Characterization and Potential Remediation Approaches for Vadose Zone Contamination at Hanford 241-SX Tank Farm – 13235

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ABSTRACT

Unplanned releases of radioactive and hazardous wastes have occurred at the 241-SX Tank Farm on the U.S. Department of Energy Hanford Site in southeast Washington State. Interim and long-term mitigation efforts are currently under evaluation for 241-SX Tank Farm.
Two contiguous interim surface barriers have been designed for deployment at 241-SX Tank Farm to reduce future moisture infiltration; however, construction of the surface barriers has been deferred to allow testing of alternative technologies for soil moisture reduction and possibly contaminant source term reduction. Previous tests performed by other organizations at the Hanford Site have demonstrated that: vadose zone desiccation using large diameter (greater than 4 inch) boreholes is feasible; under certain circumstances, mobile contaminants may be removed in addition to water vapor; and small diameter (approximately 2 inch) boreholes (such as those placed by the direct push hydraulic hammer) can be used to perform vapor extractions. Evaluation of the previous work combined with laboratory test results have led to the design of a field proof-of-principle test to remove water and possibly mobile contaminants at greater depths, using small boreholes placed with the direct push unit.

INTRODUCTION

The 241-SX Tank Farm in the Hanford 200 West Area is comprised of fifteen 75-ft diameter single-shell tanks, each one with a nominal 1-million-gallon storage capacity. Historic losses of waste from the tanks and associated equipment are believed to have released on the order of 100,000 gallons of waste into the soil.[1] Soil characterization efforts (characterization boreholes, direct push, and electrical resistivity) located one or more large plumes of Tc-99 and nitrate in the Hanford sands between the bottom of the tanks (50 feet below ground surface) and the less permeable Cold Creek Unit (approximately 130 feet below ground surface). The groundwater is approximately 220 feet below ground surface. The body of characterization data collected to date indicates that the Cold Creek Unit may be acting as a natural sub-surface barrier, slowing the vertical migration of mobile contaminants, and increasing the horizontal spread. Soil samples taken above the Cold Creek Unit have shown higher moisture content as well as high concentrations of several mobile contaminants.

Interim and long-term remediation measures are currently under evaluation for 241-SX Tank Farm. Two contiguous interim surface barriers have been designed to reduce future moisture infiltration. Construction of the surface barriers has been deferred to allow testing of potential technologies to reduce soil moisture and possibly remove some contaminants. Previous tests performed by other organizations at the Hanford Site have demonstrated that: vadose zone desiccation using large diameter (greater than 4 inch) boreholes is feasible; under certain circumstances, mobile contaminants may be mobilized and removed in addition to water vapor;

and small diameter (approximately 2 inch) boreholes (such as those placed by the direct push hydraulic hammer) can be used to perform vapor extractions. Evaluation of the previous work combined with laboratory test results have led to the design of a field proof-of-principle test to remove water and possibly mobile contaminants at greater depths, using small boreholes placed with the direct push unit. Monitoring and evaluation of the test will include deployment of electrical resistivity tomography in an effort to observe the reduction in moisture content and conductive plume constituents, such as nitrates, in the target remediation zone.

Characterization of the soil in and around the other tank farms in Hanford's 200 West Area has shown a similar pattern of moisture and mobile contamination accumulating over the Cold Creek Unit. The results of the remediation proof-of-principle test will support future planning for interim and final soil remediation measures.

CHARACTERIZATION OF 241-SX TANK FARM SOIL

A Field Investigation Report published in 2002[2] indicated that waste from tanks in the 241-SX Tank Farm have impacted groundwater with Tc-99 concentrations reaching over 80,000 picocuries per liter at the time of the study. The groundwater is approximately 220 feet below ground surface. A Surface Geophysical Exploration survey was conducted in August 2008 to collect and analyze electrical resistivity data to identify and locate low resistivity regions in and around the 241-SX Tank Farm area indicative of potential areas of increased ionic concentrations such as high nitrate or sodium contamination.[3] Figure 1 displays survey results for well-to-well resistivity measurements. Well-to-well measurements provide two-dimensional results only and do not indicate depth. Resistivity anomalies less than 1.5 ohm-meters are shown in red. Resistivity values between 1.5 and 3 ohm-meters are shown in green. Low resistivity is an indicator of increased moisture or increased concentration of electrolytes compared to background conditions. The results of the modeling show lowest resistivity near tanks that have been designated as historically leaking. In particular, these include the tanks in the central to south portion of 241-SX Tank Farm. The low resistivity appears to be centered on tank 241-SX-108.

