National Aeronautics and
Space Administration

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

April 27, 2023

Reply to Attn of: RE-23-076

New Mexico Environment Department
Attn: Dave Cobrain, Acting Bureau Chief
Hazardous Waste Bureau
2905 Rodeo Park Drive East, Building 1
Santa Fe, NM 87505

Subject: NASA WSTF Work Plan for Drilling and Installation of Monitoring Wells 600C-003-GW and 600C-004-GW

In the NASA WSTF Groundwater Monitoring Plan update for 2022, submitted on April 29, 2022, NASA indicated that NASA wells BLM-1-435 and PL-3-453 would be plugged due to continued groundwater level drop and inability to sufficiently sample these wells. On October 31, 2022, NMED approved the GMP. In the approval letter, NMED indicated that wells BLM-1-435 and PL-3-453 must be replaced and directed NASA to submit work plans for the plugging of BLM-1-435 and PL-3-453 and subsequent drilling of replacement wells 600C-003-GW and 600C-004-GW, respectively.

This submittal includes the two work plans for abandonment of BLM-1-435 and drilling and installation of replacement monitoring well 600C-003-GW and for abandonment of PL-3-453 and drilling and installation of replacement monitoring well 600C-004-GW. Enclosure 1 contains printed reports and Enclosure 2 includes a PDF of both reports on a CD-ROM.

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

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

TIMOTHY DAVIS
Digitally signed by TIMOTHY DAVIS
Date: 2023.04.27 11:27:09 -06'00'

Timothy J. Davis
Chief, Environmental Office

Enclosure

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

Work Plan for Abandonment of NASA WSTF Well BLM-1-435 and Replacement with Monitoring Well 600C-003-GW

Introduction and Background	In the February 21, 2022, *Approval with Modifications Periodic Monitoring Report Second Quarter 2021*, the New Mexico Environment Department (NMED) expressed concern about declining water levels at White Sands Test Facility (WSTF) (Figure 1) groundwater monitoring wells 300-C-128, 400-C-118, 400-C-143, BLM-1-435, and PL-3-453 (NMED, 2022a). NMED indicated that NASA could continue to evaluate these wells. In the April 29, 2022, WSTF Groundwater Monitoring Plan (GMP) update for 2022, NASA indicated that well BLM-1-435 would be plugged due to continued groundwater level drop and inability to sufficiently sample the well (NASA, 2022, pg. 20). On October 31, 2022, NMED approved the GMP with modifications (NMED, 2022b) and indicated that well BLM-1-435 must be replaced and a work plan submitted for the plugging of BLM-1-435 and subsequent drilling of the replacement well (NMED, 2022b, pg. 2). This abbreviated work plan was developed in accordance with the Hazardous Waste Permit (Permit, 2023), Section 6.2, and incorporates requirements specified in Section 5.3 of the Permit. The well is located within the southern Jornada del Muerto Basin alluvial aquifer northeast of the WSTF Plume Front Treatment System (PFTS; Figure 2).
Primary Purpose	NASA proposes to plug and abandon existing monitoring well BLM-1-435 and install replacement monitoring well 600C-003-GW adjacent to the abandoned well. Well 600C-003-GW is expected to be completed as a single zone conventional monitoring well (Figure 3). Target screened interval in the replacement well approximately mirror monitoring zones within current monitoring well BLM-1-435 at 435 ft bgs. The placement of the screened intervals within the well will be refined during drilling and/or follow-on borehole logging.
Plugging and Abandonment of Well BLM-1-435	NASA will plug and abandon existing groundwater monitoring well BLM-1-435 in accordance with WSTF Hazardous Waste Permit (Permit) Section 5.3 (NMED, 2023, pg. 78) and 19.27.4.30 New Mexico Administrative Code (NMAC). Well BLM-1-435, completed in November 1987, is equipped with 8-inch (in.) steel surface casing that extends to a depth of 32 feet (ft) below ground surface (bgs). The 8-in. diameter borehole extends from surface casing to a total depth of 500 ft bgs. The conventional portion of the monitoring well consists of 4-in. stainless-steel casing that extends from ground surface to 451 ft bgs (Figure 4). NASA proposes to plug the well by lowering tremie pipe to the bottom of the open borehole. Portland cement grout will be emplaced using a tremie pipe upward from the bottom of the borehole to the ground surface. Any discharge of fluids will be managed in accordance with the Waste Management and Characterization Section. The steel surface casing will be cut at least 6 in. bgs and a concrete cap will be emplaced over the borehole. A brass cap will be embedded in the concrete surface completion and all pertinent well information will be stamped into the brass cap. NASA will prepare a well plugging plan for well BLM-1-435 and submit the plan to the New Mexico Office of the State Engineer (NMOSE) in accordance with 19.27.4.30 NMAC. The well drilling contractor will provide NASA and NMOSE with the

	required completed well plugging record. NASA will in turn provide NMED with a copy of the completed well plugging record.
Hydrogeologic and Geochemical Objectives	The primary objective of proposed monitoring well 600C-003-GW is to provide groundwater chemical analytical data to supplement data previously obtained from well BLM-1-435, which is identified as a Main Plume monitoring well in the GMP (NASA, 2022, pg. 82). Analytical results from 600C-003-GW will also be used to supplement data collected from other wells within the WSTF groundwater monitoring system, particularly those wells in close proximity such as BLM-9-419, PFE-5, and BLM-8-418. Additional objectives are to further characterize hydrostratigraphy at the proposed location and monitor groundwater elevation.
Conceptual Model	The original location of well BLM-1-435 was chosen to support characterization of the WSTF groundwater contaminant plume (Figure 5). Replacement well 600C-003-GW will continue to serve that role in the WSTF groundwater assessment program and inform the conceptual site model. In addition to providing analytical data concerning the main plume of the WSTF groundwater plume, well 600C-003-GW will also provide water level data that will be used to inform hydrogeologic decisions. Information collected from the new well will be incorporated into the WSTF conceptual groundwater model when appropriate. Existing well BLM-1-435 was completed within the Santa Fe Alluvium; however, the borehole penetrated andesitic bedrock at approximately 457 ft bgs (Figure 6). All monitoring zones are completed within alluvium, which is generally characterized as an unconsolidated to semi-consolidated, poorly to moderately sorted, pebbly polygenetic conglomerate. Limestone and igneous clasts in the conglomerate originate from the San Andres Mountains, located to the east of WSTF. Clay lenses are also present and likely represent fine grain sediments of the distal portion of buried coalescent alluvial fan deposits. Replacement well 600C-003-GW will be located approximately 30 ft to the south of existing well BLM-1-435. Well 600C-003-GW will be completed in the alluvial basin-fill and is expected to have similar lithology to that encountered at comparable depths in the existing well. Aquifer conditions at the proposed location are expected to be unconfined. The groundwater flow direction in the area is generally west-southwest. Based on recent measurements at well BLM-1-435, NASA expects to encounter groundwater at approximately 409 ft bgs (Figure 5).
Drilling Approach	NASA will drill and install monitoring well 600C-003-GW in accordance with the requirements of Permit Section 5.1 and 5.2 (NMED, 2023, pg. 71). NASA expects to advance a minimum 12-in. borehole to the top of bedrock at approximately 457 ft bgs. NASA is considering two options for installation of the well. The preferred method is air rotary casing advance (ARCA), and the alternative method is mud rotary. The final determination of drilling method will be made following consultation with the knowledgeable drilling contractors during the competitive procurement process required by the Federal Acquisition Regulations (48 Code of Federal Regulations [CFR] Part 6). The advantages and disadvantages of both options are presented below.

Drilling Approach (cont.)

Air Rotary Casing Advance

The ARCA method drives casing 1 or 2 ft above the drill bit, thereby casing off the borehole as it is drilled. The method stabilizes the formation and prevents collapse of the borehole walls through the installation of casing while drilling. Borehole diameters are necessarily greater for this method and start at 20 to 22 in. from the surface. The borehole and casing sizes are telescoped down as the borehole is advanced over regular intervals to 18 in., 16 in., and finally 14 in. to the total depth of the borehole (diameters are approximate and may vary between drilling contractors). The ARCA method requires only minor use of polymeric or bentonite additives to aid in lifting cuttings out of the borehole. Following well casing installation, the drive casing is removed as the well is completed. Advantages include:

- Stabilization of the borehole
- No drilling mud is required so development of individual monitoring zones is more likely to be successful
- Lithologic cuttings are of better quality for characterization of the alluvium
- Formation water can be identified and sampled for characterization

Disadvantages of the ARCA method include:

- Because steel casing remains in the borehole until well installation, geophysical logging of the borehole is limited to gamma ray and neutron porosity, making it difficult to identify formation changes and productive zones
- The method has proved costly in the past, especially if casing becomes stuck and cannot be removed except by cutting

Geophysical logging of a borehole that is drilled entirely in alluvium is not considered essential, especially since it is possible to quantify water production during ARCA drilling. The ARCA drilling method has become common and many drilling contractors are installing wells successfully using the method. The level of experience among contractors has increased and should preclude problems similar to those NASA encountered using this method while drilling well PL-11 in 2016.

If the ARCA method of drilling is used, air supplied by an air compressor will serve as the drilling fluid. Air will be directed through an in-line filter system to prevent potential introduction of contaminants, such as entrained residual oils, into the borehole. The filter system will be inspected regularly by the drilling contractor to ensure the system is functioning properly. A cyclone separator or similar air containment/dust-suppression system is typically used to funnel the cuttings to one location instead of allowing the cuttings to discharge uncontrolled from the borehole. Particular attention will be paid to the management of cuttings. Dust will be minimized as much as possible with a clean water mist at the cyclone, if necessary.

Mud Rotary Drilling

Mud rotary is a standard drilling method used when penetrating alluvium or unconsolidated formation. Advantages include:

Drilling Approach (cont.)	• Relatively rapid and efficient drilling and installation of the borehole (reduced cost) • A full suite of geophysical logs can be run in a mud filled borehole • The borehole diameter is smaller at 16 to 17 in. • Drilling mud has been effective in stabilizing deep boreholes drilled in alluvium at WSTF • Monitoring zones have been successfully developed in mud drilled wells at WSTF Disadvantages to the mud rotary method are as follows: • The bentonite drilling mud has the potential to adversely affect the hydrologic properties and geochemistry of the aquifer immediately surrounding the borehole • Past experience at WSTF indicates it is difficult and time-consuming to develop monitoring zones in a mud-drilled well • Drilling fluid waste management and disposal costs can be substantially higher than those for ARCA-installed wells If the planned ARCA drilling method is not successful, and mud rotary is required to install the borehole, the appropriate mud dispersion agents will be utilized to aid in the removal of residual drilling mud during borehole/well development. Mud rotary drilling will only be considered as a last resort to advance the borehole and the decision to switch to this method will only occur with the approval of the NMED.
Groundwater Occurrence and Detection	Data from existing well BLM-1-435 indicates regional groundwater is expected to occur at a depth of approximately 409 ft bgs. Perched groundwater is not expected in alluvium. Methods for groundwater detection may include drilling observations, water level measurements, or borehole geophysics. The first identification of groundwater will likely be apparent if the ARCA method is used to install the borehole. However, the mud rotary method may mask the presence of water in the formation.
Lithological Sampling	If the borehole is drilled using ARCA, lithological samples will be collected from the cyclone discharge at a minimum of 10-ft intervals. Drill cuttings may be collected using a stainless-steel handheld screen placed in the flow of the discharged cuttings or other methods selected by the field geologist, as appropriate. Cuttings samples will be archived in chip trays for future reference. If the borehole is installed using the mud rotary method, lithologic samples will be collected directly from the drilling mud discharge location, or from the solids-separation unit (shaker table), if utilized, at a minimum of 10-ft intervals. Drill cuttings may be collected using a stainless-steel handheld screen placed in the flow of the discharged mud, by placing a shovel in the mud discharge trough to intercept cuttings, or other methods selected by the field geologist, as appropriate. Cuttings samples will be archived for future reference.

Groundwater Screening and Characterization Sampling	Based on groundwater monitoring performed at BLM-1-435, the aquifer at the proposed 600C-003-GW location is expected to be within the WSTF groundwater contaminant plume. For verification purposes and potential waste characterization, groundwater screening samples will be attempted during drilling immediately upon intercepting the water table and at least every 100 ft thereafter. Chemical analytical results from screening samples collected will be used to support the identification of potential monitoring zones, as applicable. Screening samples will be analyzed for volatile organic compounds (VOC) by the current revision of SW-846 Method 8260, semi-volatile organic compounds (SVOC) by the current revision of SW-846 Method 8270C, and N-nitrosodimethylamine (NDMA) by Modified Environmental Protection Agency (EPA) Method 607M or an acceptable low-level analytical method. Groundwater samples will be collected, if possible, utilizing a decontaminated non-dedicated bailer. If a bailer is not feasible, grab samples may be attempted through the cyclone at the surface discharge point. All samples will be managed in accordance with the WSTF GMP (NASA, 2022, pp. 36-38). Following well development and sampling system installation, groundwater characterization samples will be collected from each of the sampling zone(s) of the completed wells. Samples will be collected for the analysis of VOCs by the current revision of SW-846 Method 8260, SVOCs by the current revision of SW-846 Method 8270C, NDMA by Modified EPA Method 607M, or WSTF's current low-level analytical method, and a variety of metals by the most effective laboratory-selected analytical method. Samples will be collected and managed in accordance with the GMP (NASA, 2022).
Geophysical Logging	The potential use of the ARCA drilling method may allow for effective geophysical logging of the 600C-003-GW borehole. If the borehole remains open during and after drilling, a complete suite of open borehole geophysical logs would be attempted as a single event to aid in the selection of the potential monitoring zone. Open borehole logging would be performed by a qualified geophysical contractor and would include gamma, neutron porosity, formation resistivity, spontaneous potential, optical imaging, and caliper/borehole deviation logs. The use of drive casing with the ARCA and dual rotary drilling methods will preclude geophysical logging in the 600C-003-GW borehole. Geophysical logging would be performed if the borehole is deemed competent enough to remain open with the drive casing removed.
Well Completion	Well 600C-003-GW will be constructed in accordance with Permit Section 5.2 (NMED, 2023, pg. 71), with nominal 5-in. Schedule 80 PVC casing and screen, which allows for the use of a 4-in. diameter downhole pump for well development. A single monitoring zone is planned in the well to replace the zone previously monitored by well BLM-1-435. The screened interval may be located between 420 and 460 ft bgs. A 10-foot length of 0.020-in. slotted Schedule 80 PVC screen will be positioned at a depth indicated as a favorable monitoring zone in accordance with field screening of borehole lithology and borehole geophysical logs, if performed. The annular seal for the screened sampling zones will be comprised of bentonite chips or pellets. The general well construction configuration is presented in Figure 4 and is subject to change dependent on conditions encountered in the field or by recommendations made

