Where: tr is the maximum mean bulk temperature during transport, tf is the temperature in degrees celsius of the liquid during filling, and a is the mean coefficient of cubical expansion of the liquid between the mean temperature of the liquid during filling (tf) and the maximum mean bulk temperature during transportation (tr) both in degrees celsius. b. For liquids transported under ambient conditions may be calculated using the formula: (image) Where: d15 and d50 are the densities (in units of mass per unit volume) of the liquid at 15 C (59 F) and 50 C (122 F), respectively.
DOT Packaging Exceptions (49 CFR 173.xxx)	:	None
DOT Quantity Limitations Passenger aircraft/rail (49 CFR 173.27)	:	Forbidden
DOT Quantity Limitations Cargo aircraft only (49 CFR 175.75)	:	Forbidden
DOT Vessel Stowage Location	:	D - The material must be stowed ''on deck only'' on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overall vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded.
DOT Vessel Stowage Other	:	40 - Stow ''clear of living quarters''
Emergency Response Guide (ERG) Number	:	125 (UN1052);157 (UN1790)
Other information	:	No supplementary information available.

TDG

No additional information available

Transport by sea

UN-No. (IMDG)	:	1052
Proper Shipping Name (IMDG)	:	HYDROGEN FLUORIDE, ANHYDROUS
Class (IMDG)	:	8 - Corrosive substances
Packing group (IMDG)	:	I - substances presenting high danger

Air transport

UN-No. (IATA)	:	1052
Proper Shipping Name (IATA)	:	Hydrogen fluoride, anhydrous
Class (IATA)	:	8 - Corrosives

SECTION 15: Regulatory information

15.1. US Federal regulations

Hydrogen fluoride, anhydrous (7664-39-3)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory Listed on the United States SARA Section 302 Subject to reporting requirements of United States SARA Section 313	
SARA Section 302 Threshold Planning Quantity (TPQ)	100 lb
SARA Section 313 - Emission Reporting	1.0 %

All components of this product are listed, or excluded from listing, on the United States Environmental Protection Agency Toxic Substances Control Act (TSCA) inventory

Chemical(s) subject to the reporting requirements of Section 313 or Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR Part 372.

Hydrogen fluoride, anhydrous	CAS No 7664-39-3	100%

15.2. International regulations

CANADA

Hydrogen fluoride, anhydrous (7664-39-3)	
Listed on the Canadian DSL (Domestic Sustances List)	
WHMIS Classification	Class D Division 1 Subdivision A - Very toxic material causing immediate and serious toxic effects Class D Division 2 Subdivision A - Very toxic material causing other toxic effects Class E - Corrosive Material

EU-Regulations

No additional information available

National regulations

Hydrogen fluoride, anhydrous (7664-39-3)
Listed on the AICS (Australian Inventory of Chemical Substances) Listed on IECSC (Inventory of Existing Chemical Substances Produced or Imported in China) Listed on the Japanese ENCS (Existing & New Chemical Substances) inventory Listed on the Korean ECL (Existing Chemicals List) Listed on NZIoC (New Zealand Inventory of Chemicals) Listed on PICCS (Philippines Inventory of Chemicals and Chemical Substances) Japanese Poisonous and Deleterious Substances Control Law Japanese Pollutant Release and Transfer Register Law (PRTR Law) Listed on the Canadian IDL (Ingredient Disclosure List) Listed on INSQ (Mexican national Inventory of Chemical Substances) Listed on Turkish inventory of chemical

15.3. US State regulations

Hydrogen fluoride, anhydrous (7664-39-3)	
State or local regulations	U.S. - Massachusetts - Right To Know List U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List U.S. - Pennsylvania - RTK (Right to Know) List

California Proposition 65 - This product does not contain any substances known to the state of California to cause cancer and/or reproductive harm

SECTION 16: Other information

Revision date : 09/11/2019

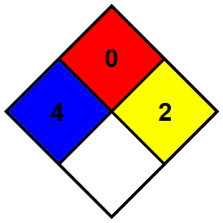
Full text of H-phrases:

Acute Tox. 1 (Dermal)	Acute toxicity (dermal) Category 1
Acute Tox. 2 (Inhalation:vapour)	Acute toxicity (inhalation:vapour) Category 2
Acute Tox. 2 (Oral)	Acute toxicity (oral) Category 2
Eye Dam. 1	Serious eye damage/eye irritation Category 1
Liquefied gas	Gases under pressure Liquefied gas
Simple Asphy	Simple Asphyxiant
Skin Corr. 1A	Skin corrosion/irritation Category 1A
STOT SE 3	Specific target organ toxicity (single exposure) Category 3
H280	Contains gas under pressure; may explode if heated
H300	Fatal if swallowed
H310	Fatal in contact with skin
H314	Causes severe skin burns and eye damage
H318	Causes serious eye damage
H330	Fatal if inhaled
H335	May cause respiratory irritation
H380	May displace oxygen and cause rapid suffocation

NFPA health hazard : 4 - Very short exposure could cause death or serious residual injury even though prompt medical attention was given.

NFPA fire hazard : 0 - Materials that will not burn.

NFPA reactivity : 2 - Normally unstable and readily undergo violent decomposition but do not detonate. Also: may react violently with water or may form potentially explosive mixtures with water.



HMIS III Rating

Health : 4 Severe Hazard - Life-threatening, major or permanent damage may result from single or repeated overexposures

Flammability : 0 Minimal Hazard - Materials that will not burn

Physical : 2 Moderate Hazard - Materials that are unstable and may undergo violent chemical changes at normal temperature and pressure with low risk for explosion. Materials may react violently with water or form peroxides upon exposure to air.

SDS US (GHS HazCom 2012)

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is offered solely for your consideration, investigation, and verification. It does not represent any guarantee of the properties of the product nor that the hazard precautions or procedures described are the only ones which exist. SynQuest shall not be held liable or any damage resulting from handling or from contact with the above product.

Terra Industries Inc.
Terra Centre – 600 Fourth Street
Sioux City, Iowa 51101

Material Safety Data Sheet (MSDS)

Dinitrogen Tetroxide, Mixed Oxides of Nitrogen

MSDS Number 2001 (Revised January 25, 2011) 10 Pages

CAUTION

INHALATION HAZARD – OXIDIZER – CORROSIVE

CAUTION: Explosions may occur on contact with ammonia, boron trichloride, carbon disulfide, cyclohexane, fluorine, formaldehyde, hydrazine, nitrobenzene, toluene, incompletely halogenated hydrocarbons, propylene, alcohols, and ozone.

1. CHEMICAL PRODUCT and EMERGENCY TELEPHONE CONTACT

Product Name:	Dinitrogen Tetroxide
Chemical Family:	Inorganic Oxidizers
Synonyms:	Nitrogen Oxide, Nitrogen Dioxide, Nitrogen Peroxide, Nitrogen Tetroxide, Dinitrogen Tetroxide, Tetra Oxide, NTO
Formula:	N_2O_4
Product Use:	Fuel Oxidizer-Propellant

EMERGENCY TELEPHONE NUMBER

CHEMTREC (U.S.):	800-424-9300
CANUTEC (Canada):	613-996-6666
HEALTH EMERGENCIES	contact Poison Control Center

2. COMPOSITION/INFORMATION ON INGREDIENTS

Ingredient Name/CAS Number	Concentration, N2O4/NO	Exposure Limits
Dinitrogen Tetroxide/ 10544-72-6	99.5/<0.5	1 ppm STEL* C* 5 ppm PEL* 20 ppm IDLH*
Nitrogen Oxides (NO, NO2, N2O3) See Table Page 10102-44-0		

Nitric Oxide (NO) See Table Page 7
10102-43-9

Note: Exposure limits listed are for nitrogen dioxide, the most hazardous constituent of N2O4. Exposure limits applicable to mixed oxides of nitrogen.

* STEL = Short Term Exposure Limit, C = Ceiling, PEL = Permissible Exposure Limit, IDLH = Immediate Danger to Life and Health

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Dinitrogen Tetroxide is an acute inhalation hazard, strong oxidizer, and highly corrosive. Avoid exposure of skin and eyes to liquid or high vapor concentrations. Where liquid is present and the concentration of vapors in the breathing zone approaches or exceeds the PEL, respiratory protection is required.

NFPA Hazard Classification	Health Hazard (Blue) ……..	4
	Flammability (Red) …….	0
	Reactivity (Yellow) …….	0
	Special (White)…….OXIDIZER (OX)	

POTENTIAL HEALTH EFFECTS

Primary Routes of Entry: Inhalation, skin contact/absorption and eye contact.

General Acute Exposure: The vapor is highly irritating to the upper respiratory tract and lungs and harmful if inhaled. If available, administer medical oxygen by trained personnel. If breathing is shallow or has stopped, ensure clear airway and apply resuscitation. The material presents a hazard from a single acute exposure. **A single acute exposure may cause death.**

Inhalation:

Acute Exposure: Principal routes of exposure are generally by inhalation of fumes or physical contact. Serious results may not be felt until hours or days after exposure, even though heavy damage has occurred. Repeated inhalation may result in bronchitis or emphysema.

Skin:

Acute Contact: The liquid is highly corrosive to the skin and may cause chemical burns. If this product comes in contact with the skin: Immediately flush body and clothes with large amounts of water, using safety shower if available. Quickly remove all contaminated clothing, including footwear. Wash affected areas with water (and soap if available) for at least 15 minutes.

Eye:
Acute Contact: The vapor is extremely irritating to the eyes and is capable of causing pain and severe conjunctivitis. If this product comes in contact with the eyes: Immediately hold the eyes open and wash continuously for at least 15 minutes with fresh running water. Ensure irrigation under eyelids by occasionally lifting the upper and lower lids.

Neurologic:
Acute Exposure: An altered mental status (coma) may be seen, but is not characteristic unless hypoxemia occurs.

Ingestion:
If this chemical has been swallowed, seek immediate medical attention.

Note to the Physician: Pneumonitis should be anticipated after inhalation or ingestion. If severe exposure is suspected, observe for 48-72 hours for delayed pulmonary edema.

Medical Conditions Aggravated by Exposure: Chronic respiratory or skin disease.

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4. FIRST AID MEASURES

First Aid for Eyes: Immediately flush eyes with copious amounts of tepid water for at least 15 minutes. If irritation, pain, swelling, excessive tearing, or light sensitivity persists, the patient should be seen in a health care facility and referral to an ophthalmologist considered.

First Aid for Skin: Immediately flush exposed area with copious amounts of tepid water for at least 15 minutes followed by washing area thoroughly with soap and water. The patient should be seen in a health care facility if irritation or pain persists.

First Aid for Inhalation: Move patient to fresh air. Monitor for respiratory distress. If cough or difficulty in breathing develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. If trained to do so administer supplemental oxygen with assisted ventilation as required. Administer artificial respiration if patient is not breathing.

First Aid for Ingestion: If this chemical has been swallowed, seek immediate medical attention.

5. FIRE FIGHTING MEASURES

Flash Point:	Not Applicable
Lower Flammable Limit:	Not Applicable
Upper Flammable Limit:.....	Not Applicable
Auto ignition Temperature.....	Not Applicable

Noncombustible Liquid/Gas, but will accelerate the burning of combustible materials.

Extinguishing Media: Chose appropriate media for surrounding fire. Water contact with liquid will create large amounts of toxic vapors. Caution: do not add water to an enclosed vessel. Water addition in a contained vessel may rapidly increase pressure due to vapor generation. Water spray or water fog will knock down vapors and is effective.

Special Fire Fighting Procedures:

a. Do not get water inside container.
b. Stop flow of gas if you can do without risk.
c. Move container from fire area if you can do it without risk.
d. Apply cooling water to sides of containers that are exposed to flames until well after fire is out. Stay away from ends of tanks due to exploding potential when tanks are involved in a fire.
e. Isolate area until gas has dispersed.
f. Use water spray or foam to control vapors.
g. Positive pressure self-contained breathing apparatus (SCBA) should be used when there is a potential for inhalation of vapors and/or fumes.
h. Chemical protective clothing that is safe for use with nitric acid involved in a fire should be worn.
i. Runoff from fire control or dilution water may cause pollution.

Fire/Explosion Hazard:

Non-flammable but strong oxidizer and will increase the intensity of a fire and support combustion. Heating may cause expansion or decomposition leading to violent rupture of containers. Contact with readily oxidizable organic material may cause ignition /fire. Decomposes on heating and produces toxic fumes of nitrogen oxides (NOx) and nitric acid. In presence of moisture, the material is corrosive to aluminum, zinc and tin producing highly flammable hydrogen gas. Reacts vigorously with alkalis. Reacts violently with incompatible materials.

6. ACCIDENTAL RELEASE MEASURES

Spill or Leak Measures:

Clear area of personnel and move upwind. Alert Fire Brigade and tell them location and nature of hazard. Wear full body protective clothing with breathing apparatus. Prevent, by any means available, spillage from entering drains or watercourses. Consider evacuation. Shut off all possible sources of ignition and increase ventilation. No smoking or naked lights within area. Stop leak if safe to do so. Do not exert excessive pressure on valve; do not attempt to operate damaged valve. Water spray or fog may be used to mitigate the inhalation hazard. Absorb or cover spill with sand, earth, inert material or vermiculite. Carefully, contain and neutralize with slaked lime. Collect residues and seal in labeled drums for disposal. After clean up operations, decontaminate protective gear and equipment by soaking in 5% soda ash solution for at least 24 hours. Rinse and dry.

Disposal:
Dispose of neutralized waste solutions and any residues in compliance with local, state, and Federal laws. Place leaking cylinder in a fume hood or safe outdoor area. When slow release of gas to air is unacceptable, attach needle valve and tube to run gas into an excess of 5 to 10% aqueous sodium hydroxide solution (with caution). Cover liquid spill with soda ash or slaked lime. Water spray or fog may be used to disperse vapors. All waste solutions are to be neutralized before disposal.

Determining Spill Size:

Generally, a small spill is one that involves a single, small container (Less than 1-gallon capacity), or a small (non-continuing) leak from a larger tank or vessel
Note: EPA Reportable Quantity (RQ) is 10 pounds.

Small Spill:

First isolate 100 feet in all directions, then protect persons downwind 0.1 mile (day) or 0.3 mile (night).

Large Spill:

First isolate 500 feet in all directions, then protect persons downwind 1.0 mile (day) or 2.5 miles (night).

7. HANDLING AND STORAGE

Caution: Dinitrogen Tetroxide is an acute inhalation hazard, strong oxidizer and highly corrosive. Avoid exposure of skin and eyes to liquid or vapors.
Note: When liquid is present and the concentration of the vapor in the breathing zone approaches or exceeds 1 ppm, SCBA respiratory protection is required.

8. EXPOSURE CONTROLS, PERSONAL PROTECTION / OSHA ASSIGNED PROTECTION FACTORS (APF)

Respiratory Protection Requirements:

<1 ppm:	No protection required.
1ppm:	Protection required if exposed for more than 15 minutes.
>1 to 20 ppm:	(APF=25) Any supplied-air respirator operated in a continuous flow mode. (APF=50) Any self-contained breathing apparatus with a full facepiece (APF=50) Any supplied-air respirator with a full facepiece

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF=10,000) Any SCBA that has a full face piece and is operated in a pressure-demand or other positive-pressure mode

(APF=10,000) Any supplied-air respirator that has a full face piece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF=50) Any appropriate escape-type, self-contained breathing apparatus.

Skin Protection Requirements: Acid resistant gloves, acid resistant safety boots, acid resistant suit, impervious protective clothing with full-length sleeves and pants.

Eye Protection Requirements:

Lab / Fume Hood: Use chemical (indirectly vented) goggles when there is a potential for contact with liquid or mist. A full-face shield is recommended in addition to goggles for added protection.

Field: Indirectly vented chemical goggles, or in lieu of goggles, eye protection provided by full face respirator is acceptable.

Note: Contact lenses pose a special hazard: soft lenses absorb irritants and all lenses concentrate them.

Other Protective Equipment: Safety shower and eyewash fountains should be available.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical Form:	Liquid
Color:	Non-flammable, yellowish to reddish-brown gas. Reddish-brown to green liquid. Forms a colorless solid. (See Table Below)
Odor:	Pungent acidic odor first perceptible at 1 to 3 ppm
Boiling Point:	See Table
Melting point:	See Table
Specific Gravity:	See Table
Vapor Density:	1.58
Vapor Pressure:	See Table
% Volatile by Volume:	100
Molecular Weight:	92.01
Density:	1.38 to 1.43 g/ml
Material Decomposes	>320º F (160ºC)
Critical Pressure:	10.1 MPa

GRADE	NTO	MON-1	MON-3	MON-10	MON-15	MON-25
Molecular Weight (N_2O_4)	92.01	92.01	92.01	92.01	92.01	92.01
Relative Vapor Density	1.58	1.58	1.58	1.58	1.58	1.58
Color	Brown	Green	Green	Green	Green	Green
NO, %	0	1	3	10	15	25
N_2O_4 + NO, %	99.5	99.5	99.5	99.5	99.5	99.5
Boiling, F	70	68	65	49	39	16
Freezing, F	12	9	5	-10	-24	-69
Vapor @77F, psia	17.5	18.5	20.5	30.0	40.5	76.0
Sp. Gravity @ 77F	1.431	1.429	1.423	1.407	1.397	1.380

10. REACTIVITY

Stability: ..... This is a stable material.
Hazardous Polymerization: ..... NA

Decomposition: Decomposes above 320°F to form nitric oxide and oxygen

Incompatibilities:

a. Incompatible with water, bases, flammable and combustible materials, copper, aluminum.

b. Forms nitric acid and nitrogen oxide vapors when exposed to moisture. Nitric acid is very corrosive to non-stainless steel metals.

c. Explosions may occur on contact with ammonia, boron trichloride, carbon disulfide, cyclohexane, fluorine, formaldehyde, hydrazine, nitrobenzene, toluene, incompletely halogenated hydrocarbons, propylene, alcohols, and ozone.

11. TOXICOLOGICAL INFORMATION

Toxicity: Highly Toxic

Acute Inhalation Toxicity
LC_{50} Rat: ..... 138 ppm (0.5hr)

Corrosiveness / Irritation
Skin Irritation / Corrosion: ..... Severe corrosive to skin
Eye Irritation / Corrosion: ..... Severe corrosive to eyes and mucous membranes

Genetic Toxicity
Mutagenic effects:……..No known significant effects or critical hazards
Reproduction Toxicity……No known significant effects or critical hazards

Carcinogen Status……ACGIH: A4 Not classified as a human carcinogen

Genetic Toxicity *in vivo*
Drosophila melanogaster:……..No evidence for mutagenicity
Carcinogenicity
All:……..No carcinogenic effects
Toxicity to Reproduction
Pig:……..Temporarily depressed mean daily gain (MDG) at 35 mg/kg in gilts (One generation study)
Human Experience
Inhalation:……It has been reported that 10-20 ppm has been mildly irritating [Patty 1963]. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary edema [NRC 1979]. It has been predicted that 50% lethality would occur following exposure to 174 ppm for 1 hour.

Ecotoxicity:

LCL Goldfish:……...750 ppm 5 hours*
LCL Fathead Minnow:……...1000 ppm for 7 hours*

*Information derived from Nitric Acid ecotoxicity data

12. ECOLOGICAL INFORMATION*

Note: Dinitrogen Tetroxide will significantly lower the pH of any water source it comes in contact with (form nitric acid)

a. Nitric acid is harmful to aquatic life in very low concentrations
b. May be dangerous if it enters water intakes. Notify operator of nearby water intakes.
c. Notify local health and wildlife officials

*Information derived from Nitric Acid ecological impact data

13. DISPOSAL CONSIDERATIONS

Dispose of neutralized waste solutions and any residues in compliance with local, state, and Federal laws. EPA RQ is 10 pounds. Place leaking cylinder in a fume hood or safe outdoor area. When slow release of gas to air is unacceptable, attach needle valve and tube to run gas into an excess of 5 to 10% aqueous sodium hydroxide solution (with caution). Cover liquid spill with soda ash or slaked lime. Water spray or fog may be used to disperse vapors. All waste solutions are to be neutralized before disposal.

14. TRANSPORTATION INFORMATION

U.S. DOT and Canadian TGD Act

Shipping Name:..... Dinitrogen Tetroxide
Hazard Class/Division:..... 2.3
Product Identification Number (PIN): ..... UN 1067
DOT Placard: ..... Poison Gas-2.3, Oxidizer-5.1, Corrosive-8
Note:…….. *Product may be shipped under different placarding/labeling for shippers holding a DOT special permit*
DOT Special Provision (49CFR172.102): .... "Inhalation Hazard", 1, B7, B14, B45, B46, B61, B66, B67, B77, T50, TP21
OSHA Label Required:..... Yes
Transportation by Air…….Forbidden
EPA RQ (Reportable Quantity): ..... 10 pounds
STCC Number: 4920174

15. REGULATORY INFORMATION

Controlled Products Regulations Classification: A: Compressed Gas; E: Corrosive
OSHA: This product is considered a hazardous material under criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200 (Toxic; Corrosive), and is listed as a Highly Hazardous Chemical subject to the requirements of the Process Safety Management Standard 29 CFR 1910.119 (Threshold Quantity 250lbs).

CAA Chemical Accident Prevention: Not a regulated chemical

SARA TITLE III:

a. EHS (Extremely Hazardous Substances) List: Listed (EPA, 1992a)
b. SARA RQ (Reportable Quantity): 10 pounds
c. TPQ (Threshold Planning Quantity): 100 pounds
d. Regulation: "Emergency Planning and Notification" – 40 CFR Part 355
e. Section 313: Dinitrogen Tetroxide does not require reporting under Section 313

CERCLA Hazardous Substances List:

a. CERCLA RQ (Reportable Quantity): 10 pounds
b. Regulation: "Designation, Reportable Quantities, Notification" - 40 CFR 302

TSCA Inventory: Dinitrogen Tetroxide is listed on the TSCA inventory

Chemical Facility Anti-Terrorism Standard (CFATS) / 6 CFR Part 27:
Dinitrogen Tetroxide is listed in Appendix A as a Chemical of Interest (COI) due to threat of theft for use as a component in a WME.
Screening Threshold Quantity (STQ): 15 pounds

CAGE Code # - 1YUW6
Contract # -SP0600-07-D-1564

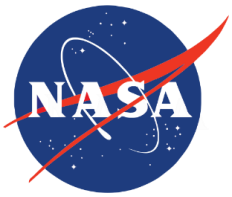
Equipment, Pressure Vessels, Testing, Etc.: All equipment used to handle, store, transfer, etc., dinitrogen tetroxide must be properly engineered, constructed and maintained in compliance with all applicable regulations and standards. Pressure vessels, piping and appurtenances should be regularly inspected and tested using methods designed to reveal external and internal deterioration or defects that may impair the integrity of the equipment such that an unintended release of dinitrogen tetroxide may result. Consult with experts, as applicable, concerning the methods that would be most appropriate given the particular circumstances.

16. OTHER INFORMATION

- 3-26-08: The MSDS was rewritten to comply with ANSI Standard Z400.1-1993, and to transfer information into the Terra format.
- 1-19-09: Updated MSDS to reflect components of N2O4 (i.e. mixed oxides of nitrogen), updated CAS numbers, updated transportation information, updated NFPA hazard classification, and various language changes for clarity.
- 1-25-11: Reviewed. Revised to include shipping information (Cage code and contract #).