The resistivity study cited above was used to define locations for additional characterization using a direct-push hydraulic hammer unit to push small diameter (1.75-inch interior diameter) boreholes for logging and sampling. The purpose of the direct push campaign was to determine the potential extent of contamination for proper placement and design of an interim surface barrier. Push locations were selected around the perimeter of the potential plume location. Boreholes were pushed to refusal, usually around 125 to 140 feet below ground surface, when the top of the Cold Creek geologic unit was encountered. Boreholes were logged for gamma and moisture, and several sample depths selected. A second borehole was pushed adjacent to the first to obtain samples. Figure 2 shows the sample locations, and Table I summarizes the results for key mobile contaminants at each location and depth.

Figure 2 displays the direct push soil sampling locations (green circles) combined with the highest nitrate analytical value for each direct push location, as well as an outline of the well-to-well resistivity results. Figure 2 includes nitrate results from two previous investigations, an angled boring completed under tank 241-SX-108 (C3082) and vertical boring completed to the southwest of tank 241-SX-115 (B8809). The highest nitrate value presented in Figure 2 is associated with the angled push investigation (C3082) at approximately 129 feet below ground surface. The sample was obtained under tank 241-SX-108; as such, the symbol is drawn at the location of the sample rather than where the direct push originated. The results of the well-to-well resistivity survey align well with the subsequent soil sampling analytical data, highlighting the region directly surrounding tank 241-SX-108, a tank identified as a known leaker. Table I presents a summary of results for this investigation with moisture content, nitrate concentration, and Tc-99 concentration with depth for each direct push sampling location. Nitrate is regulated as nitrogen in *Washington Administrative Code* Chapter 173-340, "Model Toxics Control Act – Cleanup," with a limit of 9.3 parts per million. Nearly all of the samples associated with the 241-SX Tank Farm investigations have exceeded the 9.3 parts per million *Washington Administrative Code* limit, with the highest concentrations observed between 100 and 140 feet below ground surface. The drinking water standard for Tc-99 is 900 picocuries per liter[1].[4] The observed soil concentrations of Tc-99 are anticipated to lead to groundwater concentrations that exceed the standard.

Evaluation of the soil characterization data led to the conclusion that several waste loss events had contributed to plumes of mobile contaminants in the Hanford sands between the bottom of the tanks (more than 50 feet below ground surface) and the less permeable Cold Creek Unit (approximately 130 feet below ground surface) under the 241-SX Tank Farm. The body of characterization data collected to date indicates that the Cold Creek Unit may be acting as a natural sub-surface barrier, slowing the vertical migration of mobile contaminants and increasing the horizontal spread.

SOIL REMEDIATION TEST APPROACH

Removal of mobile contaminants from the vadose zone could provide a potential method for "hot-spot" remediation of soil contamination in a number of Hanford tank farms. In addition, soil desiccation could potentially be used as an interim measure, in conjunction with or in lieu of interim surface barriers to slow the migration of the mobile contaminants. Additional testing is needed to determine the viability of either of these two techniques using approaches that could be deployed in a Hanford tank farm. Plans to perform field work inside a Hanford tank farm must consider the presence of extensive buried infrastructure and highly contaminated soil, as well as limits concerning the equipment which can be deployed over the buried underground tanks. Therefore, this test has been designed to use tank farm deployable equipment and methods, to ensure the testing represents the actual tank farm environment.