Well Completion (cont.)	by the drilling contractor. NASA will prepare a final well construction diagram for the well for NMED review and approval immediately prior to well installation. Annular materials will be emplaced using a 1 to 2-in. inner diameter 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 20/40 or similar, will be used to grade from the sand pack to a 10-ft bentonite seal composed of hydrated bentonite chips or pellets. The interval above the upper screen from the top of the hydrated bentonite chip seal to 10 ft below ground surface will be comprised of bentonite grout with at least 20% solids. The upper 10 ft of the borehole and well pad will be completed with Type II Portland cement. Figure 4 provides a diagram of the preliminary well design with annular materials.
Well Development	The well will be developed in accordance with the requirements of Section 5.2 of the Permit (NMED, 2023, pg. 71). Drilling contractor personnel will operate equipment used to develop the well under the supervision of Environmental contractor personnel. It is anticipated that initial development for the sampling zone may consist of jetting (to facilitate mud removal following mud rotary), mechanical bailing, swabbing, and pumping using a submersible pump. During development activities, Environmental contractor personnel will monitor discharged development water for parameters that will include pH, specific conductance (conductivity), temperature, and turbidity. Well development will be considered complete when measured water quality parameters are relatively stable (vary less than 10%) and turbidity is below 5 nephelometric turbidity units. Following well development, NASA expects to install a dedicated low-flow bladder pump the PVC well casing, with pump intakes located at or slightly above the midpoint of the screened interval.
Hydraulic Testing and Groundwater Sampling	Hydraulic testing will be considered during the development of monitoring well 600C-003-GW. Additional information such as drawdown and specific capacity will be recorded if this testing is conducted. Groundwater sampling following installation and development of the well will be performed using dedicated low-flow bladder pumps. Groundwater samples will be collected and managed as described in the WSTF GMP (NASA, 2022, pg. 34-38).
Investigation-Derived Waste Characterization and Management	In accordance with the NASA WSTF Hazardous Waste Permit, Section 4.3.10 (NMED, 2023), a discussion of IDW generated is provided in this work plan. All IDW will be properly managed and disposed of in accordance with NASA procedures and state and federal regulations. Information related to the characterization, management, and disposition of waste generated during this project is provided in this section. Waste characterization is conducted in accordance with Section 4.3.10 (Collection and Management of Investigation Derived Waste) of the Permit (NMED, 2023, pg. 59-60). All waste will be properly managed and disposed of in accordance with NASA procedures and state and federal regulations. The waste streams that will be generated during the abandonment of well BLM-1-435 and drilling and installation of groundwater monitoring well 600C-003-GW include: • **Drill cuttings.** Unsaturated drill cuttings are defined as soil cuttings or rock fragments generated from the vadose zone that have not come in contact with groundwater. Unsaturated cuttings are not hazardous waste. Saturated drill

Investigation-Derived Waste Characterization and Management (cont.)	cuttings are defined as soil cuttings or rock fragments generated from below the water table that have come in contact with contaminated groundwater. This environmental media potentially contains listed hazardous waste constituents from the WSTF groundwater plume. • **Drilling fluids.** Drilling fluids generated during drilling in the vadose zone are impacted with only added non-chlorinated native water from the WSTF potable water supply wells and are non-hazardous solid waste. Drilling fluids from below the water table potentially contain listed hazardous waste constituents that are present in the WSTF groundwater plume. • **Groundwater.** Groundwater produced from within the WSTF groundwater plume during well drilling and development is characterized as environmental media containing listed hazardous waste. • **Decontamination fluids.** Decontamination fluids such as water and soap solutions used to wash and decontaminate equipment generated during drilling above the water table are non-hazardous solid waste. Decontamination fluids generated by cleaning equipment that has contacted potentially contaminated soil, cuttings, or fluids generated when drilling below the water table is characterized as hazardous waste. • **Contact waste.** Contact waste, or debris, such as used disposable sampling equipment, personal protective equipment, plastic sheeting, and other debris generated during drilling above the water table is non-hazardous solid waste. Contact debris contaminated with soil, cuttings, or fluids that were generated when drilling below the water table is characterized as hazardous waste. • **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. Groundwater is known to be contaminated at concentrations above the applicable regulatory levels at well BLM-1-435. The EPA has established that groundwater, and other environmental media, is not solid waste, but is subject to regulation as if it were hazardous waste when it contains listed waste (EPA, 1991). Because groundwater and other environmental media is subject to regulation when it contains listed hazardous waste (EPA, 1991), waste generated after reaching the water table will be managed as hazardous waste. By application of the EPA Contained-In Policy, groundwater removed from the contaminated portion of the WSTF plume has been characterized as F001 and F002 listed hazardous waste. As a result, any other material classified as solid waste that comes into contact with contaminated groundwater is regulated hazardous waste or hazardous debris. Drill cuttings and drilling fluids generated from the vadose zone will not contain listed hazardous waste and will not meet the definition of a hazardous waste. Vadose zone drill cuttings, and if necessary, drilling fluids, will be managed in intermediate bulk containers, bulk containers, or earthen pits at the surface as required for project implementation. If earthen pits are used, appropriate regulatory authorization will be

Investigation-Derived Waste Characterization and Management (cont.)	obtained prior to their use, and they will be backfilled at the completion of the project. Drill cuttings and drilling fluids generated below the water table will be managed as hazardous waste. Drill cuttings will be separated from drilling fluids during the drilling process. Drill cuttings below the water table will be managed in 1-cubic yard Super Sack®[1] containers, roll-off containers, or other appropriate waste container. Waste drilling fluids will be managed in intermediate bulk Containers or tanker trailer containers. Hazardous waste generated below the water table will be containerized and managed in accordance with 20.4.1.300 NMAC and 40 CFR 262.17. The as-generated waste will be sampled and analytical data used to further characterize the waste. Waste characterization samples will be analyzed for VOC by the current revision of SW-846 Method 8260, NDMA by Modified EPA Method 607M, and RCRA metals using the current revision of EPA Method 1311 (Toxicity Characteristic Leaching Procedure) and the current revision of EPA Method 6010, or equivalent. NASA will request a "contained-in" determination from the NMED if the analytical data indicates drill cuttings and drilling fluids generated below the water table do not contain listed hazardous waste or exhibit characteristics of a hazardous waste. If the analytical data indicate the presence of listed waste or the waste exhibits characteristics of a hazardous waste, the waste will be properly treated and disposed of at a RCRA permitted treatment, storage, and disposal facility (TSDF). If possible, contaminated water may be decanted from this waste stream prior to shipment off-site and transferred to the MPITS for treatment and discharge. Contaminated groundwater generated during drilling, development, and purging, and contaminated water generated during decontamination of equipment that has come into contact with contaminated groundwater or hazardous debris from below the water table, will be accumulated in appropriately sized containers and managed as hazardous waste. The containers will be managed in accordance with requirements of 20.4.1.300 NMAC and 40 CFR 262.17. Within permissible accumulation time limits, contaminated water will be transferred to the MPITS for treatment and discharge. Contact waste, or hazardous debris, that has come into contact with contaminated groundwater will be collected at the end of each working shift and transferred to an appropriate container. All hazardous waste containers will be managed on-site in accordance with the requirements of 20.4.1.300 NMAC and 40 CFR 262.17. If analytical results from drill cuttings and fluids are favorable, this waste stream may be included in a "contained-in" determination request. If analytical results indicate the drill cuttings and fluids contain hazardous waste, or the NMED determines the waste still contains hazardous waste, this debris will be shipped off-site for treatment and disposal at a RCRA permitted TSDF within the permissible accumulation time limits. As discussed previously, NASA may request a contained-in determination for individual waste streams initially characterized as containing listed hazardous wastes, should analytical data from the as-generated waste support such a request. The chemical analytical data may be compared to the Applicability of Treatment Standards 40 CFR Part 268.40, NMED Soil Screening Levels (SSLs; NMED, 2022c), and the concentrations listed in 40 CFR Part 261.24 Subpart C (Table 1), if applicable, to determine whether the material poses an unacceptable risk. If NMED finds contaminant concentrations do not pose an unacceptable risk, then NMED may allow

---

[1] Super Sack is a registered trademark of Better Agricultural Goals Corporation DBA/ B.A.G. Corp.

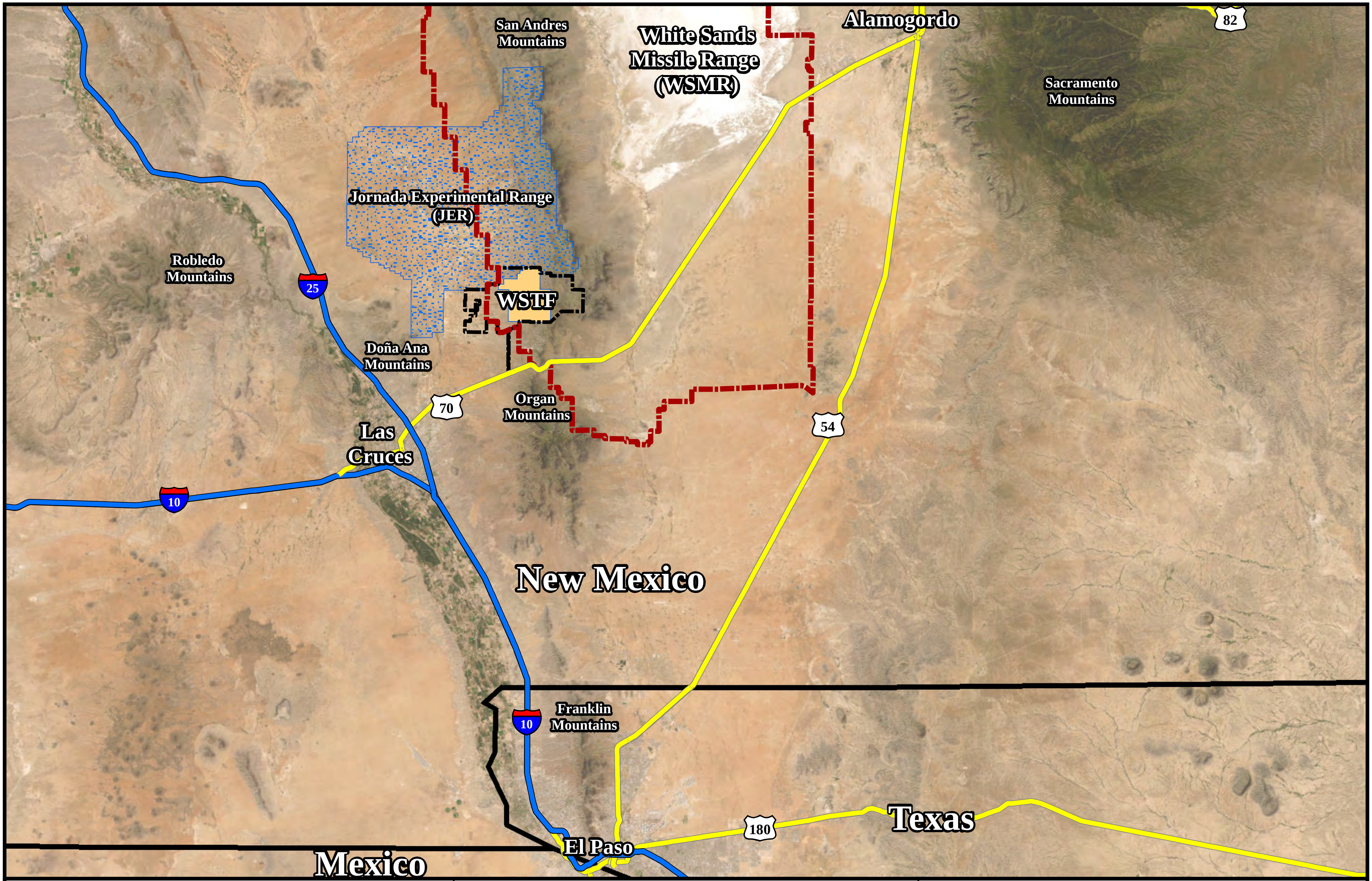
Investigation-Derived Waste Characterization and Management (cont.)	the wastes included in the request to be managed as non-hazardous solid waste that no longer contains listed waste and does not exhibit the characteristic of hazardous waste. A separate letter from NMED will be required to document such a determination. 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. Contaminated groundwater and decontamination water generated during the project will be managed at the MPITS. If that system is not capable of receiving the waste, it will be disposed of at a permitted RCRA TSDF.
Schedule	It is anticipated that drilling of proposed well 600C-003-GW will commence following NMED approval of this work plan. The anticipated schedule for completing wells is as follows: • Eight to 10 weeks for project and procurement planning, well site preparation, and drilling contractor scheduling. • Six to eight weeks for contractor mobilization, plugging and abandonment of well BLM-1-435, installation of the 600C-003-GW borehole, and conventional well installation in 600C-003-GW borehole. Additional time may be required during drilling if unexpected field or geological conditions slow the drilling process. • Six to eight weeks for well development fieldwork, sampling system design and procurement, and sampling system installation. • Eight to 12 weeks for groundwater sampling, data validation and verification, and preparation of the well completion report. The well completion report will be submitted to the NMED in accordance with Section 5.4 of the Permit (NMED, 2023, pg. 79-80).
References	Adoption of 40 CFR Part 262, Environmental Improvement Board, 20.4.1.300 NMAC (12-01-18). EPA (Environmental Protection Agency). (1991, March 26). N.t. (EPA Publication Number RO 11593). Washington, DC. Retrieved from https://yosemite.epa.gov/osw/rcra.nsf/ NASA Johnson Space Center White Sands Test Facility. (2022, April 29). *NASA WSTF Groundwater Monitoring Plan Update for 2022*. Las Cruces, NM. Navarro Research and Engineering, Inc. (2020d, July 5). *FY 2020 Evaluation of Select WSTF Wells for Rehabilitation, Plugging and Abandonment, or Continued Use*. Las Cruces, NM. NMED Hazardous Waste Bureau. (2022a, February 21). *Approval with Modifications Periodic Monitoring Report Second Quarter 2021*. Santa Fe, NM.

References (cont.)	NMED Hazardous Waste Bureau. (2022b, October 31). *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan*. Santa Fe, NM. NMED Hazardous Waste Bureau. (2022c, November). *Risk Assessment Guidance for Site Investigations and Remediation Volume I Soil Screening Guidance for Human Health Risk Assessments*. Santa Fe, NM. NMED Hazardous Waste Bureau. (2023, April 27). *Hazardous Waste Permit No. NM8800019434*. Santa Fe, NM. Well Drilling – Non-Artesian (Unconfined) Well Requirements, Office of the State Engineer, 19.27.4.30 NMAC (6-30-17).

