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Supplemental Tritium Report for Material Disposal Area V

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1.0 INTRODUCTION

This report provides an introduction and brief background description of Consolidated Unit 21-018(a)-99, also known as Material Disposal Area (MDA) V, including a discussion of field activities and the administrative record. The discussion focuses on a technical analysis of tritium vapor at the site, including a summary of field data and transport modeling results. It also recommends a path forward with respect to tritium monitoring.

MDA V is located on the southeastern section of DP Mesa, just outside of the main gate to Technical Area 21 (TA-21). MDA V consists of four inactive solid waste management units (SWMUs) and one inactive area of concern (AOC) that were consolidated in 1999 according to their related operational history as well as their proximity to one another. The sites, shown in Figure 1, are

- three wastewater absorption beds [SWMU 21-018(a)];
- a former laundry facility [building 21-020, SWMU 21-018(b)];
- a waste treatment laboratory septic system and outfall [SWMU 21-023(c)];
- two surface disposal areas [SWMU 21-013(b)]; and
- building debris located on the south-facing slope of BV Canyon [AOC 21-013(g)].

Characterization and remediation activities were conducted by the Los Alamos National Laboratory (LANL) at MDA V because of potential contamination from both hazardous and radioactive chemicals from historical operations. Tritium vapor-sampling data from a borehole at MDA V indicated the vertical extent of tritium had not been determined; therefore, the New Mexico Environment Department (NMED) could not approve LANL's request for a no further action determination. LANL and the U.S. Department of Energy (DOE) agreed that limited vapor sampling would be performed to assess the vertical extent of the tritium vapor to support an appropriate path forward.

Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with DOE policy.

2.0 FIELD ACTIVITIES, DATA COLLECTION, AND THE ADMINISTRATIVE RECORD

- The laundry facility was removed by LANL in 1966.
- An investigation work plan (IWP) was submitted to NMED in June 2004 that included 15 characterization boreholes and shallow sampling near the outfall (LANL 2004, 087358).
- The work plan was approved by NMED in 2004, and the work was subsequently conducted (NMED 2004, 090174).
- The resulting investigation report (IR), submitted to NMED in October 2006, documented that LANL excavated and disposed of the three infiltration absorption beds as part of a voluntary corrective action in 2005. Approximately 10,900 yd^3 of absorption bed material and contaminated soil and rock was shipped from the site. All remaining septic systems, the outfall infrastructure, and disposal areas were also excavated and removed (LANL 2006, 094361).
- NMED issued a notice of deficiency (NOD) to the IR in January 2007, which stated the extent of radionuclides had not been determined, specifically tritium in pore gas, and LANL was required to drill a new vapor well. Also, an area of elevated radionuclides north of Bed 3 required additional

characterization or remediation. Elevated tritium in pore gas was based on subsurface pore-gas sampling conducted in 2005 and 2006. One pore-gas sample was collected in 2005 from a single depth (15 ft below ground surface [bgs]), and two pore gas samples were collected from two depths (15 ft and 380 ft bgs) in a borehole (location 21-24524) near the absorption beds in 2006. The deeper sample had a higher tritium activity than the shallower samples (NMED 2007, 094854).

- LANL submitted response to NMED's NOD in February 2007, agreeing additional characterization or remediation was needed and DOE was evaluating the need (LANL 2007, 095248).
- LANL received a direction to modify the IR from NMED in February 2007, reiterating the reported tritium activities suggest preferential pathways for the downward transport of tritium to the groundwater and therefore NMED could not issue a Corrective Action Complete designation (NMED 2007, 096393).
- LANL submitted a sampling data and supplemental work plan to NMED in July 2007 to address the area of elevated radionuclides north of Bed 3 (LANL 2007, 097448).
- LANL also submitted to NMED a revision to the IR that reported the final surface and subsurface characterization results in July 2007, as required by the NMED-approved IWP. In this report, LANL stated that nature and extent had been defined and recommended the issuance of a Corrective Action Complete with Controls (LANL 2007, 098942).
- LANL received an approval with modification on the supplemental work plan from NMED in August 2007, stating that long-term monitoring of tritium pore gas was required and LANL was required to drill new wells for vapor monitoring (NMED 2007, 098287).
- LANL also received an approval from NMED on the revised IR in August 2007. The approval covered all the characterization and remediation, except for tritium vapor (NMED 2007, 098438).
- LANL conducted hot-spot removal and confirmation sampling in the area of elevated radionuclides north of Bed 3 in 2007. The results were submitted to NMED in a supplemental IR in February 2008. The supplemental IR concluded the hot spot had been remediated, the corrective action was complete, and extent had been defined, except for the extent of tritium (LANL 2008, 103423).
- LANL received an NOD on the supplemental IR from NMED in March 2008, stating the extent of vapor-phase tritium was still not defined and directing LANL to install a deep vapor-monitoring well at location 21-24524 to determine the vertical extent of vapor-phase tritium (NMED 2008, 100531).
- LANL submitted a response to the NOD to NMED in April 2008, stating LANL would voluntarily submit to NMED a comprehensive sampling and monitoring plan for tritium (LANL 2008, 101892.8).
- LANL submitted the subsurface vapor-moisture-monitoring plan to DOE in June 2008, proposing to drill and install a new vapor well at location 21-24524 (Figure 1) to a depth of approximately 680 ft (LANL 2008, 103406).
- In response to the LANL's response to the NOD, NMED provided direction to modify the supplemental IR in June 2008. NMED stated the following requirement for the subsurface vapor-moisture monitoring plan: "Ultimately, NMED is interested in whether or not concentrations of tritium in the subsurface pore gas would result in concentrations above the groundwater