Related Remediation Testing and Modeling

In 2009, the U.S. Department of Energy, Richland Operations Office and its contractor CH2M HILL Plateau Remediation Company performed tests of vadose zone desiccation methods in the 200 East Area, 216-B-17/-19 Cribs at Hanford.[5] The methods employed were similar to standard soil vapor extraction methods, applied to a nominal 4-inch-diameter borehole screened

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[1] U.S. Environmental Protection Agency drinking water standards for radionuclides were derived based on a 4-millirem per year dose standard using maximum permissible concentrations in water specified in National Bureau of Standards Handbook 69 (U.S. Department of Commerce, as amended August 1963).

between approximately 30 and 50 feet below ground surface. These tests demonstrated that under certain conditions, soluble contaminants (including nitrate, technetium, and other cations and anions) were removed from the soil in addition to water. The result was attributed to the high velocity air flow during the test. The flow rate of approximately 390 cubic feet per minute was estimated to provide soil gas velocity exceeding 80 kilometers per hour (50 miles per hour). The presence of significant contamination suggests that the high air flow entrained a mist of pore water droplets in addition to vapor phase water.

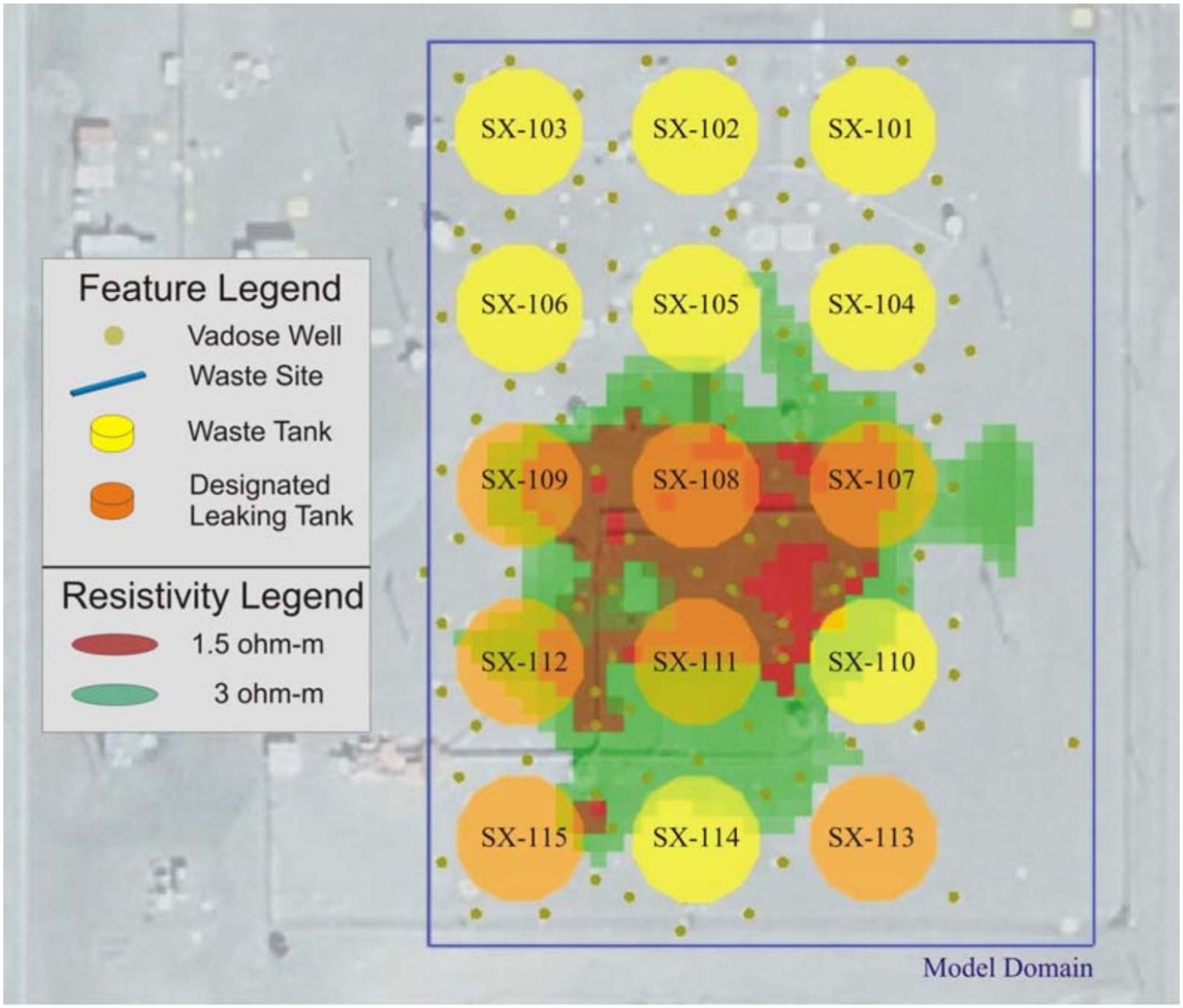
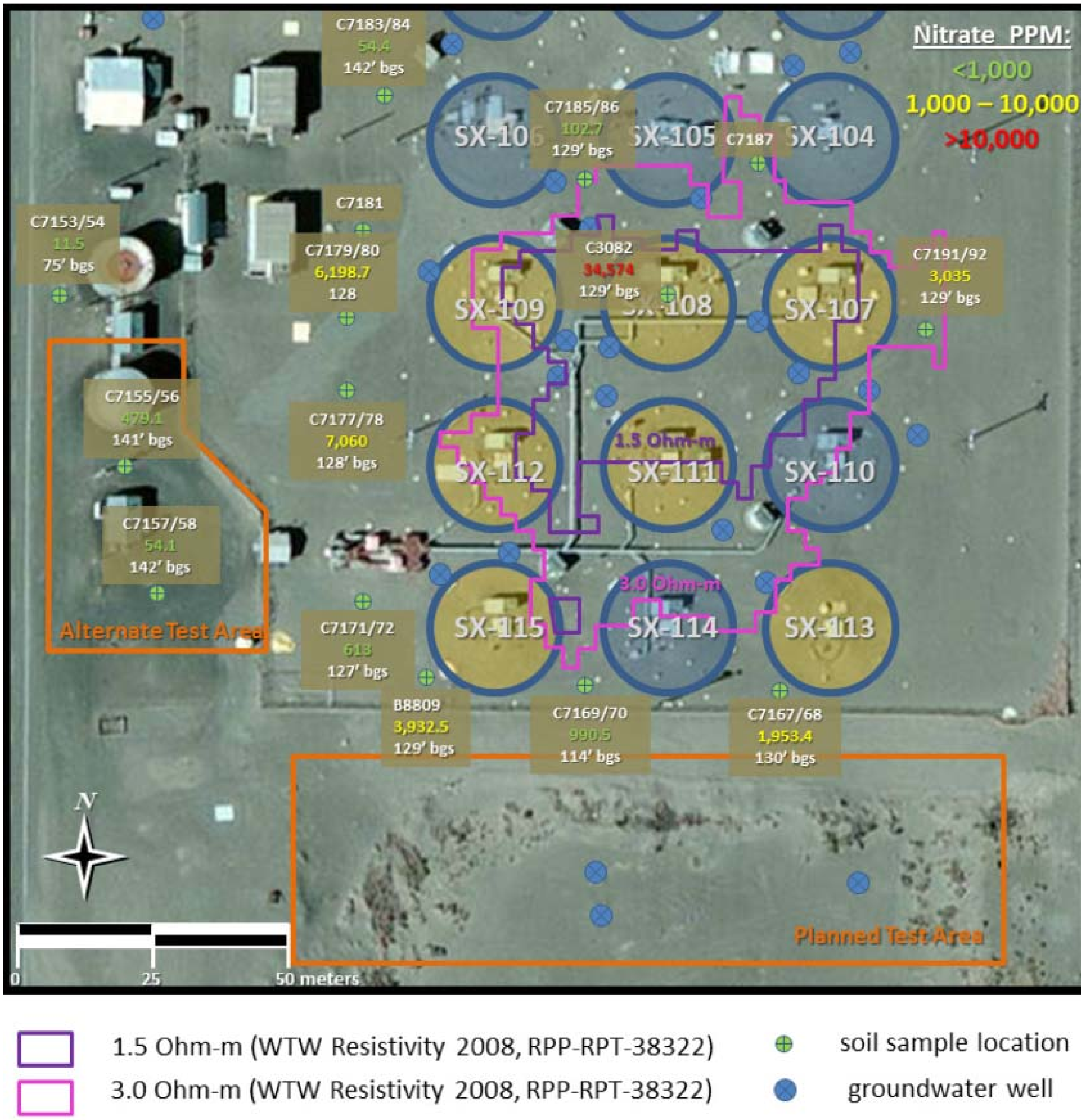