Figures

Figure 1 **WSTF Location Map**

(SEE NEXT PAGE)



WSTF Location Map

NASA Johnson Space Center
White Sands Test Facility
Las Cruces, New Mexico

Coordinate System:
NAD 1983 StatePlane New Mexico Central FIPS 3002 Feet

G:\Projects\environmental\PMR\2023\1stQuarter

🟥	WSMR Boundary
⬛	WSTF Boundary
🟧	WSTF Industrial Area
▨	Jornada Experimental Range (JER)

N
W E
S

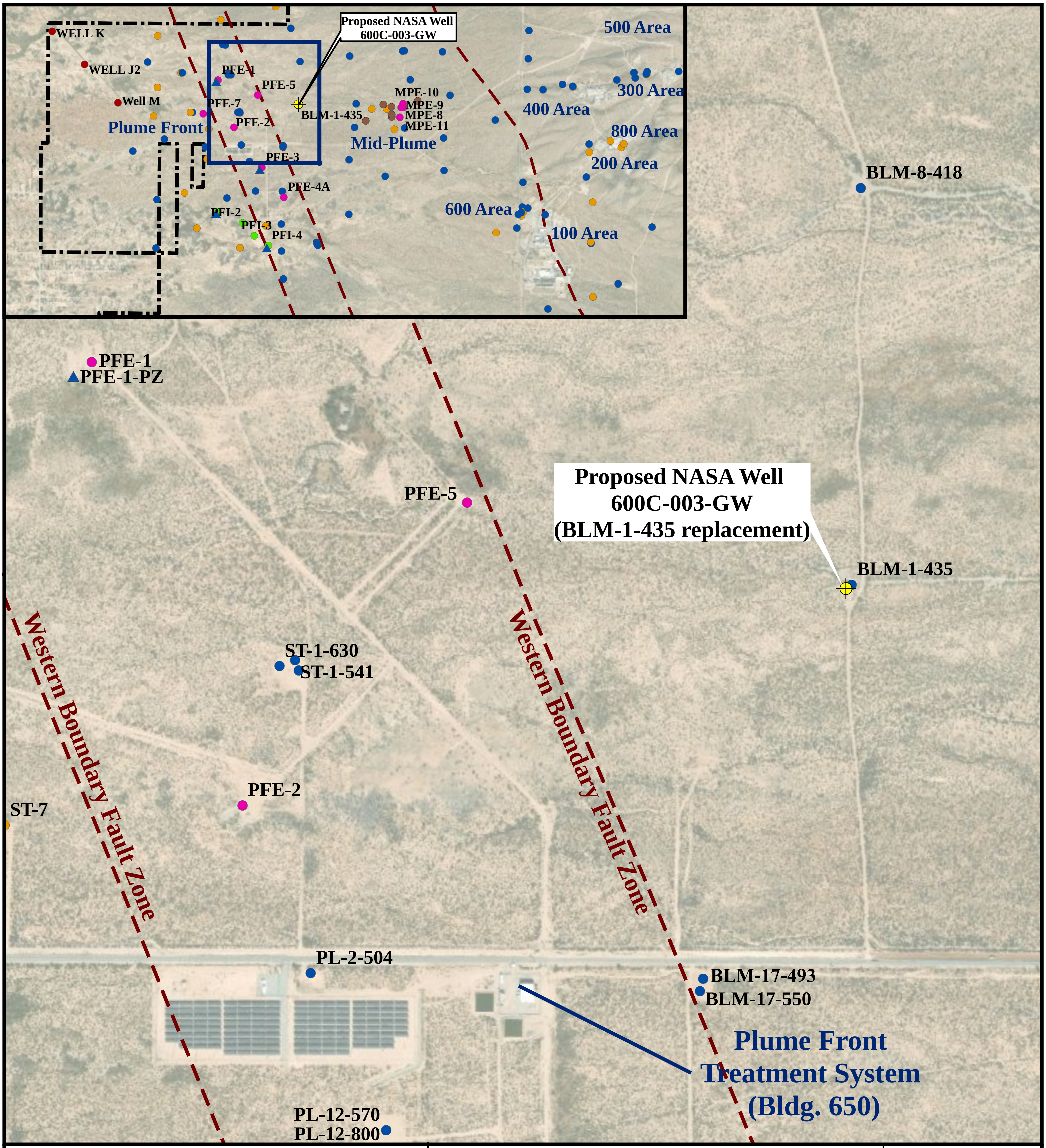
1 in = 12 miles

Miles
0 6 12 24

April 2023

Figure 2 **Proposed Location for 600C-003-GW**

(SEE NEXT PAGE)



Proposed location for 600C-003-GW (BLM-1-435 Replacement)

NASA Johnson Space Center
White Sands Test Facility Las Cruces, New Mexico

Coordinate System:
NAD 1983 HARN StatePlane New Mexico Central FIPS 3002 Feet

G:\Projects\environmental\Well_Replacement

- ⊕ Proposed Well
- ● Multiport Well
- ● Conventional Well
- ● Extraction Well
- ● Injection Well
- ▲ Piezometer
- ● Exploration Well
- ● Production Well
- — — Fault
- ▬ WSTF Boundary

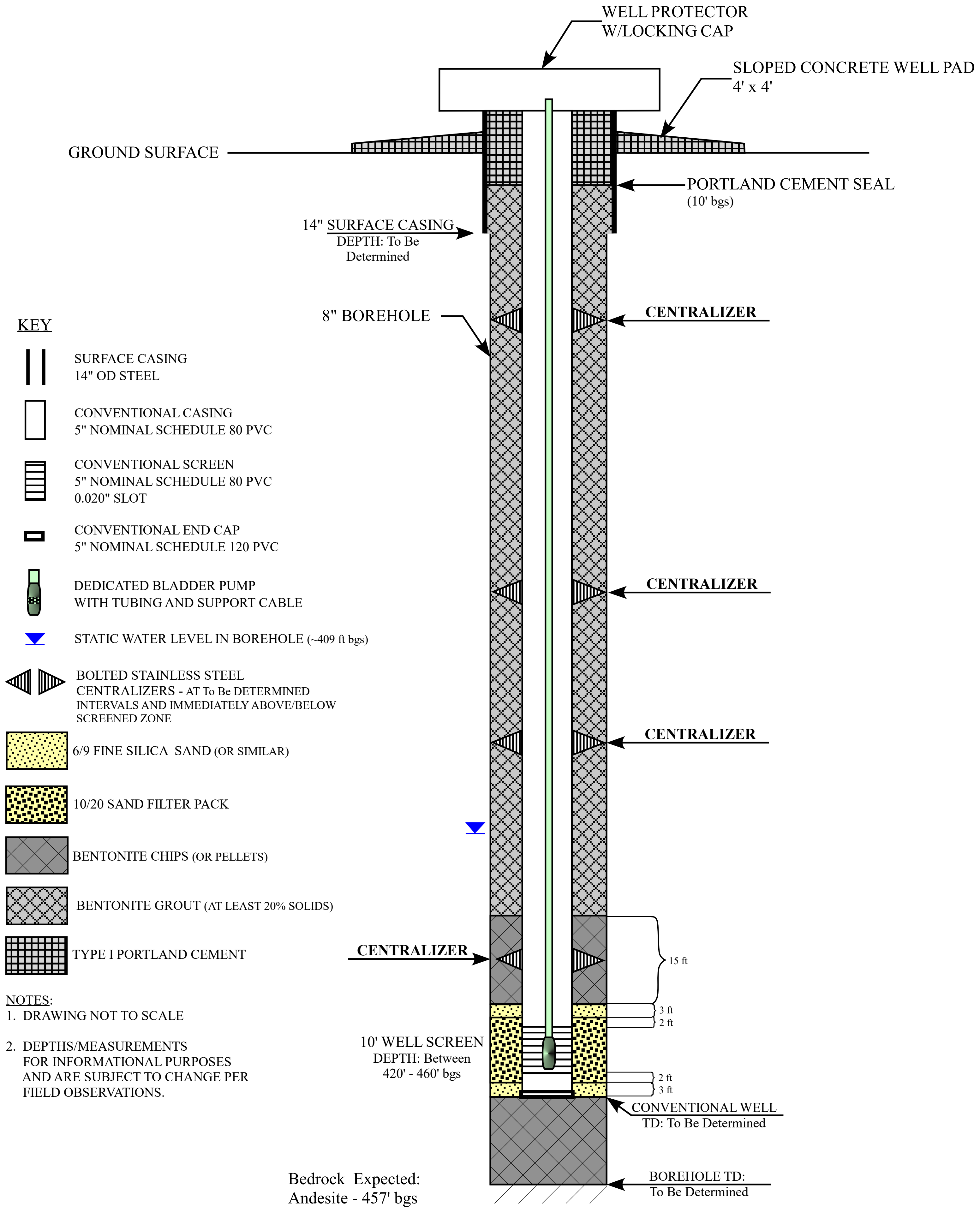
N
W E
S

1 inch = 600 feet
April 2023

0 150 300 600 Ft

Figure 3 **General 600C-003-GW Well Design**

(SEE NEXT PAGE)



NOTES:

1. DRAWING NOT TO SCALE
2. DEPTHS/MEASUREMENTS FOR INFORMATIONAL PURPOSES AND ARE SUBJECT TO CHANGE PER FIELD OBSERVATIONS.

600C-003-GW WELL DESIGN: CONVENTIONAL

Figure 4 **BLM-1-435 Well Completion Diagram**

(SEE NEXT PAGE)

JSC - White Sands Test Facility
Las Cruces, New Mexico, USA

WELL COMPLETION DIAGRAM

MONITORING WELL

Location ID: **BLM-1-435** Site ID: **NASA-WSTF, Doña Ana County, NM**

Township and Range: **SW 1/4 NW 1/4 SW 1/4 Sec.33, T20S, R3E**
NM State Plane Coordinates (NAD 83): **168873.19N 462776.98E**
Elevation (Brass Cap): **1387.95 m AMSL**
Elevation (Top of Casing): **1388.40 m AMSL**
Drilling Contractor: **Larjon Drilling Company**
Driller: **J. Gower**
Total Depth of Borehole (bgs): **500' (152.4 m)**
Borehole Diameter: **8 3/4" to 35'; ~7 7/8 to 500' (Assumed)**
Depth to Bedrock (bgs): **457' (139.3 m); Rhyolite**
Depth to Groundwater: **398.5' (121.5 m) TOSC (10/6/87)**
Total Depth Surface Casing (bgs): **32' (9.8 m)**
Diameter and Type Surface Casing: **Nominal 8" Steel**

Date(s) Well Installed: **11/11/1987**
Date(s) Well Developed: **11/19/1987 - 3/10/1988**
Field Representative(s): **E. Morse, B. Cooper, J. Kaszuba**
Total Depth Well Casing (bgs): **451' (137.5 m)**
Type of Casing: **Stainless Steel**
Diameter Well Casing: **4"**
Casing Schedule: **SCD 5 & SCD 10**
Screened Zone (bgs): **435.3' - 445.7' (132.7 - 135.8 m)**
Comments: **Original casing was pulled on 11/9/1987 and well reinstalled on 11/11/1987. Diameter not recorded.**
AMSL = Above Mean Sea Level
bgs = below ground surface

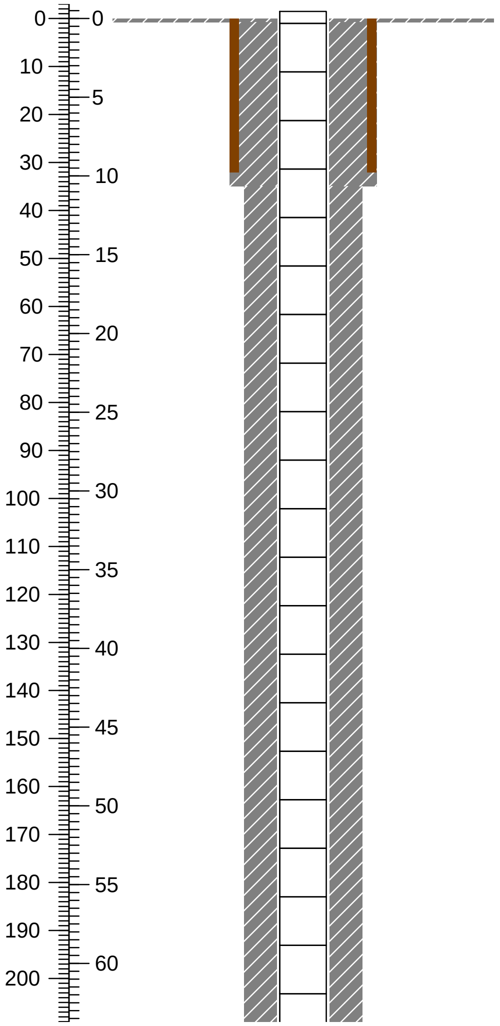
Casing Explanation:

- ▮ Surface Casing **Nominal 8" Steel**
- ▯ Conventional Casing **Nominal 4" SCH 5 Stainless Steel**
- ▯ Conventional Casing **Nominal 4" SCH 10 Stainless Steel**
- ☰ Conventional Screen **Nominal 4" SCH 10 Stainless Steel**
- ⊠ Conventional End Cap **Nominal 4" SCH 10 Stainless Steel**
- ◀▶ **Welded Stainless Steel Centralizers**
- ▼ Water Table

Annular Materials Explanation:

- ▨ Cement
- ▨ Bentonite (Grout Well DF)
- ▥ Bentonite Seal
- ▥ Bentonite Mix
- ⬡ Slough
- ▩ 8/14 Sand
- ▩ 4/8 Sand
- ▩ 6/9 Sand
- ▩ 8/12 Sand
- ▩ 8/20 Sand
- ▩ 10/20 Sand
- ▩ 16/40 Sand
- ▩ 20/40 Sand
- ▩ 30/70 Sand

Feet/Meters



Well Descriptions
All depths listed are bgs (unless noted)

Well completed with a 3' X 3' concrete slab and 4" X 2.0' stainless steel riser and locking cap.

Stick-up = 1.47' (0.45 m)

Nominal 8" steel surface casing installed to 32' (9.8 m).

Annular/Borehole Descriptions
All depths listed are bgs

0' - 397.1' (0 - 121.04 m)- Neat Cement Slurry with 5% Bentonite.

8 3/4" borehole to 35'. ~7 7/8" borehole to 500'.