Maximum Contaminant Level (MCL) of 20,000 pCi/L if vapor-phase tritium portioned to groundwater" (NMED 2008, 102044).

- LANL received an NOD from NMED on the subsurface vapor-moisture monitoring plan in December 2008, stating that LANL was required to revise the plan and to propose additional vapor-monitoring wells at MDAs A and B (NMED 2008, 104331).
- LANL submitted a response to the NOD for the subsurface vapor-moisture monitoring plan to NMED in January 2009, stating the plan would be implemented under DOE's authority and that the plan was not subject to approval under the Compliance Order on Consent (the Consent Order) (LANL 2009, 105099).
- LANL submitted a vadose zone subsurface characterization and vapor-monitoring well installation work plan to NMED in May 2009 that proposed drilling and installing a new vapor-monitoring well at location 21-24524 (LANL 2009, 106156).
- LANL received an approval with modifications of the IWP from NMED in September 2009, providing dates for the submittal of four quarterly reports in January, April, July, and October 2010 (NMED 2009, 107304).

Two new vapor-monitoring wells were installed in November 2009 within 10 ft of the location of borehole 21-24524. These wells retained the location identification number of 21-24524 but with an additional designation of west (21-24524W) and south (21-24524S) to indicate their locations relative to the location of borehole 21-24524. Monitoring well 21-24524W has seven ports from depths of 45 ft to 380 ft bgs. Monitoring well 21-24524S has two ports located at depths of 680 ft and 715 ft bgs. In this report, wells 21-24524W and 21-24524S collectively are referred to as 21-24524.

To date, vapor-monitoring well 21-24524 has been sampled for four quarters, each consisting of a single sampling event, with the exception of the first quarter, which consisted of two sampling events. The first quarterly sampling at MDA V was completed between June and October 2009 (LANL 2009, 108134); the second quarterly sampling was completed in November 2009 (LANL 2010, 109094); the third quarterly sampling was completed in February 2010 (LANL 2010, 109832); and the fourth quarterly sampling was completed in April 2010 (LANL 2010, 110834).

3.0 TECHNICAL ANALYSIS OF MDA V VAPOR-MONITORING AND MOISTURE DATA

Trend comparisons of tritium activities as a function of depth were documented and provided in the previously submitted quarterly periodic monitoring reports. In general, the tritium activity trends are consistent from quarter to quarter. Figure 2 illustrates the four quarters of tritium activities with depth, along with the completion diagram for the vapor-monitoring well, the stratigraphy, and volumetric moisture content data. A comparison in trends between the quarters indicates two peaks in tritium activity with depth. The first peak occurs at a depth of 42.5 ft to 47.5ft bgs in the Tshirege/Otowi formation, with the highest activity, 54,812 pCi/L, reported in April 2010. The second peak occurs at a depth of 300 ft to 305 ft bgs near the Tsankawi Pumice Bed (Qbtt). Tritium activities were the highest at this depth (46,830 pCi/L in June–October 2009; 67,924 pCi/L in November 2009; 69,612 pCi/L in February 2010; and 68,713 pCi/L in April 2010). Below this depth, tritium activities decrease sharply to total depth (712.5 ft to 717.5 ft bgs). In general, the data do not indicate a change in tritium activity over the time period monitored. The moisture data follow a similar trend with depth with the tritium activity, with the maximum moisture content occurring in Qbtt and the Cerro Toledo interval (Qct).