Fig. 1. 241-SX Tank Farm well-to-well resistivity results.



Note: The highest concentration for each boring and associated depth are listed. The WAC limit for nitrate in soil is 9.3 PPM as nitrogen. This map suggests that both investigation areas are well above the WAC limits.

WAC = *Washington Administrative Code* WTW = well-to-well

Fig. 2. 241-SX Tank Farm direct push borehole locations, with maximum analytical nitrate concentrations and resistivity results.

TABLE I. Quick Turnaround Analytical Results of Direct Push Samples

Sample Hole (Logging Hole in Parentheses)	Depth (feet below ground surface)	Sample ID #	%H_2O (H_2O/g soil)	Nitrate (ug/g)	Tc-99 (pCi/g)
C7192 (C7191) (~35 ft southeast of tank 241-SX-107)	100-102	B20750	15.81	176.9	29.18
	128-130	B20752	18.34	3,035.0	705.93
	140-142	B20754	17.64	268.5	82.75
C7178 (C7177) (~75 ft southwest of tank 241-SX-109)	89-91	B20708	2.8	1,494	290
	127-129	B20710	17.6	7,060	1,561
	149-151	B20712	11	35.8	0.1
C7172 (C7171) (~40 ft northwest of tank 241-SX-115)	46-48	B206Y1	13.84	5.51	<0.0656 (U)
	75.5-77.5	B206Y3	14.28	51.8 (E)	1.02
	97.5-99.5	B206Y5	18.96	266	50.3
	126-128	B20H52	20.33	613	115
C7180 (C7179) (50 ft west of tank 241-SX-109)	93-95	B20714	5.54	215.7	36.89
	104-106	B20716	7.77	1,767.4	270.87
	127-129	B20718	12.75	6,198.7	1,089.53
	152-154	B20H67	15.31	36.1	1.13
C7170 (C7169) (~20 ft southeast of tank 241-SX-115)	81.5-83.5	B206X4	2.75	174	14.3
	113-115	B206X6	5.22	990	76.8
	133-135	B206X8	15.69	27.0	0.53
	150-152	B20H47	18.67	41.2	0.0296 (J)
C7158 (C7157) (150 ft west of tank 241-SX-115)	87-89	B206R8	2.16	2.1	<0.0711 (U)
	124-126	B206T0	14.08	17.3	0.456 (J)
	141-143	B206T2	13.89	54.1	4.01
C7168 (C7167) (~10 ft southwest of tank 241-SX-113)	81-83	B206W8	10.86	958	65.8
	129-131	B206X0	13.94	1.95E+03	136.95
	145-147	B206X2	17.03	66.2	2.48
C7184 (C7183) (~35 ft west of tank 241-SX-106)	83-85	B20727	4.56	8.1	<0.07 (U)
	104-106	B20728	12.37	102	8.53
	128-130	B20730	11.66	20.3	0.23 (J)
	141-143	B20VK6	19.36	54.4	<0.09 (U)
C7186 (C7185) (50 ft northwest of tank 241-SX-108)	105-107	B20732	9.75	71.2	1.99
	128-130	B20734	18.52	102.7	2.76
	145-147	B20736	12.99	72.6	7.03
C7154 (C7153) (200 ft west of tank 241-SX-109)	74-76	B206P6	16.65	11.5	<0.09
	106-108	B206P8	11.58	8.8	<0.08
C7156 (C7155) (100 ft west of tank 241-SX-112)	92-94	B206R2	12.23	8.9	<0.08
	126-128	B206R4	17.92	165.2	31.9
	140-142	B206R6	21.13	479.1 (E)	92.4

J – Result < Quantification Limit >Minimum Detection Limit   E – Exceeded the calibration range   U – not detected

The above test was performed using large diameter boreholes. Use of the small diameter direct push boreholes is the preferred approach for tank farm soil remediation applications. Use of the small diameter direct push borehole method has been chosen for two primary reasons.