The information and recommendations herein are taken from data contained in independent, industry-recognized references including but not limited to NIOSH, OSHA, ANSI, NFPA, DOT ERG, the TFI Product Testing Program, Global Engineering Documents, MEDITEXT, HAZARDTEXT, SARATEXT, CHRIS, OHM/TADS, and IRIS. Terra Industries Inc. makes no guarantee, warranty or other representation concerning this substance, since conditions of its use are beyond the control of the company. Terra Industries Inc. disclaims any liability for loss or damage incurred in connection with the use of this substance.

National Aeronautics and Space Administration



500 Area Former Oxidizer Burner

Historical Information Summary

August 2022

Revised December 2023

NM8800019434

Executive Summary

This Historical Information Summary (HIS) provides information regarding historical site operations, facilities, hazardous chemical use, and waste management practices related to the 500 Area Former Oxidizer Burner (FOB) at the National Aeronautics and Space Administration (NASA) White Sands Test Facility (WSTF). The FOB was discovered during closure activities at the Fuel Treatment Unit (FTU). NASA notified the New Mexico Environment Department (NMED) in a letter dated October 16, 2019 that the former location of the FOB was a SWMU (NASA, 2019). The notification was submitted within 15 days of discovery, in accordance with section VII.D of the then Permit (NMED, 2009, pp74-75). On November 13, 2019, NMED requested additional information be provided in a release assessment report in accordance with the Section V.II.F.1 of the then Permit (NMED, 2009, pp75-76). NASA submitted the 500 Area Newly Identified SWMU Release Assessment Report on June 22, 2020. On December 20, 2021, NMED approved the RAR and directed NASA to proceed with investigation of the reported release. No later than August 31, 2022, NASA was required to submit an investigation work plan to further evaluate the site in accordance with then Permit Section VII.F.2., Requirement to Proceed (NMED, 2009, p76). This HIS is provided in conjunction with the Investigation Work Plan in accordance with Section VII.H.1.c of the 2009 Permit~~, Historical Information Summary~~ (NMED, 2009, pp 78-79) and Section 3.10.2 of the 2023 Permit (NMED, 2023, p32).

The objective of this HIS is to identify any known or potential releases of hazardous waste or hazardous substances to the environment related to the 500 Area FOB in preparation for the investigation work plan. NASA reviewed historical documentation, reports, photographs, and interviewed both retired and long-term site employees to understand the historical management and waste management practices related to the 500 Area FOB and determine the nature and timeframes of any releases.

The use of trademarks or names of manufacturers is for accurate reporting and does not constitute an official endorsement either expressed or implied of such products or manufacturers by the National Aeronautics and Space Administration.

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List of Acronyms

amsl	Above mean sea level
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
DOD	Department of Defense
ETU	Evaporative Tank Unit
FOB	Former Oxidizer Burner
FSA	Fuel Storage Area
ft	Feet
FTU	Fuel Treatment Unit
gal	Gallon
HIS	Historical Information Summary
IPA	Isopropyl alcohol
IWP	Investigation Work Plan
JDMB	Jornada del Muerto Basin
JER	Jornada Experimental Range
mi	Mile
mm Hg	Millimeter of mercury
MMH	Monomethylhydrazine
MSDS	Material Safety Data Sheet
N_2O_4	Dinitrogen tetroxide
NASA	National Aeronautics and Space Administration
NMED	New Mexico Environment Department
NMSLO	New Mexico State Land Office
NO_2	Nitrogen dioxide
OOSA	Original Oxidizer Storage Area
PWCAA	Propellant Waste Central Accumulation Area
SAM	San Andres Mountains
SWMU	Solid Waste Management Unit
UDMH	Unsymmetrical dimethylhydrazine
WSTF	White Sands Test Facility

1.0 Introduction

1.1 Purpose and Regulatory Criteria

The 500 Area Former Oxidizer Burner (FOB) was discovered during the 500 Area Fuel Treatment Unit (FTU) closure fieldwork activities when field personnel noted an unidentified stub out line. NASA reviewed 500 Area records and interviewed former employees who worked in the area. The stub out line was identified as the location of an oxidizer burner that operated from 1965 through 1973. NASA notified the New Mexico Environment Department (NMED) in a letter dated October 16, 2019, that the former location of the FOB was a newly identified solid waste management unit (SWMU; NASA, 2019). The notification was submitted within 15 days of discovery, in accordance with section VII.D of the 2009 National Aeronautics and Space Administration (NASA) Hazardous Waste Permit (Permit; NMED, 2009, p73). On November 13, 2019, NMED requested additional information be provided in a Release Assessment Report (RAR) in accordance with the Section V.II.F.1 of the 2009 Permit (NMED, 2009, p74). NASA provided the RAR on June 22, 2020. On December 20, 2021, NMED approved the RAR and directed NASA to list the 500 Area FOB as a "SWMU requiring corrective action during a Permit renewal, or during a 40 CFR 270.42 Permit modification" (NMED, 2021). NASA updated the SWMU list for the Permit renewal to include the 500 Area FOB as SWMU 54. NASA will proceed with investigation in accordance with NMED's direction and 2009 and 2023 Permit Sections VII.F.2~~, Requirement to Proceed~~ and 3.8.3, respectively (NMED, 2009, p76; NMED, 2023, p31).

This Historical Information Summary (HIS) summarizes information regarding site use, waste management, and assessment of known or potential releases of hazardous substances at the 500 Area FOB. This is a requirement of Section VII.H.1.c of the 2009 Permit (NMED, 2009, p77) and Section 3.10.2 of the 2023 Permit (NMED, 2023, p35). The preparation and submittal of this HIS coincides with the Investigation Work Plan (IWP) for the 500 Area FOB.

1.1.1 Scope

The objective and scope of this HIS is to provide a summary of all available information for the 500 Area FOB operational history. This summary compiles data obtained from the review of relevant and pertinent historical documentation (e.g., reports, maps, and engineering drawings) and interviews with current and former employees (Appendix A).

1.1.2 Limitations and Assumptions

NASA performed due diligence in reviewing historical files, correspondence, and reports, and obtaining information from current and former employees with knowledge of 500 Area FOB operations. All known historical reference resources were examined to evaluate operational and environmental management practices during operation of the unit. This report is limited to records currently available in WSTF files and recollections of current and former WSTF personnel that were directly or indirectly involved in the 500 Area FOB operations.

2.0 Site Description

2.1 Location

WSTF is located in Doña Ana County, 18 miles (mi) northeast of Las Cruces, New Mexico and 65 mi north of El Paso, Texas. Figure 2.1 provides a WSTF location map. Access to the site is provided via a paved road with a guarded security gate. NASA Road intersects U.S. Highway 70, 6 mi west of Organ, New Mexico (Figure 2.1).

2.2 Land Ownership

WSTF administrative and testing facilities are located on White Sands Missile Range (WSMR), owned by the U.S. Department of Defense, Department of the Army (DoD). NASA operates the facility under an inter-agency agreement with the U.S. Army (DoD, 2019). NASA also maintains land-use agreements with the Bureau of Land Management (BLM; a right-of-way agreement, 2012), the New Mexico State Land Office (NMSLO; a right-of-way easement; NMSLO, 1963; a water exploration/development easement; NMSLO, 1989; a water monitoring easement, NASA, 2021b), and the U.S. Department of Agriculture, Agricultural Research Service Jornada Experimental Range (JER; an easement deed; USDA, 2003) for the use of lands located to the west of the industrial facility. In 2014, the National Defense Authorization Act set aside lands previously owned by the BLM for a buffer to WSMR to prevent development close to the missile range. Figure 2.2 provides an ownership overview of lands used by NASA.

2.3 Land Use

The 500 Area FOB is located within the 500 Area of the WSTF industrial area. There are no residents at WSTF, and all WSTF areas are strictly for industrial use. Security and firefighting personnel staff the facility 24-hours per day, seven days per week. WSTF is a restricted access area closed to the public, and access by visitors is provided only in accordance with NASA Johnson Space Center policies.

2.4 General Physical Setting

WSTF is located on soil composed of coalescent alluvial fans that are locally dissected by arroyos. The north-south trending San Andres Mountains (SAM) that ascend over 6,000 feet (ft) above mean sea level (amsl) border the facility on the east. The WSTF site is bordered on the west by a broad uniformly sloping alluvial pediment plain extending into the southern Jornada del Muerto Basin (JDMB) and the Doña Ana Mountains. The major alluvial fan systems originate from Bear Canyon to the northeast and Loman Canyon to the southeast of WSTF. Foothills on the western pediment of the SAM at WSTF are typically 4,800 to 5,000 ft amsl, are moderately sloping (15 to 25%), and consist of thin layers of alluvium covering fractured limestone and volcanic bedrock. The numerous dissecting arroyos only flow during periods of heavy rainfall. Figure 2.3 provides a topographic map of WSTF and surrounding areas.

3.0 500 Area Former Oxidizer Burner Area

3.1 Location

Figure 3.1 provides the location of the 500 Area FOB and surrounding WSTF structures. The 500 Area FOB is located northwest of the 500 Area cryogenic and inert gas storage Area and the 300 Area, northeast of the 400 Area, and southeast of the 500 Fuel Storage Area (FSA). It is located in Section 35 of Township 20 South, Range 3 East. Access to this area is provided by a paved road (Road P) that intersects Apollo Boulevard and ends at the 500 Area FSA (Figure 3.1).

3.2 500 Former Oxidizer Burner Area Physical Setting

The most prominent topographic features in the vicinity of the 500 Area are the adjacent SAM that includes Quartzite Mountain (6,768 ft amsl) to the southeast and Bear Canyon to the east (Figure 2.3). The 500 Area is situated atop the Bear Canyon alluvial fan. The elevation at the 500 Area FOB is approximately 4,960 ft amsl (Figure 2.3). Figure 3.2 provides the arroyos and topographic features within the 500 Area. Several ephemeral arroyos originating from the Bear Canyon area transect the 500 Area and drain west and southwest toward the southern JDMB (Figure 3.2).

3.2.1 Soils and Geologic Setting

WSTF soils are described in detail in the Draft Resource Conservation and Recovery Act Facility Investigation (NASA, 1996, p25). Soils in the 500 Area are associated with alluvial fans, gentle slopes, and arroyos and identified as the Tencee-Nickel Association. The Tencee Series is comprised of shallow, well-drained soils which formed in calcareous gravelly loamy alluvial sediments on ancient alluvial fans. The upper 5 ft are characterized by brown to light-brown gravelly loam with interbeds of pink indurated caliche. The Nickel Series comprises deep, well-drained soils on ancient alluvial fans. The soils are formed in gravelly, medium-textured alluvial sediments. The upper 5 ft are characterized by light brown to pink gravelly to fine sandy loam. Gravel contents are typically 50%.

Tencee Very Gravelly Loam is typically light to dark brown, coarse, and has a subangular blocky structure. The soil is slightly hard, dry, and very friable. Interstitial pores are common. The soil is approximately 30 to 45% caliche and gravel, strongly calcareous, and has nearly continuous lime coatings on all clasts. The Tencee-Nickel, Gently Sloping unit of the 500 Area is approximately 65% Tencee Very Gravelly Loam and 20% Nickel Fine Sandy Loam. The soil is gently sloping and occurs on ancient alluvial fans. Included within these soils are arroyo bottoms and areas of soils similar to Tencee and Nickel soils except containing less than 35% coarse fragments.

Runoff ranges from slow to rapid and permeability is slow to moderately rapid. There are no wells in the immediate 500 Area; as a result, subsurface parameters are estimated from wells in the surrounding areas. Alluvial cover is estimated to be approximately 90 to 115 ft thick. The bedrock immediately below the alluvium is inferred to be Tertiary Orejon Andesite that dips two to four degrees to the west.

3.2.2 Groundwater and Surface Water

Based on nearby wells in the 300 and 400 Areas, groundwater resides within a fractured bedrock aquifer, at approximate elevations of 4,700 to 4,820 ft amsl. Irregular groundwater flow through the fractured bedrock of the WSTF industrial area is primarily to the west with estimated flow rates indicative of relatively steep mountain-front topography ranging from 0.3 to 1.6 ft per day.

There is no surface water in the vicinity of the 500 Area FOB. The nearest man-made water bodies are the WSTF Test Stand 302 cooling water pond to the southeast and the 400 Area Salt Ponds to the south. The only natural water body located within WSTF's industrial area is Gardner Spring, located approximately 1.5 mi southeast, which forms a small sporadic pool. Bear Creek is approximately 0.75 mi north of the 500 Area FOB, but only contains water periodically during rainfall events. The nearest natural water body of significant scale is the ephemeral Isaacs Lake located approximately 10 mi to the southwest of WSTF within the lowest point of the southern JDMB at an elevation of 4,285 ft amsl.

3.3 Description of Structures

The 500 Area FOB was originally constructed as part of the Original Oxidizer Storage Area (OOSA) at WSTF. Structures near the 500 Area FOB currently include a control building (Building 521) that was historically used for the OOSA and later the FTU, electrical poles, an asphalt parking lot, an emergency shower, and utility lines that were associated with the FTU. The area used for the FTU is still within a chain-link fence. All other structures were removed, and the area was graded level during FTU closure activities.

3.4 Current Uses of Adjoining Properties

3.4.1 Propellant Waste Central Accumulation Area (PWCAA)

The Propellant Waste Central Accumulation Area (PWCAA) is currently located in the WSTF 500 Area and is used to manage aqueous propellant waste generated throughout the facility (NASA, 2021a, pp18-19). It is located adjacent to the former FTU location and is operated in accordance with the conditions for exemption for a large quantity generator that accumulates hazardous waste (40 CFR 262.17). Aqueous hydrazine-type and oxidizer propellant hazardous waste is transferred, from points of generation in the 200, 300, 400, 500, and 800 Areas in containers, to the PWCAA prior to shipment for off-site disposal. All propellant hazardous waste is shipped off-site prior to 90-days from when waste was first placed in a container. This waste may be combined to facilitate shipment in fewer containers, or the waste may be transferred to a tanker for transportation to the disposal facility.

3.4.2 Current Oxidizer Storage Area

NASA designed a new oxidizer storage area to the south of the original area (Figure 3.3) prior to constructing the FTU at the 500 OOSA location. This was required to separate hydrazine fuels and oxidizer propellant products. The new area was completed September 6, 1995. From 1993 to September 1995, oxidizer cylinders were stored temporarily at the original hydrogen storage area (Appendix A).

3.5 Former Uses of Adjoining Properties

3.5.1 Original Oxidizer Storage Area

The 500 OOSA was originally set up in 1964 to store oxidizer (N_2O_4) for use in propulsion testing in the WSTF 300 and 400 Areas (NASA, 1994). Long-term WSTF personnel stated that the 500 Area FSA and the OOSA were built similarly, with large storage tanks and piping with shelters to protect the tanks and piping from weather damage, concrete pads (with curbs to provide secondary containment) and a gunite-lined channel leading to a gunite-lined rectangular containment basin or ponding area that was designed to be used only for secondary emergency containment if the large storage tank failed or there was a large spill (Appendix A).

Structures within the 500 OOSA consisted of utilities, an oxidizer storage tank (Tank 522), a sprinkler system in case of fire, steel piping and valves for oxidizer transfer and transport to the WSTF propulsion testing areas, a steel shade to cover the tank, a sprinkler system, a portion of the piping (Appendix A), a secondary containment area for the oxidizer tank, a control building (Building 521), an oxidizer containment basin or ponding area, and an open trench that led to the ponding area. The oxidizer storage tank had a capacity of 19,700 gallons (gal), was horizontal, and sat on two concrete pedestals (NASA, 1994) inside a concrete secondary containment and oxidizer transfer area in the northern part of the OOSA. South of the tank and secondary containment area was an adjacent concrete pad for truck parking (Figure 3.3). In the southeast corner of the oxidizer tank secondary containment area, there was an opening in the containment wall which connected to a gunite-lined open trench or channel (Appendix B). The open trench was 2 ft wide by 76 ft long and ended in an area described on historical WSTF drawings as an oxidizer containment basin (Figure 3.3) and referred to by WSTF personnel as a ponding area. The oxidizer containment basin or ponding area was rectangular (50 ft by 75 ft exterior and 40 ft by 65 ft interior) and gunite-lined (Appendix B). The basin contained a drain 10 ft from the west edge and centered. The drain emptied into a 4-in. (inch) steel pipe (Appendix B) that extended 50 ft to the west of the basin and terminated with a 4-in. shear gate shut off valve.

In preparation for the construction of the FTU, the OOSA was dismantled, leaving only the concrete pad and secondary containment area where the oxidizer tank was, the oxidizer containment basin or ponding area, and the utilities. The large 19,700-gal oxidizer tank was removed from the OOSA on July 18, 1995, prior to the first hypergolic fuel waste received (Appendix A). The OOSA became part of the FTU, with the oxidizer containment basin, or ponding area remaining abandoned outside the FTU fencing. Refer to Section 3.5.2 for a description and brief history of the FTU.

During research for the RAR (NASA, 2020), the oxidizer containment basin drain and drainpipe were located. Photographs are provided in Appendix B. The end of the drainpipe was located 32.5 ft west of the drain, instead of 50 ft as originally installed. The pipe appeared to have been cut off with a saw. No soil staining was visible.

3.5.2 Fuel Treatment Unit

Initially, in the 1960s until closure of the units in the mid-1980s, the 300 and 400 Area impoundments were used to treat hydrazine fuel wastes by oxidation. After closure of the impoundments, hydrazine fuels were still treated at WSTF in a mobile tanker, but NASA wished to have a permitted, more permanent treatment facility for use at WSTF. The FTU was designed and permitted to be that more permanent treatment facility. The location for the FTU was chosen to be the 500 OOSA. The OOSA already had concrete areas with secondary containment. The FTU incorporated the truck parking concrete area into the FTU design. The FTU was designed to treat hydrazine fuel wastes by oxidation using chlorine gas. Construction of the FTU began in 1991 and was completed by September 1994 (NASA, 1995). Photographs during construction are provided in Appendix B. The concrete pad originally used for the truck parking and transfer area was used for the FTU treatment tank, and a new concrete pad with secondary containment was built for the FTU storage tank and the sodium hydroxide tank. The FTU began receiving waste on August 23, 1995. The oxidation treatment using chlorine was tested between November 6, 1995 and February 20, 1996. During the initial testing, the chlorine gas damaged some system parts, and due to newly enacted regulations (evaporative tank unit [ETU] waste had to be <500 ppm) volatile organic compounds at the point of generation, the treated waste from the FTU could not be disposed at the ETU. Therefore, no further oxidation of aqueous hydrazine fuel waste was attempted at the FTU after the initial testing phase. Aqueous fuel waste was instead stored and diluted prior to being shipped off-site for disposal at a RCRA permitted facility. Only hydrazine fuels (aqueous hydrazine, Monomethylhydrazine [MMH], and Unsymmetrical dimethylhydrazine [UDMH]) were stored and treated at the FTU. FTU closure activities began on December 11, 2018.

3.6 Other 500 Areas

The 500 Area was designed to store non-hazardous and hazardous substances needed for WSTF operations. There are three separate geographic areas with a total of six separate areas that have been used to store various products throughout WSTF history, and a brief summary of the six areas is provided below. Historical 500 Areas are shown on Figure 3.1.

3.6.1 Cryogenic and Inert Gas Storage

The cryogenic and inert gas storage area (Figure 3.1) was completed in 1964 and has been used at WSTF to store liquid and gaseous nitrogen and generate breathing air used for human support. Building 536 contains two breathing air compressors/systems that have supplied and continue to supply breathing air to all air stations at WSTF (for mobile trailers, and in the 200, 300, 400, 500, and 800 Areas; Appendix A) (NASA, 1994).

3.6.2 Hydrogen Storage

The initial hydrogen storage area (Figure 3.1) was completed in 1964 (NASA, 1994). Hydrogen was stored in a large above-ground tank that was removed in approximately 1990. Oxidizer cylinders were briefly stored in the initial hydrogen area from approximately 1993 to September 1995 when the 500 OOSA was being converted to the FTU and the new oxidizer storage area was not completed yet (Appendix A). Currently, the original hydrogen storage area is being used as an alcohol storage area with a maximum of 65, 55-gal drums (3,250 gal or 21,287.5 pounds of isopropyl alcohol (IPA) and ethyl alcohol are stored for use at WSTF (Appendix A).

3.6.3 Alcohol Storage

The initial alcohol storage area was also completed in 1964 (NASA, 1994) and was located between the original hydrogen storage area and the 500 FSA (Figure 3.1). Alcohol (IPA) was stored in a large above ground tank that has subsequently been removed. Other alcohols stored in this area were methanol and ethyl alcohol. Methanol was used for a rocket engine propellant for testing in the propulsion department. The initial alcohol storage area is currently not being used for storage.

3.6.4 Fuel Storage

The 500 FSA was constructed in 1964 and 1965. The large fuel tank (21,000 ga]) was installed in 1964 and historically stored Aerozine 50 (a 50/50 mixture of hydrazine and UDMH). The shelter above the tank was installed in 1965. The large tank was “closed down” between July 1 and September 30, 1973, and abandoned in place (Dynalectron, 1973). After the large tank was abandoned, NASA continued using the area for fuel storage, but with smaller 55-gal drums of hydrazine fuels (mostly MMH). The large tank was decontaminated and removed in 2011 (Appendix A). Currently, the smaller 55-gal drums of hydrazine fuels are stored in the FSA on a cement pad under the shelter/cover where the large tank was originally located and within the tanker transfer area as needed (Appendix A).

4.0 Historical Records Review

4.1 Record Sources

As part of the HIS process, records relevant to the area history, operations, and environmental conditions are reviewed. The type and location of these records are as follows:

- NASA Environmental Records – Located on-site in the WSTF Environmental Department, available in electronic form and some in paper copy form. Records reviewed included correspondence, maps, memoranda, regulatory submittals, and reports.
- NASA Drafting Records – Located on-site in the WSTF Drafting Department, available in paper copy files and some in electronic form.
- NASA Photographic Archives – Located on-site in the WSTF Photographic Laboratory. Negative logs were reviewed, and pertinent photographs were obtained for review.

4.2 Interviews and Questionnaires

In addition to the historical records review, interviews with current and former long-term employees were conducted. Refer to Appendix A for a summary of information from interviews conducted for this HIS.

5.0 Operational History

5.1 Pre-WSTF History

From the early 1800s to approximately 1935, the Organ Mountains and the SAM were mined for gold, silver, zinc, copper, and lead. There were several established mines and numerous prospect mines located in the SAM. The nearest established mine to WSTF was the Smith Mine located approximately 1 mi southeast of WSTF within the Loman Canyon area. The Smith mine produced approximately $30,000 of silver ore during its operation. Deposits of galena (lead sulfide) and barite (barium sulfate) were also mined just north of the eastern mouth of Bear Canyon (Seager, 1981, p87).

Lands now occupied by WSTF were historically open-range grazing lands. The ruins of a historic ranch house (Gardner Ranch, operated prior to 1960) are located just east of the current 200 Area laboratory facilities (southeast of the 500 Area), and Love Ranch (believed to be in operation from the early 1900s until 1960) is located approximately 2 mi northeast of the 500 Area. These properties were acquired by the federal government to become a part of WSMR.