Conceptual Model of Tritium Transport

Tritium migrates in the environment as part of a water molecule in both the liquid-water phase and the air phase (as water vapor). The conceptual model for tritium transport in the unsaturated zone beneath MDA V is that initially, while the adsorption beds were actively receiving liquid waste, tritium migrated predominantly in the liquid phase. Migration probably occurred through both the porous tuff matrix and through fractures in the uppermost tuff units, because the Tshirege Member tuffs (Qbt units) beneath MDA V are highly fractured (Wohletz 1995, 054404). Fracture flow was probably limited in the deeper units Qbtt, Qct, and the Otowi Member (Qbof) because these units do not support fractures. These mechanisms likely helped set up the bimodal tritium distribution and higher moisture content near the surface and at approximately 300 ft bgs, as shown in Figure 2. Matrix flow yielded the shallow peaks, while fracture flow yielded the deeper peaks. The higher permeability and porosity and lack of fractures in Qbtt and Qct compared with the units above probably presented an effective geologic control on the downward transport of liquid during and after liquid disposal operations at MDA V.

After liquid disposal ceased, liquid migration slowed and the air-phase transport of tritium became relatively more important. Under current conditions, coupled transport in both the liquid and the air phases describes tritium transport more accurately than the liquid-dominated flow discussed above. This current condition is used as the basis of the transport modeling discussed below.

Transport Modeling

This section describes an analysis of tritium transport at MDA V based on recent data obtained from vapor-monitoring well 21-24524. The goal of the analysis is to estimate the maximum tritium activity at the regional aquifer that might occur beneath MDA V based on site data.

The analysis takes into account that tritium transport in the vadose (unsaturated) zone is impacted by gas- (air-) and liquid- (water-) phase migration. The analysis ignores (1) radioactive decay of tritium and (2) tritium partitioning between the gas and liquid phases during its migration in the vadose zone. Both these processes will further reduce predicted tritium activities in the regional aquifer. Therefore, the results obtained for tritium activities in the regional aquifer are conservative. The analysis also assumes the current reported tritium activities in the vadose zone act as a continuous, constant concentration source. This is also a conservative assumption, given that the source has been removed.

If tritium were to reach the aquifer, groundwater flow through the regional aquifer would cause mixing within the screened interval of a monitoring well. The analysis is designed to estimate the tritium activity that would be observed at a regional aquifer monitoring well drilled immediately adjacent to the location where the contaminant could potentially arrive at the regional water table. The well screen is assumed to be 3 m (~10 ft) long, which is consistent with the well construction of regional monitoring wells on the Pajarito Plateau. The screen is placed immediately below the regional water table (rather than deeper in the regional aquifer), which will produce conservative (the highest) predicted contaminant concentrations.

When tritium migrates through the vadose zone in the water phase, the following equation can be applied to calculate the dimensionless dilution factor for water-phase transport (F_{dw}):

$$F_{dw} = \frac{C_{wt}^{w}}{C_{aq}^{w}} = 1 + \frac{kId_m}{RL} \qquad \textbf{Equation 1}$$

where C_{wt}^{w} is the contaminant concentration in the infiltrating water [M/L^3], C_{aq}^{w} is the contaminant concentration in the regional aquifer within the mixing zone [M/L^3], I is the hydraulic gradient in the regional aquifer [L/L], R is the infiltration rate through the vadose zone [L/T], L is the length of the source at the top of the regional aquifer parallel to groundwater flow, [L], k is the aquifer hydraulic conductivity [L/T], and d_m is aquifer mixing zone depth [L], which is calculated as

$$d_m = \begin{cases} if\ d_a \le d_c & d_a \\ if\ d_a > d_c & d_c \end{cases}$$

Equation 2

where

$$d_c = 0.105830052L + d_a\left(1 - \exp\left(-\frac{RL}{kId_a}\right)\right)$$

Equation 3

and d_a [L] is the aquifer thickness where the mixing is expected to occur (e.g., well-screen length) and d_c [L] is the computed depth within which the contaminants are expected to migrate. If $d_a > d_c$, a conservative assumption is made that the mixing zone is equal to the well screen. Equations 1, 2, and 3 are based on a U.S. Environmental Protection Agency (EPA) guidance document (EPA 1996, 059902, Equations 37 and 45, respectively). They account for the impact of infiltration, which carries the contaminants, and on the structure of groundwater flow in the regional aquifer.