1. The direct push approach penetrates the soil by moving the unconsolidated solids aside, without bringing any soil to the surface. The less mobile waste contaminants from tank waste system leaks (notably cesium and strontium) tend to be concentrated near the source of the leak. Any soil excavation actions would involve contact with very highly contaminated soil. Use of the direct push prevents handling of this contaminated soil, reducing exposure and waste generation.

2. The smaller diameter hole can be placed among the infrastructure more easily than a large diameter borehole. In addition to the tanks, 241-SX Tank Farm contains extensive infrastructure, including miles of buried pipelines. The hydraulic hammer unit is mounted on a back-hoe with a much smaller surface footprint than other drill rigs, making it a better choice for maneuvering among the aboveground structures in the farm.

A test of soil vapor extraction using small diameter direct push boreholes was performed by the CH2M HILL Plateau Remediation Company to extract carbon tetrachloride from the vadose zone in the Hanford 200 West Area.[6] In this test, carbon tetrachloride was successfully extracted from boreholes with an exterior diameter of approximately 1.5 inch, screened between approximately 58 and 64 feet below ground surface.

Evaluation of the previous work combined with laboratory test results have led to the design of a field proof-of-principle test to remove water and possibly mobile contaminants at greater depths, using small diameter boreholes placed with the direct push unit.

241-SX Tank Farm Field Test Configuration and Plan

The purpose of this test is to determine if soil water extraction using tank farm-deployable equipment is a viable technology for soil remediation within a tank farm. To this end, this test will use small diameter (approximately 1.75-inch inside diameter) boreholes placed with a direct push hydraulic hammer. Direct push technology is used throughout the tank farms for subsurface investigations that include geophysical logging, equipment placement, and sample collection activities. Direct push technology is used at tank farms due to its low cost, rapid borehole placement, and the fact that it does not produce excavated soil which can lead to worker exposure and increased waste disposal costs and issues. In addition, the direct push hydraulic hammer is a relatively small unit compared to other drilling equipment and can be placed in locations where placement of a larger drill rig would problematic.

Questions to be answered include:

1. Can soluble contaminants in liquid phase pore water be removed using small diameter direct push boreholes?

2. What equipment configuration is required to extract liquid phase pore water containing contaminants through a direct push borehole?

3. If liquid phase water containing contaminants cannot be removed, can vapor phase moisture be removed using the small diameter boreholes placed with the direct push unit?

The proof-of-principle testing will be performed in three stages as illustrated in Figure 3. The first stage proof-of-principle testing will be field activities to obtain additional information about three prospective test locations south of the 241-SX Tank Farm fence line. This first stage will involve pushing and logging these three test drywells at select locations to determine if the locations have good moisture peaks as determined by reviewing neutron log data collected from the borehole. The second stage of proof-of-principle testing will be pushing boreholes adjacent to the first boreholes, collecting samples, identifying a preferred test location, and designing the test equipment and associated monitoring system. The third stage of the proof-of-principle testing will be to procure equipment, install the test and monitoring equipment, and to conduct the water extraction test itself using the installed boreholes.