5.2 Inception of WSTF

NASA Headquarters announced selection of a testing site in south-central New Mexico on July 6, 1962. The site was chosen for the isolated location and topography, which minimize the inherent hazards of aerospace propulsion testing to the general population. From the date of the official announcement until January 1965, the site was known as the Propulsion Systems Development Facility. From January to June 1965, the official designation was White Sands Operations. On June 16, 1965, the official name of the installation was changed to White Sands Test Facility (NASA, 1994).

Site planning activities began in August 1962. Exploratory drilling to locate a water supply source began in December 1962, with drilling of water supply wells completed in May 1963. Development of the site location began in May 1963 with construction of the access road (NASA Road) from U.S. Highway 70. The access road was completed in October 1963 (NASA, 1980, p.22, 1986 p.2). The first increment of the 300 Propulsion Test Area was completed in January 1964, followed by completion of the second increment of the 300 Propulsion Test Area by June 1964.

5.3 500 Area Oxidizer Burner and Vent Stack

An oxidizer burner (with the associated 500-gal propane tank, vent stack, and control unit with cabling) was added to the 500 OOSA in 1965 (NASA, 1967a, pp2-3; NASA, 1994). “The burner consists of an injector system for the propane and the nitrogen tetroxide, a mixing chamber, a burner head…, a spark-plug igniter system, and windshield” (NASA, 1967a, p2).

Drawing number 019-14800 (Appendix B, pB-2) shows that the instrumentation or control cabling for the oxidizer burner was buried underground on a direct path northeast to the burner from the eastern portion of the OOSA (Appendix B). The location of the 500 Area FOB was documented on WSTF drawing number 500-CP-04. From that drawing, aerial photography, and locating the remaining concrete and steel footings or stands in the field, the location where the 500 Area oxidizer burner was installed was determined and added to a map (Figure 3.3).

A vent stack at WSTF is a tall (approximately 20 ft) pipe-like structure that is part of the oxidizer burner system. The vent stack was designed to release to the atmosphere very small amounts of residual oxidizer vapors in the lines following oxidizer disposal/flaring by the burner (Appendix A). Like other oxidizer burners on site at WSTF, the 500 Area FOB was designed with a vent stack as well, located adjacent to

the oxidizer burner (Figure 3.3). A historical photograph of the 500 Area FOB oxidizer burner (in use) and the adjacent vent stack from 1967 is provided in Appendix B. The burner/vent stack system was used in the 500 OOSA to dispose of excess oxidizer until the large oxidizer tank was abandoned following the Apollo program work at WSTF in 1973.

The fate of the 500 Area oxidizer burner was also explained on historical WSTF 500 Area drawings. On the drawing 500-CP-18, written directly adjacent to the enlarged oxidizer burner detail, it states, "equip. to be relocated – see DWG (drawing) 284-10964…Equipment will be disconnected…and delivered to construction site for reinstallation…" The corresponding WSTF drawing 284-10964 shows the 800 Area with an oxidizer burner area that references back to drawing "CP-18." The 800 Area drawing (284-10964) was made in June 1973. Long-term WSTF personnel also stated that the 800 Area facility was established at WSTF in 1974, and an employee confirmed that the 500 Area oxidizer burner system was moved to the 800 Area from the 500 Area (Appendix A). This coincides with the timing of 500 OOSA large oxidizer tank closure (between July and September 30, 1973; Dynalectron, 1973), providing further evidence that the 500 Area oxidizer burner was removed and reinstalled for use in the 800 Area. The 800 Area Oxidizer Burner is identified as SWMU 20 in Attachment 22 of the 2009 Permit (NMED, 2009, p106) and Attachment 4 of the 2023 Permit (NMED, 2023) . Appendix B shows a photograph taken in May 2000 of the oxidizer burner located in the 800 Area.

6.0 Findings

6.1 Evidence of Hazardous Substances - Dinitrogen Tetroxide (N_2O_4)

The primary oxidizer used at WSTF from the inception of the site is N_2O_4 (NASA, 2020, p5). It is a strong oxidizing agent, has a high vapor pressure (1,551 millimeters of mercury [mm Hg]), a low boiling point (70.1° Fahrenheit [F] at 760 mm Hg), and a density greater than air (1.45 g/cm^3 at 68° F; U.S. National Library of Medicine, n.d.). Due to the low boiling point and high vapor pressure of N_2O_4, any potential oxidizer released would have become vapor and dissipated into the air.

N_2O_4 and nitrogen dioxide (NO_2) form a gas phase equilibrium, with N_2O_4 prevalent in the liquid phase and NO_2 prevalent in the gas phase. Vapors of NO_2 are reddish-brown in color and have been described as a "cloud" (NASA, 2010, pp2-3). With the highly corrosive nature of N_2O_4 (Terra Industries, 2011), any N_2O_4 or NO_2 present in soils would result in low (acidic) soil pH (due to the formation of nitrous and nitric acids with rainwater), likely much lower than 7.0. Nitrite does not persist in soils; however, the ultimate fate of N_2O_4 is the formation of nitrates with minerals in the soil (Gray and Yoffe, 1955 pp1069-1154, Greene and McClure, 2014; Terra Industries, 2011). The Material Safety Data Sheet (MSDS) for N_2O_4 is provided in Appendix C.

6.2 FOB Oxidizer Flaring and Oxidizer Disposal

Oxidizer disposal at the 500 Area FOB was documented by an employee in a memorandum dated May 23, 1967 (with attached report) titled Appraisal of Environmental Hazards in Treatment, Storage, and Disposal of Liquid Propellants and Other Chemicals at White Sands Test Facility (NASA, 1967b, p9). This document states:

> A complete estimate of the quantities of fuel and oxidizer disposed of in the storage area is not known. Currently, waste N_2O_4 which results from transporter off-loads and transfer operations is burned with propane. N_2O_4 from sample remainders (estimated to be 12 gallons per month) is vented to the atmosphere in the storage area…

The practice of burning oxidizer with propane identified in the document is referring to the process where propane is ignited, and oxidizer is added for destruction by flaring or burning at the burner. The oxidizer

burners at WSTF were similarly constructed and were "designed to dispose of at least 10 pounds of nitrogen tetroxide per minute" (NASA, 1967a, p.2). The employee estimated 12 gal of oxidizer per month was processed through the burner and vent stack. Oxidizer vent stacks at WSTF are also similarly constructed, and only release small quantities of oxidizer vapor at a time (Appendix A). The venting occurs from the top of the vent stack, approximately 20 ft above the soil. Due to the volatility of oxidizer and the small amounts of oxidizer vented during each event, it is unlikely oxidizer came into contact with soil. But, as discussed in Section 6.3.1, oxidizer added to the burner at non-optimum flaring configurations may have caused some oxidizer liquid or vapor to contact the ground.

6.3 Indication of Releases to the Environment

The following sections discuss releases to the environment of N_2O_4 in the 500 Area.

6.3.1 500 Area FOB Oxidizer Output Test

An Oxidizer Output Test was conducted in 1966 using the 500 Area FOB to identify the combustion products emitted by the burner (NASA, 2020, p6). When the burner was operated in accordance with NASA's normal operating procedures (slightly propane-rich), samples were collected "by holding an inverted funnel witch [sic] was connected to a flex hose leading to an evacuated 3-liter pressure bottle over the densest portion of the flame; the sample valve on the bottle was then opened to pull in the sample" (NASA, 1967a, p3). All sample system parts were constructed of stainless-steel or Teflon®[1]-lined components. The testing concluded that when the burner was operated with a slightly greater than 1:1 ratio of propane to oxidizer (propane-rich), the process of flaring/burning oxidizer with propane completely destroyed the oxidizer, releasing to the atmosphere only carbon dioxide, water vapor, nitrogen, and small amounts of unburned propane (NASA, 1967a, p4). If the burner was operated too propane-rich, "then such products as unburned propane, methane, ethane, and carbon monoxide, in addition to the normal combustion products, could be found in the exhaust. These predictions do not consider the fact that the hot gases are expelled into the atmosphere. Subsequently, a portion of the unburned propane and its degradation products would be burned with the oxygen in the air rather than with the nitrogen tetroxide" (NASA, 1967a, p3).

However, releases of liquid oxidizer/gaseous nitrogen dioxide from the burner were possible if the mixture was less than 1:1 ratio of propane to oxidizer (oxidizer-rich), if the operating procedure was not followed, or if equipment malfunctioned. This would result in incomplete combustion of oxidizer, releasing to the atmosphere "such products as nitrogen dioxide, nitrogen tetroxide, nitric oxide, and nitrous oxide, in addition to the normal combustion products, could be found in the exhaust" (NASA, 1967a, p3).

6.3.2 Oxidizer Release Testing

Prior to computer modelling capabilities, NASA conducted testing using video to determine characteristics of a potential large or catastrophic oxidizer release at WSTF. This testing was conducted in June 1979 at the 500 Area OOSA. Oxidizer was released to concrete in two sessions in amounts estimated by WSTF personnel to be approximately 250 gal for the first test and approximately 70 gal for the second test. The oxidizer immediately vaporized to nitrogen dioxide (NO_2), as shown by the red color, and began dissipating. As part of the testing, employees in protective suits released white balloons into the vapor cloud to assist visualization for tracking wind direction, cloud intensity, and distance. The maximum

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

distance estimated by a WSTF employee that the oxidizer cloud could have reached was the base of the canyon near Quartzite Mountain.

~~6.3.2~~6.3.3 Spills

NASA maintains logs of spills that occur at WSTF. No spills or leaks at the 500 Area FOB or OOSA were documented in spill logs. However, these spill logs have only been generated and maintained at WSTF since 1985. A long-term employee remembered hearing of one incident from an employee present during an oxidizer transfer from a truck to the large oxidizer tank during the Apollo testing in the 1960s. A spill to the truck loading pad concrete containment occurred because a valve was not closed completely. When the truck driver disconnected the transfer line, oxidizer sprayed on the driver (and in the transfer area). This spill area was on concrete, and there was no reported oxidizer spilled to soil. The oxidizer volatilized and evaporated. The amount spilled is unknown. There were no known spills large enough to have oxidizer flow to the ponding area or containment basin (Appendix A).

7.0 Uncertainty

WSTF historical operations and waste management practices were not well documented from the inception of the site in 1963 through the mid-1980s, and the formation of a full-time Environmental Department. And over such a long operational history with few to no regulations requiring records retention, historical records were sometimes discarded or were retained by contractors upon departure, and some historical records were stored on media that is currently inaccessible. Also, information from employee interviews is subject to the limitations of the recollection of the individuals interviewed, which could result in uncertainty and contradictory information. NASA used the available records and documentation for this HIS whenever possible to minimize uncertainty.

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Figures

Figure 2.1 **WSTF Location Map**

(SEE NEXT PAGE)

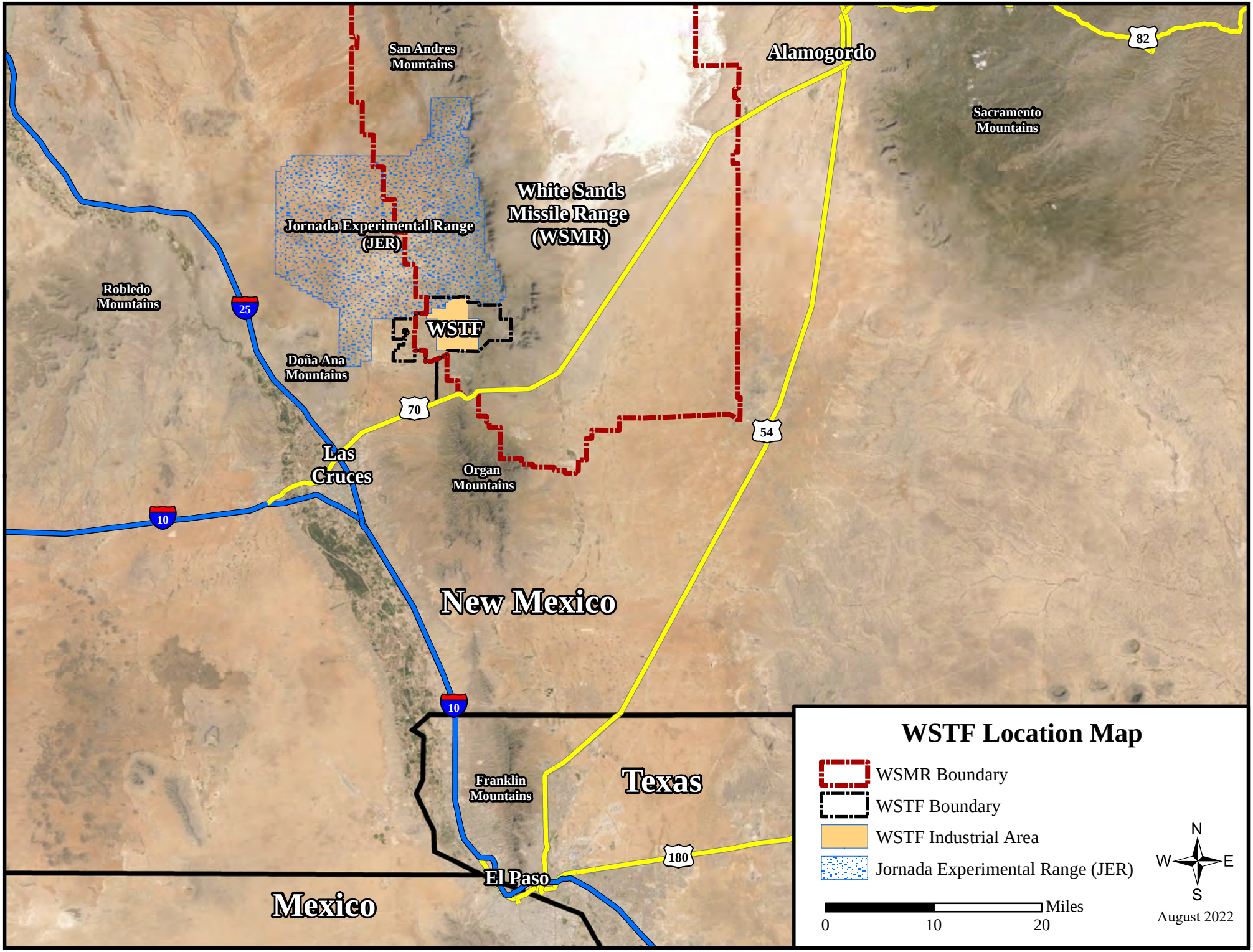

San Andres Mountains
Alamogordo
82
Sacramento Mountains
White Sands Missile Range (WSMR)
Jornada Experimental Range (JER)
Robledo Mountains
25
WSTF
Doña Ana Mountains
70
54
Las Cruces
Organ Mountains
10
New Mexico
10
Franklin Mountains
Texas
180
El Paso
Mexico
WSTF Location Map
WSMR Boundary
WSTF Boundary
WSTF Industrial Area
Jornada Experimental Range (JER)
Miles
0
10
20
N
W
E
S
August 2022

Figure 2.2 **Land Ownership Map**

(SEE NEXT PAGE)

1,505,558 1,515,558 1,525,558 1,535,558 1,545,558 1,555,558

563,526

553,526

543,526

533,526

United States Department of Agriculture
Jornada Experimental Range

White Sands Missile Range
Department of Defense
NASA Tenant

United States Fish and Wildlife Service

White Sands Missile Range
Department of Defense
NASA Tenant

New Mexico State
Land Office

Bureau of Land
Management
Withdrawn

NASA Owned

White Sands Missile Range
Department of Defense
NASA Tenant

WSTF Industrial Area
(White Sands Missile Range)

Private Land

Forward Guard Gate

Bureau of Land Management

New Mexico State
Land Office

White Sands Missile Range
Department of Defense

Private Land

Bureau of Land Management

WSTF Land Use Map

- WSTF Boundary
- Building
- WSTF Industrial Area
- NASA Tenant - WSMR Owned
- BLM Withdrawn Land
- United States Fish and Wildlife Service
- Bureau of Land Management
- NASA Property
- NM State Land Office
- Jornada Experimental Range
- White Sands Missile Range
- White Sands Missile Range Boundary
- Private Land

N
W E
S

July 2022

0 0.5 1 2 Miles

Coordinate System: NMSP, Central Zone, Ft. NAD83

Figure 2.3 **WSTF Topographic Map**

(SEE NEXT PAGE)

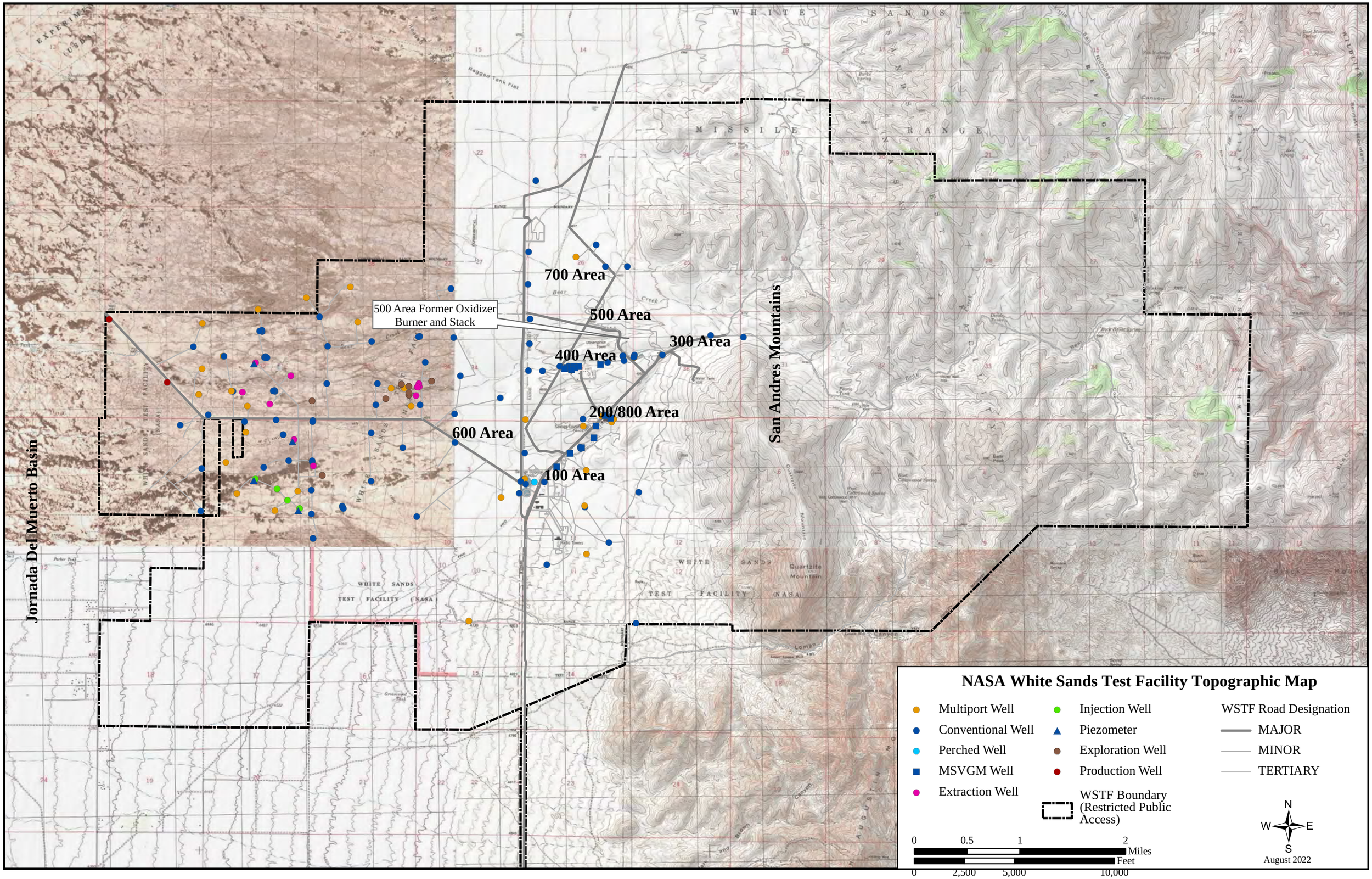

700 Area
500 Area Former Oxidizer Burner and Stack
500 Area
300 Area
400 Area
200/800 Area
600 Area
100 Area
San Andres Mountains
Jornada Del Muerto Basin
WHITE SANDS TEST FACILITY (NASA)
MISSILE RANGE
Ragged Tank Flat
Bear Creek
Quartzite Mountain
NASA White Sands Test Facility Topographic Map
Multiport Well
Conventional Well
Perched Well
MSVGM Well
Extraction Well
Injection Well
Piezometer
Exploration Well
Production Well
WSTF Boundary (Restricted Public Access)
WSTF Road Designation
MAJOR
MINOR
TERTIARY
0 0.5 1 2 Miles
0 2,500 5,000 10,000 Feet
N
W E
S
August 2022

Figure 3.1 **500 Area Structures**

(SEE NEXT PAGE)

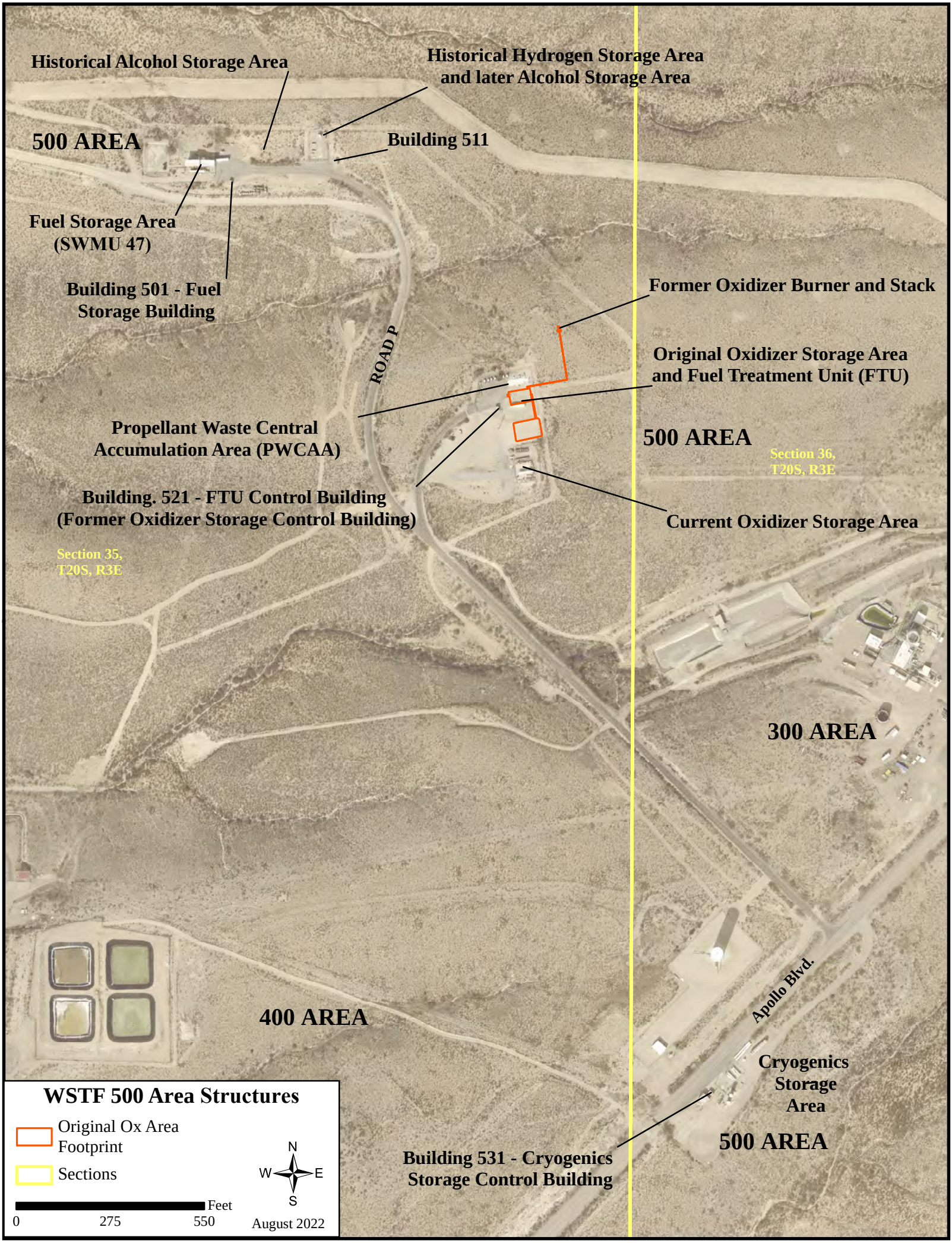

Historical Alcohol Storage Area
Historical Hydrogen Storage Area and later Alcohol Storage Area
500 AREA
Building 511
Fuel Storage Area (SWMU 47)
Building 501 - Fuel Storage Building
ROAD P
Former Oxidizer Burner and Stack
Original Oxidizer Storage Area and Fuel Treatment Unit (FTU)
Propellant Waste Central Accumulation Area (PWCAA)
500 AREA
Section 36, T20S, R3E
Building. 521 - FTU Control Building (Former Oxidizer Storage Control Building)
Current Oxidizer Storage Area
Section 35, T20S, R3E
300 AREA
400 AREA
Apollo Blvd.
Cryogenics Storage Area
500 AREA
Building 531 - Cryogenics Storage Control Building
WSTF 500 Area Structures
Original Ox Area Footprint
Sections
N
W
E
S
Feet
0
275
550
August 2022