Casing Explanation:

Surface Casing **Nominal 8" Steel**

Conventional Casing **Nominal 4" SCH 5 Stainless Steel**

Conventional Casing **Nominal 4" SCH 10 Stainless Steel**

Conventional Screen **Nominal 4" SCH 10 Stainless Steel**

Conventional End Cap **Nominal 4" SCH 10 Stainless Steel**

Welded Stainless Steel Centralizers

Water Table

Annular Materials Explanation:

▨ Cement

▨ Bentonite (Grout Well DF)

▥ Bentonite Seal

Slough

1/8 Gravel

8/14 Sand

4/8 Sand

6/9 Sand

8/12 Sand

8/20 Sand

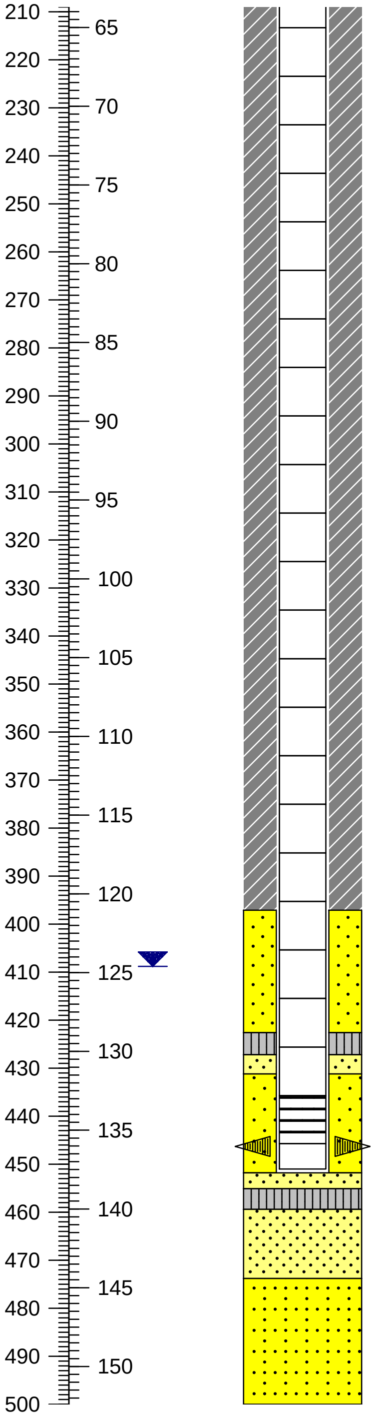
10/20 Sand

16/40 Sand

20/40 Sand

30/70 Sand

Feet/Meters



Well Descriptions
All depths listed are bgs (unless noted)

All casing above 334.6' is SCH 5 Nominal 4" Stainless Steel.

All casing and screen below 334.6' is SCH 10 Nominal 4" Stainless Steel.

408.8 (124.60 m)- Static water level in cased borehole.

435.3 (132.68 m)- Top of SCH 10 Nominal 4" Stainless Steel 0.02 slot screen.

445.7 (135.85 m)- Bottom of SCH 10 Nominal 4" Stainless Steel 0.02 slot screen.

446.3 (136.03 m)- Stainless Steel Centralizer.

451.0 (137.46 m)- Nominal 4" SCH 10 Stainless Steel casing TD.

Annular/Borehole Descriptions
All depths listed are bgs

397.1' (121.04 m)- Top of 10/20 Sand.

422.6' (128.81 m)- Top of Bentonite Plug (Pellets).

427.2' (130.21 m)- Top of 16/40 Sand.

431.2' (131.43 m)- Top of 8/20 Sand.

451.8' (137.71 m)- Top of 16/40 Sand.

455.1' (138.71 m)- Top of Bentonite Plug (Pellets).

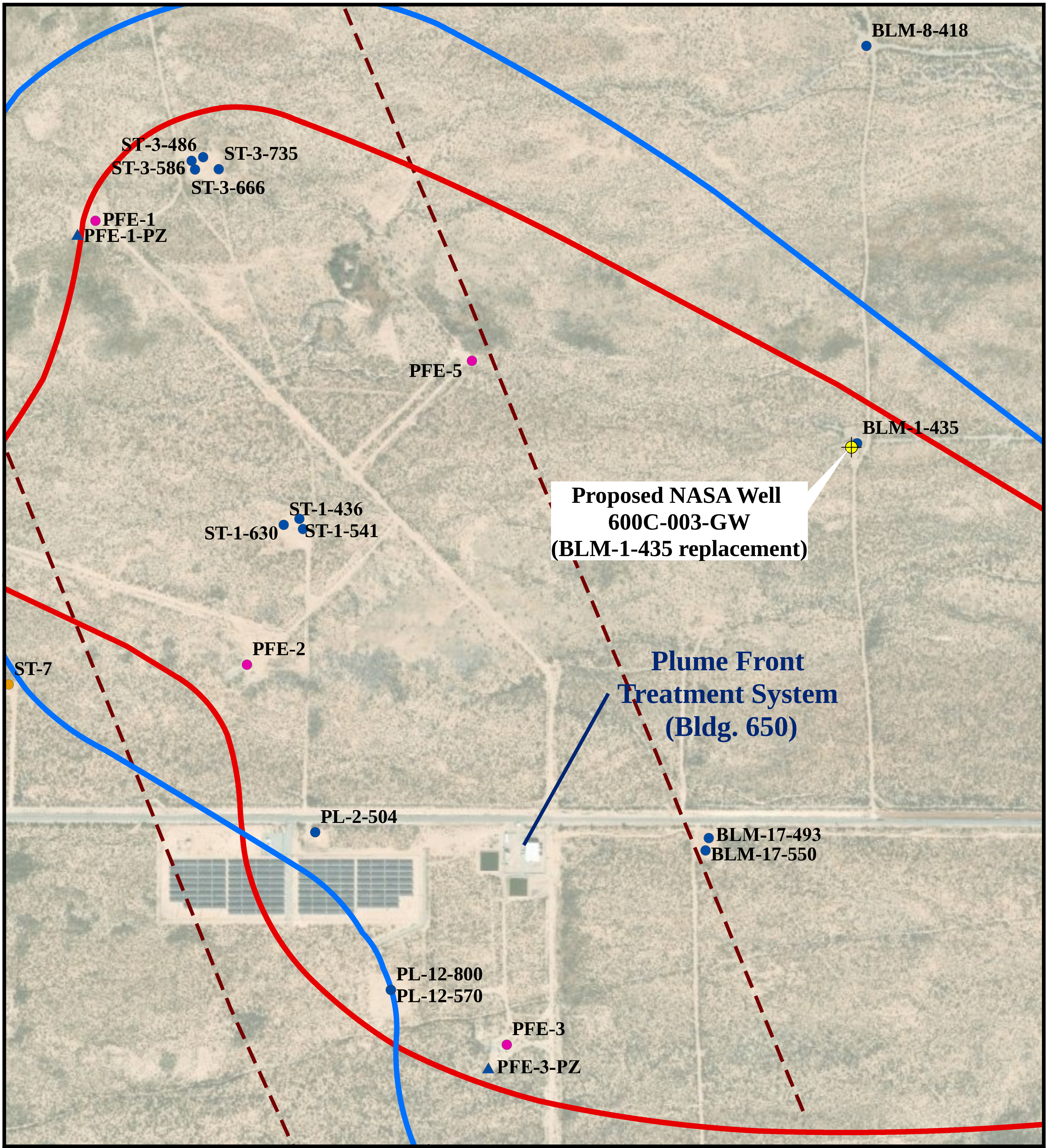
459.4' (140.03 m)- Top of 16/40 Sand.

473.8' (144.41 m)- Top of 8/14 Sand.

500' (152.4 m)- ~7 7/8" Borehole TD.

Figure 5 **Proposed Well Location with Plume Extent**

(SEE NEXT PAGE)



Proposed location for 600C-003-GW (BLM-1-435 Replacement) in Relation to NDMA and TCE Plumes

NASA Johnson Space Center
White Sands Test Facility Las Cruces, New Mexico

Coordinate System:
NAD 1983 HARN StatePlane New Mexico Central FIPS 3002 Feet

G:\Projects\environmental\Well_Replacement

- ⊕ Proposed Well
- ● Multiport Well
- ● Conventional Well
- ● Extraction Well
- ● Injection Well
- ▲ Piezometer
- ● Exploration Well
- ● Production Well
- ━ NDMA Cleanup Level (1.1 ng/L)
- ━ TCE Cleanup Level (4.9 ug/L)
- ╍ Western Boundary Fault Zone

N
W E
S

1 inch = 600 feet
April 2023

0 150 300 600 Ft

Figure 6 **BLM-1-435 Borehole Lithology Log**

(SEE NEXT PAGE)

JSC - White Sands Test Facility
Las Cruces, New Mexico, USA

BOREHOLE LITHOLOGIC LOG

Location ID: **BLM-1-435**

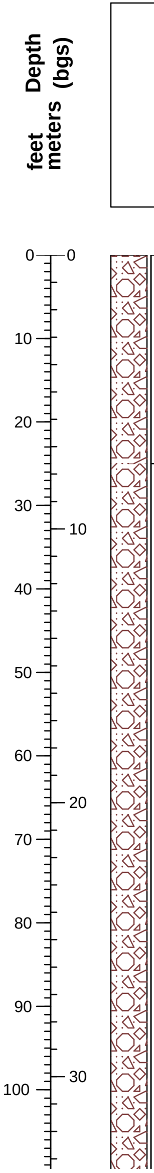
Site ID: **NASA-WSTF, Doña Ana County, NM**

Township and Range: **SW 1/4 NW 1/4 SW 1/4 Sec.33 T20S R3E**
NM State Plane Coordinates (NAD 83): **168873.19 N 462776.98 E**
Elevation (Brass Cap): **1387.95 m AMSL**
Total Depth of Borehole (bgs): **500' (152.4 m)**
Depth to Bedrock (bgs): **457' (139.29 m); Rhyolite**
Drilling Method: **Mud/Air-Foam Rotary**
Drilling Contractor: **Larjon Drilling Company**
Driller: **J. Gower**

Depth to Groundwater: **398.5' (121.5 m) TOSC (10/6/87)**
Surface Casing Depth and Diameter: **Nominal 8" Carbon Steel to 32'**
Borehole Diameter: **8 3/4" to 35'; 7 7/8"? to 500'**
Geologist Field Rep: **E. Morse, J. Kaszuba, B. Cooper**
Dates Drilling Started and Completed: **9/23/1987 - 9/29/1987**
Geophysical Contractor: **Southwest Surveys**
Logger: **D. Pearson**
Comments: **Bedrock originally logged as andesite. Core description renamed unit as Porphyritic Latite. This is grouped as rhyolite for modeling purposes.**
AMSL = Above Mean Sea Level TOSC = Top of Surface Casing

Explanation:

- Alluvium
- Volcanic Alluvium
- Caliche
- Gravel & Sand
- Clay
- Quartzite
- Siltstone
- Sandstone
- Limestone and Shale Interbeds
- Conglomerate
- Shale
- Limestone
- Rhyolite
- Andesite
- Volcanics



Lithology

ALLUVIUM 0 - 25' (0 - 7.6 m):

Santa Fe Group: Surficial Sand and Soil. Fine-grained sand to pebbles with silt and clay. Color is pale yellowish-brown (10YR 5/4). Cuttings are angular to rounded and consist of limestone siltstone granite dolostone quartzite and volcanics. Samples are unconsolidated and very sandy. Some organic material is present.

15 - 20' (4.6 - 6.1 m): Increased clay content.

ALLUVIUM 25 - 457' (7.6 -139.3 m):

Santa Fe Group: Gravelly Alluvium. Poorly to moderately consolidated fine-grained sand to pebble size cuttings of angular to subrounded clasts of limestone dolostone volcanics granite siltstone quartzite caliche and quartz. Color is light gray but individual grains range from white (N9) to black (N1) to dusky red (5R 3/4).

30 - 40' (9.1 - 12.2 m): Abundant caliche and caliche-coated grains.

40 - 50' (12.2 - 15.2 m): Significant increase in cutting size. Cuttings up to 1.0 inch in diameter.

50 - 60' (15.2 - 18.3 m): Cutting size decreases to clay and sand, with large caving interval. Apparently represents another soil horizon.

60 - 65' (18.3 - 19.8 m): Large cuttings mixed with silty clay material.

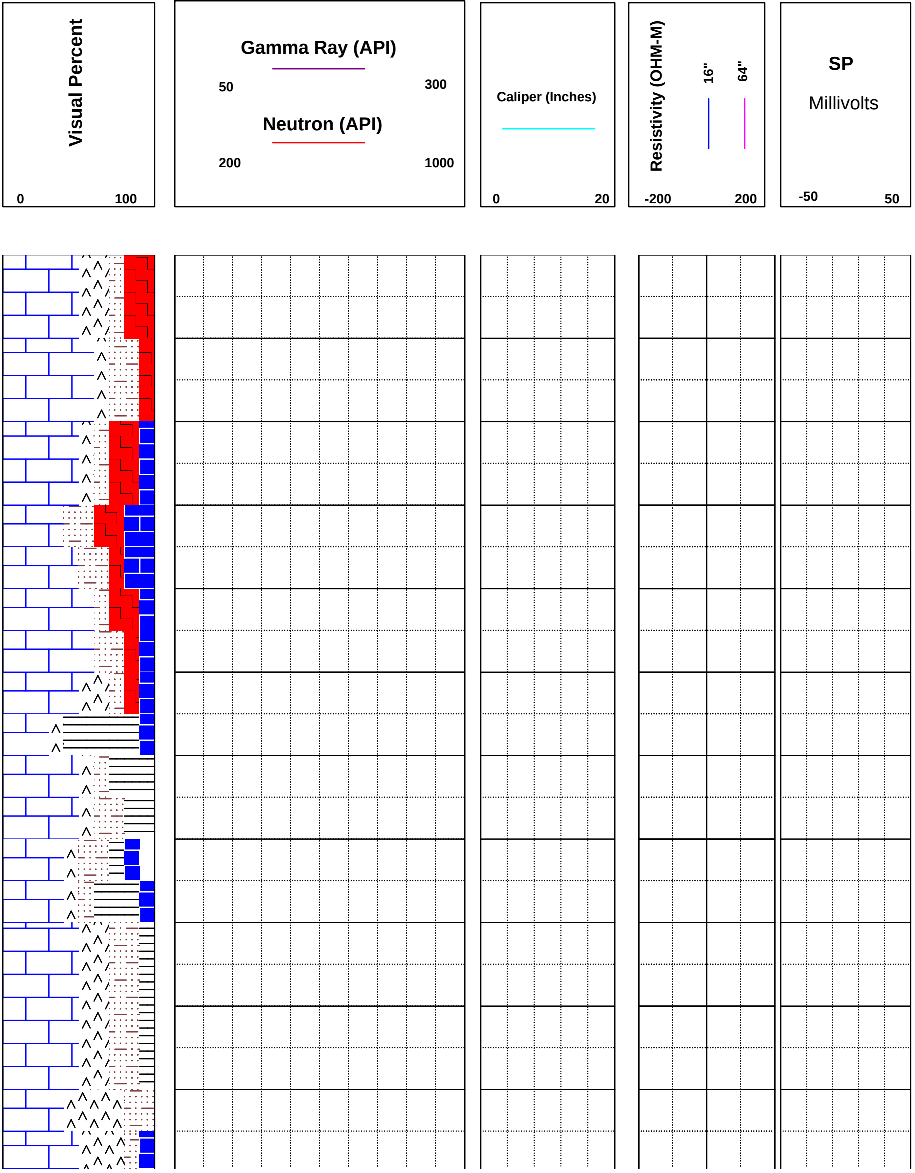
65 - 75' (19.8 - 22.9 m): Large cuttings predominate, with clay-silts content decreasing.