If the contaminants migrate through the vadose zone in the vapor (air, gas) phase, then diffusion of contaminants through the vadose zone and partitioning of the contaminants at the water table should be taken into account. In the case of contaminant diffusion through the vadose zone, the water table can be viewed as a boundary at which contaminants leave the vadose zone and migrate into the regional aquifer. The diffusive flux depends on the contaminant concentrations at the vadose-zone source and at the water table. When the groundwater flux along the water table is relatively slow compared to diffusive vapor flux in the vadose zone, it is important to account for the contaminant concentration at the water table (the concentration is initially zero but will increase with time).

The diffusion coefficient [L^2/T] of tritiated water vapor in air, D_a, is approximately 2.57×10^{-5} m^2/s (Montgomery 1947, 111469). The simulations used values of both 2.57×10^{-5} and 10^{-3} m^2/s (Table 1). The higher value diffusion coefficient is applied to account for the potential fast diffusive transport through fractures and for barometric pressure effects (Vold and Eklund 1996, 070156). The diffusion coefficient [L^2/T] in water, D_w, for tritium is assumed to be equal to 2.27×10^{-9} m^2/s (1.96×10^{-4} m^2/d) (Tanaka 1978, 111468) (Table 1). These coefficients can be modified to account for diffusion through a porous medium using the following equation (Millington and Quirk 1961, 110521):

$$D_{ap} = D_a \frac{(n-\theta)^{10/3}}{n^2}$$

Equation 4

$$D_{wp} = D_w n^{4/3}$$

Equation 5

where n is porosity of the porous medium [L^3/L^3], and θ [L^3/L^3] is the volumetric water content.

Henry's law defines the amount of tritium that will be dissolved in the regional groundwater. At the water table, Henry's law is expressed using the concentrations of the gas, C_{wt}^{g} [M/L^3], and the water, C_{wt}^{w} [M/L^3], phases along the regional water table at equilibrium:

$$C_{wt}^{w} = \frac{C_{wt}^{g}}{H}$$

Equation 6

where H is the dimensionless Henry's law constant. In the current analyses, H is 1.28×10^{-5}, based on the temperature and pressure observed in the vadose zone (Table 1).

Truex et al. (2009, 108331) have proposed a technique to compute the dimensionless dilution factor of the vapor-phase contaminants (F_{dg}) adjacent to the water table into the regional aquifer:

$$F_{dg} = \frac{C_{wt}^{a}}{C_{aq}^{w}} = \frac{2Hd_a}{d_m} \qquad \textbf{Equation 7}$$

where the mixing zone depth is calculated as

$$d_m = \sqrt{\frac{2d_a D_{wp}}{kI}}\,. \qquad \textbf{Equation 8}$$

It is important to note that the mixing zone is created by molecular diffusion only. Truex et al. (2009, 108331) also proposed an approach to compute the dilution factor of the vapor-phase contaminants into the regional aquifer, taking into account diffusion of the contaminant in the vadose zone under steady state conditions:

$$F_{dg} = \frac{C_{vz}^{a}}{C_{aq}^{w}} = \frac{2Hd_a\left[1+\frac{d_{vz}}{Hd_a D_{ap}}\sqrt{\frac{kId_a D_{wp}}{2}}\right]}{d_m} \qquad \textbf{Equation 9}$$

where d_{vz} is the vertical distance between the vapor contaminant source and the regional water table (if the contaminant source is at the ground surface, it will be the thickness of the vadose zone), and C_{vz}^{a} is the source vapor concentration in the vadose zone.

A steady state condition is a conservative assumption for the expected values for diffusion coefficients, vadose-zone thickness (~300 m), and available time for contaminant migration through the vadose zone (approximately 40 to 60 yr). Equation 9 takes into account the impact of the vapor-contaminant concentration at the water table on the diffusive flux of the vapor-phase contaminants occurring through the vadose zone. However, it does not account for aquifer dispersion. If vertical dispersion causes the plume to exceed the aquifer thickness under consideration in this analysis, the dispersion will increase mixing in the regional aquifer. However, this effect is not expected to occur within the current range of aquifer thickness values considered (aquifer thickness greater than 3 m). On the other hand, dispersion in the aquifer may increase the vapor-phase contaminant flux because it will decrease the contaminant concentration in the liquid phase at the water table, which will decrease the contaminant concentration in the vapor phase adjacent to the regional water table (the fractionation between the vapor- and liquid-phase concentrations at the water-table interface is assumed to be at steady state and controlled by the Henry's law constant). As a result, the vertical dispersion is not expected to increase the vertical mixing of contaminants in the regional aquifer.