Figure 3.2 500 Area Arroyos and Topographic Structures

(SEE NEXT PAGE)

Fuel Storage Area

500 Area

Former Oxidizer Burner and Stack

Road P

Original Oxidizer Storage Area and
Former Fuel Treatment Unit (FTU)

Propellant Waste Central
Accumulation Area (PWCAA)

Current Oxidizer Storage Area

400 Area

300 Area

4880 4890 4900 4910 4920 4930 4940 4950 4960 4970 4980 4990 5000 5010 5020 5030 5040 4850 4860 4870

500 Area Topographic Map

10-ft Contours

Arroyo

Original Ox Area Footprint

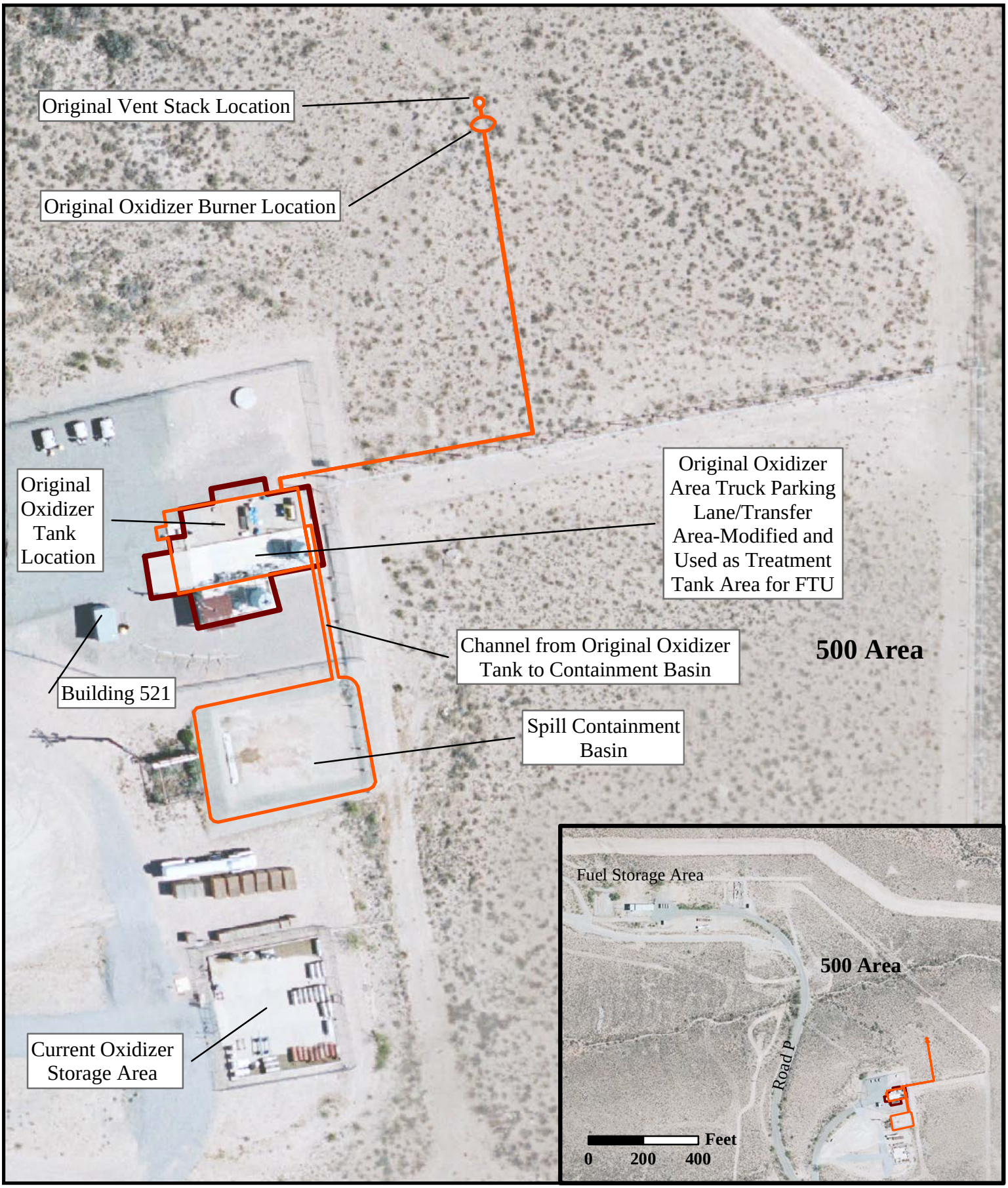
N W E S

0 125 250 500 Feet

August 2022

Figure 3.3 500 Area Former Oxidizer Burner and Original Oxidizer Storage Area

(SEE NEXT PAGE)



500 Area Original Oxidizer Storage Area (1963-1973) and Fuel Treatment Unit (FTU; 1995-2018)

FTU Footprint

Original Oxidizer Area Footprint

Feet
0 40 80

N
W E
S

August 2022

Appendix A
500 Area Summary of Findings from Employee Interviews or Questionnaires

Appendix A 500 Area Summary of Findings from Employee Interviews or Questionnaires

Position	Significant 500 Area Information	Other Information or Comments
Environmental Department 1989-2010	The 500 Area stored 55-gallon drums of chemicals. The employee had no knowledge of any leaks or spills. The Fuel Treatment Unit (FTU) contained an unregistered above ground tank that stored oxidizer. The Fuel Storage Area contained an unregistered above ground tank that stored Aerozine-50. There may have been burning or treating of fuel in 500 Area in the past.	The employee provided information in May 2011 in a questionnaire.
Propulsion Department, Environmental Department 1990-2012	The employee provided the following information regarding the 500 Fuel Storage Area (FSA) but also applies to the **500 Original Oxidizer Storage Area (OOSA)**: "The sump is a low point in the spalled (blown) concrete pond below ground surface, so liquids will drain there." The pipe leading from the sump area within the pond is buried underground until the discharge point and currently (2011) closed. Water does not drain out. Other OOSA information provided: Building 521 was the OOSA control building, but became the FTU (fuel treatment unit) control building when the FTU was built. The original large oxidizer tank was approximately 19,700 gallons. It was used from the mid-1960s to the mid-1970s. It was removed (information from a logbook) on 7/18/1995. If there was a shelter above the large tank, it had been removed prior to 1990 when the employee was hired. The oxidizer and fuel lines that connected the 500 fuel and oxidizer storage areas to the WSTF testing areas (300 and 400 Areas) were decontaminated and dismantled beginning January 2011. The employee stated that hydrogen Fluoride for use at HELSTF (high energy laser systems test facility) was briefly stored at the OOSA (in the tank transfer/parking area) from at ~1990 when the employee was hired) to 1993. No spills/leaks occurred. A new oxidizer storage area was built south of the original. Construction began 9/6/1995 (information from a logbook).	The employee was interviewed in May 2011. The employee also provided in depth information regarding the 500 fuel storage area and permitted fuel treatment unit that is not provided here.

Position	Significant 500 Area Information	Other Information or Comments
	FTU: Part of the FTU tanks were built on the previous OOSA concrete, and part were built on a new concrete pad built for the FTU. The NAOH tank is on the new concrete pad with one of the 4,000 gallon tanks. Physical construction of the FTU was complete in 1993, engineer certified the build in 1994; NMED approved the use in 1995. June 1, 1995 (from the employee's logbook) was the first day the facility was open. The first fuel waste was received on 8/23/1995. System testing was conducted 11/6/1995 through 2/20/1996. The chlorine damaged the system during testing. The system was fixed, but it was decided not to treat fuel waste using chlorine, but to store fuel waste at the FTU and ship off-site for disposal. Chlorine left WSTF 7/9/1997. The first fuel waste was shipped off-site 7/8/1997. FTU was classified in its history as a storage unit and a treatment unit. (Later, still a treatment unit due to dilution of fuel waste.) The employee provided information regarding the **original hydrogen storage area**: The original hydrogen storage tank was removed in approximately 1990. The only remaining (in 2011) structures are the original concrete pad and concrete pedestal where the tank was located. Prior to building/finishing the new oxidizer storage area, the oxidizer cylinders were stored in the original hydrogen area until the oxidizer area was built in 9/1995. When the oxidizer was moved to the new oxidizer storage area, alcohol began being stored at the original hydrogen storage area. The area has become the alcohol storage area, storing individual drums of alcohol. Currently (in 2011) the alcohol stored is a maximum of 65 55-gallon drums (3,250 gallons; 21, 287.5 lbs) of IPA and ethyl alcohol can be stored. The employee provided information regarding the **original alcohol storage area**: Built in the mid-1960s. The tank has been removed "many years ago". The site now has the original concrete pad and concrete pedestal where the tank was located. Methanol was also stored in the original alcohol area. It was used for a rocket engine fuel propellant in the propulsion department.	

Position	Significant 500 Area Information	Other Information or Comments
	This area is not currently being used. Nothing is stored there now. The employee provided information regarding the **500 FSA**: The fuel storage area control building (501) contains no controls, since the tank is out of service. The building contains lights and a telephone. From January to May 2011, the storage tank (21,000-gallon capacity) was decontaminated to non-detect (which took 7 rinses), and is currently "abandoned in place." (The tank was removed in 2012). The FSA "currently stores 55-gallon drums of fuel on the cement pad that holds the tank." Fuel is provided to any area at WSTF that requires fuel from the FSA. The tank is currently (2011) covered with a sun shelter. The shelter is scheduled to be moved to shade more of the 55-gallon drums (lowered after large tank removal). The employee provided information for the **cryogenic and inert gas storage area**: Building 536 contains a breathing air system that supplies breathing air to all air stations at WSTF. Air stations are located in the 200, 300, 400, 500, and 800 Areas. There are also mobile air station trailers for supplying breathing air for WSTF operations. Liquid and gaseous nitrogen is stored in the cryogenic area and sent to any WSTF area that requires gaseous operations.	
Anonymous	The large tank in the FSA was used for Aerozine-50. The employee provided information for the 500 FSA but also applies to the 500 OOSA: "The concrete pad to the south of the large tank was for transporters (tankers) to back into for transferring [fuel] into the tank." "…the tanker pad and the storage pad are sloped to drain to the ditch and then to the pond…" (The ditch is the flume or channel that leads to the containment pond, both are gunnite-lined.)	The employee provided information in May 2011. The employee provided additional information regarding SWMU 47, (the FSA) that is not provided here.
800 Area 1976~2015	The 800 Area test cells were constructed in approximately 1974. The employee stated that personnel were not concerned with small amounts of oxidizer released when fittings were disconnected	Employee was interviewed in April 2015

Position	Significant 500 Area Information	Other Information or Comments
	because "oxidizer boils at 70 degrees; it flashes to vapor and is gone."	Employee provided additional information regarding SWMU 19, the below grade storage tank, and 800 Area that are not provided here.
800 Area 1974-2010; consulted until 2013	The 800 Area test cells were constructed in 1974. It took approximately 18 months to build the 800 Area. The employee stated that SWMU 19, the below grade storage tank, was originally designed to have small amounts of fuel and oxidizer enter the tank underwater. However, "an old oxidizer burner…" that wasn't being used was added to the 800 Area, and all oxidizer from 800 Area testing was always disposed of by the oxidizer burner and vent stack. Employee stated that "oxidizer boils off at normal temperatures and pressures." Oxidizer was sent to the burner for disposal.	Employee was interviewed in April 2015 Employee provided additional information regarding SWMU 19, the below grade storage tank, SWMU 10, the hazardous waste transmission line, and 800 Area that are not provided here.
800 Area 1978-present (2019)	The oxidizer burner systems at WSTF also contain a separate vent stack. The vent stack is much taller than the burner and was used for releasing small amounts of oxidizer vapor in the lines after testing was completed and the oxidizer had been disposed of with the burner. The vent stack currently has a screen to prevent debris from entering. However, the vent stack was historically open at the top (in the 800 Area). The employee stated that releases of red colored vapor oxidizer was common from the 800 Area oxidizer burner. Oxidizer evaporates and dissipates.	Employee was interviewed in June 2015 Employee provided additional information regarding SWMU 19, the below grade storage tank, SWMU 10 and 800 Area that are

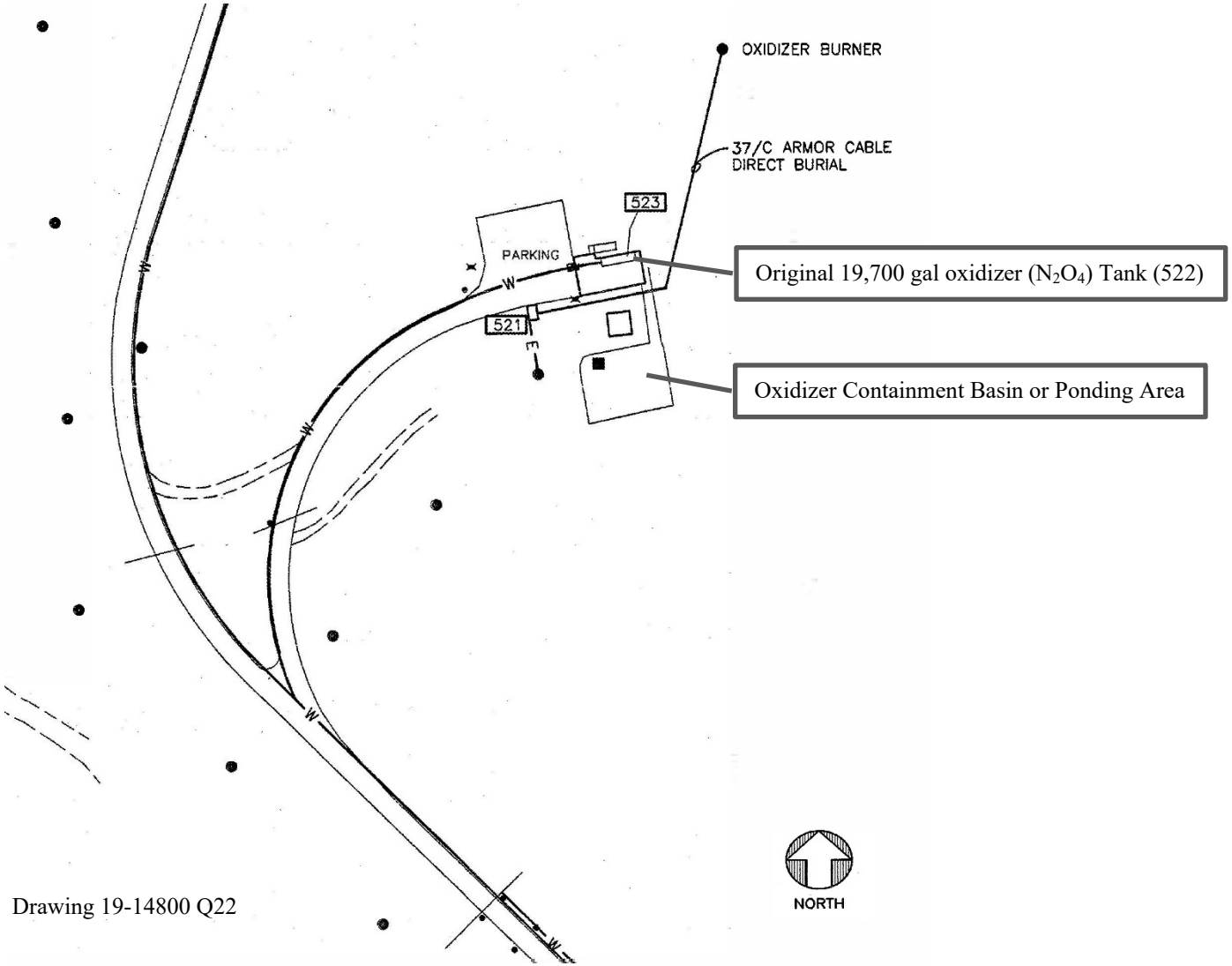
Position	Significant 500 Area Information	Other Information or Comments
	When liquid and gaseous spills occurred in the past onto soil, no clean-up was ever conducted. In the early WSTF history (1960s-early 1980s), employees did not always wear protective suits and employees were exposed to oxidizer vapors.	not provided here.
Propulsion Department (~1976-current [2019])	The employee stated that when the employee began working at WSTF, the original oxidizer storage area was no longer in use. The oxidizer containment basin was used as a spill containment area for the large oxidizer storage tank when it was in use.	Interviewed September 2018
800 Area and Propulsion 1977~1980; Safety Department 2002-2012	The employee stated that NASA performed testing at the 500 OOSA on "the concrete catch pad" using oxidizer (N_2O_4) in 1977, 1978, or 1979, but he believed 1978. The employee believed that the WSTF photo lab had taken pictures, so the year might be found from photographs. This was before computer modelling, so NASA needed to perform testing with video to determine characteristics of a potential large or "catastrophic" oxidizer release at WSTF. "The two tests were done because NASA wanted data to understand oxidizer. However, this only provided video of what a release would look like and a visual look at how far the cloud could spread. This didn't have quantitative data." Employees in protective suits released balloons into the oxidizer vapor cloud to assist visualization. "The balloons helped track wind direction and cloud intensity." The employees in the protective suites were to release the balloons when told to at a certain time to be used in the video to help see wind direction and to track the oxidizer cloud. "It was important to know how far the cloud went and what direction". The employee stated that two tests were performed at the original oxidizer storage area many months apart. The amount of oxidizer released was estimated by the employee as ~250 gallons for the first test and ~70 gallons for the second test. The employees in protective suits walked through the liquid oxidizer on the concrete pad sometimes "ankle deep". The employee estimated that the NO_2 vapor cloud could have reached as far as the base of the canyon near Quartzite Mountain from the first test. "No environmental cleaning was done."	Interviewed October 2019 The employee also discussed WSTF and WSMR history and groundwater contamination that is not provided here.

Position	Significant 500 Area Information	Other Information or Comments
	The only thing ever stored at the 500 OOSA was oxidizer, the employee said. The purpose of the ponding area/oxidizer basin was "to catch any liquid oxidizer from the big tank" if workers had to do an emergency "dump". The employee heard from a longer term employee that when the 500 OOSA was in use during the Apollo testing in the 1960s that there was one incident of an oxidizer spill at the storage area. "A truck came in unloading into the big tank. The driver was not taking safety seriously and only wearing gloves, no other PPE. A valve wasn't closed all the way. When the driver disconnected the 3" or 4" transfer line, oxidizer sprayed all over him...Technicians present at the time soaked him in the emergency shower there…He was ok in the end…The oxidizer volatized and evaporated." The employee did not know the amount of oxidizer spilled, but the transfer area was concrete, not released to soil. The ponding area or containment basin never held oxidizer to the employee's knowledge. "The 500 OOSA was abandoned by the time of the oxidizer testing in the late 1970s. The area was only used for the Apollo program. After the Apollo program, fuel use went from UDMH and Aerozine 50 to MMH. These fuels weren't compatible for use in the same tank. The oxidizer tank (and fuel tank) was a huge tank. Originally, lines were built from the 500 Area to the test areas (300/400 Areas)…Any fuel or oxidizer not used during a test was pushed back into the 500 Area again…NASA thought they were losing fuel or oxidizer [by having product remain in the lines] by pushing them all the way back to the storage areas." Fuel and oxidizer was stored in the manufacturer's storage tanks. The manufacturer's tanks were called "pigs" and were much smaller than the original large tanks. These "pigs" were stored in the concrete areas next to the big tanks until they were needed for a test. Then the "pig" would be transported to the 300 or 400 Area. Then the leftover (unused) "pig" of fuel or oxidizer was kept at the 300 or 400 Area. "So with this system, the big tanks and transfer lines in the 500 Area were not needed. NASA isolated the 500 Area and abandoned the big tanks." The employee stated that the 500 Area oxidizer burner became the 800 Area oxidizer burner. Any oxidizer that couldn't be sent back to the tank was burned in the oxidizer burner.	