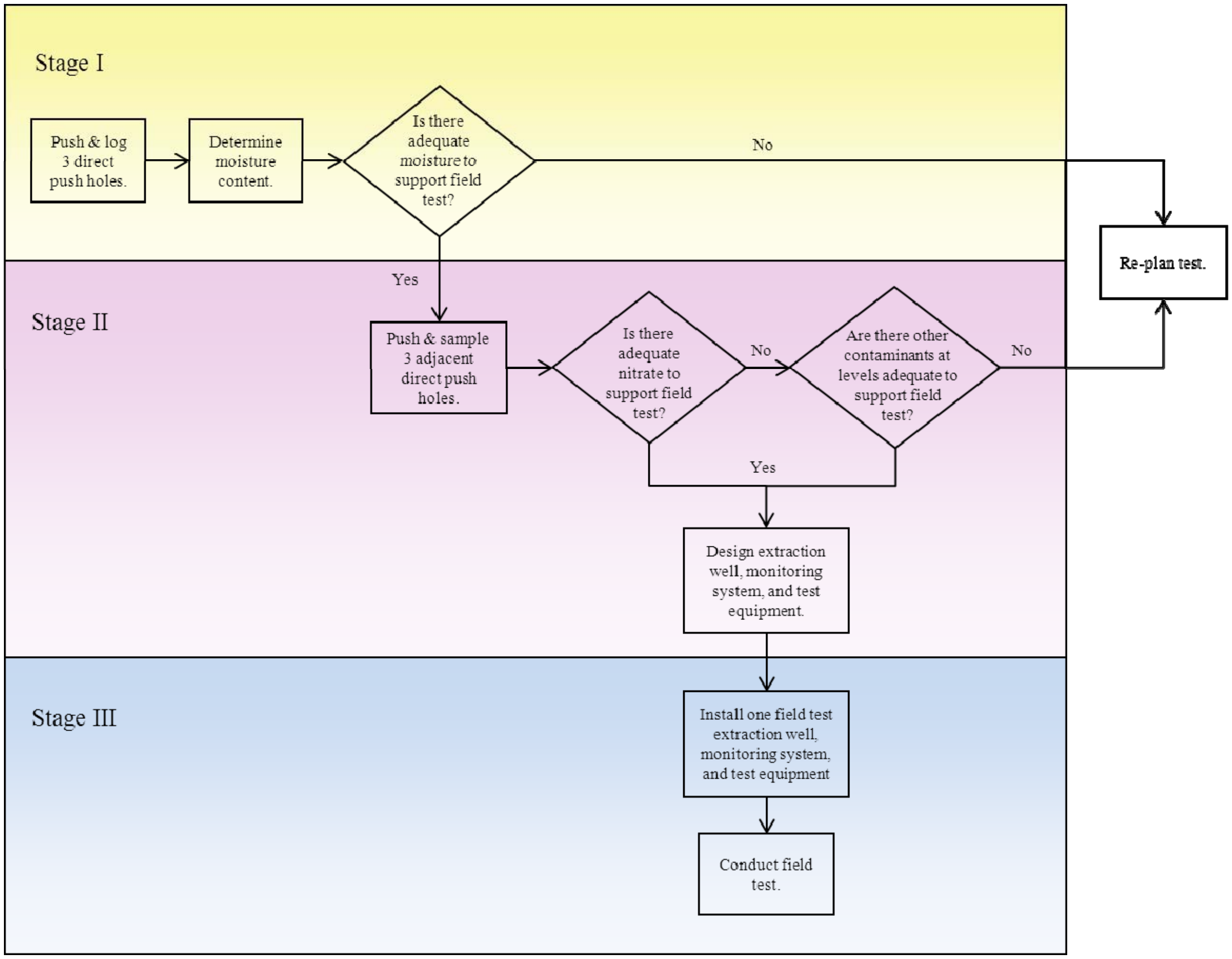


Fig. 3. Push test flow chart.

Stage I – The first stage of the proof-of-principle testing will be field activities to obtain moisture information about three prospective test locations south of the 241-SX Tank Farm fence line. The three prospective test locations will be located within one of the two areas outlined in orange in Figure 2. Ground penetrating radar and electrical ground scans will be performed before probe holes are pushed, to identify sub-surface infrastructure and support citing of the test boreholes. The combination of sub-surface infrastructure and surface accessibility will determine the exact location of each borehole. Boreholes will be pushed and logged at each of the three prospective test locations to determine moisture content. Moisture content will be determined by reviewing neutron log data collected from the borehole. Although the determination of the prospective test location's viability based on moisture content will be primarily qualitative, the minimum moisture content required to select the site is generally thought to be greater than 20% by volume based on work performed by Pacific Northwest National Laboratory (PNNL) and documented in PNNL-21882.[7] Existing data shows that high moisture zones should be found at these prospective test locations.