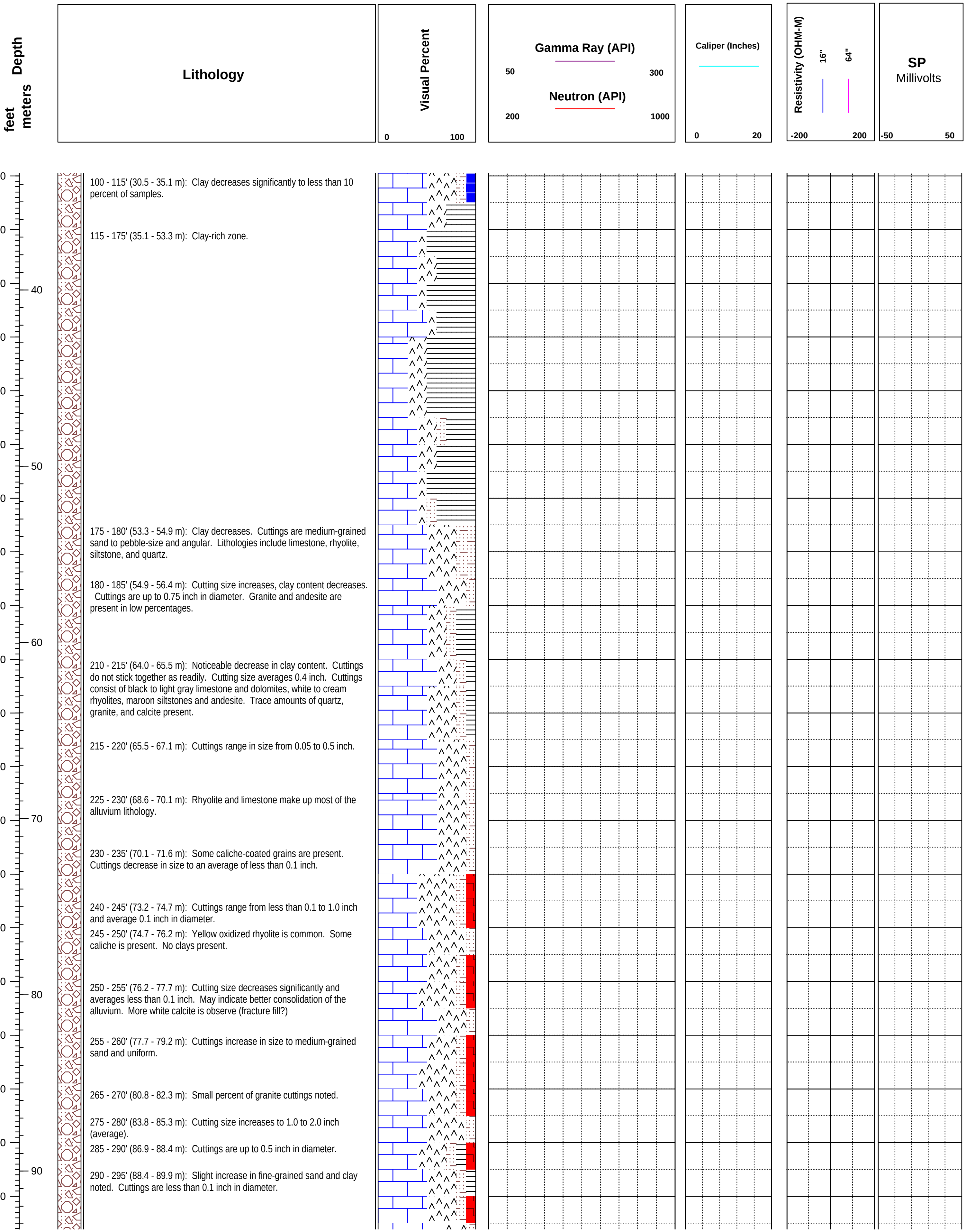
75 - 80' (22.9 - 24.4 m): Increased clay content.

80 - 85' (24.4 - 25.9 m): Clays decrease. Cutting size averages 0.2 inch.

85 - 90' (25.9 - 27.4 m): Very large cuttings less abundant. Cuttings are typically angular, but rounded and sub-rounded cuttings are present.

90 - 100' (27.4 - 30.5 m): Average size of cuttings is 0.4 inch. Alluvium is weakly cemented. Rhyolite clasts and clay are abundant.





100 - 115' (30.5 - 35.1 m): Clay decreases significantly to less than 10 percent of samples.

115 - 175' (35.1 - 53.3 m): Clay-rich zone.

175 - 180' (53.3 - 54.9 m): Clay decreases. Cuttings are medium-grained sand to pebble-size and angular. Lithologies include limestone, rhyolite, siltstone, and quartz.

180 - 185' (54.9 - 56.4 m): Cutting size increases, clay content decreases. Cuttings are up to 0.75 inch in diameter. Granite and andesite are present in low percentages.

210 - 215' (64.0 - 65.5 m): Noticeable decrease in clay content. Cuttings do not stick together as readily. Cutting size averages 0.4 inch. Cuttings consist of black to light gray limestone and dolomites, white to cream rhyolites, maroon siltstones and andesite. Trace amounts of quartz, granite, and calcite present.

215 - 220' (65.5 - 67.1 m): Cuttings range in size from 0.05 to 0.5 inch.

225 - 230' (68.6 - 70.1 m): Rhyolite and limestone make up most of the alluvium lithology.

230 - 235' (70.1 - 71.6 m): Some caliche-coated grains are present. Cuttings decrease in size to an average of less than 0.1 inch.

240 - 245' (73.2 - 74.7 m): Cuttings range from less than 0.1 to 1.0 inch and average 0.1 inch in diameter.

245 - 250' (74.7 - 76.2 m): Yellow oxidized rhyolite is common. Some caliche is present. No clays present.

250 - 255' (76.2 - 77.7 m): Cutting size decreases significantly and averages less than 0.1 inch. May indicate better consolidation of the alluvium. More white calcite is observe (fracture fill?)

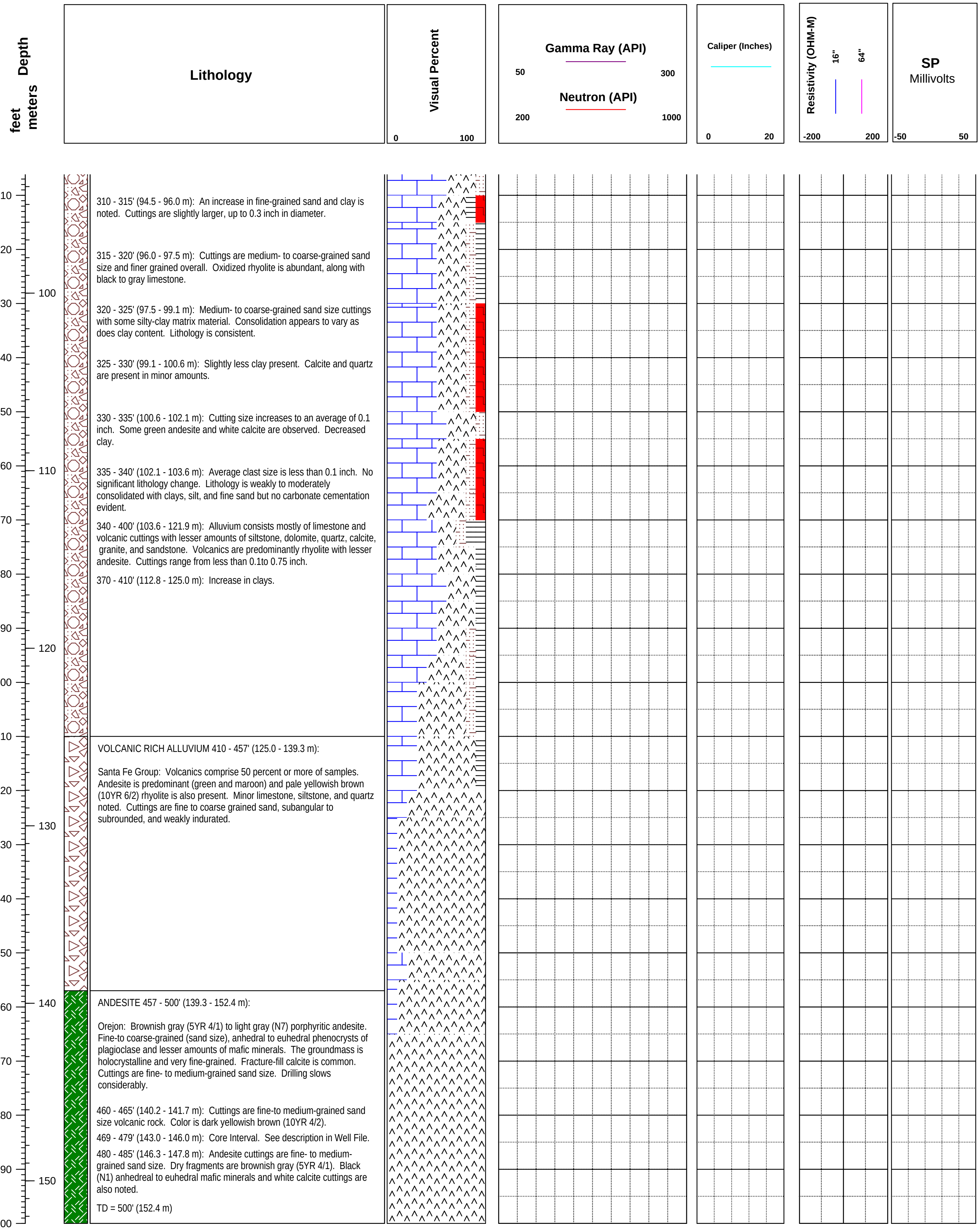
255 - 260' (77.7 - 79.2 m): Cuttings increase in size to medium-grained sand and uniform.

265 - 270' (80.8 - 82.3 m): Small percent of granite cuttings noted.

275 - 280' (83.8 - 85.3 m): Cutting size increases to 1.0 to 2.0 inch (average).

285 - 290' (86.9 - 88.4 m): Cuttings are up to 0.5 inch in diameter.

290 - 295' (88.4 - 89.9 m): Slight increase in fine-grained sand and clay noted. Cuttings are less than 0.1 inch in diameter.



310 - 315' (94.5 - 96.0 m): An increase in fine-grained sand and clay is noted. Cuttings are slightly larger, up to 0.3 inch in diameter.

315 - 320' (96.0 - 97.5 m): Cuttings are medium- to coarse-grained sand size and finer grained overall. Oxidized rhyolite is abundant, along with black to gray limestone.

320 - 325' (97.5 - 99.1 m): Medium- to coarse-grained sand size cuttings with some silty-clay matrix material. Consolidation appears to vary as does clay content. Lithology is consistent.

325 - 330' (99.1 - 100.6 m): Slightly less clay present. Calcite and quartz are present in minor amounts.

330 - 335' (100.6 - 102.1 m): Cutting size increases to an average of 0.1 inch. Some green andesite and white calcite are observed. Decreased clay.

335 - 340' (102.1 - 103.6 m): Average clast size is less than 0.1 inch. No significant lithology change. Lithology is weakly to moderately consolidated with clays, silt, and fine sand but no carbonate cementation evident.

340 - 400' (103.6 - 121.9 m): Alluvium consists mostly of limestone and volcanic cuttings with lesser amounts of siltstone, dolomite, quartz, calcite, granite, and sandstone. Volcanics are predominantly rhyolite with lesser andesite. Cuttings range from less than 0.1to 0.75 inch.

370 - 410' (112.8 - 125.0 m): Increase in clays.

VOLCANIC RICH ALLUVIUM 410 - 457' (125.0 - 139.3 m):

Santa Fe Group: Volcanics comprise 50 percent or more of samples. Andesite is predominant (green and maroon) and pale yellowish brown (10YR 6/2) rhyolite is also present. Minor limestone, siltstone, and quartz noted. Cuttings are fine to coarse grained sand, subangular to subrounded, and weakly indurated.

ANDESITE 457 - 500' (139.3 - 152.4 m):

Orejon: Brownish gray (5YR 4/1) to light gray (N7) porphyritic andesite. Fine-to coarse-grained (sand size), anhedral to euhedral phenocrysts of plagioclase and lesser amounts of mafic minerals. The groundmass is holocrystalline and very fine-grained. Fracture-fill calcite is common. Cuttings are fine- to medium-grained sand size. Drilling slows considerably.

460 - 465' (140.2 - 141.7 m): Cuttings are fine-to medium-grained sand size volcanic rock. Color is dark yellowish brown (10YR 4/2).

469 - 479' (143.0 - 146.0 m): Core Interval. See description in Well File.

480 - 485' (146.3 - 147.8 m): Andesite cuttings are fine- to medium-grained sand size. Dry fragments are brownish gray (5YR 4/1). Black (N1) anhedral to euhedral mafic minerals and white calcite cuttings are also noted.

TD = 500' (152.4 m)

Drilling Work Plan for Proposed NASA WSTF Well 600C-004-GW

Introduction and Background	In the February 21, 2022, *Approval with Modifications Periodic Monitoring Report Second Quarter 2021*, the New Mexico Environment Department (NMED) expressed concern about declining water levels at White Sands Test Facility (WSTF; Figure 1) groundwater monitoring wells 300-C-128, 400-C-118, 400-C-143, BLM-1-435, and PL-3-453 (NMED, 2022a). NMED indicated that National Aeronautics and Space Administration (NASA) could continue to evaluate these wells. In the NASA WSTF groundwater Monitoring Plan (GMP) Update for 2022, submitted on April 29, 2022, NASA indicated that NASA well PL-3-453 would be plugged due to continued groundwater level drop and inability to sufficiently sample the well (NASA, 2022). On October 31, 2022, NMED approved the GMP. In the approval letter, NMED indicated that well PL-3-453 must be replaced and directed NASA to submit a work plan for the plugging of PL-3-453 and subsequent drilling of its replacement well (NMED, 2022a). This abbreviated work plan was developed in accordance with the Hazardous Waste Permit (Permit, 2023), Section 6.2, and incorporates requirements specified in Section 5.3 of the Permit. This well is located within the southern Jornada del Muerto Basin alluvial aquifer and south of the WSTF Plume Front Treatment System (PFTS; Figure 2).
Primary Purpose	PL-3-453 is a sentinel well located southwest and outside of the mapped Plume Front contamination plume area and is upgradient of Plume Front Remediation System injection wells. Sentinel wells are those groundwater monitoring wells installed beyond the leading edge of the conceptualized contaminant plume that have not been impacted by historical or current operations at WSTF. Sentinel wells provide monitoring points at depths within the aquifer where contaminant migration is a concern. Evidence of WSTF COC at these wells or zones indicate uncontrolled migration of contaminants beyond a defined spatial limit (such as a capture zone) and may initiate changes in remediation system operation or other actions to prevent further contaminant migration. For this reason, PL-3-453 will be replaced with a new monitoring well. The new monitoring well will be located in close proximity to well PL-3-453, and the screened interval will be set at a depth that allows for the sampling of the same groundwater as that original monitoring well for continued groundwater characterization. Well 600C-004-GW will be completed as a 5-in. Schedule 80 polyvinyl chloride (PVC) single-screened well drilled to approximately 600 ft bgs for continued characterization of aquifer conditions at this location (Figure 2). The well is expected to consist of a single screened interval, the exact placement of which will be determined during drilling to allow for sampling from the same zone as PL-3-453 previously. Specific consideration will be given to the depth of the water table, known depth of contamination at nearby monitoring wells within the WSTF groundwater contaminant plume, interfaces between lithologic units, and any inferred high transmissive zones. A conventional low-flow groundwater monitoring sampling system is expected to be installed within the PVC well to complete the wells construction (Figure 3).