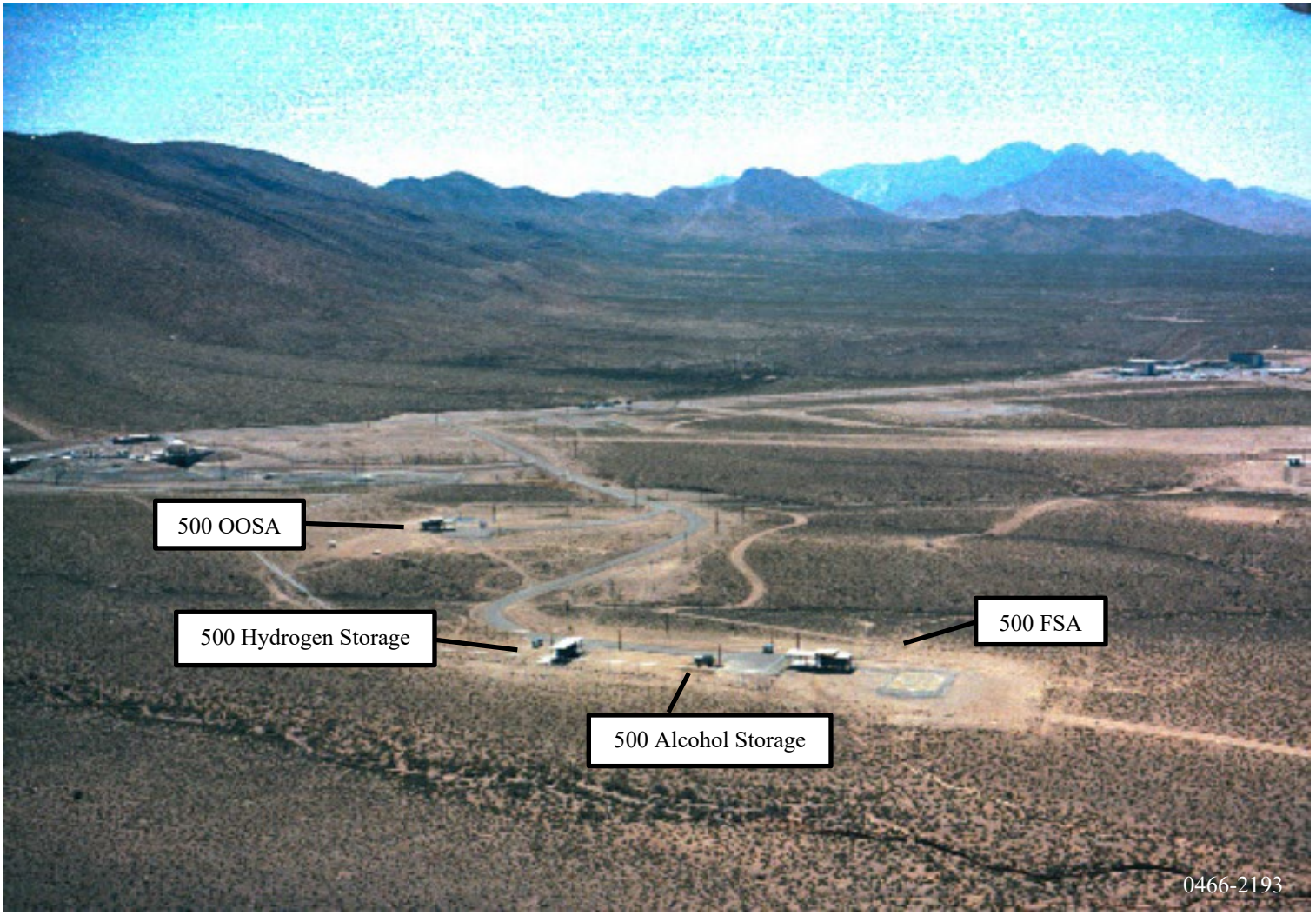
Position	Significant 500 Area Information	Other Information or Comments
	Both in the 500 Area fuel and oxidizer storage areas, there was a shade to cover the big tanks, and sprinkler systems to turn on a water deluge in case of fire.	
	A logbook for 500 Area operations was located, providing dates for 500 OOSA tank removal, FTU operations, and other 500 Area activities.	

Appendix B
500 Fuel Oxidizer Burner Historical Photographs

Figure B.1 **Schematic of the 500 OOSA and FOB**

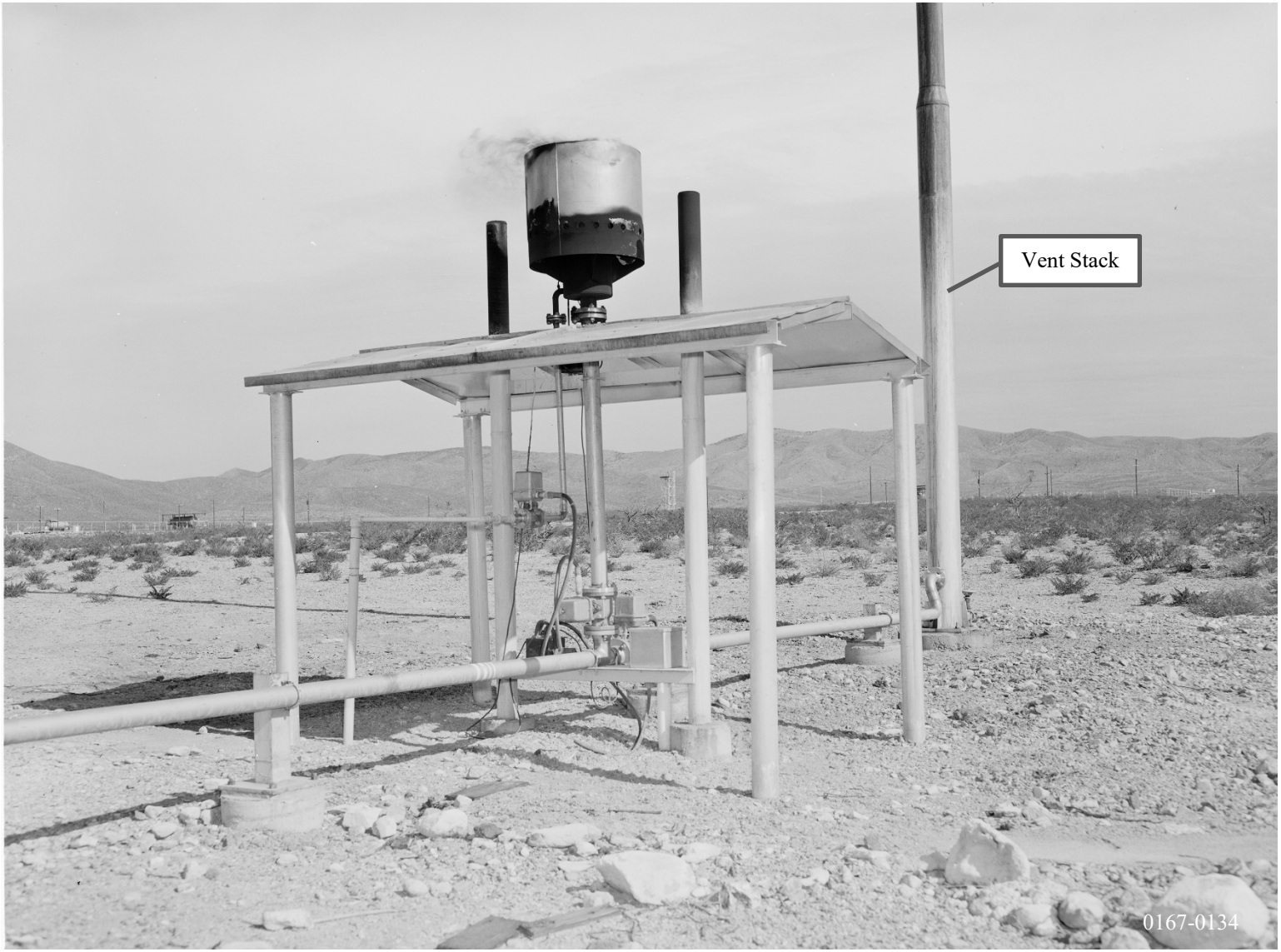


This schematic shows the 500 Original Oxidizer Storage Area (OOSA) and the location of the former oxidizer burner (FOB) and associated underground conduit and cabling. The diagram identifies the control building (B521), the original 19,700-gallon oxidizer tank (B523 is the tank shed cover), and the oxidizer containment basin or ponding area.



This photograph shows the 500 Area OOSA, Hydrogen Storage Area, Alcohol Storage Area, and Fuel Storage Area (FSA) in April 1966.

Figure B.3 **500 Area Former Oxidizer Burner (1967) – view to the east**



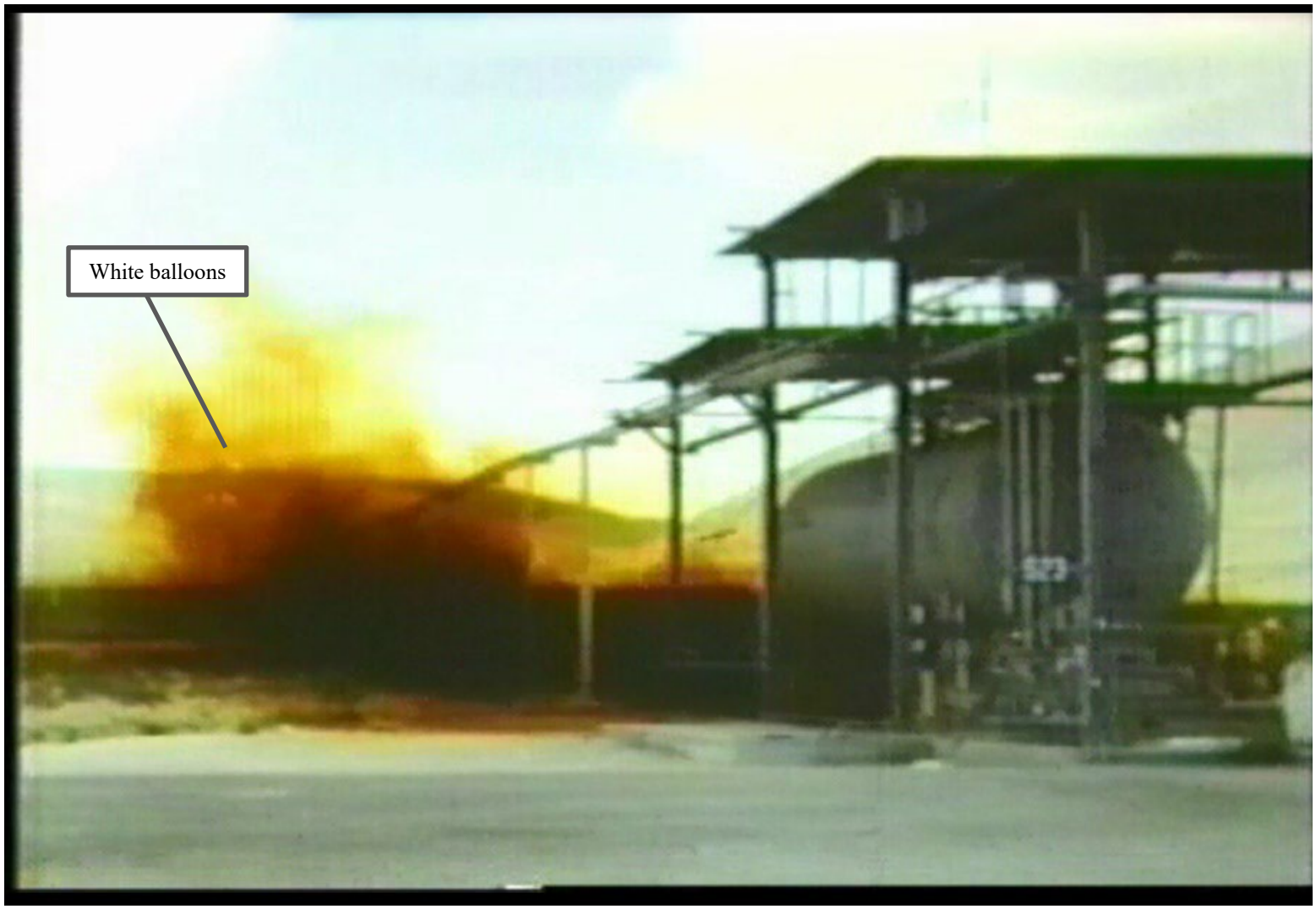
This photograph shows the 500 Area FOB in use and the adjacent vent stack in January 1967.

This photograph shows technicians in protective suits working at the 500 OOSA in May 1967.

Figure B.5 Conducting Oxidizer Testing in 500 OOSA (1979) – view to the east

This photograph shows testing in the 500 OOSA in 1979 to determine characteristics of a potential catastrophic oxidizer release at WSTF. Notice the N_2O_4 is actively being released onto concrete and immediately vaporizing to reddish-brown NO_2.

Figure B.6 **Conducting Oxidizer Testing in 500 OOSA (1979) – view to the east**



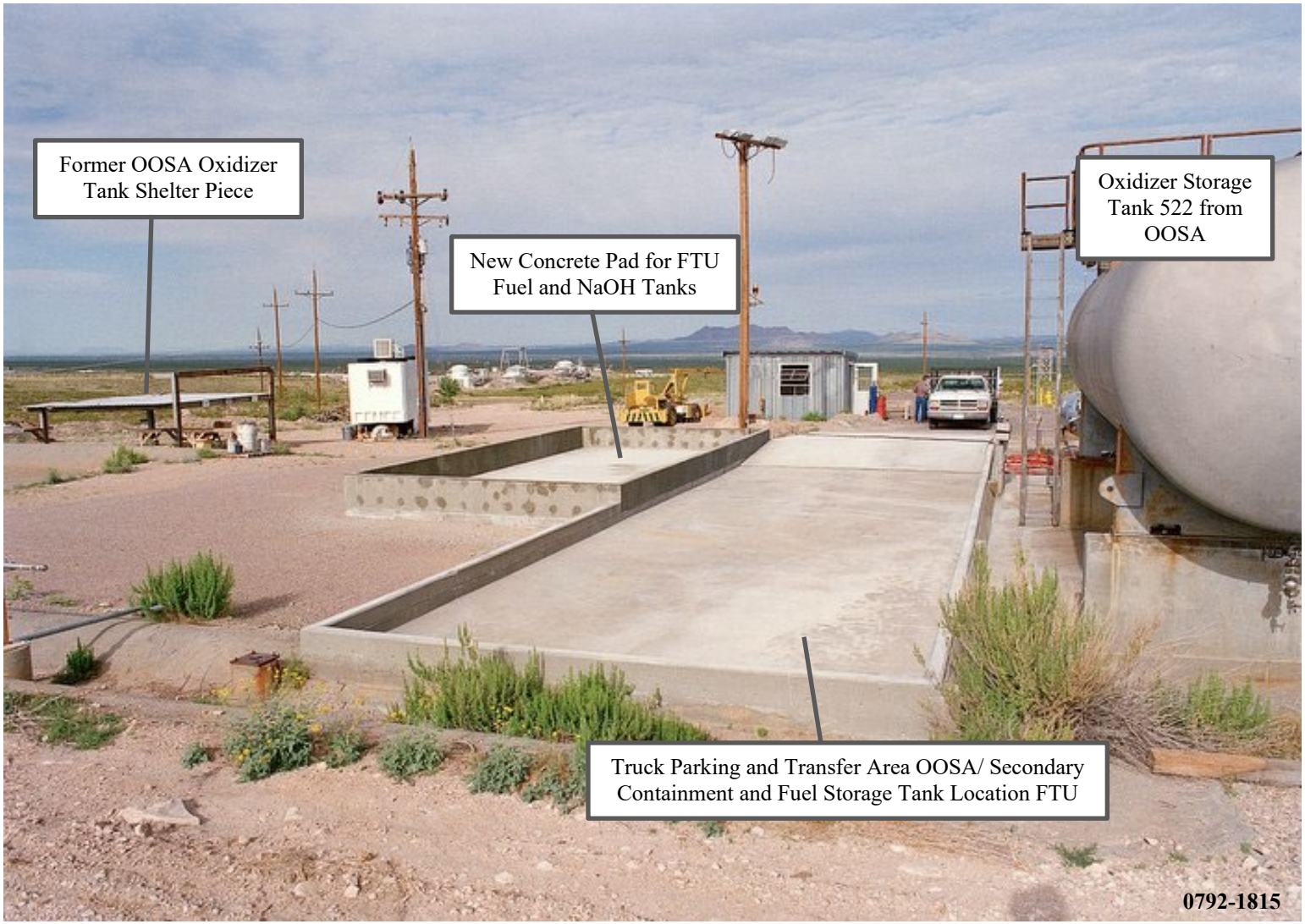
This photograph shows testing in the 500 OOSA in 1979 to determine characteristics of a potential catastrophic oxidizer release at WSTF. Notice the reddish-brown NO_2 vapor has drifted northeast with the wind compared to the previous photo (B.5).

Figure B.7 Conducting Oxidizer Testing in 500 OOSA (1979) – view to the northeast

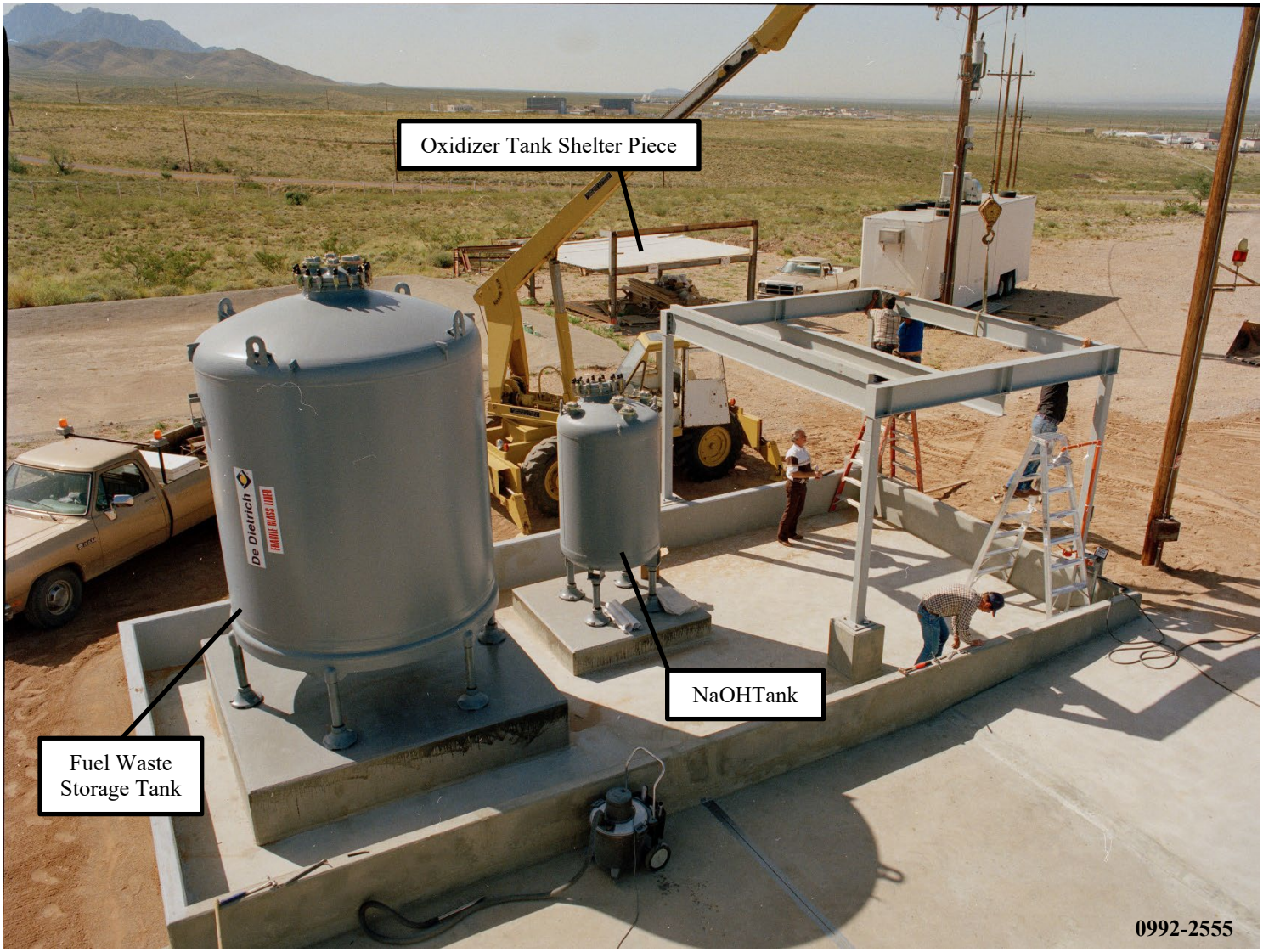
This photograph shows technicians in protective suits working in the released oxidizer during testing in the 500 OOSA in June 1979.

This photograph shows the 500 Area in September 1974. The large oxidizer tank had been "closed" and abandoned and the oxidizer burner moved to the 800 Area.

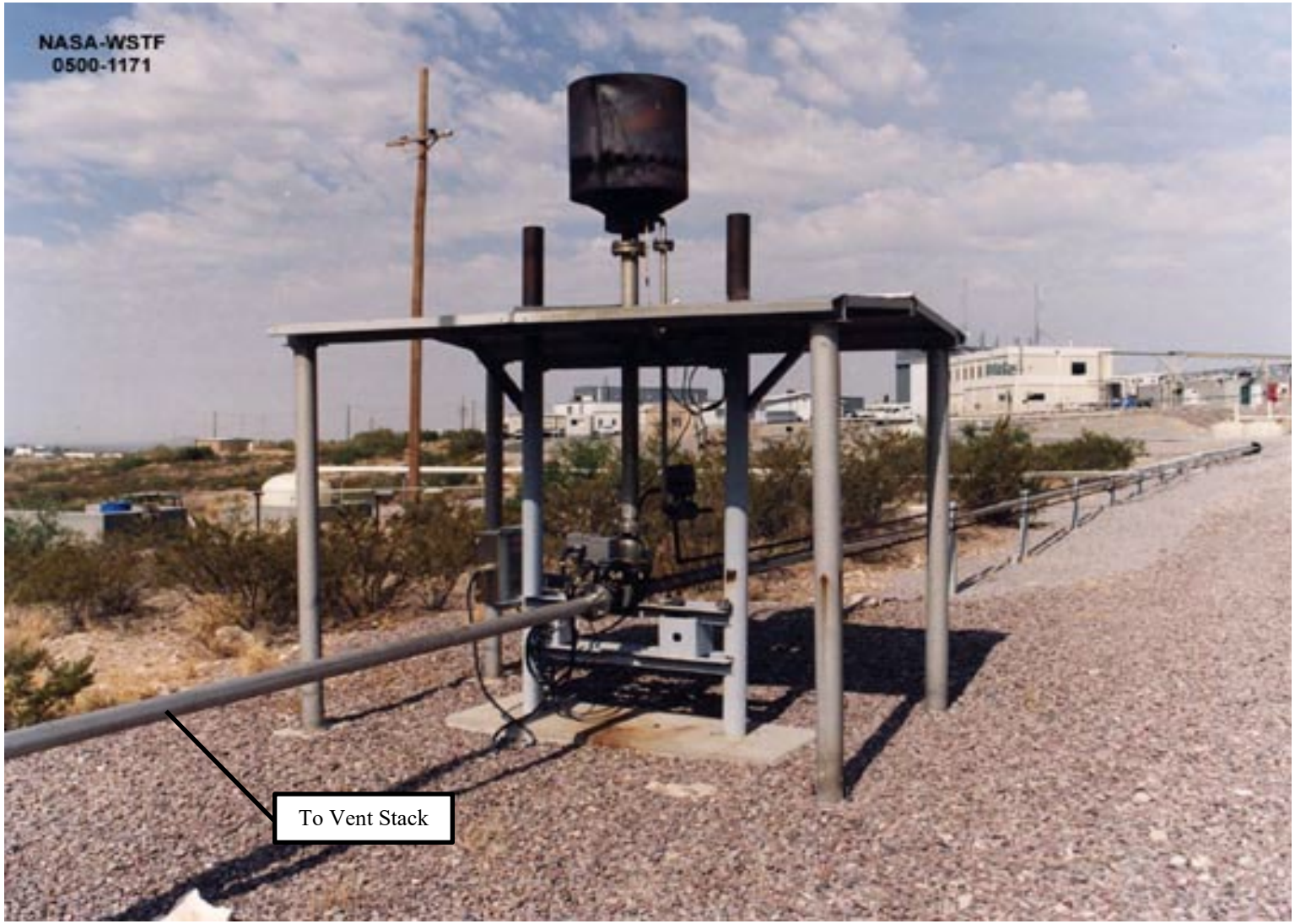
Figure B.9 **Constructing the FTU (1992) – view to the west**



This photograph shows the 500 OOSA undergoing construction to become the Fuel Treatment Unit (FTU) in July 1992. The original 19,700-gallon oxidizer tank is still in place, and to become part of the FTU, the truck parking and transfer area has been modified, and a new concrete pad with containment has been added.