The analysis presented above follows the methodology of Truex et al. (2009, 108331), which is based on an assumption that the considered thickness of the regional aquifer (d_a above; U in Truex et al. [2009, 108331]) is equal to the lateral length of the source area parallel to groundwater flow (L). However, this is not the case in the present analyses where the considered thickness of the regional aquifer is 3 m (~10 ft), representing the length of a typical monitoring screen in the regional aquifer beneath MDA V, and the source length is considered to be on the order of 30 m. The source length is based on spatial analyses of the observed concentrations beneath MDA V. As a result, Equation 9 is modified accordingly:

$$F_{dg} = \frac{d_a}{L}\,\frac{2Hd_a\left[1+\frac{d_{vz}}{Hd_a D_{ap}}\sqrt{\frac{kId_a D_{wp}}{2}}\right]}{d_m} \qquad \textbf{Equation 10}$$

Equations 1 and 10 are used to calculate the dilution factors for tritium migrating in the water and vapor phases through the vadose zone. The results are presented in Table 1.

Table 1 presents four different model cases. Cases 1 and 2 assume the reported tritium activities in the vadose zone are continuous constant-activity sources at two different depths: ~70,000 pCi/L at 300 m above the regional aquifer (Case 1) and 1000 pCi/L at 150 m above the regional aquifer (Case 2). Cases 1a and 2a are based on expected air dispersivity (2.57×10^{-5} m^2/s). Cases 1b and 2b assume higher air dispersivity to account for fast diffusion through fractures (10^{-3} m^2/s). In all the presented cases, the predicted activities in the regional aquifer are substantially below the drinking water maximum contaminant level (MCL) for tritium (20,000 pCi/L). The simulations indicate the maximum future tritium activity that could occur in the aquifer should be less than 45 pCi/L because of vapor-phase transport through the vadose zone and subsequent mixing in the regional aquifer. The simulations also indicate the maximum future tritium activity in the aquifer should be less than 6000 pCi/L because of the mixing of tritium present in pore water into the regional aquifer. The liquid-phase calculation assumes the maximum vadose-zone concentration (located several hundred meters above the aquifer) mixes directly with regional aquifer water; the estimate does not include any decrease in activity because of liquid-phase transport through the vadose zone.

It is important to emphasize the analyses are based on several conservative assumptions, and the predicted tritium activities are much higher than are expected ever to occur. First, the analyses ignore (1) radioactive decay of tritium (half-life of approximately 12.5 yr) and (2) tritium partitioning between the gas and liquid phase during its migration through the vadose zone. The analyses also assume the reported tritium activities in the vadose zone represent a continuous constant-concentration source in the vadose zone. Finally, the tritium activity in the aquifer calculated for liquid-phase transport through the mesa is based on an assumption that the source concentration mixes directly into the aquifer rather than accounting for any transport through the thick vadose zone. All these assumptions result in higher predicted future tritium activities in the regional aquifer than would be expected. Therefore, the maximum predicted future tritium activities in the regional aquifer are conservative. None of the predicted activities exceed the EPA MCL of 20,000 pCi/L.

4.0 SUMMARY OF RESULTS IN SUPPORT OF THE PATH FORWARD

All characterization and remediation activities have been completed at MDA V. Corrective actions effectively removed the contaminant source terms from the site. Data indicate the vertical and lateral extents of tritium vapor are defined, and confirmation sampling indicates the site meets residential cleanup standards.

NMED’s requirement for four quarterly reports was met with the submittal of the fourth quarterly MDA V periodic monitoring report on October 2, 2010.

The sampling data collected during the four quarters show very low tritium activities, consistent trends of tritium with depth, and no discernable evidence of downward migration. These tritium activities are lower than activities reported for the 2005–2006 investigation for samples collected from the same location and at similar depths. Furthermore, tritium has been reported at low and nondetect activities in the two deepest sampling ports, at 680 ft and 715 ft bgs.

The quarterly trends of tritium with depth for MDA V, which are similar to those observed at MDA T, show a maximum tritium activity at a depth of approximately 300 ft bgs, very near the occurrence of the Tsankawi Pumice Bed. The higher permeability and porosity and lack of fractures in this bed compared with the units in the upper vadose zone probably presented an effective geologic control on the downward transport of liquid following liquid disposal operations at MDA V. The maximum tritium activity and higher moisture content at this location may be residual effects from active disposal rather than from more recent migration.