Plugging and Abandonment of Well PL-3-453	NASA will plug and abandon existing groundwater monitoring well PL-3-453 as directed in accordance with WSTF Hazardous Waste Permit (Permit) Section 5.3 (NMED, 2023) and 19.27.4.30 New Mexico Administrative Code (NMAC). Well PL-3-453, completed in November 1988, is equipped with 10-inch (in.) carbon steel surface casing that extends to a depth of 87 feet (ft) below ground surface (bgs). Borehole diameters are 12 ¼ in. from 0-89 ft; reamed to 16 in. to 85 ft; and 9 7/8 in. from 89 ft to a total depth of 497 ft bgs. The conventional portion of the monitoring well consists of nominal 4-in. stainless-steel casing that extends from ground surface to 469.1 ft bgs (Figure 4), with a single screened interval running from 453.4 to 463.8 ft bgs. NASA proposes to plug the well by lowering tremie pipe to the bottom of the open borehole. Portland cement grout will be emplaced using a tremie pipe upward from the bottom of the borehole to the ground surface. Any discharge of fluids will be managed in accordance with the Waste Management and Characterization Section. The steel surface casing will then be cut at least 6 in. bgs and a concrete cap will be emplaced over the borehole. Finally, a brass cap will be embedded in the concrete surface completion and all pertinent well information will be stamped into the brass cap. NASA will prepare a well plugging plan for well PL-3-453 and submit the plan to the New Mexico Office of the State Engineer (NMOSE) in accordance with 19.27.4.30 NMAC. The well drilling sub-contractor will provide NASA and NMOSE with the required completed well plugging record. NASA will in turn provide NMED with a copy of the completed well plugging record.
Hydrogeologic and Geochemical Objectives	The primary objective of the proposed monitoring well is to provide continued characterization and vertical delineation of groundwater chemistry between existing wells PL-6 and PL-8. Also serving its purpose as a sentinel well beyond the leading edge of the plume. Analytical results from well 600C-004-GW will be used to supplement data collected from wells within the WSTF groundwater monitoring system. Additional objectives are to further characterize hydrostratigraphy at the proposed location and monitor groundwater elevations.
Conceptual Model	The proposed location for well 600C-004-GW was chosen to provide for continued groundwater characterization of the alluvial aquifer adjacent to abandoned well PL-3 and between existing multi-port wells PL-6 and PL-8 (Figure 2). The well is envisioned to be located approximately 20 feet (ft) northwest of wells PL-3 to minimize effects from the PFTS injection wells that are located to the south and southeast of the proposed location. In addition to providing analytical data for WSTF contaminants of concern, the well will also provide water level data that will be used to interpret PFTS plume capture effectiveness. Information collected from the replacement well will also be incorporated into the WSTF conceptual groundwater model. Well PL-3 is located approximately 20 ft southeast of the proposed 600C-004-GW location and comprising of a single monitoring zone from 453.4 to 463.8 ft bgs. Well PL-3 was completed entirely in Santa Fe Group alluvium, which is generally characterized as an unconsolidated to semi-consolidated poorly to moderately sorted pebbly polygenetic conglomerate. Limestone and igneous clasts in the conglomerate originate from the San Andres Mountains that are located to the east of WSTF.

Conceptual Model (cont.)	Interbedded siltstone and clay layers are also present, and likely represent fine grain sediments of the distal portion of buried coalescent alluvial fan deposits. No confirmed detections of WSTF groundwater contaminants have occurred at this location. The proposed monitoring well will replace PL-3 as well as supplement existing sentinel wells located in the west-southwest Plume Front Area. The proposed 600C-004-GW location is west of the Western Boundary Fault Zone, which is an area of sub-parallel half-graben step faults where Tertiary volcanic bedrock is offset to a depth of over 2,000 ft into the southern JDMB. The well will be completed in the basin fill Tertiary to Quaternary Santa Fe Group alluvium and is expected to have similar lithology to that encountered at the PL-3, PL-6, and PL-8 boreholes. Measured water elevation at wells PL-3, PL-6, and PL-8 indicate depth to water in the area of the proposed 600C-004-GW location is approximately 465 ft bgs. Aquifer conditions at the proposed location are expected to be unconfined to semi-confined in limited areas. The groundwater flow direction in the area is generally west-southwest, assuming there is no significant influence from the PFTS injection wells at the proposed location. The groundwater decline at well PL-3 from end of November 2021 to mid-December 2022 was just shy of 2 ft. Groundwater declines are expected to continue over time in the southern JDMB due to extensive pumping in the basin by other municipal and private entities.
Drilling Approach	NASA will drill and install the monitoring well in accordance with the requirements of Permit Section 5.2 (NMED, 2023, pg. 71). Air rotary casing advance (ARCA) or dual rotary drilling have been selected as the preferred drilling techniques for the proposed well. The diameter of the borehole will be 11 in. Advancement of drive casing with these methods will stabilize the borehole during drilling with no, or only minor, use of polymeric or bentonite additives. A final choice between these methods will occur once a drilling subcontractor has been selected through the competitive procurement process. Air and, as necessary, potable non-chlorinated water will be primarily used to provide circulation within the borehole. All attempts will be made to limit the use of polymeric and bentonite additives within approximately 50 ft of the anticipated top of the aquifer to the total depth of the borehole. However, a National Sanitation Foundation Standard 60-certified polymeric drill foam (or equivalent) may be required to enhance cuttings recovery. Using stiff foam with both polymeric and bentonite additives is not anticipated but may be used if deemed necessary during drilling. Mud rotary drilling would be used in the unlikely event ARCA or dual rotary drilling is unsuccessful in advancing the borehole. This method would also require the installation of a surface casing, which is not required with the ARCA or dual rotary methods. The decision to utilize mud rotary drilling would only occur with the approval of the NMED. No other drilling methods or additives will be used without prior approval from the NMED. **ARCA or Dual Rotary Drilling (Preferred Methods)** Dual rotary drilling uses a drill bit that rotates or hammers while an independent lower rotary drive is used to advance the steel casing through unconsolidated overburden. Cuttings generated at the drill bit are then lifted through the borehole to the surface by compressed air. Polymeric foam or, in extreme cases, bentonite mud may also be used to circulate chips to the surface. The circulation of the compressed air not only removes the cuttings from the borehole, but also helps to cool the drill bit. The ARCA drilling method uses a similar methodology as air rotary drilling, but

Drilling Approach (cont.)	instead hammers a temporary steel casing downhole as the drilling bit advances. This casing when used keeps the borehole open without having to flood it with drilling fluid. The dual rotary drilling method is quite similar to the air rotary casing advance method, but the drive casing is rotated instead of hammered while drilling advances. When using air supplied by an air compressor as the drilling fluid, the air compressor will have an in-line filter system to prevent potential introduction of contaminants, such as entrained residual oils, into the borehole. The filter system will be inspected regularly by the drilling subcontractor to ensure that the system is functioning properly. A cyclone separator or similar air containment/dust-suppression system is typically used to funnel the cuttings to one location instead of allowing the cuttings to discharge uncontrolled from the borehole. Particular attention will be paid to the management of cuttings and dust will be minimized as much as possible with a clean water mist at the cyclone, if necessary. **Mud Rotary Drilling (Contingency Method)** Mud rotary is a standard drilling method used when encountering challenging subsurface lithologies, however this method can present the challenge of removing from the formation after drilling. Conventional mud rotary drilling circulates drilling mud down through the drill pipe, which is then returned back up the borehole. Reverse mud rotary drilling circulates mud down the borehole and back up through the drill pipe. The drilling mud stabilizes the borehole wall, cools the drill bit, and carries the drill cuttings up to the surface. It is recognized that drilling mud can adversely affect the hydrologic properties and geochemistry of the aquifer. If mud rotary is used, the appropriate mud dispersion agents will be utilized (if required) to aid in the removal of residual drilling mud during borehole/well development. Mud rotary drilling will only be considered as a last resort to advance the borehole and the decision to switch to this method will only occur with the approval of the NMED.
Potential Groundwater Occurrence and Detection	**Perched Groundwater** Perched groundwater is not anticipated at the proposed 600C-004-GW location. However, drilling will be suspended at any depth in the vadose zone where potential saturation is indicated. Screening of damp soil zones will be conducted with a photoionization detector equipped with a 10.6 eV detection lamp to evaluate the presence of volatile organic compounds (VOCs) in the field. Groundwater samples will be collected using a decontaminated non-dedicated bailer, if there is sufficient water at the time present in the borehole. **Regional Groundwater** The top of groundwater is expected to occur at a depth of approximately 420 to 450 ft bgs. However, exact depth to water is uncertain as a result of variability within the alluvial stratigraphy and the possibility for semi-confined conditions. Methods for groundwater detection may include drilling observations, water level measurements, borehole video, or borehole geophysics, if possible. The first identification of groundwater will likely be most apparent if the casing advance drilling method without liquid drilling fluids can be successfully utilized to install the borehole.

Lithological Sampling	Lithological samples will be collected from the cyclone discharge at the drilling rig on 10-ft centers, at a minimum. Chip samples will be archived in chip trays for future reference.
Groundwater Screening and Characterization Sampling	The aquifer at the proposed 600C-004-GW location is expected to be outside the projected WSTF groundwater contaminant plume. For verification purposes and investigation-derived waste (IDW) characterization, groundwater screening samples will be attempted during drilling immediately upon intercepting the water table if possible. Chemical analytical results from screening samples collected will be used to support the identification of potential monitoring zones, as applicable, and waste characterization activities. Screening samples will be analyzed for VOCs by the current revision of SW-846 Method 8260, semi-volatile organic compounds (SVOCs) by the current revision of SW-846 Method 8270C, and N-nitrosodimethylamine (NDMA) by Modified EPA Method 607M or an acceptable low-level analytical method. Groundwater samples will be collected, if possible, utilizing a decontaminated non-dedicated bailer. If a bailer is not feasible, grab samples may be attempted through the cyclone at the surface discharge point. All samples will be managed in accordance with the WSTF GMP (NASA, 2022b, pp. 36-38). Following well development and sampling system installation, groundwater characterization samples will be collected from the completed well. Samples will be collected for the analysis of VOCs by the current revision of SW-846 Method 8260, SVOCs by the current revision of SW-846 Method 8270C, NDMA by Modified EPA Method 607M, or WSTF’s current low-level analytical method, and a variety of metals by the most effective laboratory-selected analytical method. Samples will be collected and managed in accordance with the WSTF GMP (NASA, 2022b).
Geophysical Logging	The use of drive casing with ARCA and dual rotary drilling methods will preclude the use of geophysical logging in the 600C-004-GW borehole. Geophysical logging may take place if the borehole is deemed competent enough to remain open with the drive casing removed, but this is not anticipated. If geophysical logging is performed, a complete suite of open borehole geophysical logs would be attempted as a single event to aid in the selection of a potential monitoring zone. Open borehole logging would be performed by a qualified geophysical subcontractor, and would likely include gamma, neutron porosity, formation resistivity, spontaneous potential logs, and caliper logs/borehole deviation logs.
Well Completion	The well will be constructed in accordance with Permit Section 5.2 (NMED, 2023, pg. 71) with nominal 5-in. Schedule 80 PVC casing and screen. A single monitoring zone is planned for this well installation. The screened interval will be placed as proximal to the water table as possible while ensuring that the zone will remain saturated to provide groundwater for sampling for at least 10 years. A 10-foot length of 0.020-in. slotted Schedule 80 PVC screen will be positioned at a depth indicated as a favorable monitoring zone in accordance with field screening of borehole lithology and borehole geophysical logs, if performed. The annular seal for the screened sampling zones will be comprised of bentonite chips or pellets. A proposed well construction configuration is presented in Figure 3 and is subject to change dependent on conditions encountered in the field.

Well Completion (cont.)	Annular materials will be emplaced using a 1 to 2 in. tremie pipe. A 10/20 silica sand filter pack will be placed to a height of 2 ft above and below each monitoring screen. Three feet of fine silica sand, such as 6/9 or similar, will be used to grade from the sand pack to a 15 ft bentonite seal composed of hydrated bentonite chips or pellets. Intervals between the individual bentonite seals will be comprised of bentonite grout with at least 20% solids. The upper 10 ft of the borehole and well pad will be completed with Type I/II Portland cement. Figure 3 provides a diagram of the preliminary well design with annular materials.
Well Development	The well will be developed in accordance with the requirements of Section 5.2 of the Permit (NMED, 2023, pg. 71). Drilling contractor personnel will operate equipment used to develop the well under the supervision of contractor environmental organization personnel. It is anticipated that initial development will consist of mechanical bailing, swabbing, and pumping using a submersible pump. During development activities, Environmental contractor personnel will sample and monitor discharged development water for parameters that will include pH, specific conductance (conductivity), temperature, and turbidity. Well development will be considered complete when measured water quality parameters are relatively stable (varies less than 10%) and turbidity is below 5 nephelometric turbidity units. The screened interval will be developed to ensure that the well will yield a representative groundwater sample from that depth of the formation. Following well development, a purgeable low-flow conventional sampling system will be installed (Figure 3).
Hydraulic Testing and Groundwater Sampling	Hydraulic testing will be considered during the development of the well. Additional information such as drawdown and specific capacity will be recorded if this testing is conducted. Groundwater sampling following installation and development of the well will be performed using the installed conventional groundwater sampling system. Groundwater samples will be collected and managed as described in the WSTF GMP (NASA, 2022, pg. 34-38).
Investigation-Derived Waste Characterization and Management	In accordance with the NASA WSTF Hazardous Waste Permit, Section 4.3.10 (NMED, 2023), a discussion of IDW generated is provided in this work plan. All IDW will be properly managed and disposed of in accordance with NASA procedures and state and federal regulations. IDW will be characterized and managed in accordance with the Hazardous Waste Permit (Permit, 2023). The remainder of this section summarizes IDW waste characterization and management for the 600C-004-GW project. The types of potential IDW anticipated during drilling and installation of the multi-level monitoring wells include: • Drill cuttings – unsaturated and saturated rock fragments generated during the drilling process. Unsaturated cuttings are defined as soil cuttings generated from the vadose zone that have not come in contact with groundwater. Saturated cuttings are defined as soil cuttings generated below the water table that have come in contact with the potentially contaminated groundwater. • Drilling fluids generated during drilling from the vadose zone above the water table – impacted with only potable water.