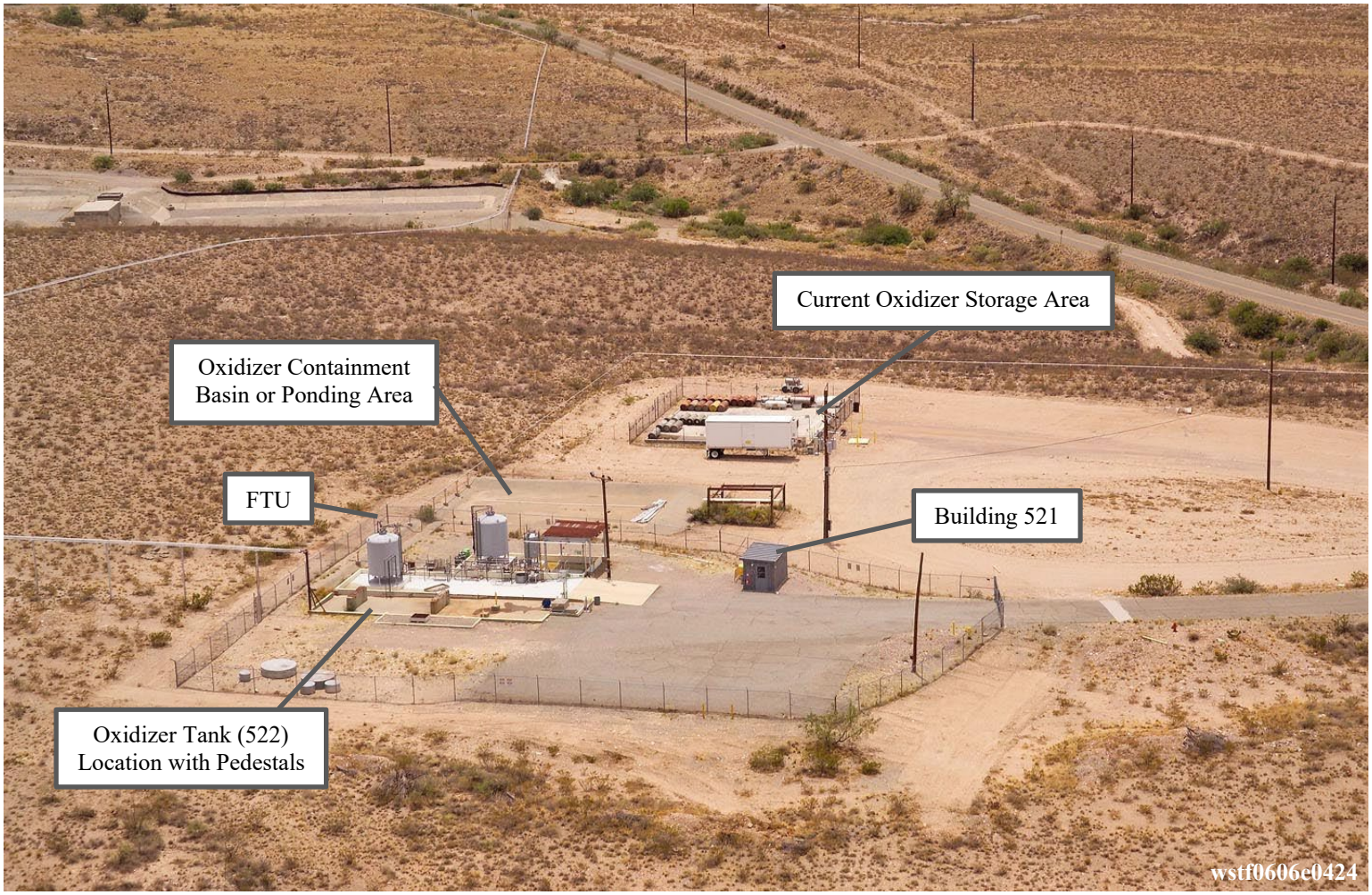


This photograph was taken from the stairs of the large oxidizer tank and shows installation of the fuel and sodium hydroxide (NaOH) tanks on the newly made concrete containment area to become part of the FTU.



This photograph taken May 2000 shows the 800 Area oxidizer burner (1974-present) that currently disposes of leftover oxidizer after testing in the WSTF 800 Area. This burner was previously the 500 OOSA oxidizer burner from 1965-1974. The vent stack is not shown in the photo.

Figure B.12 **500 OOSA and FTU (2006) – view to the south**



This photograph shows the 500 OOSA in June 2006. Notice the secondary containment concrete pad and pedestals for the original 19,700-gallon oxidizer tank (Tank 522) are still present. The current oxidizer storage area is located to the south towards the top of the photo.

Figure B.13 Oxidizer Containment Basin or Ponding Area (2018) – view to the northeast

This photograph shows the gunite-lined oxidizer containment basin or ponding area for the 500 OOSA. The area was originally used only for potential secondary emergency oxidizer containment if the large tank failed or there was a large spill or leak. The drain for the area is marked with a stick and leads to a pipe with a gate valve. This area was not used as part of the FTU.

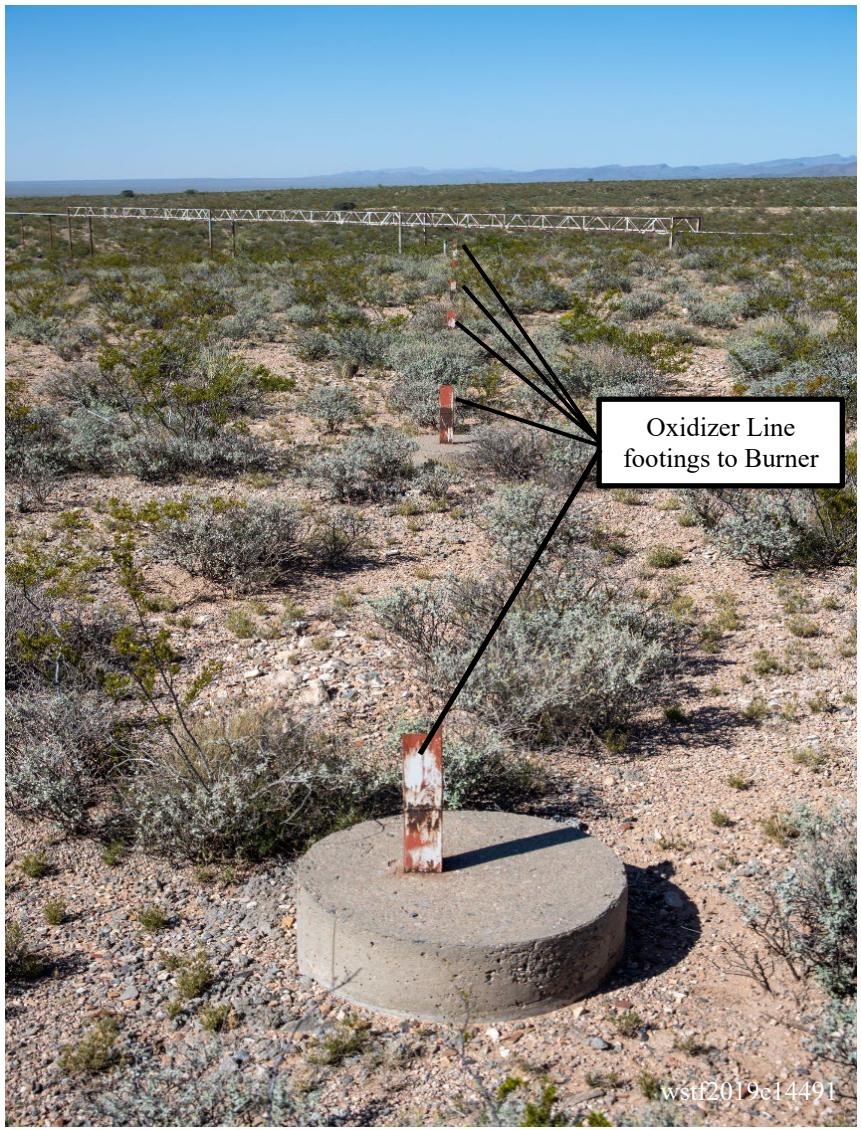
This photograph shows the 500 OOSA oxidizer containment basin or ponding area. There is a channel or open trench from the oxidizer tank concrete pad to the containment basin.

This photograph shows the FTU, the secondary containment and pedestal for the original oxidizer tank, and the opening in the southeast corner of the containment wall that drained to the gunite-lined channel or open trench to the oxidizer containment basin or ponding area. The entire channel was gunite lined during operation of the oxidizer tank, but a portion of the gunite has been removed where the channel meets the tank area opening (likely during FTU construction). Soil has washed into the channel as seen in the photo.

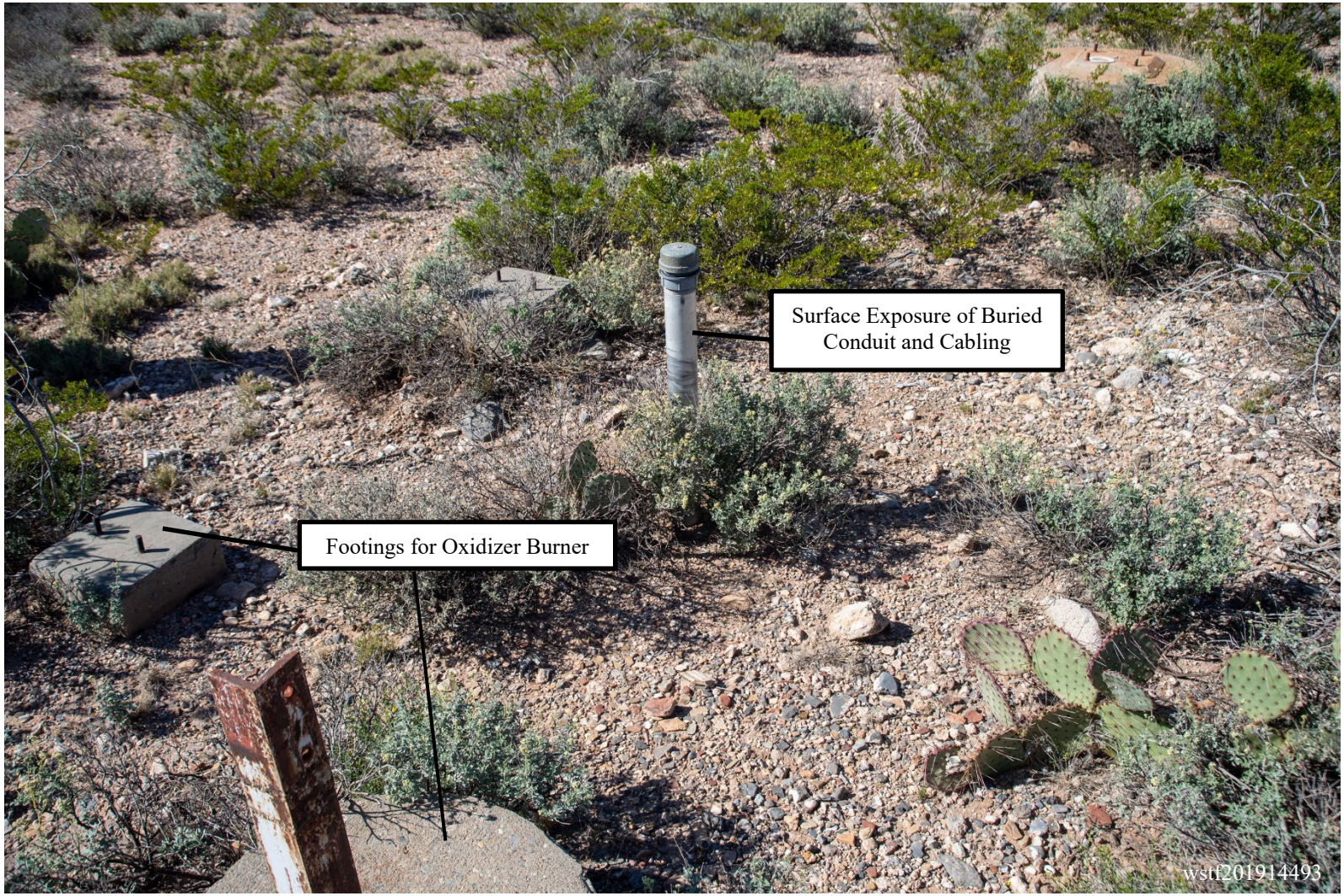
This photograph shows the 4-in. steel pipe that drained the 500 OOSA oxidizer containment basin or ponding area. The pipe end had been cut in the past. The wet area is rain water.

This photograph shows the demolition of the 500 OOSA oxidizer containment basin or ponding area as part of FTU closure procedures.

This is a photograph showing the demolition of the original oxidizer tank (522) area with the concrete pad, pedestals, secondary containment as part of FTU closing procedures.



This photograph shows the remaining abandoned footings to the oxidizer line for the 500 Area FOB as part of the OOSA.



This photograph shows the abandoned footings and conduit with cabling for the 500 Area FOB. The burner and vent stack were removed and installed in the 800 Area in 1974.

Figure B.21 Historical Aerial Imagery of the 500 Area Former Oxidizer Burner (1985, 1996-98, 2014, and Current Esri Imagery)

Appendix C
Material Safety Data Sheets/Safety Data Sheets

MSDS Material Safety Data Sheet

From: Mallinckrodt Baker, Inc.
222 Red School Lane
Phillipsburg, NJ 08865

Mallinckrodt CHEMICALS J.T.Baker

24 Hour Emergency Telephone: 908-859-2151
CHEMTREC: 1-800-424-9300

National Response in Canada
CANUTEC: 613-996-6666

Outside U.S. and Canada
Chemtrec: 703-527-3887

NOTE: CHEMTREC, CANUTEC and National Response Center emergency numbers to be used only in the event of chemical emergencies involving a spill, leak, fire, exposure or accident involving chemicals.

All non-emergency questions should be directed to Customer Service (1-800-582-2537) for assistance.

HYDROFLUORIC ACID

1. Product Identification

Synonyms: Fluorohydric acid; fluoric acid; Hydrogen fluoride solution
CAS No.: 7664-39-3
Molecular Weight: 20.01
Chemical Formula: HF in Aqueous Solution.
Product Codes:
J.T. Baker: 5368, 5659, 5818, 5823, 5824, 5840, 5865, 5900, 6904, 9559, 9560, 9563, 9564, 9567, 9572, 9573, 9574
Mallinckrodt: 2640, 2648, V141, V580

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous
Hydrogen Fluoride	7664-39-3	48 - 52%	Yes
Water	7732-18-5	48 - 52%	No

3. Hazards Identification

Emergency Overview

POISON! DANGER! CORROSIVE. EXTREMELY HAZARDOUS LIQUID AND VAPOR. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. MAY BE FATAL IF SWALLOWED OR INHALED. LIQUID AND VAPOR CAN BURN SKIN, EYES AND RESPIRATORY TRACT. CAUSES BONE DAMAGE. REACTION WITH CERTAIN METALS GENERATES FLAMMABLE AND POTENTIALLY EXPLOSIVE HYDROGEN GAS.

SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 4 - Extreme (Poison)
Flammability Rating: 0 - None
Reactivity Rating: 2 - Moderate
Contact Rating: 4 - Extreme (Corrosive)
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Exposure to hydrofluoric acid can produce harmful health effects that may not be immediately apparent.

Inhalation:
Severely corrosive to the respiratory tract. May cause sore throat, coughing, labored breathing and lung congestion/inflammation.
Ingestion:
Corrosive. May cause sore throat, abdominal pain, diarrhea, vomiting, severe burns of the digestive tract, and kidney dysfunction.
Skin Contact:
Corrosive to the skin. Skin contact causes serious skin burns which may not be immediately apparent or painful. Symptoms may be delayed 8 hours or longer. The fluoride ion readily penetrates the skin causing destruction of deep tissue layers and even bone.
Eye Contact:
Corrosive to the eyes. Symptoms of redness, pain, blurred vision, and permanent eye damage may occur.
Chronic Exposure:
Intake of more than 6 mg of fluorine per day may result in fluorosis, bone and joint damage. Hypocalcemia and hypomagnesemia can occur from absorption of fluoride ion into blood stream.
Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders, eye problems, or impaired kidney or respiratory function may be more susceptible to the effects of this substance.

4. First Aid Measures

For any route of contact: Detailed First Aid procedure should be planned before beginning work with HF.
Inhalation:
Get medical help immediately. If patient is unconscious, give artificial respiration or use inhalator. Keep patient warm and resting, and send to hospital after first aid is complete.
Ingestion:
If swallowed, DO NOT INDUCE VOMITING. Give large quantities of water. Never give anything by mouth to an unconscious person. Get medical attention immediately.
Skin Contact:
1) Remove the victim from the contaminated area and immediately place him under a safety shower or wash him with a water hose, whichever is available. 2) Remove all contaminated clothing. Handle all HF-contaminated material with gloves made of appropriate material, such as PVC or neoprene. 3) Keep washing with large amounts of water for a minimum of 15 minutes. 4) Have someone make arrangements for medical attention while you continue flushing the affected area with water. 5) If the following materials are available, limit the washing to five minutes and immerse the burned area in a solution of 0.2% iced aqueous Hyamine 1622 or 0.13% iced aqueous Zephiran Chloride. If immersion is not practical, towels should be soaked with one of the above solutions and used as compresses for the burn area. Ideally compresses should be changed every 2 minutes. Alternately, 2.5% calcium gluconate gel should be massaged into the affected area. 6) Seek medical attention as soon as possible for all burns regardless of how minor they may appear initially. Hyamine 1622 is a trade name for tetracaine benzethonium chloride, Merck Index Monograph 1078, a quaternary ammonium compound sold by Rohm & Haas, Philadelphia. Zephiran Chloride is a trade name for benzalkonium chloride, Merck Index Monograph 1059, also a quaternary ammonium compound, sold by Sanofi-Synthelabo Inc., New York, NY.
Eye Contact:
1) Irrigate eyes for at least 30 minutes with copious quantities of water, keeping the eyelids apart and away from eyeballs during irrigation. 2) Get competent medical attention immediately, preferably an eye specialist. 3) If a physician is not immediately available, apply one or two drops of ophthalmic anesthetic, (e.g., 0.5% Pontocaine Hydrochloride solution). 4) Do not use oily drops, ointment or HF skin burn treatments. Place ice pack on eyes until reaching emergency room.

Note to Physician:
General: For burns of moderate areas, (greater than 8 square inches), ingestion and significant inhalation exposure, severe systemic effects may occur, and admission to a critical care unit should be considered. Monitor and correct for hypocalcemia, cardiac arrhythmias, hypomagnesemia and hyperkalemia. In some cases renal dialysis may be indicated.

Inhalation: Treat as chemical pneumonia. Monitor for hypocalcemia, 2.5% calcium gluconate in normal saline by nebulizer or by IPPB with 100% oxygen may decrease pulmonary damage. Bronchodilators may also be administered.

Skin: For deep skin burns or contact with concentrated HF (over 50%) solution, consider infiltration about the affected area with 5% calcium gluconate [equal parts of 10% calcium gluconate and sterile saline for injection]. Burns beneath the nail may require splitting the nail and application of calcium gluconate to the exposed nail bed. For certain burns, especially of the digits, use of intra-arterial calcium gluconate may be indicated.

Eyes: Irrigation may be facilitated by use of Morgan lens or similar ocular irrigator, using 1% aqueous calcium gluconate solution [50ml of calcium gluconate 10% in 500 ml normal saline].

AN ALTERNATIVE FIRST AID PROCEDURE: The effect of HF, i.e. onset of pain, particularly in dilute solutions, may not be felt for up to 24 hours. It is important, therefore, that persons using HF have immediate access to an effective antidote even when they are away from their work place in order that first aid treatment can be commenced immediately.
We recommend that any person in contact with HF should carry, or have access to a tube of HF Antidote Gel at all times; ideally with one tube at the work place, one on the person and one at home.
It is imperative that any person who has been contaminated by HF should seek medical advice when the treatment by HF Antidote Gel has been applied.
REFERENCES: 1. Browno, T.D. Treatment of Hydrofluoric Acid Burns 2. Sprout, W.L. et al Treatment of Severe Hydrofluoric Acid Exposures (Journal of American Occupational Medicine 25:12, 1993) 3. Bracken, W.M. et al Comparative Effectiveness of Topical Treatments for Hydrofluoric Acid Burns, University of Kansas (Journal of Occupational Medicine 27:10:1985) 4. Burke, W.J. , et al Systemic Fluoride Poisoning Resulting from A Fluoride Skin Burn (Journal of Occupational Medicine (5,39:1973)

HF ANTIDOTE GEL:
Distributed by Pharmascience Inc.
8400 Darnley Rd. Montreal, Canada. H4T 1M4
Phone: (514) 340 - 1114
Fax: (514) 342 - 7764
U.S. (Buffalo, NY) distributor: 1-800-207-4477

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5. Fire Fighting Measures

Fire:
Not considered to be a fire hazard. Fire may produce poisonous or irritating gases.
Explosion:
Violent exothermic reaction occurs with water. Sufficient heat may be produced to ignite combustible materials. Reacts with metals forming flammable Hydrogen gas.
Fire Extinguishing Media:
Keep upwind of fire. Use water or carbon dioxide on fires in which Hydrofluoric Acid is involved. Halon or foam may also be used. In case of fire, the sealed containers can be kept cool by spraying with water.
Special Information:
In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full facepiece operated in the pressure demand or other positive pressure mode. Avoid getting water in tanks or drums; water can cause generation of heat and spattering. In contact with air, the acid gives off corrosive fumes which are heavier than air.

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6. Accidental Release Measures

Notify safety personnel, provide adequate ventilation, and remove ignition sources since hydrogen may be generated by reactions with metals. Wear appropriate personal protective equipment as specified in Section 8. Do not flush to sewers or waterways. Spills: Evacuate the danger area. Apply magnesium sulfate (dry) to the spill area. Follow up with inert absorbent and add soda ash or magnesium oxide and slaked lime. Collect in appropriate plastic containers and save for disposal. Wash spill site with soda ash solution. NOTE: Porous materials (concrete, wood, plastic, etc.) will absorb HF and become a hazard for an indefinite time. Such spills should be cleaned and neutralized immediately. US Regulations (CERCLA) require reporting spills and releases to soil, water and air in excess of reportable quantities. The toll free number for the US Coast Guard National Response Center is (800) 424-8802.