LANL has conducted modeling analyses of the tritium transport in the vadose zone and the regional aquifer beneath MDA V. The analyses suggest if the highest reported tritium activity (~70,000 pCi/L) in the vadose zone were assumed to be a continuous constant-concentration source, the drinking water MCL for tritium (20,000 pCi/L) for the regional groundwater would not be exceeded. The analyses take into account the processes of contaminant transport in the vadose zone and the regional aquifer.

The residual tritium below MDA V will slowly decrease over time because of the removal of the source term and because of tritium's relatively short half-life, coupled with the lack of a mechanism to rapidly move the residual tritium from the vadose zone into the groundwater.

5.0 RECOMMENDATIONS

LANL recommends discontinuing further vapor sampling of monitoring well 21-24524. This recommendation recognizes that the current tritium vapor present in the subsurface media below MDA V poses no human health or ecological issues warranting continued monitoring or further action and natural decay and dispersion processes will continually decrease tritium activity.

With the questions raised by NMED as to the nature and extent of tritium at MDA V addressed, LANL recommends reinstating the closure process for the MDA V site by the appropriate processes consistent with Consent Order requirements.

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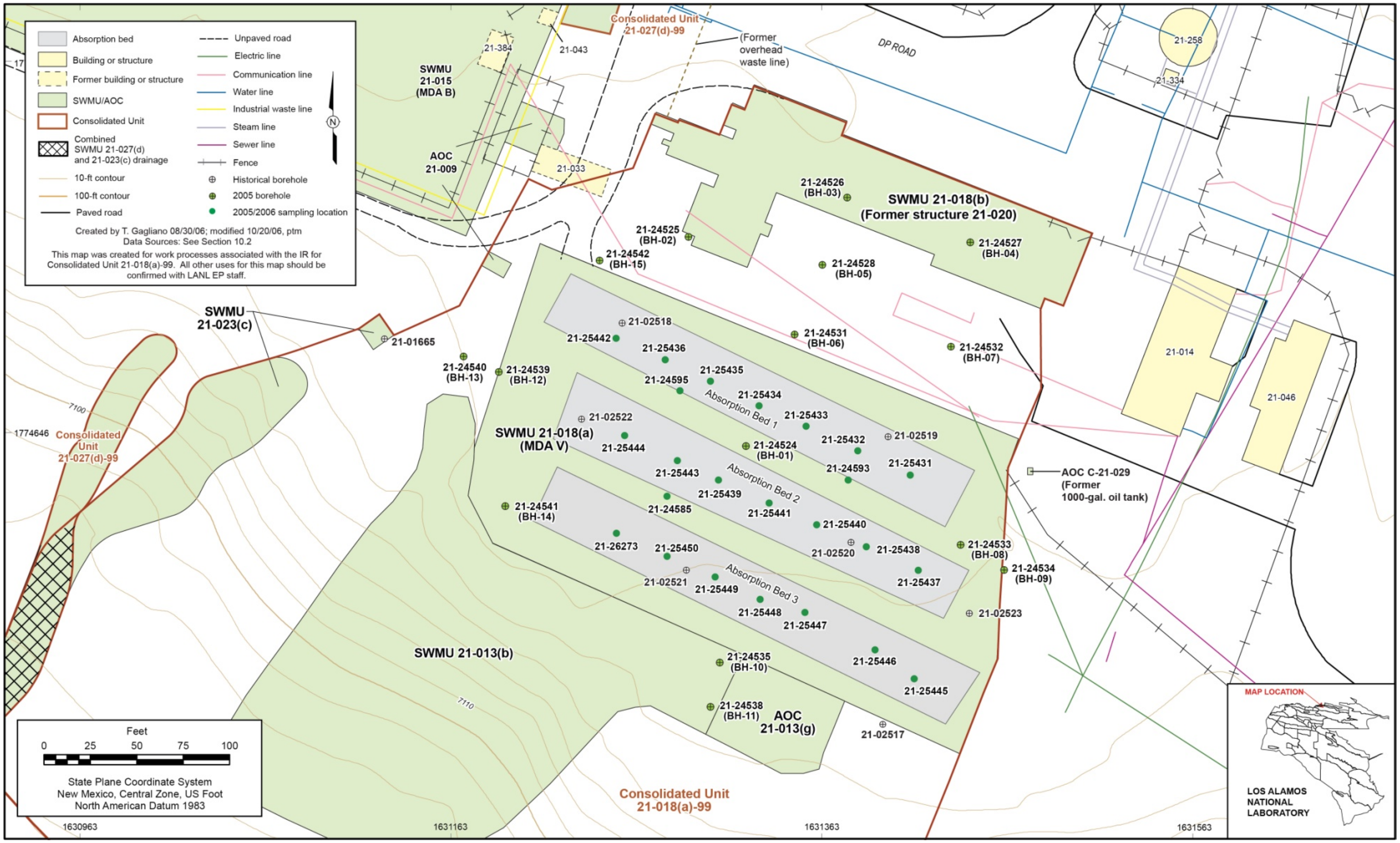
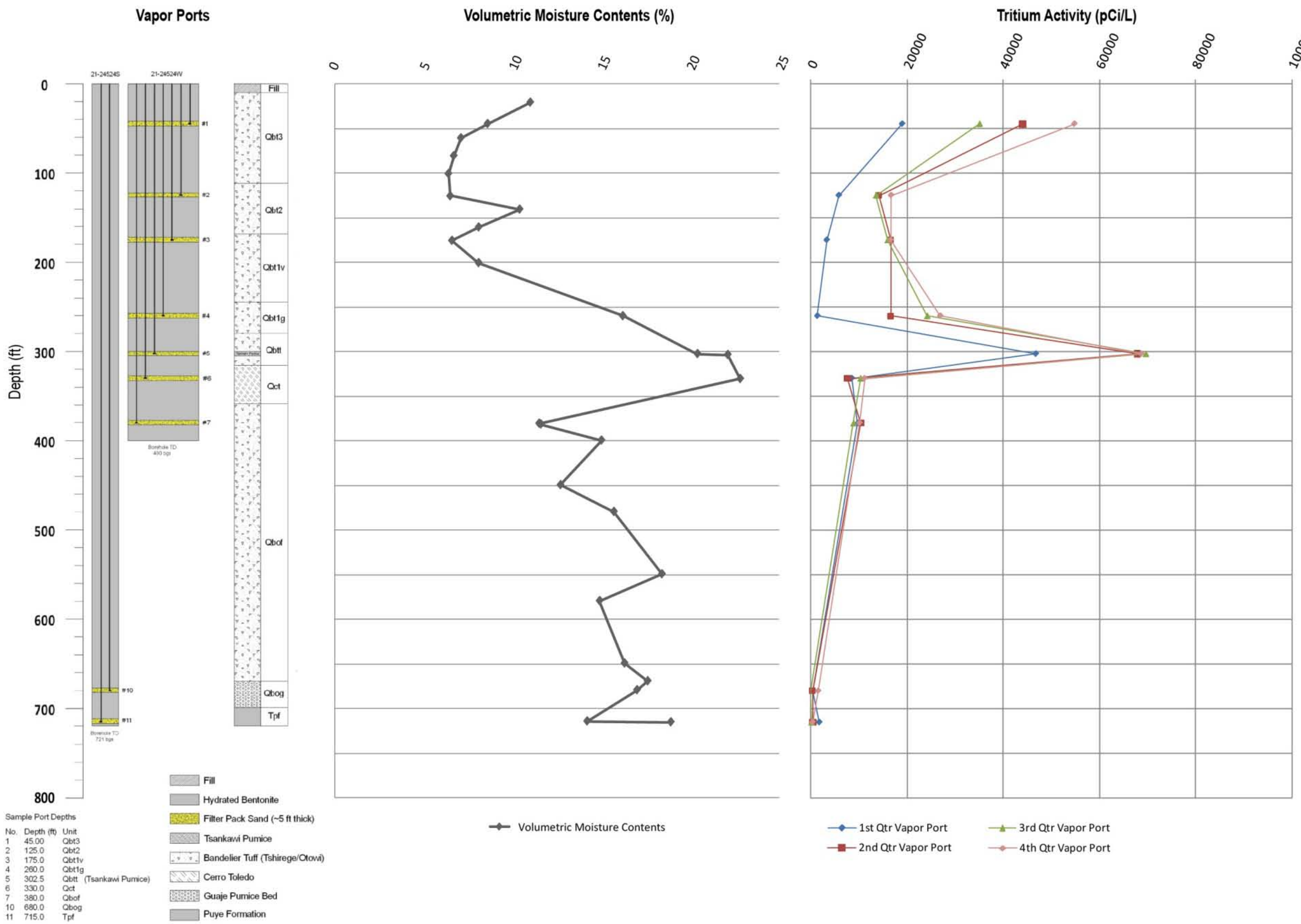


Figure 1 Locations of SWMUs, boreholes, and other subsurface sampling locations at Consolidated Unit 21-018(a)-99