Investigation-Derived Waste Characterization and Management (cont.)	• Drilling fluids from below the water table – potentially impacted with groundwater plume contaminants. • Groundwater produced during well development. • Contact waste including used sampling equipment, personal protective equipment (PPE), plastic sheeting, and other debris that has contacted potentially contaminated soil or fluids. • Decontamination fluids – i.e., water and soap solutions used to wash and decontaminate equipment. IDW generated prior to reaching groundwater will be managed as solid waste. At the time that IDW is generated (removed from the ground, comes in contact, etc.), it will be managed separately in accordance with WSTF waste management procedures that incorporate 40 CFR 262.34. Because there is the slight potential that groundwater contaminant concentrations may exceed clean up levels, IDW generated after reaching groundwater will be managed as hazardous waste, pending final analysis. Once groundwater is encountered during drilling, cuttings and associated IDW will be segregated into a separate lined earthen pit. Grab samples will be collected at the water table and every 100 ft until the borehole is terminated. Fluid and cutting samples will be analyzed for the primary WSTF COCs for hazardous waste characterization as indicated previously in this work plan. Per 40 CFR § 264.1080(b)(5) subpart CC, air emission standards do not apply to waste management units that are used solely for on-site storage of hazardous waste that is placed in the unit as a result of implementing remedial activities required under the corrective action authorities of Resource Conservation and Recovery Act (RCRA). Final characterization and hazardous waste determinations of these waste streams will follow procedures outlined in Appendix B, Section 2.0, of the previously approved work plan (NASA, 2010). To perform a “no longer contained-in” determination for listed hazardous wastes, the chemical analytical data generated from borehole composite grab sampling may be compared to the Applicability of Treatment Standards 40 CFR Part 268.40 and the NMED Soil Screening Levels (SSLs; 2022c) to determine whether the material poses an unacceptable risk. If contaminant concentrations are found to not pose an unacceptable risk, then NMED may determine that the wastes can be managed as no longer containing listed wastes. A separate letter from NMED would be required to document such a determination. To evaluate the toxicity characteristic, the total concentration of each reported constituent may be divided by 20 to determine the maximum theoretical leachate concentration that could result from performing the Toxicity Characteristic Leaching Procedure (TCLP – EPA Method 1311). These concentrations will be compared to the values listed in 40 CFR Part 261.24 Subpart C (Table 1) to determine if the waste exhibits the characteristic of toxicity. For IDW that is characterized as hazardous waste, land disposal notifications, disposal facility profiles, and hazardous waste manifests will be completed as required. Hazardous waste will be transported for treatment and disposal at a permitted RCRA Treatment, Storage, and Disposal Facility. Wastewater generated during the investigation will be managed at the Mid-plume Interception and

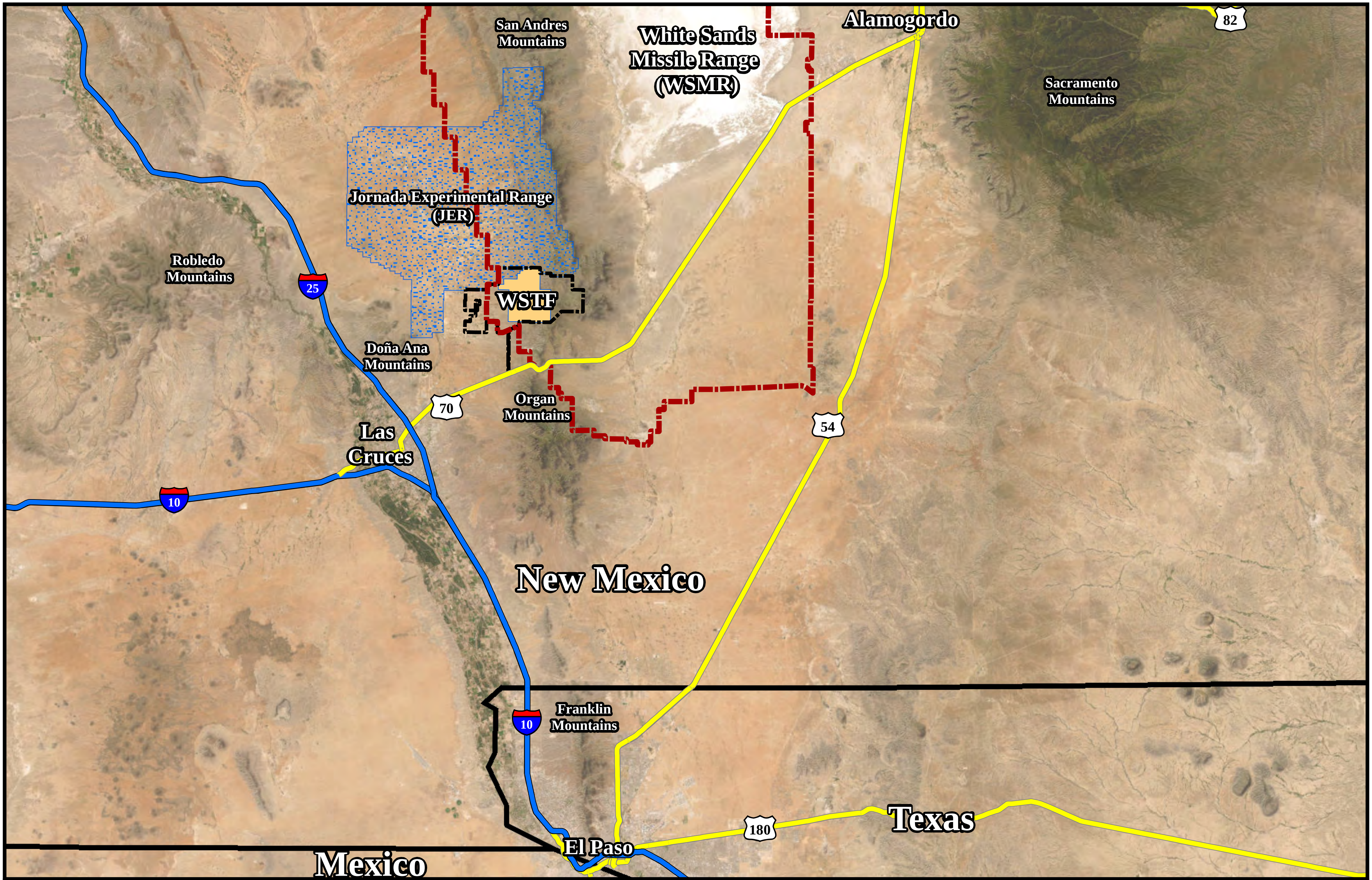
Investigation-Derived Waste Characterization and Management (cont.)	Treatment System (MPITS). If that system is not capable of receiving the waste, it will be disposed of at a permitted RCRA Treatment, Storage, and Disposal Facility. Any IDW drill cuttings that do not meet the definition of a hazardous waste and do not contain hazardous constituents at concentrations above soil screening levels will be spread on the ground near the well installation. In the event that IDW drill cuttings do not meet the definition of a hazardous waste, but does contain hazardous constituents above industrial SSLs, then NASA will discuss disposition options with NMED. Contact waste and IDW debris that is determined to be non-hazardous waste will be disposed of as 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. Depending on the results of waste characterization, development water will be discharged at the well site or containerized for proper disposal. If chemical analytical data generated from grab samples of saturated fluids/cuttings confirm they are not hazardous waste, it will be concluded that the groundwater is not contaminated with WSTF COCs. If this determination is made, NASA expects to discharge development water from monitoring well to grade or the earthen pit at the well site. NASA will submit a Notice of Intent to the NMED Ground Water Quality Bureau in accordance with 20.6.2 NMAC before discharging any development water at the well site. If initial chemical analytical data result in the characterization of drilling fluids and borehole cuttings as hazardous waste, it will be concluded that the groundwater is contaminated. Development water will be collected at the drilling location in temporary (less than 90 day) containers. Temporary storage requirements are based on the target development volume and may consist of portable small or large fluid storage tanks. Temporary containers will be managed in accordance with applicable regulations. Contained development water will be transported to the MPITS for disposal within 90 days of the start of accumulation in temporary containers.
Schedule	It is anticipated that drilling of proposed monitoring well 600C-004-GW will commence following NMED approval of this DWP. The anticipated schedule for planning and installation is as follows: • Eight to 10 weeks for project and procurement planning and well site preparation. • Six to eight weeks for drilling contractor scheduling, contractor mobilization, borehole installation, and multi-screen conventional well installation fieldwork. • Six to eight weeks for well development fieldwork and conventional monitoring system installation. • Eight to 12 weeks for groundwater sampling, data validation and verification, and preparation of the well completion report. The well completion report will be submitted to the NMED in accordance with Section 5.4 of the Permit (NMED, 2023, pg. 79-80). Additional time may be required during drilling if unanticipated issues slow drilling or if swelling clays are encountered. Groundwater monitoring conducted after

Schedule (cont.)	installation of well 600C-004-GW will be implemented in accordance with the WSTF GMP (NASA, 2022b).
References	Ground and Surface Water Protection, Water Quality Control Commission, 20.6.2 NMAC (12-1-95). NASA Johnson Space Center White Sands Test Facility. (2010, June 24). *NASA WSTF Monitoring Well Work Plan*. Las Cruces, NM. NASA Johnson Space Center White Sands Test Facility. (2022, April 29). *WSTF Groundwater Monitoring Plan (GMP) update for 2022.* Las Cruces, NM. NMED Hazardous Waste Bureau. (2011, February 23). *Notice of Approval with Modifications Groundwater Monitoring Well Work Plan*. Santa Fe, NM. NMED Hazardous Waste Bureau. (2022a, February 21). *Approval with Modifications Periodic Monitoring Report Second Quarter 2021.* Santa Fe, NM. NMED Hazardous Waste Bureau. (2022b, October 31). *Approval with Modifications White Sands Test Facility Groundwater Monitoring Plan*. Santa Fe, NM. NMED Hazardous Waste Bureau. (2022c, November). *Risk Assessment Guidance for Site Investigations and Remediation Volume I Soil Screening Guidance for Human Health Risk Assessments*. Santa Fe, NM. NMED Hazardous Waste Bureau. (2023, April 27). *Hazardous Waste Permit No. NM8800019434*. Santa Fe, NM. Well Drilling – Non-Artesian (Unconfined) Well Requirements, Office of the State Engineer, 19.27.4.30 NMAC (6-30-17).

Figures

Figure 1 **WSTF Location Map**

(SEE NEXT PAGE)



WSTF Location Map

NASA Johnson Space Center
White Sands Test Facility
Las Cruces, New Mexico

Coordinate System:
NAD 1983 StatePlane New Mexico Central FIPS 3002 Feet

G:\Projects\environmental\PMR\2023\1stQuarter

- WSMR Boundary
- WSTF Boundary
- 🟧 WSTF Industrial Area
- ▨ Jornada Experimental Range (JER)

1 in = 12 miles

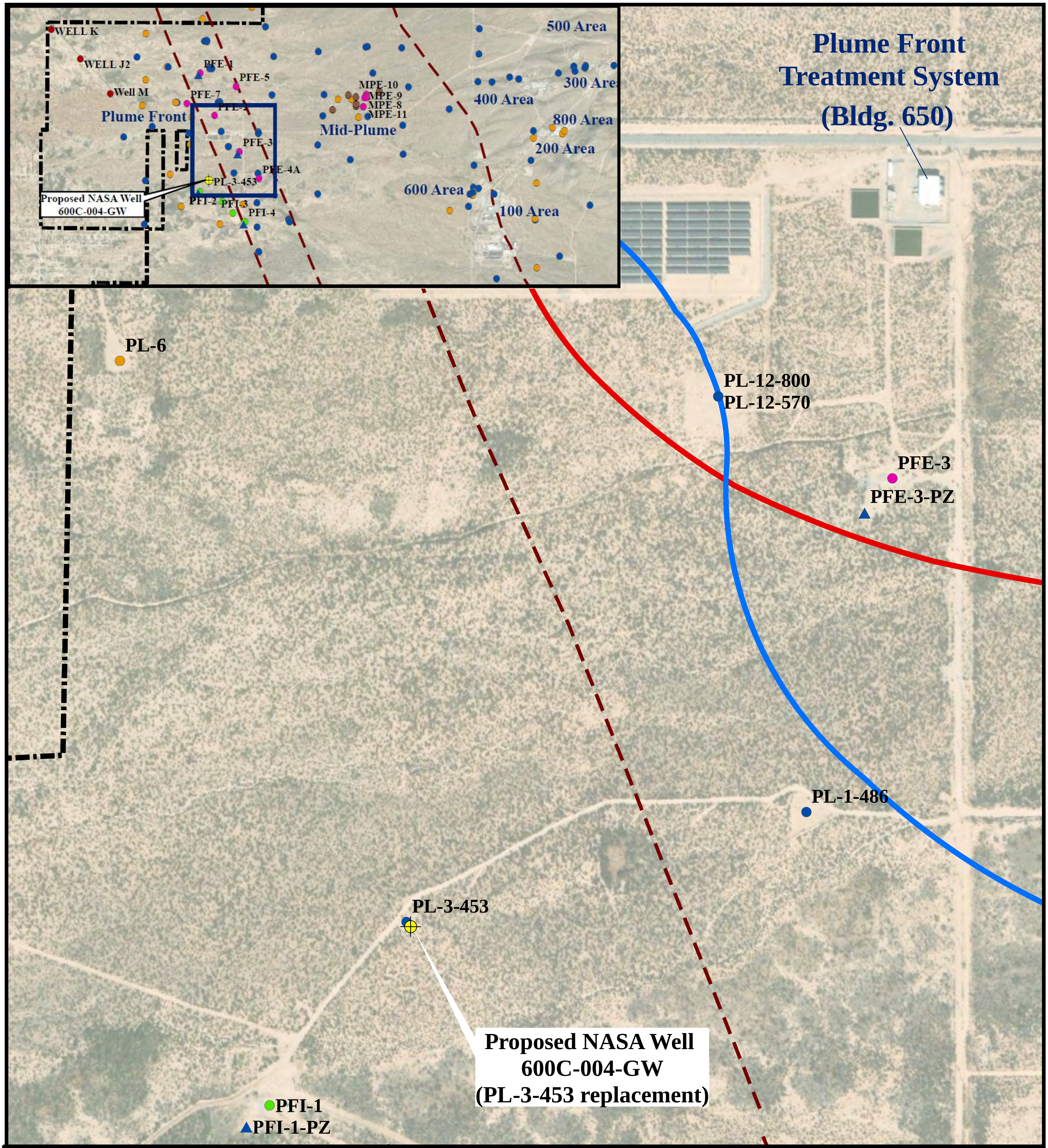
Miles 0 6 12 24

N W E S

April 2023

Figure 2 **Proposed Location for 600C-004-GW**

(SEE NEXT PAGE)