J. T. Baker Hydrofluoric Acid Emergency Cleanup Kit is recommended for spills of this product.

7. Handling and Storage

Keep in tightly closed polyethylene containers. Store in a cool, dry place with adequate ventilation separated from other chemicals. Protect from physical damage. Storage facilities should be constructed for containment and neutralization of spills. Handling and storage of HF requires special materials and technology for containers, pipes, valves, etc., which is available from suppliers. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:
Hydrogen fluoride:
-OSHA Permissible Exposure Limit (PEL):
3 ppm (TWA)
ACGIH Threshold Limit Value (TLV):
3 ppm Ceiling as F
Ventilation System:
A system of local and/or general exhaust is recommended to keep employee exposures as low as possible. Local exhaust ventilation is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, *Industrial Ventilation, A Manual of Recommended Practices*, most recent edition, for details.
Personal Respirators (NIOSH Approved):
If the exposure limit is exceeded, a full facepiece respirator with an acid gas cartridge may be worn up to 50 times the exposure limit or the maximum use concentration specified by the appropriate regulatory agency or respirator supplier, whichever is lowest. For emergencies or instances where the exposure levels are not known, use a full-facepiece positive-pressure, air-supplied respirator. WARNING: Air purifying respirators do not protect workers in oxygen-deficient atmospheres. Since the IDLH is low (30 ppm), the above cartridge system is not specifically approved for HF. (3M Respirator Selection Guide)
Skin Protection:
Wear protective clothing, including boots or safety shoes with polyvinyl chloride (PVC) or neoprene. Use chemical goggles and/or a full face shield. Wear coveralls with long sleeves, gauntlets and gloves of PVC or neoprene. A high degree of protection is obtained with an air-inflated suit with mask and safety belt. Use protection suitable for conditions.
Eye Protection:
Use chemical safety goggles and/or full face shield where splashing is possible. Maintain eye wash fountain and quick drench facilities in work area.

9. Physical and Chemical Properties

Appearance:
Colorless, fuming liquid.
Odor:
Acrid odor. Do not breathe fumes.
Solubility:
Infinitely soluble.
Specific Gravity:
1.15 -1.18
pH:
1.0 (0.1M solution)
% Volatiles by volume @ 21C (70F):
100 (as water and acid)
Boiling Point:
108C (226F)
Melting Point:
< -36C (< -33F)
Vapor Density (Air=1):
1.97
Vapor Pressure (mm Hg):
25 @ 20C (68F)
Evaporation Rate (BuAc=1):
No information found.

10. Stability and Reactivity

Stability:
Stable at room temperature (68F) when stored and used under proper conditions.
Hazardous Decomposition Products:
On contact with metals, liberates hydrogen gas. On heating to decomposition, could yield toxic fumes of fluorides. Attacks glass and other silicon containing compounds. Reacts with silica to produce silicon tetrafluoride, a hazardous colorless gas.
Hazardous Polymerization:
Will not occur.
Incompatibilities:
Hydrofluoric acid is incompatible with arsenic trioxide, phosphorus pentoxide, ammonia, calcium oxide, sodium hydroxide, sulfuric acid, vinyl acetate, ethylenediamine, acetic anhydride, alkalis, organic materials, most common metals, rubber, leather, water, strong bases, carbonates, sulfides, cyanides, oxides of silicon, especially glass, concrete, silica, fluorine. Will also react with steam or water to produce toxic fumes.
Conditions to Avoid:
Moisture and incompatibles.

11. Toxicological Information

Hydrofluoric acid: Inhalation rat LC50: 1276 ppm/1H; Investigated as a mutagen, reproductive effector.

--------\Cancer Lists\----------

Ingredient	---NTP Carcinogen--- Known	Anticipated	IARC Category
Hydrogen Fluoride (7664-39-3)	No	No	None
Water (7732-18-5)	No	No	None

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12. Ecological Information

Environmental Fate:
If the pH is > 6.5, soil can bind fluorides tightly. High calcium content will immobilize fluorides, which can be damaging to plants when present in acid soils.
Environmental Toxicity:
This material is expected to be slightly toxic to aquatic life. 60 ppm/*/Fish/Lethal/Fresh Water *=time period not specified. > 300ppm/48hr./Shrimp/LC50/Aerated Saltwater

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13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved incinerator or disposed in a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

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14. Transport Information

Domestic (Land, D.O.T.)

Proper Shipping Name: RQ, HYDROFLUORIC ACID (WITH NOT MORE THAN 60% STRENGTH)
Hazard Class: 8, 6.1
UN/NA: UN1790
Packing Group: II
Information reported for product/size: 500LB

International (Water, I.M.O.)

Proper Shipping Name: HYDROFLUORIC ACID (WITH NOT MORE THAN 60% STRENGTH)
Hazard Class: 8, 6.1
UN/NA: UN1790
Packing Group: II
Information reported for product/size: 500LB

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15. Regulatory Information

--------\Chemical Inventory Status - Part 1\----------

Ingredient	TSCA	EC	Japan	Australia
Hydrogen Fluoride (7664-39-3)	Yes	Yes	Yes	Yes
Water (7732-18-5)	Yes	Yes	Yes	Yes

--------\Chemical Inventory Status - Part 2\----------

Ingredient	--Canada-- Korea	DSL	NDSL	Phil.
Hydrogen Fluoride (7664-39-3)	Yes	Yes	No	Yes
Water (7732-18-5)	Yes	Yes	No	Yes

--------\Federal, State & International Regulations - Part 1\----------

Ingredient	-SARA 302- RQ	TPQ	------SARA 313------ List	Chemical Catg.
Hydrogen Fluoride (7664-39-3)	100	100	Yes	No
Water (7732-18-5)	No	No	No	No

--------\Federal, State & International Regulations - Part 2\----------

Ingredient	CERCLA	-RCRA- 261.33	-TSCA- 8(d)
Hydrogen Fluoride (7664-39-3)	100	U134	No
Water (7732-18-5)	No	No	No

Chemical Weapons Convention: Yes TSCA 12(b): No CDTA: No
SARA 311/312: Acute: Yes Chronic: Yes Fire: No Pressure: No
Reactivity: Yes (Mixture / Liquid)

Australian Hazchem Code: 2R
Poison Schedule: S7
WHMIS:
This MSDS has been prepared according to the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

16. Other Information

NFPA Ratings: Health: **4** Flammability: **0** Reactivity: **1**
Label Hazard Warning:
POISON! DANGER! CORROSIVE. EXTREMELY HAZARDOUS LIQUID AND VAPOR. CAUSES SEVERE BURNS WHICH MAY NOT BE IMMEDIATELY PAINFUL OR VISIBLE. MAY BE FATAL IF SWALLOWED OR INHALED. LIQUID AND VAPOR CAN BURN SKIN, EYES AND RESPIRATORY TRACT. CAUSES BONE DAMAGE. REACTION WITH CERTAIN METALS GENERATES FLAMMABLE AND POTENTIALLY EXPLOSIVE HYDROGEN GAS.
Label Precautions:
Do not get in eyes, on skin, or on clothing.
Do not breathe vapor.
Cool before opening.
Use only with adequate ventilation.
Wash thoroughly after handling.
Store in a tightly closed container.
Label First Aid:
IN ALL CASES, CALL PHYSICIAN IMMEDIATELY. First Aid procedures should be pre-planned for HF emergencies. A supply of 50:50 water/magnesium sulfate paste or 2 1/2% Calcium Gluconate paste should be available where first aid medications are administered. If ingested, DO NOT INDUCE VOMITING. If patient is conscious, give large quantities of milk or water and send to hospital. If inhaled and patient is unconscious, give artificial respiration or use inhalator and send to hospital. In case of eye contact, wash open eyes with large but gentle stream of water for 15 minutes. Place ice pack on eyes until reaching emergency room. In case of skin contact, remove contaminated clothing and wash burn area with plenty of water to remove acid. Cover burn area with a poultice of 50:50 water/magnesium sulfate paste or 2 1/2% calcium gluconate paste. Leave in place until medical help arrives or patient is transferred to hospital.
Product Use:
Laboratory Reagent.
Revision Information:
MSDS Section(s) changed since last revision of document include: 6.
Disclaimer:
****
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****
Prepared by: Environmental Health & Safety
Phone Number: (314) 654-1600 (U.S.A.)

Hydrogen fluoride, anhydrous

Safety Data Sheet M009301

according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

Revision date: 09/11/2019 Version: 1.1

SECTION 1: Identification

1.1. Identification

Product form	:	Substance
Substance name	:	Hydrogen fluoride, anhydrous
CAS No	:	7664-39-3
Product code	:	M009-3-01
Formula	:	FH

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of the substance/mixture	:	Laboratory chemicals Manufacture of substances Scientific research and development

1.3. Details of the supplier of the safety data sheet

SynQuest Laboratories, Inc.
P.O. Box 309
Alachua, FL 32615 - United States of America
T (386) 462-0788 - F (386) 462-7097
info@synquestlabs.com - www.synquestlabs.com

1.4. Emergency telephone number

Emergency number	:	(844) 523-4086 (3E Company - Account 10069)

SECTION 2: Hazard(s) identification

2.1. Classification of the substance or mixture

Classification (GHS-US)

Simple Asphy	H380 -	May displace oxygen and cause rapid suffocation
Liquefied gas	H280 -	Contains gas under pressure; may explode if heated
Acute Tox. 2 (Oral)	H300 -	Fatal if swallowed
Acute Tox. 1 (Dermal)	H310 -	Fatal in contact with skin
Acute Tox. 2 (Inhalation:vapour)	H330 -	Fatal if inhaled
Skin Corr. 1A	H314 -	Causes severe skin burns and eye damage
Eye Dam. 1	H318 -	Causes serious eye damage
STOT SE 3	H335 -	May cause respiratory irritation

Full text of H-phrases: see section 16

2.2. Label elements

GHS-US labeling

Hazard pictograms (GHS-US) :

GHS04 GHS05 GHS06 GHS07

Signal word (GHS-US) : Danger

Hazard statements (GHS-US) :
H280 - Contains gas under pressure; may explode if heated
H300+H310+H330 - Fatal if swallowed, in contact with skin or if inhaled
H314 - Causes severe skin burns and eye damage
H335 - May cause respiratory irritation
H380 - May displace oxygen and cause rapid suffocation

Precautionary statements (GHS-US) :
P260 - Do not breathe dust/fume/gas/mist/vapors/spray
P262 - Do not get in eyes, on skin, or on clothing
P264 - Wash skin thoroughly after handling
P270 - Do not eat, drink or smoke when using this product
P271 - Use only outdoors or in a well-ventilated area
P280 - Wear protective gloves/protective clothing/eye protection/face protection
P284 - In case of inadequate ventilation wear respiratory protection
P301+P310 - If swallowed: Immediately call a poison center/doctor/…
P301+P330+P331 - If swallowed: rinse mouth. Do NOT induce vomiting
P303+P361+P353 - If on skin (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower
P304+P340 - If inhaled: Remove person to fresh air and keep comfortable for breathing

P305+P351+P338 - If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing
P310 - Immediately call a POISON CENTER or doctor/ physician
P320 - Specific treatment is urgent (see supplemental first aid instructions on this label)
P321 - Specific treatment (see supplemental first aid instructions on this label)
P330 - Rinse mouth
P361 - Take off immediately all contaminated clothing
P363 - Wash contaminated clothing before reuse
P403+P233 - Store in a well-ventilated place. Keep container tightly closed
P405 - Store locked up
P410+P403 - Protect from sunlight. Store in a well-ventilated place
P501 - Dispose of contents/container to an approved waste disposal plant

2.3. Other hazards

No additional information available

2.4. Unknown acute toxicity (GHS US)

Not applicable

SECTION 3: Composition/information on ingredients

3.1. Substance

Substance type : Mono-constituent

Name	Product identifier	%	Classification (GHS-US)
Hydrogen fluoride, anhydrous (Main constituent)	(CAS No) 7664-39-3	<= 100	Simple Asphy, H380 Liquefied gas, H280 Acute Tox. 2 (Oral), H300 Acute Tox. 1 (Dermal), H310 Acute Tox. 2 (Inhalation:vapour), H330 Skin Corr. 1A, H314 Eye Dam. 1, H318 STOT SE 3, H335

Full text of H-phrases: see section 16

3.2. Mixture

Not applicable

SECTION 4: First aid measures

4.1. Description of first aid measures

First-aid measures general : In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible). Move the affected personnel away from the contaminated area.

First-aid measures after inhalation : Remove person to fresh air and keep comfortable for breathing. If not breathing, give artificial respiration. Get immediate medical advice/attention.

First-aid measures after skin contact : Wash with plenty of soap and water. Remove contaminated clothing and shoes. In case of skin contact, wearing rubber gloves rub 2.5% calcium gluconate gel continuously into the affected area for 1.5 hours or until further medical care is available. Get immediate medical advice/attention.

First-aid measures after eye contact : Immediately flush eyes thoroughly with water for at least 15 minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Get immediate medical advice/attention.

First-aid measures after ingestion : Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth out with water. Get immediate medical advice/attention.

4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries : The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11.

Symptoms/injuries after inhalation : Material is destructive to tissue of the mucuous membranes and upper respiratory tract. Cough, shortness of breath, headache, nausea.

4.3. Indication of any immediate medical attention and special treatment needed

Treat symptomatically. Absorption of excessive F- can result in acute systemic fluorosis with hypocalcemia, interference with various metabolic functions and organ damage (heart, liver, kidneys).

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media : Use extinguishing media appropriate for surrounding fire.

5.2. Special hazards arising from the substance or mixture

Fire hazard : Thermal decomposition generates: Carbon oxides. Hydrogen fluoride.

Explosion hazard : Risk of explosion if heated under confinement. Use water spray or fog for cooling exposed containers.

Reactivity : Reacts with water, generates gases or heat. Reacts on exposure to water with some metals to release highly explosive/flammable hydrogen gas.

5.3. Advice for firefighters

Firefighting instructions : In case of fire: Evacuate area. Fight fire remotely due to the risk of explosion.

Protection during firefighting : Wear gas tight chemically protective clothing in combination with self contained breathing apparatus. For further information refer to section 8: "Exposure controls/personal protection".

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

General measures : Evacuate unnecessary personnel. Ensure adequate air ventilation. May cause suffocation by reducing oxygen available for breathing. Do not breathe gas, fumes, vapor or spray.

6.1.1. For non-emergency personnel

Emergency procedures : Only qualified personnel equipped with suitable protective equipment may intervene.

6.1.2. For emergency responders

Protective equipment : Do not attempt to take action without suitable protective equipment. For further information refer to section 8: "Exposure controls/personal protection".

Emergency procedures : Gas/vapor heavier than air. May accumulate in confined spaces, particularly at or below ground level.

6.2. Environmental precautions

Avoid release to the environment. Notify authorities if product enters sewers or public waters.

6.3. Methods and material for containment and cleaning up

For containment : Stop leak if safe to do so. Dike for recovery or absorb with appropriate material.

Methods for cleaning up : Take up large spills with pump or vacuum and finish with dry chemical absorbent. Use explosion-proof equipment. Take up small spills with dry chemical absorbent. Sweep or shovel spills into appropriate container for disposal. Ventilate area.

Other information : For disposal of solid materials or residues refer to section 13 : "Disposal considerations".

6.4. Reference to other sections

No additional information available

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Additional hazards when processed : Pressurized container: Do not pierce or burn, even after use. Close valve after each use and when empty.

Precautions for safe handling : Do not handle until all safety precautions have been read and understood. Ensure good ventilation of the work station. Do not breathe fumes, gas, mist, spray, vapors. Wear personal protective equipment. Avoid contact with skin and eyes.

Safe handling of the gas receptacle : Securely chain cylinders when in use and protect against physical damage.

Hygiene measures : Handle in accordance with good industrial hygiene and safety procedures. Do not eat, drink or smoke when using this product. Always wash hands after handling the product.

7.2. Conditions for safe storage, including any incompatibilities

Technical measures : Comply with applicable regulations.

Storage conditions : Protect from sunlight. Do not expose to temperatures exceeding 50 °C. Keep container closed when not in use. Moisture sensitive.

Incompatible materials : Refer to Section 10 on Incompatible Materials.

Storage area : Store in dry, cool, well-ventilated area.

Special rules on packaging : Do not store in glass.

SECTION 8: Exposure controls/personal protection

8.1. Control parameters

Hydrogen fluoride, anhydrous (7664-39-3)		
ACGIH	ACGIH TWA (ppm)	0.50 ppm
ACGIH	ACGIH Ceiling (ppm)	2 ppm
ACGIH	Remark (ACGIH)	URT, LRT, skin, & eye irr

Hydrogen fluoride, anhydrous (7664-39-3)		
OSHA	OSHA PEL (TWA) (ppm)	3 ppm
OSHA	Remark (OSHA)	(2) See Table Z-2.

8.2. Exposure controls

Appropriate engineering controls : Ensure good ventilation of the work station. Emergency eye wash fountains and safety showers should be available in the immediate vicinity of any potential exposure. Systems under pressure should be regularily checked for leakage. Oxygen detectors should be used when asphyxiating gases may be released. Gas detectors should be used when toxic gases may be released.

Hand protection : Protective gloves. 29 CFR 1910.138: Hand Protection.

Eye protection : Chemical goggles or safety glasses. Face shield. 29 CFR 1910.133: Eye and Face Protection.

Skin and body protection : Wear suitable protective clothing.

Respiratory protection : In case of inadequate ventilation wear respiratory protection. 29 CFR 1910.134: Respiratory Protection.

Other information : Safety shoes. 29 CFR 1910.136: Foot Protection.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Physical state : Liquid

Appearance : Colorless gas. Liquid under pressure or at low temperature.

Color : Colorless

Odor : sharp Irritating

Odor threshold : No data available

pH : No data available

Melting point : -83.7 °C

Freezing point : No data available

Boiling point : 19.5 °C

Flash point : No data available

Relative evaporation rate (butyl acetate=1) : No data available

Flammability (solid, gas) : No data available

Explosion limits : No data available

Explosive properties : No data available

Oxidizing properties : No data available

Vapor pressure : 1053 hPa (at 20 °C)

Relative density : No data available

Relative vapor density at 20 °C : No data available

Specific gravity / density : 1.015 g/cm³ (@ 0 °C)

Solubility : Water: 719.8 g/l (at 20 °C)

Log Pow : -1.4

Auto-ignition temperature : No data available

Decomposition temperature : No data available

Viscosity : No data available

Viscosity, kinematic : No data available

Viscosity, dynamic : No data available

9.2. Other information

No additional information available

SECTION 10: Stability and reactivity

10.1. Reactivity

Reacts with water, generates gases or heat. Reacts on exposure to water with some metals to release highly explosive/flammable hydrogen gas.

10.2. Chemical stability

The product is stable at normal handling and storage conditions.

10.3. Possibility of hazardous reactions

Contact with acids liberates toxic gas. Contact with water liberates toxic gas.

10.4. Conditions to avoid

Protect from sunlight. Do not expose to temperatures exceeding 50 °C. Keep away from heat, sparks and flame.

10.5. Incompatible materials

Acids. Glass. Strong bases. Strong oxidizing agents. Water.

10.6. Hazardous decomposition products

Under normal conditions of storage and use, hazardous decomposition products should not be produced. Hazardous decomposition products in case of fire, see Section 5.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Acute toxicity : Oral: Fatal if swallowed. Dermal: Fatal in contact with skin. Inhalation:vapour: Fatal if inhaled.

Hydrogen fluoride, anhydrous (7664-39-3)	
LC50 inhalation rat (mg/l)	0.79 mg/l (Exposure time: 1 h)
ATE US (oral)	5.000 mg/kg body weight
ATE US (dermal)	5.000 mg/kg body weight
ATE US (vapors)	0.790 mg/l/4h
ATE US (dust, mist)	0.790 mg/l/4h

Skin corrosion/irritation : Causes severe skin burns and eye damage.

Serious eye damage/irritation : Causes serious eye damage.

Respiratory or skin sensitization : Not classified

Germ cell mutagenicity : Not classified

Carcinogenicity : Not classified

Reproductive toxicity : Not classified

Specific target organ toxicity (single exposure) : May cause respiratory irritation.

Specific target organ toxicity (repeated exposure) : Not classified

Aspiration hazard : Not classified

Potential Adverse human health effects and symptoms : Absorption of excessive F- can result in acute systemic fluorosis with hypocalcemia, interference with various metabolic functions and organ damage (heart, liver, kidneys).

Symptoms/injuries after inhalation : Material is destructive to tissue of the mucuous membranes and upper respiratory tract. Cough, shortness of breath, headache, nausea.

SECTION 12: Ecological information

12.1. Toxicity

Hydrogen fluoride, anhydrous (7664-39-3)	
EC50 Daphnia 1	270 mg/l (Exposure time: 48 h - Species: Daphnia species)

12.2. Persistence and degradability

No additional information available

12.3. Bioaccumulative potential

Hydrogen fluoride, anhydrous (7664-39-3)	
BCF fish 1	(no bioaccumulation)
Log Pow	-1.4

12.4. Mobility in soil

No additional information available

12.5. Other adverse effects

No additional information available

SECTION 13: Disposal considerations

13.1. Waste treatment methods

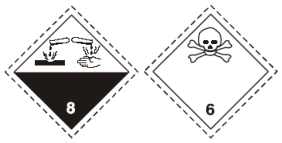
Regional legislation (waste)	:	U.S. - RCRA (Resource Conservation & Recovery Act) - Hazardous Constituents - Appendix VIII to 40 CFR 261. U.S. - RCRA (Resource Conservation & Recovery Act) - U Series Wastes - Acutely Toxic Wastes & Other Hazardous Characteristics.
Waste treatment methods	:	Remove to an authorized incinerator equipped with an afterburner and a flue gas scrubber.
Waste disposal recommendations	:	Dispose of contents/container in accordance with licensed collector's sorting instructions.
Additional information	:	Recycle the material as far as possible.

SECTION 14: Transport information

Department of Transportation (DOT)

In accordance with DOT

Transport document description	:	UN1052 Hydrogen fluoride, anhydrous, 8, I
UN-No.(DOT)	:	UN1052
Proper Shipping Name (DOT)	:	Hydrogen fluoride, anhydrous
Transport hazard class(es) (DOT)	:	8 - Class 8 - Corrosive material 49 CFR 173.136
Hazard labels (DOT)	:	8 - Corrosive 6.1 - Poison



Packing group (DOT)	:	I - Great Danger
DOT Packaging Non Bulk (49 CFR 173.xxx)	:	163
DOT Packaging Bulk (49 CFR 173.xxx)	:	243
DOT Special Provisions (49 CFR 172.102)	:	3 - This material is poisonous by inhalation (see 171.8 of this subchapter) in Hazard Zone C (see 173.116(a) of this subchapter), and must be described as an inhalation hazard under the provisions of this subchapter. B7 - Safety relief devices are not authorized on multi-unit tank car tanks. Openings for safety relief devices on multi-unit tank car tanks shall be plugged or blank flanged. B46 - The detachable protective housing for the loading and unloading valves of multi-unit tank car tanks must withstand tank test pressure and must be approved by the Associate Administrator. B77 - Other packaging are authorized when approved by the Associate Administrator. N86 - UN pressure receptacles made of aluminum alloy are not authorized. T10 - 4 6 mm Prohibited 178.275(g)(3). TP2 - a. The maximum degree of filling must not exceed the degree of filling determined by the following: (image) Where: tr is the maximum mean bulk temperature during transport, tf is the temperature in degrees celsius of the liquid during filling, and a is the mean coefficient of cubical expansion of the liquid between the mean temperature of the liquid during filling (tf) and the maximum mean bulk temperature during transportation (tr) both in degrees celsius. b. For liquids transported under ambient conditions may be calculated using the formula: (image) Where: d15 and d50 are the densities (in units of mass per unit volume) of the liquid at 15 C (59 F) and 50 C (122 F), respectively.
DOT Packaging Exceptions (49 CFR 173.xxx)	:	None
DOT Quantity Limitations Passenger aircraft/rail (49 CFR 173.27)	:	Forbidden
DOT Quantity Limitations Cargo aircraft only (49 CFR 175.75)	:	Forbidden
DOT Vessel Stowage Location	:	D - The material must be stowed ''on deck only'' on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers or one passenger per each 3 m of overall vessel length, but the material is prohibited on passenger vessels in which the limiting number of passengers is exceeded.
DOT Vessel Stowage Other	:	40 - Stow ''clear of living quarters''
Emergency Response Guide (ERG) Number	:	125 (UN1052);157 (UN1790)
Other information	:	No supplementary information available.