Stage II – During the second stage, the prospective test locations with adequate moisture content will be characterized for the presence of nitrate. A second borehole will be pushed adjacent to the first borehole placed in Stage I. The second borehole will be sampled at two depths, based on the logging results and other information available about the location. The samples will be analyzed on a "quick-turnaround" basis for moisture content, nitrate, technetium, particle size, pH, and conductivity. Based on nitrate content from each location, a location will be chosen for the proof-of-principle test. If a location cannot be chosen based on nitrate, other contaminants may be considered, and with agreement of the State of Washington Department of Ecology and U.S. Department of Energy, Office of River Protection, could form the basis for the selection of one of the three prospective test locations for the test location.

Also in Stage II, the design of the extraction well, monitoring system, and test equipment will be completed, and a test procedure will be developed for conducting the test. At this point, the specific equipment and test configuration is not known. It is anticipated that the test configuration will include a vacuum pump to facilitate extraction of the pore water and a micro pump to transfer the pore water to the surface. Specific equipment design, test configuration, and operating plans will be developed as a part of the test design.

Stage III – In Stage III, an extraction well, monitoring system, and test equipment will be installed and operated to complete the test. Conceptually, testing will determine if water containing mobile contaminants can be extracted using the direct push boreholes. The test will also determine if vapor phase water can be extracted, which could potentially have application for soil desiccation rather than contaminant removal. The configuration design of the extraction boreholes is also informed by modeling and testing performed by PNNL.[8] Screening of the boreholes is a particularly important consideration, since high-porosity soil layers could give rise to preferential air flow paths that prevent effective application of a vacuum to adjacent lower porosity layers.

As noted above, a detailed field test procedure will be developed during Phase II.

If the initial tests show that the soil desiccation and pore water extraction approaches have merit when applied to the tank farms, a more extensive test is anticipated.

MONITORING APPROACHES

Monitoring and evaluation of the range of influence of the desiccation and remediation test will employ several measurement methods.

Neutron logging of multiple boreholes associated with the test will provide a moisture profile at the specific borehole location. Neutron logging will be performed prior to starting the tests, and at specified times during and after the tests.

Laboratory analysis of water (removed pore water and/or condensed vapor) will be performed to evaluate the concentrations of expected background components and contaminants of interest.

Moisture and contaminant distribution will be mapped using one-, two- or three-dimensional electrical geophysics prior to initiating moisture and contaminant removal as a baseline measurement dataset. Continued monitoring at discrete intervals will be completed in an effort to observe the reduction in moisture content and conductive plume constituents, such as nitrates, in the target remediation zone. Depth electrodes (i.e., resistivity sensors placed at a discrete depth within the soil column) will be used to augment the planned geophysical monitoring.

FUTURE APPLICATIONS

Characterization of the soil in and around the other tank farms in Hanford's 200 West Area has shown a similar pattern of moisture and mobile contamination accumulating over the Cold Creek Unit. The results of the remediation proof-of-principle test will support future planning for interim and final soil remediation measures.

CONCLUSIONS

Interim and long-term remediation measures are currently under evaluation for 241-SX Tank Farm. Two contiguous interim surface barriers have been designed to reduce future moisture infiltration. Construction of the surface barriers has been deferred to allow testing of potential technologies to reduce soil moisture and possibly remove some contaminants. Evaluation of the previously completed pore-water extraction work combined with laboratory test results have led to the design of a field proof-of-principle test to remove water and possibly mobile contaminants at greater depths, using small boreholes placed with the direct push unit. The proof-of-principle test is to be deployed during fiscal year 2013, with testing to be completed during fiscal year 2014.

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