Proposed NASA Well
600C-004-GW
(PL-3-453 replacement)

PL-3-453 Well Replacement Proposed Location in Relation to NDMA and TCE Plumes

NASA Johnson Space Center
White Sands Test Facility Las Cruces, New Mexico

Coordinate System:
NAD 1983 HARN StatePlane New Mexico Central FIPS 3002 Feet

G:\Projects\environmental\Well_Replacement

- ⊕ Proposed Well
- ● Multiport Well
- ● Conventional Well
- ● Extraction Well
- ● Injection Well
- ▲ Piezometer
- ● Exploration Well
- ● Production Well
- — NDMA Cleanup Level (1.1 ng/L)
- — TCE Cleanup Level (4.9 ug/L)
- - - Western Boundary Fault Zone
- -·- WSTF Boundary

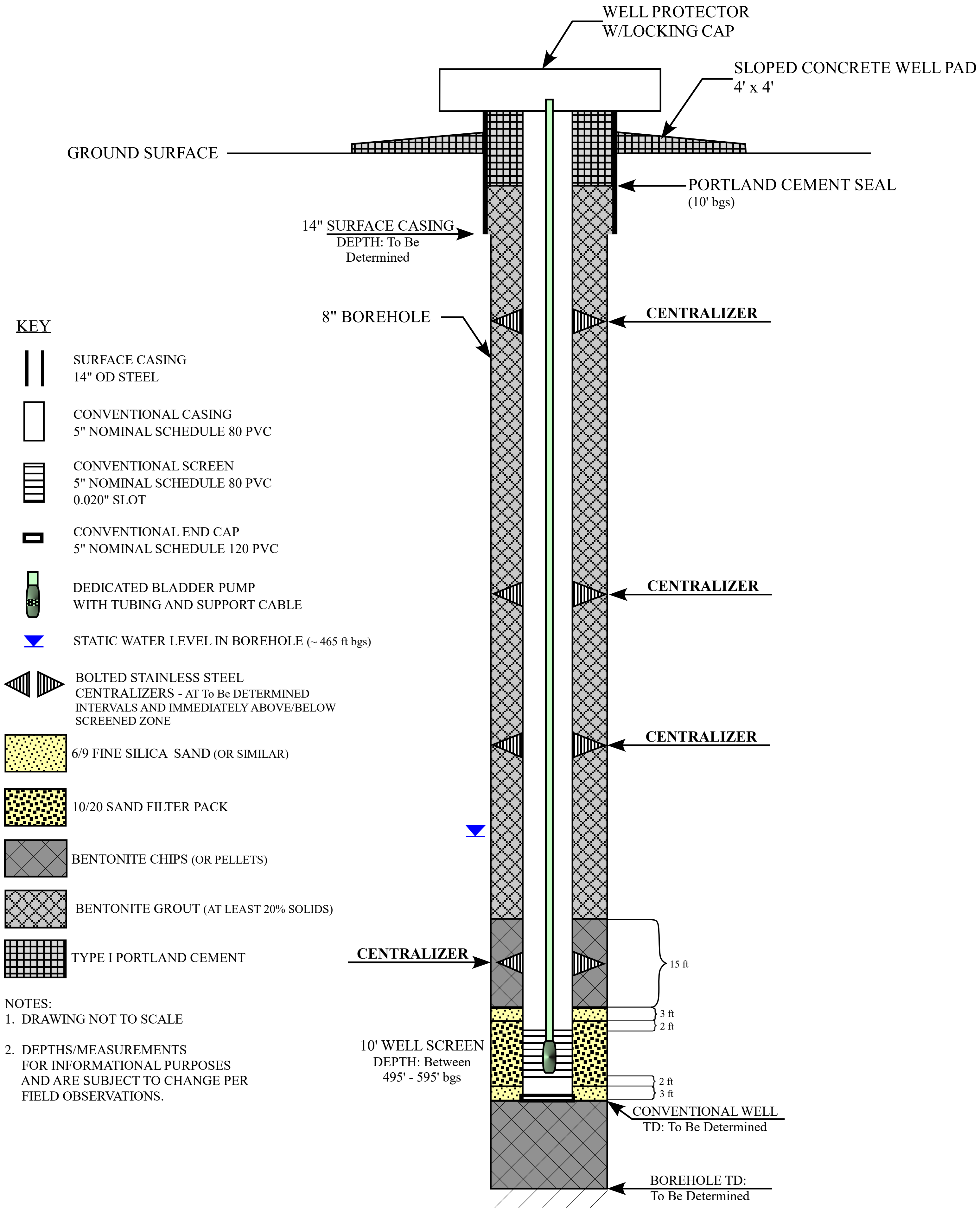
N
W E
S

1 inch = 400 feet
April 2023

Ft
0 100 200 400

Figure 3 600C-004-GW Well Design

(SEE NEXT PAGE)



NOTES:

1. DRAWING NOT TO SCALE
2. DEPTHS/MEASUREMENTS FOR INFORMATIONAL PURPOSES AND ARE SUBJECT TO CHANGE PER FIELD OBSERVATIONS.

600C-004-GW WELL DESIGN: CONVENTIONAL

Figure 4 **PL-3-453 Well Completion Diagram**

(SEE NEXT PAGE)

NASA
JSC - White Sands Test Facility
Las Cruces, New Mexico, USA

WELL COMPLETION DIAGRAM

CONVENTIONAL MONITORING

Location ID: **PL-3-453** Site ID: **NASA-WSTF, Doña Ana County, NM**

Township and Range: **NW 1/4 NW 1/4 SE 1/4 Sec 5, T21S, R3E**
NM State Plane Coordinates (NAD 83): **167594.58N 461816.61E**
Elevation (Brass Cap): **1371.24 m AMSL**
Elevation (Top of Casing): **1371.89 m AMSL**
Drilling Contractor: **Larjon Drilling Company**
Driller: **T. Crawford**
Total Depth of Borehole (bgs): **497' (151.5 m)**
Borehole Diameter: **12 1/4" 0-89'; reamed 16" to 85'; 9 7/8" 89-497'**
Depth to Bedrock (bgs): **Not Reached**
Depth to Groundwater: **425.3' (129.63 m) bgs (11/1/88)**
Total Depth Surface Casing (bgs): **87' (26.5 m)**
Diameter and Type Surface Casing: **Nominal 10" Carbon Steel**

Date(s) Well Installed: **11/1/88 - 11/4/88**
Date(s) Well Developed: **11/7/88 (bail and pump)**
Field Representative(s):**J. Kaszuba**
Total Depth Well Casing (bgs): **469.10' (142.98 m)**
Type of Casing: **Stainless Steel**
Diameter Well Casing: **Nominal 4" (~4.5" OD; ~3.75" ID)**
Casing Schedule: **Stainless Steel SCD 5 to 383.44'; SCD 10 to 469.10'**
Screened Zone (bgs): **453.44' - 463.82' (138.21 - 141.37 m)**
Comments: **bgs = below ground surface TOC = Top of Casing**
Surface Casing Stick-Up = ~1.74' (0.53 m)
AMSL = Above Mean Sea Level SCD = Schedule

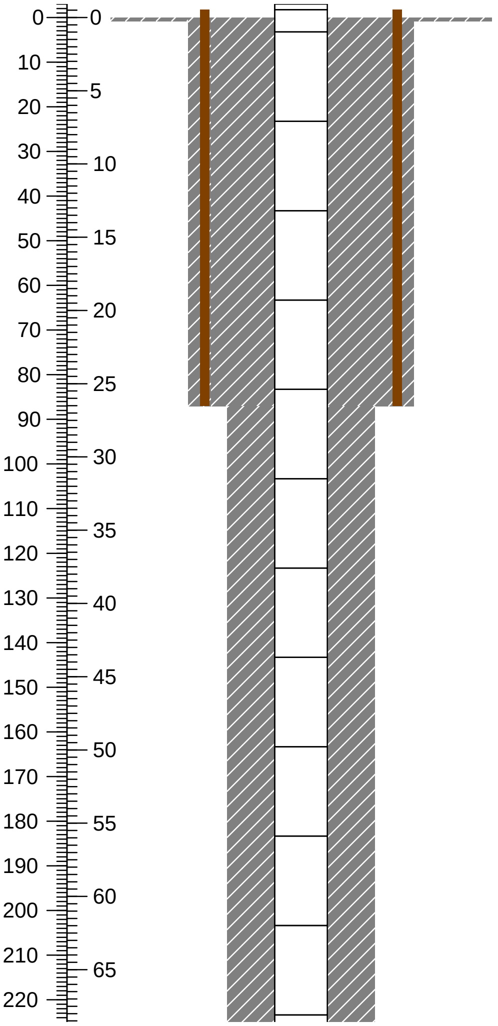
Casing Explanation:

- ▮ Surface Casing **Nominal 10" Carbon Steel**
- ▯ Conventional Casing **Nominal 4" PVC**
- ▯ Conventional Casing **Nominal 4" Stainless Steel**
- ▤ Conventional Screen **Nominal 4" Stainless Steel 0.020"-Slot (Extra Strength)**
- ▩ Conventional End Cap **Nominal 4" Stainless Steel**
- ◀▶ **Welded Stainless Steel Centralizers**
- ▼ Water Table

Annular Materials Explanation:

- ▨ Cement
- ▨ Bentonite (Grout Well DF)
- ▥ Bentonite Seal
- ▥ 10/20 Sand/ Bentonite Mix
- ⬡ Slough
- ▦ 8/20-16/40 Sand Mix
- ▦ 4/8 Sand
- ▦ 6/9 Sand
- ▦ 8/12 Sand
- ▦ 8/20 Sand
- ▦ 10/20 Sand
- ▦ 16/40 Sand
- ▦ 20/40 Sand
- ▦ 30/70 Sand

Feet/Meters



Well Descriptions
All depths listed are bgs (unless noted)

Conventional Well Stick-Up = 3.49' (1.06 m) at installation. 2.12' (0.65 m) final. Stick-up consists of 1.75' well casing stick-up plus a 1.74' riser.

Surface Casing Stick-Up = ~1.74' (0.53 m)

Well completed with ~3' x ~3' cement pad, barrier posts, and locking steel well cap surrounding the casing at ground surface

Nominal 10" Steel Surface Casing Depth = 87' (26.5 m)

NOTE: Exact order of casing joints are inferred. Casing was tallied but order not specified. Adaptors between schedule 5/10 were not listed.

Annular/Borehole Descriptions
All depths listed are bgs

Top of Neat Cement (with 5% bentonite) = 0'

Santa Fe Group Alluvium from surface to 497' (151.5 m total depth)

16" Borehole TD = 85' (25.9 m). Pilot hole: 12 1/4" 0-89'

NOTE: Sounded annular depths are corrected for discovered sounder error.

Casing Explanation:

▮ Surface Casing **Nominal 10" Carbon Steel**

▯ Conventional Casing **Nominal 4" PVC**

▯ Conventional Casing **Nominal 4" Stainless Steel**

▤ Conventional Screen **Nominal 4" Stainless Steel 0.020"-Slot (Extra Strength)**

▩ Conventional End Cap **Nominal 4" Stainless Steel**

◀ ▶ **Welded Stainless Steel Centralizers**

▼ Water Table

Annular Materials Explanation:

▨ Cement

▨ Bentonite (Grout Well DF)

▥ Bentonite Seal

▨ Slough

▩ 1/8 Gravel

▨ 8/20-16/40 Sand Mix

▨ 4/8 Sand

▨ 6/9 Sand

▨ 8/12 Sand

▨ 8/20 Sand

▨ 10/20 Sand

▨ 16/40 Sand

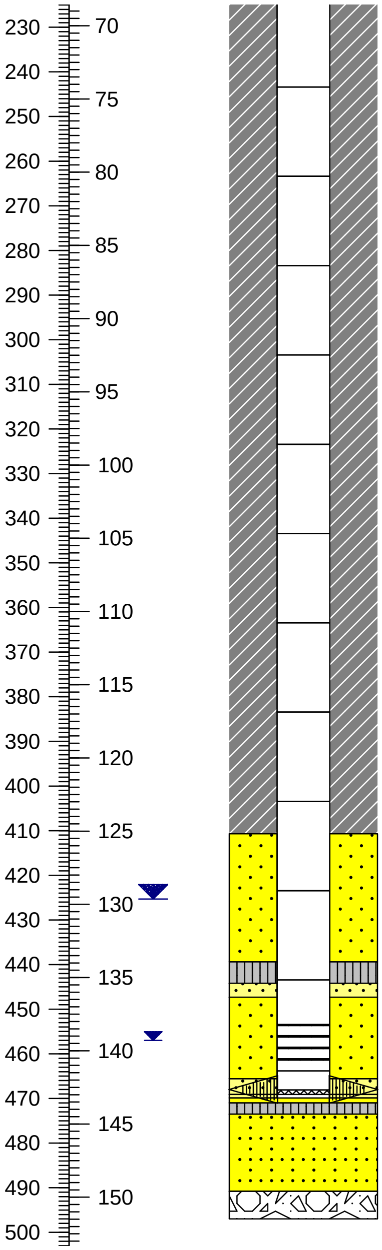
▨ 20/40 Sand

▨ 30/70 Sand

Feet/Meters

Well Descriptions
All depths listed are bgs (unless noted)

Annular/Borehole Descriptions
All depths listed are bgs



Well Descriptions

All Casing Above 383.44' (116.87 m) = Schedule 5 Stainless Steel

All Casing and Screen Below 383.44' (116.87 m) = Schedule 10 Stainless Steel

Water Table = 425.3' bgs (129.63 m); measured 11/1/88 before casing installation

Top of Screen (Extra Strength) = 453.44' (138.21 m)

First Occurrence of Groundwater During Drilling = Observed 457' (139.3 m), but could be earlier

Bottom Screen (Extra Strength) = 463.82' (141.37 m)

Three or four steel plates (centralizers) welded to casing at ~468' (142.65 m)

Sump consists of 5' blank riser and end cap

Nominal 4" Schedule 5&10 Stainless Steel Casing TD = 469.10' (142.98 m)

Annular/Borehole Descriptions

Top of Upper 8/20 Silica Sand = 410.7' (125.18 m)

Volcanic Alluvium Depth Not Noted

Top of Upper Bentonite Seal = ~439.4' (133.93 m). Estimated depth, not measured

Top of Upper 16/40 Silica Sand = 444.2' (135.39 m)

Top of 8/20 Silica Sand = 447.3' (136.34 m)

Top of Lower 16/40 Silica Sand = 465.6' (141.91 m)

Top of 8/20 Silica Sand = 469.9' (143.23 m)

Top of Lower Bentonite Seal = 471.0' (143.56 m)

Top of 8/20 & 16/40 Silica Sand Mix (~1:1 ratio) = 473.5' (144.32 m)

Top of Slough = 490.8' (149.60 m; measured 11/1/88, corrected for sounder error)

9 7/8" Borehole TD = 497' (151.5 m)