Sample Port Depths

No.	Depth (ft)	Unit
1	45.00	Qbt3
2	125.0	Qbt2
3	175.0	Qbt1v
4	260.0	Qbt1g
5	302.5	Qbtt (Tsankawi Pumice)
6	330.0	Qct
7	380.0	Qbof
10	680.0	Qbog
11	715.0	Tpf

Figure 2 **Construction, stratigraphy, volumetric moisture content, and quarterly tritium activities at vapor-monitoring well 21-24524**

Table 1
Predicted Tritium Activities in the Regional Aquifer for Four Different Model Cases

	Parameters		Unit	Case 1a	Case 1b	Case 2a	Case 2b
Source properties	Screeening Level (SL) / Maximum tritium Level (MCL)		pCi/L	20000	20000	20000	20000
	Henry's law coefficient (dimensionless)	H	-	1.280E-05	1.280E-05	1.280E-05	1.280E-05
	Tritium activity in the porewater phase in the vadose zone at the source	C^{w}_{vz}	pCi/L	70000	70000	1000	1000
	Equivalent tritium activity in the gas phase in the vadose zone at the source	C^{g}_{vz}	pCi/m^3	896	896	12.8	12.8
	Distance from the vadose zone source to the water table	d_{vz}	m	300	300	150	150
	Source length along the regional groundwater flow direction	L	m	30	30	30	30
Aquifer	Hydraulic conductivity in the regional aquifer	k	m/d	1	1	1	1
	Hydraulic gradient in the regional aquifer	I	m/m	0.003	0.003	0.003	0.003
	Considered aquifer thickness (e.g. screen length of a monitoring well)	d_a	m	3	3	3	3
	Darcy velocity	v	m/d	0.003	0.003	0.003	0.003
Porewater-phase migration	Infiltration rate through the vadose zone	R	m/a	0.01	0.01	0.01	0.01
	Infiltration flux	q_{inf}	m^2/d	8.219E-04	8.219E-04	8.219E-04	8.219E-04
	Regional aquifer flux (unit length perpendicular to the groundwater flow)	q_{aq}	m^2/d	0.009	0.009	0.009	0.009
	Tritium flux from the vadose-zone source to the water table under steady-state	q_{ssw}	m/d*pCi/m^3	1917.8	1917.8	27.4	27.4
	Aquifer mixing zone	d_m	m	3	3	3	3
	Dilution factor	F_{dw}	-	11.95	11.95	11.95	11.95
	Tritium activity in the aquifer within the mixing zone	C^{w}_{aq}	pCi/L	5858	5858	84	84
	COPC of concern based on pore-water migration? [yes/no]	-	yes/no	no	no	no	no
Gas-phase migration	Diffusion coefficient of tritium in air	D_a	m^2/s	2.57E-05	0.001	2.57E-05	0.001
	Diffusion coefficient of tritium in air	D_a	m^2/d	2.22048	86.4	2.22048	86.4
	Diffusion coefficient of tritium in air in the vadose zone	D_{ap}	m^2/d	0.1154	4.4913	0.1154	4.4913
	Diffusion coefficient of tritium in water	D_w	m^2/d	1.96E-04	1.96E-04	1.96E-04	1.96E-04
	Diffusion coefficient of tritium in the aquifer	D_{wp}	m^2/d	3.94E-05	3.94E-05	3.94E-05	3.94E-05
	Porosity	n	-	0.3	0.3	0.3	0.3
	Volumetric moisture content in the vadose zone	θ	-	0.1	0.1	0.1	0.1
	Air-phase tritium activity in the vadose zone directly above the water table under steady state	C^{g}_{wt}	pCi/m^3	0.03	1.22	0.00	0.03
	Water-phase tritium activity in the vadose zone directly above the water table under steady state	C^{w}_{wt}	pCi/m^3	2457	95486	70	2724
	Tritium flux from the vadose-zone source to the water table under steady-state	q_{ssg}	m/d*pCi/m^3	0.34	13.40	0.01	0.38
	Maximum tritium flux from the VZ source to the WT (conc = 0)	q_{max}	m/d*µg/m^3	0.34	13.41	0.01	0.38
	Aquifer mixing zone (only due to diffusion; if dispersion is included the tritium flux will increase)	d_m	m	0.28	0.28	0.28	0.28
	Dilution factor	F_{dg}	-	0.78	0.02	0.39	0.01
	Tritium activity in the aquifer within the mixing zone	C^{w}_{aq}	pCi/L	1.15	44.65	0.03	1.27
	COPC of concern based on air-phase migration? [yes/no]	-	yes/no	no	no	no	no

Note: Shaded cells indicate calculated aquifer activities. - = Unitless or not applicable.