TDG

No additional information available

Transport by sea

UN-No. (IMDG)	:	1052
Proper Shipping Name (IMDG)	:	HYDROGEN FLUORIDE, ANHYDROUS
Class (IMDG)	:	8 - Corrosive substances
Packing group (IMDG)	:	I - substances presenting high danger

Air transport

UN-No. (IATA)	:	1052
Proper Shipping Name (IATA)	:	Hydrogen fluoride, anhydrous
Class (IATA)	:	8 - Corrosives

SECTION 15: Regulatory information

15.1. US Federal regulations

Hydrogen fluoride, anhydrous (7664-39-3)	
Listed on the United States TSCA (Toxic Substances Control Act) inventory Listed on the United States SARA Section 302 Subject to reporting requirements of United States SARA Section 313	
SARA Section 302 Threshold Planning Quantity (TPQ)	100 lb
SARA Section 313 - Emission Reporting	1.0 %

All components of this product are listed, or excluded from listing, on the United States Environmental Protection Agency Toxic Substances Control Act (TSCA) inventory

Chemical(s) subject to the reporting requirements of Section 313 or Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR Part 372.

Hydrogen fluoride, anhydrous	CAS No 7664-39-3	100%

15.2. International regulations

CANADA

Hydrogen fluoride, anhydrous (7664-39-3)	
Listed on the Canadian DSL (Domestic Sustances List)	
WHMIS Classification	Class D Division 1 Subdivision A - Very toxic material causing immediate and serious toxic effects Class D Division 2 Subdivision A - Very toxic material causing other toxic effects Class E - Corrosive Material

EU-Regulations

No additional information available

National regulations

Hydrogen fluoride, anhydrous (7664-39-3)
Listed on the AICS (Australian Inventory of Chemical Substances) Listed on IECSC (Inventory of Existing Chemical Substances Produced or Imported in China) Listed on the Japanese ENCS (Existing & New Chemical Substances) inventory Listed on the Korean ECL (Existing Chemicals List) Listed on NZIoC (New Zealand Inventory of Chemicals) Listed on PICCS (Philippines Inventory of Chemicals and Chemical Substances) Japanese Poisonous and Deleterious Substances Control Law Japanese Pollutant Release and Transfer Register Law (PRTR Law) Listed on the Canadian IDL (Ingredient Disclosure List) Listed on INSQ (Mexican national Inventory of Chemical Substances) Listed on Turkish inventory of chemical

15.3. US State regulations

Hydrogen fluoride, anhydrous (7664-39-3)	
State or local regulations	U.S. - Massachusetts - Right To Know List U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List U.S. - Pennsylvania - RTK (Right to Know) List

California Proposition 65 - This product does not contain any substances known to the state of California to cause cancer and/or reproductive harm

SECTION 16: Other information

Revision date : 09/11/2019

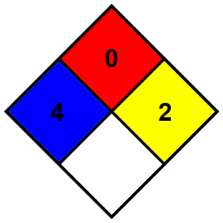
Full text of H-phrases:

Acute Tox. 1 (Dermal)	Acute toxicity (dermal) Category 1
Acute Tox. 2 (Inhalation:vapour)	Acute toxicity (inhalation:vapour) Category 2
Acute Tox. 2 (Oral)	Acute toxicity (oral) Category 2
Eye Dam. 1	Serious eye damage/eye irritation Category 1
Liquefied gas	Gases under pressure Liquefied gas
Simple Asphy	Simple Asphyxiant
Skin Corr. 1A	Skin corrosion/irritation Category 1A
STOT SE 3	Specific target organ toxicity (single exposure) Category 3
H280	Contains gas under pressure; may explode if heated
H300	Fatal if swallowed
H310	Fatal in contact with skin
H314	Causes severe skin burns and eye damage
H318	Causes serious eye damage
H330	Fatal if inhaled
H335	May cause respiratory irritation
H380	May displace oxygen and cause rapid suffocation

NFPA health hazard : 4 - Very short exposure could cause death or serious residual injury even though prompt medical attention was given.

NFPA fire hazard : 0 - Materials that will not burn.

NFPA reactivity : 2 - Normally unstable and readily undergo violent decomposition but do not detonate. Also: may react violently with water or may form potentially explosive mixtures with water.



HMIS III Rating

Health : 4 Severe Hazard - Life-threatening, major or permanent damage may result from single or repeated overexposures

Flammability : 0 Minimal Hazard - Materials that will not burn

Physical : 2 Moderate Hazard - Materials that are unstable and may undergo violent chemical changes at normal temperature and pressure with low risk for explosion. Materials may react violently with water or form peroxides upon exposure to air.

SDS US (GHS HazCom 2012)

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is offered solely for your consideration, investigation, and verification. It does not represent any guarantee of the properties of the product nor that the hazard precautions or procedures described are the only ones which exist. SynQuest shall not be held liable or any damage resulting from handling or from contact with the above product.

Terra Industries Inc.
Terra Centre – 600 Fourth Street
Sioux City, Iowa 51101

Material Safety Data Sheet (MSDS)

Dinitrogen Tetroxide, Mixed Oxides of Nitrogen

MSDS Number 2001 (Revised January 25, 2011) 10 Pages

CAUTION

INHALATION HAZARD – OXIDIZER – CORROSIVE

CAUTION: Explosions may occur on contact with ammonia, boron trichloride, carbon disulfide, cyclohexane, fluorine, formaldehyde, hydrazine, nitrobenzene, toluene, incompletely halogenated hydrocarbons, propylene, alcohols, and ozone.

1. CHEMICAL PRODUCT and EMERGENCY TELEPHONE CONTACT

Product Name:	Dinitrogen Tetroxide
Chemical Family:	Inorganic Oxidizers
Synonyms:	Nitrogen Oxide, Nitrogen Dioxide, Nitrogen Peroxide, Nitrogen Tetroxide, Dinitrogen Tetroxide, Tetra Oxide, NTO
Formula:	N_2O_4
Product Use:	Fuel Oxidizer-Propellant

EMERGENCY TELEPHONE NUMBER

CHEMTREC (U.S.):	800-424-9300
CANUTEC (Canada):	613-996-6666
HEALTH EMERGENCIES	contact Poison Control Center

2. COMPOSITION/INFORMATION ON INGREDIENTS

Ingredient Name/CAS Number	Concentration, N2O4/NO	Exposure Limits
Dinitrogen Tetroxide/ 10544-72-6	99.5/<0.5	1 ppm STEL* C* 5 ppm PEL* 20 ppm IDLH*
Nitrogen Oxides (NO, NO2, N2O3) See Table Page 10102-44-0		

Nitric Oxide (NO) See Table Page 7
10102-43-9

Note: Exposure limits listed are for nitrogen dioxide, the most hazardous constituent of N2O4. Exposure limits applicable to mixed oxides of nitrogen.

* STEL = Short Term Exposure Limit, C = Ceiling, PEL = Permissible Exposure Limit, IDLH = Immediate Danger to Life and Health

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Dinitrogen Tetroxide is an acute inhalation hazard, strong oxidizer, and highly corrosive. Avoid exposure of skin and eyes to liquid or high vapor concentrations. Where liquid is present and the concentration of vapors in the breathing zone approaches or exceeds the PEL, respiratory protection is required.

NFPA Hazard Classification	Health Hazard (Blue) ……..	4
	Flammability (Red) …….	0
	Reactivity (Yellow) …….	0
	Special (White)…….OXIDIZER (OX)	

POTENTIAL HEALTH EFFECTS

Primary Routes of Entry: Inhalation, skin contact/absorption and eye contact.

General Acute Exposure: The vapor is highly irritating to the upper respiratory tract and lungs and harmful if inhaled. If available, administer medical oxygen by trained personnel. If breathing is shallow or has stopped, ensure clear airway and apply resuscitation. The material presents a hazard from a single acute exposure. **A single acute exposure may cause death.**

Inhalation:

Acute Exposure: Principal routes of exposure are generally by inhalation of fumes or physical contact. Serious results may not be felt until hours or days after exposure, even though heavy damage has occurred. Repeated inhalation may result in bronchitis or emphysema.

Skin:

Acute Contact: The liquid is highly corrosive to the skin and may cause chemical burns. If this product comes in contact with the skin: Immediately flush body and clothes with large amounts of water, using safety shower if available. Quickly remove all contaminated clothing, including footwear. Wash affected areas with water (and soap if available) for at least 15 minutes.

Eye:
Acute Contact: The vapor is extremely irritating to the eyes and is capable of causing pain and severe conjunctivitis. If this product comes in contact with the eyes: Immediately hold the eyes open and wash continuously for at least 15 minutes with fresh running water. Ensure irrigation under eyelids by occasionally lifting the upper and lower lids.

Neurologic:
Acute Exposure: An altered mental status (coma) may be seen, but is not characteristic unless hypoxemia occurs.

Ingestion:
If this chemical has been swallowed, seek immediate medical attention.

Note to the Physician: Pneumonitis should be anticipated after inhalation or ingestion. If severe exposure is suspected, observe for 48-72 hours for delayed pulmonary edema.

Medical Conditions Aggravated by Exposure: Chronic respiratory or skin disease.

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4. FIRST AID MEASURES

First Aid for Eyes: Immediately flush eyes with copious amounts of tepid water for at least 15 minutes. If irritation, pain, swelling, excessive tearing, or light sensitivity persists, the patient should be seen in a health care facility and referral to an ophthalmologist considered.

First Aid for Skin: Immediately flush exposed area with copious amounts of tepid water for at least 15 minutes followed by washing area thoroughly with soap and water. The patient should be seen in a health care facility if irritation or pain persists.

First Aid for Inhalation: Move patient to fresh air. Monitor for respiratory distress. If cough or difficulty in breathing develops, evaluate for respiratory tract irritation, bronchitis, or pneumonitis. If trained to do so administer supplemental oxygen with assisted ventilation as required. Administer artificial respiration if patient is not breathing.

First Aid for Ingestion: If this chemical has been swallowed, seek immediate medical attention.

5. FIRE FIGHTING MEASURES

Flash Point:	Not Applicable
Lower Flammable Limit:	Not Applicable
Upper Flammable Limit:.....	Not Applicable
Auto ignition Temperature.....	Not Applicable

Noncombustible Liquid/Gas, but will accelerate the burning of combustible materials.

Extinguishing Media: Chose appropriate media for surrounding fire. Water contact with liquid will create large amounts of toxic vapors. Caution: do not add water to an enclosed vessel. Water addition in a contained vessel may rapidly increase pressure due to vapor generation. Water spray or water fog will knock down vapors and is effective.

Special Fire Fighting Procedures:

a. Do not get water inside container.
b. Stop flow of gas if you can do without risk.
c. Move container from fire area if you can do it without risk.
d. Apply cooling water to sides of containers that are exposed to flames until well after fire is out. Stay away from ends of tanks due to exploding potential when tanks are involved in a fire.
e. Isolate area until gas has dispersed.
f. Use water spray or foam to control vapors.
g. Positive pressure self-contained breathing apparatus (SCBA) should be used when there is a potential for inhalation of vapors and/or fumes.
h. Chemical protective clothing that is safe for use with nitric acid involved in a fire should be worn.
i. Runoff from fire control or dilution water may cause pollution.

Fire/Explosion Hazard:

Non-flammable but strong oxidizer and will increase the intensity of a fire and support combustion. Heating may cause expansion or decomposition leading to violent rupture of containers. Contact with readily oxidizable organic material may cause ignition /fire. Decomposes on heating and produces toxic fumes of nitrogen oxides (NOx) and nitric acid. In presence of moisture, the material is corrosive to aluminum, zinc and tin producing highly flammable hydrogen gas. Reacts vigorously with alkalis. Reacts violently with incompatible materials.

6. ACCIDENTAL RELEASE MEASURES

Spill or Leak Measures:

Clear area of personnel and move upwind. Alert Fire Brigade and tell them location and nature of hazard. Wear full body protective clothing with breathing apparatus. Prevent, by any means available, spillage from entering drains or watercourses. Consider evacuation. Shut off all possible sources of ignition and increase ventilation. No smoking or naked lights within area. Stop leak if safe to do so. Do not exert excessive pressure on valve; do not attempt to operate damaged valve. Water spray or fog may be used to mitigate the inhalation hazard. Absorb or cover spill with sand, earth, inert material or vermiculite. Carefully, contain and neutralize with slaked lime. Collect residues and seal in labeled drums for disposal. After clean up operations, decontaminate protective gear and equipment by soaking in 5% soda ash solution for at least 24 hours. Rinse and dry.

Disposal:
Dispose of neutralized waste solutions and any residues in compliance with local, state, and Federal laws. Place leaking cylinder in a fume hood or safe outdoor area. When slow release of gas to air is unacceptable, attach needle valve and tube to run gas into an excess of 5 to 10% aqueous sodium hydroxide solution (with caution). Cover liquid spill with soda ash or slaked lime. Water spray or fog may be used to disperse vapors. All waste solutions are to be neutralized before disposal.

Determining Spill Size:

Generally, a small spill is one that involves a single, small container (Less than 1-gallon capacity), or a small (non-continuing) leak from a larger tank or vessel
Note: EPA Reportable Quantity (RQ) is 10 pounds.

Small Spill:

First isolate 100 feet in all directions, then protect persons downwind 0.1 mile (day) or 0.3 mile (night).

Large Spill:

First isolate 500 feet in all directions, then protect persons downwind 1.0 mile (day) or 2.5 miles (night).

7. HANDLING AND STORAGE

Caution: Dinitrogen Tetroxide is an acute inhalation hazard, strong oxidizer and highly corrosive. Avoid exposure of skin and eyes to liquid or vapors.
Note: When liquid is present and the concentration of the vapor in the breathing zone approaches or exceeds 1 ppm, SCBA respiratory protection is required.

8. EXPOSURE CONTROLS, PERSONAL PROTECTION / OSHA ASSIGNED PROTECTION FACTORS (APF)

Respiratory Protection Requirements:

<1 ppm:	No protection required.
1ppm:	Protection required if exposed for more than 15 minutes.
>1 to 20 ppm:	(APF=25) Any supplied-air respirator operated in a continuous flow mode. (APF=50) Any self-contained breathing apparatus with a full facepiece (APF=50) Any supplied-air respirator with a full facepiece

Emergency or planned entry into unknown concentrations or IDLH conditions:

(APF=10,000) Any SCBA that has a full face piece and is operated in a pressure-demand or other positive-pressure mode

(APF=10,000) Any supplied-air respirator that has a full face piece and is operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained positive-pressure breathing apparatus

Escape:

(APF=50) Any appropriate escape-type, self-contained breathing apparatus.

Skin Protection Requirements: Acid resistant gloves, acid resistant safety boots, acid resistant suit, impervious protective clothing with full-length sleeves and pants.

Eye Protection Requirements:

Lab / Fume Hood: Use chemical (indirectly vented) goggles when there is a potential for contact with liquid or mist. A full-face shield is recommended in addition to goggles for added protection.

Field: Indirectly vented chemical goggles, or in lieu of goggles, eye protection provided by full face respirator is acceptable.

Note: Contact lenses pose a special hazard: soft lenses absorb irritants and all lenses concentrate them.

Other Protective Equipment: Safety shower and eyewash fountains should be available.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical Form:	Liquid
Color:	Non-flammable, yellowish to reddish-brown gas. Reddish-brown to green liquid. Forms a colorless solid. (See Table Below)
Odor:	Pungent acidic odor first perceptible at 1 to 3 ppm
Boiling Point:	See Table
Melting point:	See Table
Specific Gravity:	See Table
Vapor Density:	1.58
Vapor Pressure:	See Table
% Volatile by Volume:	100
Molecular Weight:	92.01
Density:	1.38 to 1.43 g/ml
Material Decomposes	>320º F (160ºC)
Critical Pressure:	10.1 MPa

GRADE	NTO	MON-1	MON-3	MON-10	MON-15	MON-25
Molecular Weight (N_2O_4)	92.01	92.01	92.01	92.01	92.01	92.01
Relative Vapor Density	1.58	1.58	1.58	1.58	1.58	1.58
Color	Brown	Green	Green	Green	Green	Green
NO, %	0	1	3	10	15	25
N_2O_4 + NO, %	99.5	99.5	99.5	99.5	99.5	99.5
Boiling, F	70	68	65	49	39	16
Freezing, F	12	9	5	-10	-24	-69
Vapor @77F, psia	17.5	18.5	20.5	30.0	40.5	76.0
Sp. Gravity @ 77F	1.431	1.429	1.423	1.407	1.397	1.380

10. REACTIVITY

Stability: ..... This is a stable material.
Hazardous Polymerization: ..... NA

Decomposition: Decomposes above 320°F to form nitric oxide and oxygen

Incompatibilities:

a. Incompatible with water, bases, flammable and combustible materials, copper, aluminum.

b. Forms nitric acid and nitrogen oxide vapors when exposed to moisture. Nitric acid is very corrosive to non-stainless steel metals.

c. Explosions may occur on contact with ammonia, boron trichloride, carbon disulfide, cyclohexane, fluorine, formaldehyde, hydrazine, nitrobenzene, toluene, incompletely halogenated hydrocarbons, propylene, alcohols, and ozone.

11. TOXICOLOGICAL INFORMATION

Toxicity: Highly Toxic

Acute Inhalation Toxicity
LC_{50} Rat: ..... 138 ppm (0.5hr)

Corrosiveness / Irritation
Skin Irritation / Corrosion: ..... Severe corrosive to skin
Eye Irritation / Corrosion: ..... Severe corrosive to eyes and mucous membranes

Genetic Toxicity
Mutagenic effects:……..No known significant effects or critical hazards
Reproduction Toxicity……No known significant effects or critical hazards

Carcinogen Status……ACGIH: A4 Not classified as a human carcinogen

Genetic Toxicity *in vivo*
Drosophila melanogaster:……..No evidence for mutagenicity
Carcinogenicity
All:……..No carcinogenic effects
Toxicity to Reproduction
Pig:……..Temporarily depressed mean daily gain (MDG) at 35 mg/kg in gilts (One generation study)
Human Experience
Inhalation:……It has been reported that 10-20 ppm has been mildly irritating [Patty 1963]. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary edema [NRC 1979]. It has been predicted that 50% lethality would occur following exposure to 174 ppm for 1 hour.

Ecotoxicity:

LCL Goldfish:……...750 ppm 5 hours*
LCL Fathead Minnow:……...1000 ppm for 7 hours*

*Information derived from Nitric Acid ecotoxicity data

12. ECOLOGICAL INFORMATION*

Note: Dinitrogen Tetroxide will significantly lower the pH of any water source it comes in contact with (form nitric acid)

a. Nitric acid is harmful to aquatic life in very low concentrations
b. May be dangerous if it enters water intakes. Notify operator of nearby water intakes.
c. Notify local health and wildlife officials

*Information derived from Nitric Acid ecological impact data

13. DISPOSAL CONSIDERATIONS

Dispose of neutralized waste solutions and any residues in compliance with local, state, and Federal laws. EPA RQ is 10 pounds. Place leaking cylinder in a fume hood or safe outdoor area. When slow release of gas to air is unacceptable, attach needle valve and tube to run gas into an excess of 5 to 10% aqueous sodium hydroxide solution (with caution). Cover liquid spill with soda ash or slaked lime. Water spray or fog may be used to disperse vapors. All waste solutions are to be neutralized before disposal.

14. TRANSPORTATION INFORMATION

U.S. DOT and Canadian TGD Act

Shipping Name:..... Dinitrogen Tetroxide
Hazard Class/Division:..... 2.3
Product Identification Number (PIN): ..... UN 1067
DOT Placard: ..... Poison Gas-2.3, Oxidizer-5.1, Corrosive-8
Note:…….. *Product may be shipped under different placarding/labeling for shippers holding a DOT special permit*
DOT Special Provision (49CFR172.102): .... "Inhalation Hazard", 1, B7, B14, B45, B46, B61, B66, B67, B77, T50, TP21
OSHA Label Required:..... Yes
Transportation by Air…….Forbidden
EPA RQ (Reportable Quantity): ..... 10 pounds
STCC Number: 4920174

15. REGULATORY INFORMATION

Controlled Products Regulations Classification: A: Compressed Gas; E: Corrosive
OSHA: This product is considered a hazardous material under criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200 (Toxic; Corrosive), and is listed as a Highly Hazardous Chemical subject to the requirements of the Process Safety Management Standard 29 CFR 1910.119 (Threshold Quantity 250lbs).

CAA Chemical Accident Prevention: Not a regulated chemical

SARA TITLE III:

a. EHS (Extremely Hazardous Substances) List: Listed (EPA, 1992a)
b. SARA RQ (Reportable Quantity): 10 pounds
c. TPQ (Threshold Planning Quantity): 100 pounds
d. Regulation: "Emergency Planning and Notification" – 40 CFR Part 355
e. Section 313: Dinitrogen Tetroxide does not require reporting under Section 313

CERCLA Hazardous Substances List:

a. CERCLA RQ (Reportable Quantity): 10 pounds
b. Regulation: "Designation, Reportable Quantities, Notification" - 40 CFR 302

TSCA Inventory: Dinitrogen Tetroxide is listed on the TSCA inventory

Chemical Facility Anti-Terrorism Standard (CFATS) / 6 CFR Part 27:
Dinitrogen Tetroxide is listed in Appendix A as a Chemical of Interest (COI) due to threat of theft for use as a component in a WME.
Screening Threshold Quantity (STQ): 15 pounds

CAGE Code # - 1YUW6
Contract # -SP0600-07-D-1564

Equipment, Pressure Vessels, Testing, Etc.: All equipment used to handle, store, transfer, etc., dinitrogen tetroxide must be properly engineered, constructed and maintained in compliance with all applicable regulations and standards. Pressure vessels, piping and appurtenances should be regularly inspected and tested using methods designed to reveal external and internal deterioration or defects that may impair the integrity of the equipment such that an unintended release of dinitrogen tetroxide may result. Consult with experts, as applicable, concerning the methods that would be most appropriate given the particular circumstances.

16. OTHER INFORMATION

- 3-26-08: The MSDS was rewritten to comply with ANSI Standard Z400.1-1993, and to transfer information into the Terra format.
- 1-19-09: Updated MSDS to reflect components of N2O4 (i.e. mixed oxides of nitrogen), updated CAS numbers, updated transportation information, updated NFPA hazard classification, and various language changes for clarity.
- 1-25-11: Reviewed. Revised to include shipping information (Cage code and contract #).

The information and recommendations herein are taken from data contained in independent, industry-recognized references including but not limited to NIOSH, OSHA, ANSI, NFPA, DOT ERG, the TFI Product Testing Program, Global Engineering Documents, MEDITEXT, HAZARDTEXT, SARATEXT, CHRIS, OHM/TADS, and IRIS. Terra Industries Inc. makes no guarantee, warranty or other representation concerning this substance, since conditions of its use are beyond the control of the company. Terra Industries Inc. disclaims any liability for loss or damage incurred in connection with the use of this substance.